

functionality is provided by encapsulation of the Ethernet sublayer information within LLC Protocol Data Units (PDUs), using the Subnetwork Access Protocol specified in Clause 10 of this standard.

Optionally, some Integrated Service LANs and MANs may also support ITU-T compatible isochronous bearer services at the Physical layer.

The OSI/RM is referred to by the IEEE 802 Standards because of the following:

- a) The OSI/RM provides a common vehicle for understanding and communicating the various components and interrelationships of the standards.
- b) The OSI/RM helps define terms.
- c) The OSI/RM provides a convenient framework to aid in the development and enhancement of the standards.
- d) The use of the OSI/RM facilitates a higher degree of interoperability than might otherwise be possible.

Figure 1 shows the architectural view of LAN&MAN/RM and its relation to the OSI/RM.

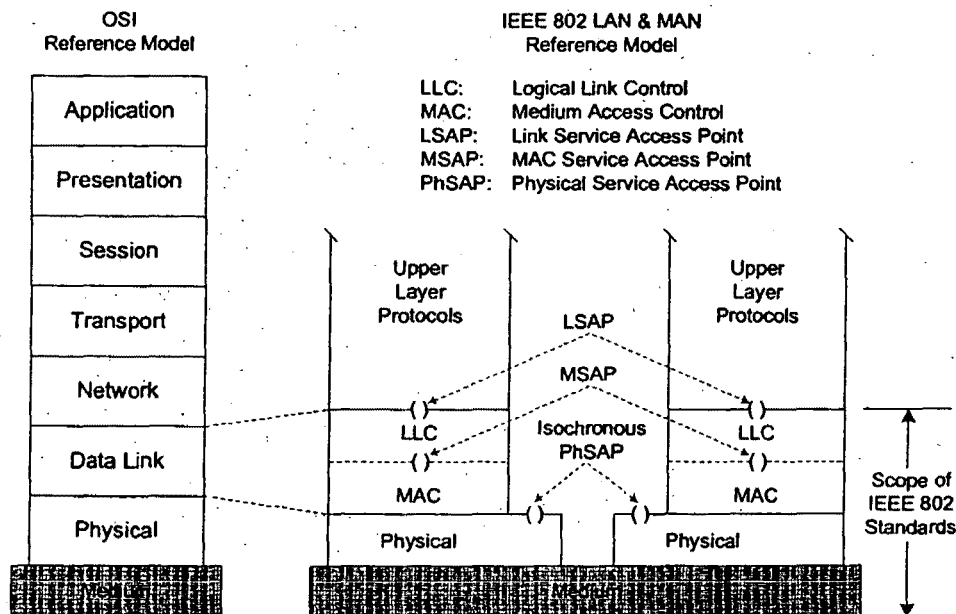


Figure 1—IEEE 802 RM for end stations (LAN&MAN/RM)

The LAN&MAN/IM is more specific than the LAN&MAN/RM, allowing differentiation between implementation approaches (e.g., of carrier sense multiple access with collision detection [CSMA/CD], and token passing). Figure 2 shows two implementation views of LAN&MAN/IMs and their relation to the LAN&MAN/RM.

Both Figure 1 and Figure 2 illustrate the application of the models in LAN end stations. A variation of the model applies within bridges (see 6.3.2). Also, Figure 1 and Figure 2 illustrate only the basic transfer of user data between end stations.

|      |                            |      |                            |
|------|----------------------------|------|----------------------------|
| LLC: | Logical Link Control       | 1:   | Attachment Unit Cable      |
| MAC: | Medium Access Control      | 2:   | Attachment Unit Connectors |
| PHY: | Physical Layer             | AUI: | Attachment Unit Interface  |
| PLS: | Physical Layer Signaling   | MAU: | Medium Attachment Unit     |
| PMA: | Physical Medium Attachment | MDI: | Medium Dependent Interface |

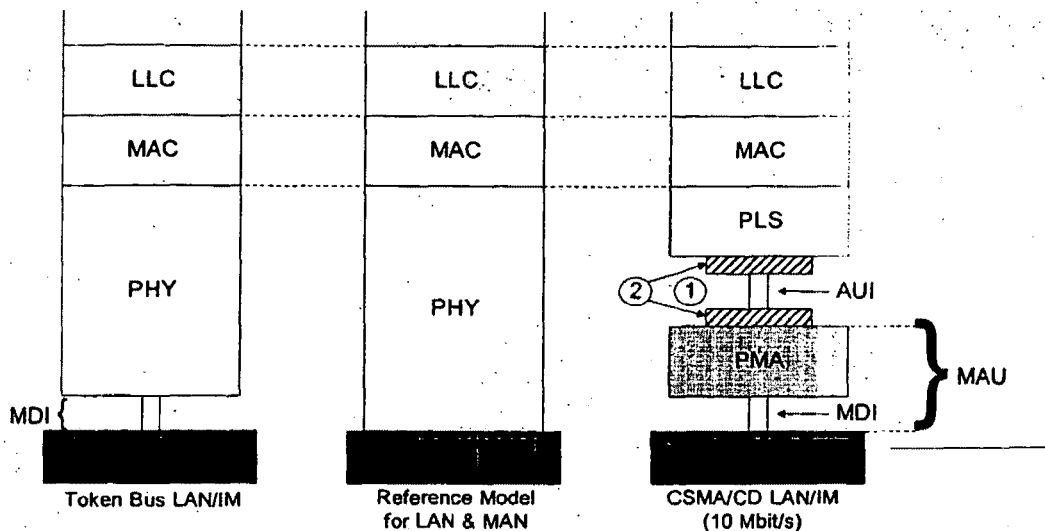


Figure 2—IEEE 802 RM and two examples of end-station implementation model

Considerations of management and security in LANs and MANs are also covered by IEEE 802 standards; these optional features lead to an elaboration of the RM (Figure 3). LAN/MAN management provides a Data Link layer management protocol for exchange of management information between LAN stations; managed objects are defined for all LAN/MAN protocol standards. The Secure Data Exchange (SDE) entity forms part of the LLC sublayer and provides a secure connectionless service immediately above the MAC sublayer.

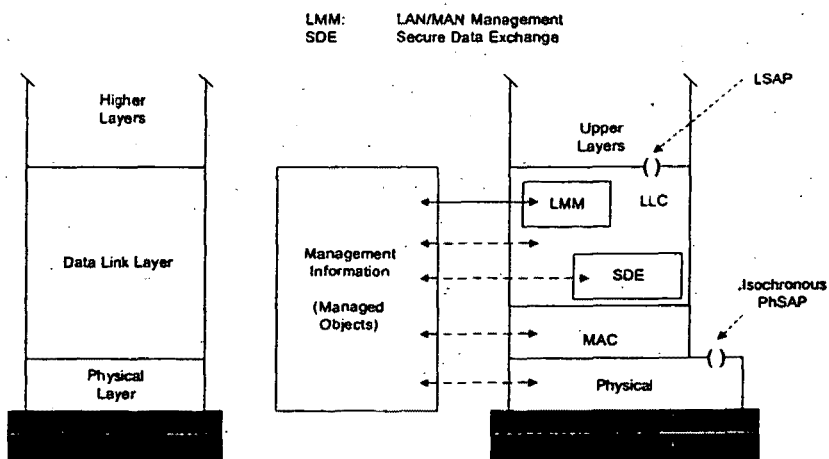


Figure 3—IEEE 802 RM with end-station management and security

## 6.2 RM description for end stations

The LAN&MAN/RM maps to the OSI/RM as shown in Figure 1. The applicable part of the OSI/RM consists of the lowest two layers: the Data Link layer and the Physical layer. These map onto the same two layers in the IEEE LAN&MAN/RM. The MAC sublayer of the LAN&MAN/RM exists between the Physical layer and the LLC sublayer to provide a common service for the LLC sublayer (certain MAC types provide additional MAC service features that can be used by LLC, in addition to the common core features). Service access points (SAPs) for addressing endpoints are shown.

### 6.2.1 Service access points (SAPs)

Multiple-link service access points (LSAPs) provide interface ports to support multiple higher layer users above the LLC sublayer.

The MAC sublayer provides a single MAC service access point (MSAP) as an interface port to the LLC sublayer in an end station. In general, the MSAP is identified (for transmission and reception) by a single individual MAC address and (for reception) by the LAN-wide broadcast MAC address; it can also be identified (for reception) by one or more group MAC addresses. Clause 9 provides details of how these MAC addresses are constructed and used; see also ISO/IEC 15802-1.

A user of LLC is identified by, at a minimum, the logical concatenation of the MAC address field and the LLC address field in a frame. See ISO/IEC 8802-2 and ISO/IEC TR 11802-1 for a description of LLC addresses.

The Physical layer provides an interface port to a single MAC station, and in the case of ISLANs and MANs, it may optionally offer isochronous bearer services at multiple Physical service access points (PhSAPs). See 11.3 for a more detailed description of ISLAN and MAN PhSAP addressing requirements.

### 6.2.2 LLC sublayer

The LLC sublayer standard, ISO/IEC 8802-2, describes three types of operation for data communication between service access points: unacknowledged connectionless-mode (type 1), connection-mode (type 2), and acknowledged connectionless-mode (type 3).

With type 1 operation, information frames are exchanged between LLC entities without the need for the prior establishment of a logical link between peers. The LLC sublayer does not provide any acknowledgments for these LLC frames, nor does it provide any flow control or error recovery procedures.

LLC type 1 also provides a TEST function and an Exchange Identification (XID) function. The capability to act as responder for each of these functions is mandatory. This allows a station that chooses to support initiation of these functions to check the functioning of the communication path between itself and any other station, to discover the existence of other stations, and to find out the LLC capabilities of other stations.

With type 2 operation, a logical link is established between pairs of LLC entities prior to any exchange of information frames. In the data transfer phase of operation, information frames are transmitted and delivered in sequence. Error recovery and flow control are provided, within the LLC sublayer.

With type 3 operation, information frames are exchanged between LLC entities without the need for the prior establishment of a logical link between peers. However, the frames are acknowledged to allow error recovery and proper ordering. Further, type 3 operation allows one station to poll another for data.

NOTE—ISO/IEC 8802-2 defines four classes of LLC, each of which groups together support for a different combination of LLC types. All classes include mandatory support of type 1.

The Secure Data Exchange (SDE) entity forms part of the LLC sublayer and provides a secure connectionless service immediately above the MAC sublayer. The operation of the SDE entity is described in IEEE Std 802.10™.

### 6.2.3 MAC sublayer

The MAC sublayer performs the functions necessary to provide packet-based, connectionless-mode (datagram style) data transfer between stations in support of the LLC sublayer or of the Ethernet sublayer (see 6.1) for LANs that support it. The term *MAC frame*, or simply *frame*, is used to describe the packets transferred within the MAC sublayer. In some MAC types (e.g., Token Ring), some MAC frames are used in support of the MAC sublayer functionality itself, rather than for transfer of LLC data.

The principal functions of the MAC sublayer comprise the following:

- Frame delimiting and recognition
- Addressing of destination stations (both as individual stations and as groups of stations)
- Conveyance of source-station addressing information
- Transparent data transfer of LLC PDUs, or of equivalent information in the Ethernet sublayer
- Protection against errors, generally by means of generating and checking frame check sequences
- Control of access to the physical transmission medium

Other functions of the MAC sublayer—applicable particularly when the supporting implementation includes interconnection devices such as hubs or bridges—include flow control between an end station and an interconnection device (see 6.3), and filtering of frames according to their destination addresses to reduce the extent of propagation of frames in parts of a LAN or MAN that do not contain communication paths leading to the intended destination end station(s).

The functions listed are those of the MAC sublayer as a whole. Responsibility for performing them is distributed across the transmitting and receiving end stations, and any interconnection devices such as bridges. Devices with different roles therefore can behave differently in support of a given function. For example, transmission of a MAC frame by a bridge is very similar to transmission by an end station, but not identical. Principally, the handling of source-station addressing is different.

The various MAC specifications all specify MAC frame formats in terms of a serial transmission model for the service provided by the supporting Physical layer. This model supports concepts such as “first bit (e.g., of a particular octet) to be transmitted,” and a strict order of octet transmission, in a uniform manner. However, the ways in which the model has been applied in different MAC specifications are not completely uniform with respect to bit-ordering within octets (see Clause 9, and particularly 9.5, for examples and explanation).

NOTE—The serial transmission model does not preclude current or future MAC specifications from using partly or wholly octet-oriented specifications of frame formats or of the interface to the Physical layer.

### 6.2.4 Physical layer

The Physical layer provides the capability of transmitting and receiving bits between Physical layer entities. A pair of Physical layer entities identifies the peer-to-peer unit exchange of bits between two MAC users, and in the case of ISLANs and MANs, it may optionally support the exchange of bits with end-to-end timing preserved between isochronous-service PhSAPs.

The Physical layer provides the capability of transmitting and receiving modulated signals assigned to specific frequency channels, in the case of broadband or wireless, or to a single-channel band, in the case of baseband.



Note that, whereas the service offered to the MAC sublayer is expressed as the transfer of bits (in sequences representing MAC frames), the actual symbols that are encoded for transmission do not always represent individual bits. Particularly at speeds of 100 Mbit/s and above, or for wireless transmission, the Physical layer can map blocks of several bits (e.g., 4, 5, or 8 bits) to different multi-element symbols. In some Physical-layer encodings, these symbols are subject to further transformation before transmission, and in some cases, the transmission is spread over multiple physical data paths. The actual transmission on physical media can therefore be far removed from the simple bit-serial representation of a MAC frame (as was specified, for example, in the original ISO/IEC 8802-3 and ISO/IEC 8802-5 Physical layers).

### 6.2.5 Layer and sublayer management

The LLC sublayer, MAC sublayer, and Physical layer standards also include a management component that specifies managed objects and aspects of the protocol machine that provides the management view of these resources. See Clause 8 for further information.

## 6.3 Interconnection and interworking

In some cases, the end systems on a LAN or MAN have no need to communicate with end systems on other networks (other LANs, WANs, etc.). However, this is not expected to be the norm; there are many cases in which end stations on a LAN or MAN will need to communicate with end systems on other networks and so devices that interconnect the LAN or MAN with other kinds of networks are required. In addition, several standard methods have been developed that permit a variety of interconnection devices to operate transparently to end stations on a LAN or MAN in order to extend the LAN/MAN capabilities available to end stations, particularly in terms of the geographical extent and/or total number of end stations that can be supported.

Standard methods of interworking fall into the following three general categories, depending on the layer at which the corresponding interconnection devices operate:

- Physical-layer interconnection, using devices usually termed *repeaters* or *hubs* (6.3.1)
- MAC-sublayer interconnection, using devices termed *bridges* (6.3.2)
- Network-layer interconnection, using devices usually termed *routers* (6.3.3)

See also Clause 11 of this standard, for an outline of the optional methods by which ISLANs and MANs may support isochronous interworking with WANs and with remote ISLANs and MANs.

### 6.3.1 Physical-layer interconnection: repeaters and hubs

The original IEEE 802 LAN specifications were for end stations attached to a shared communication medium. This basic LAN configuration is referred to as a single *access domain*; the domain consists of the set of LAN stations such that at most one can be transmitting at a given time, with all other stations acting as (potential) receivers.

A repeater is a device used to interconnect segments of the physical communications media, for example, to extend the range of a LAN when the physical specifications of the technology would otherwise be exceeded, while providing a single access domain for the attached LAN stations. Repeaters used in support of multiple end stations attached by star-wired network topologies are frequently referred to as hubs.

### 6.3.2 MAC-sublayer interconnection: bridges

#### 6.3.2.1 Bridges and bridged LANs

Bridges (see 3.1.3) are devices that interconnect multiple access domains. ISO/IEC 15802-3 provides the basic specification for bridge interworking among IEEE 802 networks. A *bridged LAN* (see 3.1, of ISO/IEC 15802-3) consists of one or more bridges together with the complete set of access domains that they interconnect. A bridged LAN provides end stations belonging to any of its access domains with the appearance of a LAN that contains the whole set of attached end stations.

A bridged LAN can provide for the following:

- Communication between stations attached to LANs of different MAC types
- An increase in the total throughput of a LAN
- An increase in the physical extent of, or number of permissible attachments to, a LAN
- Partitioning of the physical LAN for administrative or maintenance reasons

The term *switch* is often used to refer to some classes of bridge. However, there is no consistent meaning applied to the distinction between the terms bridge and switch, and ISO/IEC 15802-3 does not make any such distinction. Hence, this standard only uses the term bridge.

#### 6.3.2.2 Relaying and filtering by bridges

A bridge processes protocols in the MAC sublayer and is functionally transparent to LLC and higher layer protocols. MAC frames are forwarded between access domains, or filtered (i.e., not forwarded to certain access domains), on the basis primarily of MAC addressing information. Figure 4 shows the position of the bridging functions within the MAC sublayer; note particularly that the relaying and filtering functions are considered to belong entirely within the MAC sublayer.

Filtering by bridges tends to confine traffic to only those parts of the bridged LAN that lie between transmitting end stations and the intended receivers. This permits a bridged LAN to support several transmitting end stations at any given time (up to the total number of access domains present).

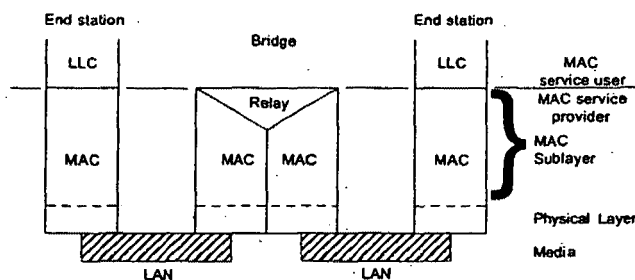


Figure 4—Internal organization of the MAC sublayer with bridging

#### 6.3.2.3 The Spanning Tree Protocol

A key aspect of ISO/IEC 15802-3 is its specification of the Spanning Tree Protocol, which is used by bridges to configure their interconnections in order to prevent looping data paths in the bridged LAN. In the event that the basic interconnection topology of bridges and LANs contains multiple possible paths between certain points, use of the Spanning Tree Protocol blocks some paths in order to produce a simply connected

active topology for the flow of MAC user traffic between end stations. For each point of attachment of a bridge to a LAN, the Spanning Tree Protocol selects whether or not MAC user traffic is to be received and transmitted by the bridge at that point of attachment.

The Spanning Tree Protocol adapts to changes in the configuration of the bridged LAN, maintaining connectivity while avoiding data loops. Some configuration changes can cause temporary interruptions of connectivity between parts of the bridged LAN, typically lasting for a few tens of seconds at most.

#### 6.3.2.4 Transparent bridging and source routing

ISO/IEC 15802-3 specifies *transparent bridging* operation, so called because the MAC bridging function does not require the MAC user frames transmitted and received to carry any additional information relating to the operation of the bridging functions; end-station operation is unchanged by the presence of bridges.

Also specified, in an annex to ISO/IEC 15802-3, is the operation of a Source Routing Transparent (SRT) bridge. This adds the ability for a *source-routing* function in a bridge to use explicit MAC-sublayer routing information contained in MAC user frames; this source-routing information is inserted by the transmitting end station. Source routing is specified only for ISO/IEC 8802-5 Token Ring and ISO/IEC 9314 FDDI LANs, and for IEEE 802.12™ Demand Priority LANs when operating with 8802-5 format frames.

#### 6.3.2.5 Remote MAC bridging

ISO/IEC 15802-5 extends the specification in ISO/IEC 15802-3 to cover remote MAC bridging, where non-IEEE 802 communications technologies are used to interconnect bridges, for example, to allow a bridged LAN to include WAN links to provide greatly extended geographical range. Figure 5 shows the corresponding organization of the MAC sublayer.

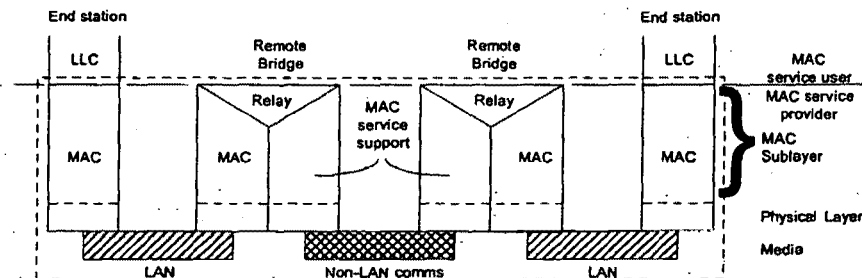


Figure 5—Internal organization of MAC sublayer with remote bridges

#### 6.3.2.6 Bridging example

Some bridges are used to interconnect access domains each containing a very small number of end stations (often, a single end station). Others interconnect multiple access domains containing principally other bridges, thus, forming a backbone for the bridged LAN. (Hybrid configurations, with characteristics of both kinds of bridge, are of course possible.) Bridged LAN configurations involving these kinds of interconnection have become widespread as the IEEE 802 LAN technologies have developed. As noted in 1.2, they allow the construction of networks with much larger numbers of end stations and much higher aggregate throughput than was previously achievable.

Figure 6 illustrates the kind of bridged LAN that can be configured with bridge-style interconnection. The bridges A and B, and the CSMA/CD LAN configurations to which they attach, are typical of the older style of bridged LAN in which a bridge interconnects a small number of access domains each containing many end stations, as is similar with K, L, and M and their Token Ring LANs. On the other hand, the bridges S, T,

and U function as bridges in a high-speed backbone that combines FDDI and 100-Mbit/s IEEE 802.3 LANs. S is a backbone bridge, handling a number of high-speed LAN attachments. T and U are bridges that support multiple end stations, with connection to the backbone. B and K also provide access to the backbone. The end station shown connected to S by a point-to-point link could be a server system, as might the end stations attached to the FDDI LAN.

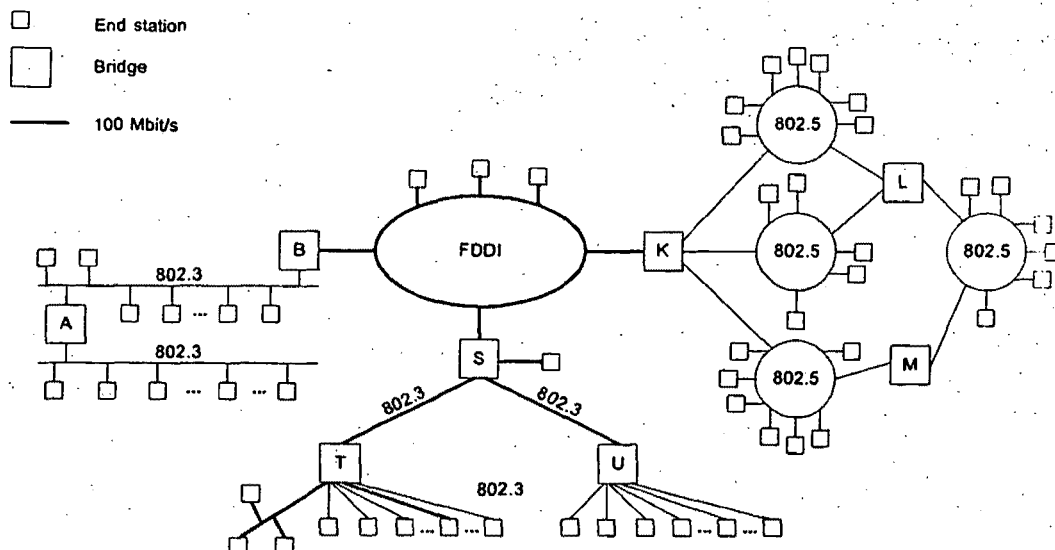


Figure 6—A bridged LAN

### 6.3.3 Network-layer interconnection: routers

The third category of interconnection uses Network-layer interconnection devices, generally known as routers, that operate as LAN/MAN end stations. These process Network layer protocols that operate directly above the LLC sublayer or equivalent, with forwarding decisions based on Network layer addresses. Details of this kind of interconnection lie outside of the scope of IEEE 802 LAN/MAN Standards, but the various standard and proprietary Network-layer protocols involved represent a very substantial part of the user traffic on many real IEEE 802 networks. In particular, IEEE 802 LANs and MANs are often interconnected by routers for the Internet Protocol (IP) and its related routing and management protocols, either directly to other LANs or by means of WAN links.

## 7. General requirements for an 802 LAN or MAN

### 7.1 Services supported

With the descriptions in Clause 6 as a basis, an IEEE 802 LAN or MAN can be characterized as a communication resource that provides sufficient capabilities to support the MAC service defined in ISO/IEC 15802-1, between two or more MSAPs. In particular, this requires the ability to convey LLC data from one MSAP to  $n$  other MSAPs, where  $n$  can be any number from 1 to all of the other MSAPs on the network. An IEEE 802 LAN is required, at a minimum, to support both LLC Type 1 and the MAC Internal Sublayer Service defined in ISO/IEC 15802-3. In addition, an ISLAN or MAN may optionally support isochronous bearer services compatible with ISDN services as defined in the ITU-T I-series Recommendations.

## 7.2 Size and extent

The original IEEE 802 LAN and MAN technologies were designed to be capable of supporting access domains containing at least 200 end stations and with geographical extent of at least 2 km for LANs (using Physical-layer repeaters if necessary) and 50 km for MANs. Subsequent developments in IEEE 802 LAN technology and performance have been accompanied by a reduction in the size and extent required in individual access domains, recognizing that these can readily and cost-effectively be interconnected in bridged LANs that are capable of offering at least the original minimum size and extent, with increased overall bandwidth and performance. Size and extent requirements for future IEEE 802 LAN technologies are, similarly, expected to be determined by application needs and opportunities.

## 7.3 Error rates

Error performance of IEEE 802 LANs and MANs is required to be such as follows:

- a) For wired or optical fiber physical media: Within a single access domain, the probability that a transmitted MAC frame (excluding any preamble) is not reported correctly at the Physical Service interface of an intended receiving peer MAC entity, due only to operation of the Physical layer, shall be less than  $8 \times 10^{-8}$  per octet of MAC frame length.
- b) For wireless physical media: Within a single access domain, the probability that a MAC Service Data Unit (MSDU) is not delivered correctly at an MSAP of an intended receiving MAC service user, due to the operation of the Physical layer and the MAC protocol, shall be less than  $8 \times 10^{-8}$  per octet of MSDU length.

NOTE—The performance measure stated in (a) defines a highly desirable characteristic of LAN performance, as it has a bearing on other aspects of the delivered service, such as frame loss and transmission delays caused by the need to retransmit. However, this measure is not realistic for all physical media; for example, wireless media may be unable to meet this level of physical layer performance due to the inherent transmission characteristics of the medium. In such cases, the operation of the MAC protocol must employ additional mechanisms, for example, error detection and correction mechanisms, in order to enable the MAC service provider to meet the performance levels implied by this condition in the service offered at the MAC service boundary.

- c) The probability that an MSDU delivered at an MSAP contains an undetected error, due to operation of the MAC service provider, shall be less than  $5 \times 10^{-14}$  per octet of MSDU length.

NOTE—For example, (a) the worst-case probability of losing a maximum-length IEEE 802.3 frame (1518 octets) through physical-layer damage is to be less than  $1.21 \times 10^{-4}$ , or approximately 1 in 8250; (c) the worst-case probability that a similar frame, which contains an MSDU of 1500 octets, is delivered with an undetected error is to be less than  $7.5 \times 10^{-11}$ , or approximately 1 in 13 300 000 000.

## 7.4 Service availability

Insertion of a device into, or removal of a device from, a LAN or MAN shall cause at most a transient loss of availability of the access domain(s) to which the device attaches, lasting not more than 1 s. Failure of a device, including loss of power, shall not cause more than a transient fault for the access domain(s) to which it attaches, with duration of order 1 s.

NOTE—In a bridged LAN, reconfiguration of the topology in response to logical insertion or removal of a bridge, or to changes in a bridge's configuration parameters, can cause loss of communication between some access domains for longer periods, typically a few tens of seconds; ISO/IEC 15802-3 contains the full specification.

## 7.5 Safety, and lightning and galvanic protection

Equipment implementing IEEE 802 LAN and MAN standards is typically subject to guidance and requirements relating to safety and to protection of the equipment and its users from lightning and galvanic effects. Such guidance and requirements are outside of the scope of IEEE 802 standardization; they are

typically specified by other organizations with different legal, geographical, and industrial scope. However, the general underlying concerns can have an influence on the Physical layer aspects of IEEE 802 LAN and MAN standards.

## 7.6 Regulatory requirements

Equipment implementing IEEE 802 LAN and MAN standards may be subject to regulations imposed within particular geographical and political domains. For example, the deployment of equipment implementing IEEE 802 wireless LAN standards may be subject to local regulations that pertain to the use of radio-frequency transmission. Such regulations are outside of the scope of IEEE 802 standardization; they are typically specified by other organizations with different legal, geographical, and industrial scope. However, the general underlying concerns can have an influence on the Physical layer aspects of IEEE 802 LAN and MAN standards.

## 8. LAN/MAN management

The provision of an adequate means of remote management is an important factor in the design of today's LAN equipment. Such management mechanisms fall into two broad categories: those that provide general-purpose management capability, allowing control and monitoring for a wide variety of purposes, and those that provide specific capabilities aimed at a particular aspect of management. These aspects of management are discussed in 8.1 and 8.2, respectively.

### 8.1 General-purpose LAN/MAN management

This subclause introduces the functions of management to assist in the identification of the requirements placed on IEEE 802 LAN/MAN equipment for support of management facilities, and it identifies general-purpose management standards that may be used as the basis of developing management specifications for such equipment.

#### 8.1.1 Management functions

Management functions relate to users' needs for facilities that support the planning, organization, supervision, control, protection and security of communications resources, and account for their use. These facilities may be categorized as supporting the functional areas of configuration, fault, performance, security, and accounting management. These can be summarized as follows.

- Configuration management provides for the identification of communications resources, initialization, reset and close-down, the supply of operational parameters, and the establishment and discovery of the relationships between resources.
- Fault management provides for fault prevention, detection, diagnosis, and correction.
- Performance management provides for evaluation of the behavior of communications resources and of the effectiveness of communication activities.
- Security management provides for the protection of resources.
- Accounting management provides for the identification and distribution of costs and the setting of charges.
- Management facilities in LAN/MAN equipment will address some or all of these areas, as appropriate to the needs of that equipment and the environment in which it is to be operated.

### 8.1.2 Management architecture

The management facilities defined in IEEE 802 LAN and MAN standards are based on the concept of managed objects, which model the semantics of management operations. Operations on a managed object supply information concerning, or facilitate control over, the process or entity associated with that object.

Operations on a managed object can be initiated by mechanisms local to the equipment being managed (e.g., via a control panel built into the equipment), or can be initiated from a remote management system by means of a general-purpose management protocol carried using the data services provided by the LAN or MAN to which the equipment being managed is connected:

There are two general-purpose management protocols of relevance to the management of LAN/MAN equipment, as follows:

- The Simple Network Management Protocol (SNMP), as described in RFC 1157
- The OSI common management information protocol (CMIP), as described in ISO/IEC 9595 and ISO/IEC 9596 and related standards

NOTE—In addition to operation of CMIP over a full OSI protocol stack, two standards define the use of CMIP over simpler protocol support. ISO/IEC 15802-2 (IEEE Std 802.1B™-1995) defines a means of using CMIP over a simple Data Link layer protocol stack in LANs; RFC 1095 describes the use of CMIP over a TCP/IP protocol stack.

Of the two protocols, SNMP is the more significant in terms of its wide application across the spectrum of LAN/MAN products in today's marketplace; however, in some markets, and where it is desirable to integrate LAN management with management of wide-area networking and telephony equipment, use of the OSI management protocols may be important.

### 8.1.3 Managed object definitions

In order for an IEEE 802 standard to specify management facilities, it is necessary for them to define managed objects that model the operations that can be performed on the communications resources specified in the standard. There are essentially two components to a managed object definition, as follows:

- 1) A definition of the functionality provided by the managed object, and the relationship between this functionality and the resource to which it relates
- 2) A definition of the syntax that is used to convey management operations, and their arguments and results, in a management protocol

The functionality of a managed object can be described in a manner that is independent of the protocol that will be used; this abstract definition can then be used in conjunction with a definition of the syntactic elements required in order to produce a complete definition of the object for use with specific management protocols.

Each management protocol has its notation for defining managed objects, as follows:

- a) SNMP has standards for the structure of management information known as SMIV1 (RFC 1155, RFC 1212 and RFC 1215) and SMIV2 (RFC 1902, RFC 1903 and RFC 1904), which provides ASN.1-based macros for defining managed objects.
- b) CMIP has a standard language, known as GDMO (ISO/IEC 10165-4), which is used along with ASN.1 to define both the syntactic and semantic aspects of managed objects.

The choice of notational tools for defining managed objects will depend on which of the available management protocols the standard will support.

## NOTES

1—IEEE Std 802.1F™ provides additional guidance for use of GDMO in LAN/MAN standards.

2—Some IEEE 802 standards have used GDMO as the notation for their managed object definitions, with SNMP management information base (MIB) definitions being developed subsequently within the IETF, using automatic tools for translating GDMO definitions into equivalent SNMP definitions.

## 8.2 Special-purpose LAN/MAN management standards

Special-purpose protocols relating to the management functionality of IEEE 802 stations can be developed where the use of a general-purpose management protocol is inappropriate. An example of a special-purpose management protocol is ISO/IEC 15802-4, which defines the services and protocols for remote station loading in a LAN/MAN environment. This protocol permits the simultaneous loading of multiple stations by use of the group-addressing capability in IEEE 802 technologies.

## 9. Universal addresses and protocol identifiers

The IEEE makes it possible for organizations to employ unique individual LAN MAC addresses, group addresses, and protocol identifiers. It does so by assigning Organizationally Unique Identifiers (OUIs), which are three octets (24 bits) in length. Because the assignment of the OUI in effect reserves a block of each derivative identifier (i.e., blocks of individual LAN MAC addresses, group addresses, and protocol identifiers), the address space of the OUI is chosen to be large. Although the OUIs are 24 bits in length, their true address space is 22 bits. The LSB of the first octet can be set to 1 or 0 depending on the application. The next-to-LSB of the first octet is 0, for all assignments. The remaining 22 bits, which shall not be changed by the assignee, result in 2<sup>22</sup> (approximately 4 million) identifiers; see Figure 7.

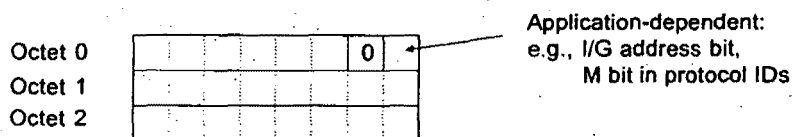


Figure 7—OUI

The universal administration of LAN MAC addresses began with the Xerox Corporation administering Block Identifiers (Block IDs) for Ethernet addresses. Block IDs were assigned by the Ethernet Administration Office and were 24 bits in length (three octets). An organization developed addresses by assigning the remaining 24 bits. For example, the address as represented by the six octets P-Q-R-S-T-U comprises the Block ID, P-Q-R, and the locally assigned octets S-T-U.

The IEEE, because of the work in Project 802 on standardizing LAN technologies, has assumed the responsibility of defining and carrying out procedures for the universal administration of addresses for IEEE and ISO/IEC LANs (e.g., CSMA/CD, Token Bus, Token Ring, and FDDI). In carrying out the procedures, the IEEE acts as the Registration Authority for OUIs.<sup>7</sup> The responsibility for defining the procedures is discharged by the IEEE Registration Authority Committee (RAC), which is chartered by the IEEE Standards Association Board of Governors.

The IEEE honors the Block ID assignments made by the predecessor administration office where those assignments fall—as the great majority of them do—within the space administered by the IEEE. The Block ID is referred to as the OUI by the IEEE.

<sup>7</sup> Interested applicants should contact the IEEE Registration Authority, Institute of Electrical and Electronic Engineers Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.



## 9.1 OUI

OUIs allow a general means of assuring unique identifiers for a number of purposes. Currently, the IEEE assigns OUIs to be used for generating LAN MAC addresses and protocol identifiers. Assuming correct administration by the IEEE Registration Authority and the assignee, the LAN MAC addresses and protocol identifiers will be universally unique.

OUIs are assigned as three-octet values. Both values (0, 1) are assigned to the LSB of the first octet. The next-to-LSB of the first octet is set to 0; this bit of the OUI being set to 0 indicates that the assignment is universal. Three-octet values occupying the same fields as OUIs can occupy, but with the next-to-LSB of the first octet set to 1, are locally assigned and have no relationship to the IEEE-assigned values (as described herein).

The standard representation of the OUI is as a string of three octets, using the hexadecimal representation (see 3.1.8).

## 9.2 48-bit universal LAN MAC addresses

### 9.2.1 Concept

The concept of universal addressing is based on the idea that all potential members of a network need to have a unique identifier (if they are going to coexist in the network). The advantage of a universal address is that a station with such an address can be attached to any LAN in the world with an assurance that the address is unique.

A 48-bit universal address consists of two parts. The first 24 bits correspond to the OUI as assigned by the IEEE, except that the assignee may set the LSB of the first octet to 1 for group addresses or set it to 0 for individual addresses. The second part, comprising the remaining 24 bits, is administered by the assignee. In the 48-bit LAN MAC address, an example of which is shown in Figure 8, the OUI is contained in octets 0, 1, 2, and the value assigned by the assignee is contained in octets 3, 4, 5. This address, including its OUI, is used throughout this document as the basis for examples of LAN MAC addresses and protocol identifiers.

**NOTE**—The requirement for the use of 64-bit addresses in new applications is under consideration by the IEEE Registration Authority (RAC).

The standard representation of a 48-bit LAN MAC address is as a string of six octets, using the hexadecimal representation (3.1.8). In certain contexts associated with use of IEEE 802.5 frame formats, LAN MAC addresses may be represented using the alternative bit-reversed representation (3.1.2). See 9.5 for further specification relating to use of the bit-reversed representation.

**NOTE**—The upper, bit-stream representation of the universal address in Figure 8 shows the LSB of each octet first; this corresponds to the data-communications convention for representing bit-serial transmission in left-to-right order, applied to the model for transmission of LAN MAC address fields (see 6.2.3). See also 9.5 for further discussion of bit-ordering issues. The lower, octet-sequence representation shows the bits within each octet in the usual order for binary numerals; the order of octet transmission is from the top downward.

Hexadecimal representation: AC-DE-48-00-00-80  
 Bit-reversed representation: 35:7B:12:00:00:01

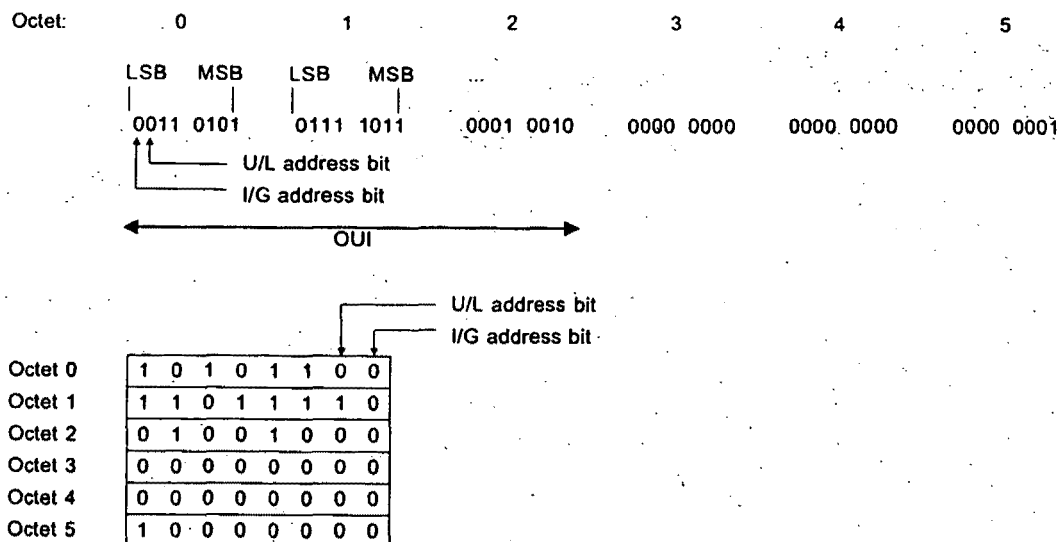


Figure 8—Universal address

The Individual/Group (I/G) address bit (LSB of octet 0) is used to identify the destination address as an individual address or a group address. If the I/G address bit is 0, it indicates that the address field contains an individual address. If this bit is 1, the address field contains a group address that identifies one or more (or all) stations connected to the LAN. The all-stations broadcast address is a special, predefined group address of all 1's.

The Universally or Locally administered (U/L) address bit is the bit of octet 0 adjacent to the I/G address bit. This bit indicates whether the address has been assigned by a local or universal administrator. Universally administered addresses have this bit set to 0. If this bit is set to 1, the entire address (i.e., 48 bits) has been locally administered.

### 9.2.2 Assignment by organizations

Varying the last 24 bits in the block of MAC addresses for a given OUI allows the OUI assignee approximately 16 million unique individual addresses and 16 million unique group addresses that no other organization may assign (i.e., universally unique). The IEEE intends not to assign additional OUIs to any organization unless the organization has exhausted this address block. Therefore, it is important for the IEEE to maintain a single point of contact with each assignee to avoid complicating the assignment process. It is important to note that in no way should these addresses be used for purposes that would lead to skipping large numbers of them (for example, as product identifiers for the purpose of aiding company inventory procedures). The IEEE asks that organizations not misuse the assignments of the last 24 bits and thereby unnecessarily exhaust the block. There are sufficient identifiers to satisfy most needs for a long time, even in volume production; however, no address space is infinite.

The method that an assignee uses to ensure that no two of its devices carry the same address will, of course, depend on the assignment or manufacturing process, the nature of the organization, and the organization's philosophy. However, the users of networks worldwide expect to have unique addresses. The ultimate responsibility for assuring that user expectations and requirements are met, therefore, lies with the organization offering such devices.

### 9.2.3 Uniqueness of address assignment

An issue to be considered is the nature of the device to which uniqueness of address assignment applies.

The recommended approach is for each device associated with a distinct point of attachment to a LAN to have its own unique MAC address. Typically, therefore, a LAN adapter card (or, e.g., an equivalent chip or set of chips on a motherboard) should have one unique MAC address for each LAN attachment that it can support at a given time.

**NOTE**—It is recognized that an alternative approach has gained currency in some LAN implementations, in which the device is interpreted as a complete computer system, which can have multiple attachments to different LANs. Under this interpretation, a single LAN MAC address is used to identify all of the system's points of attachment to the LANs in question. This approach, unlike the recommended one, does not automatically meet the requirements of IEEE Std 802.1D-1998 MAC bridging.

### 9.3 Protocol identifiers

Clause 10 specifies the Subnetwork Access Protocol (SNAP), which permits multiplexing and demultiplexing of private and public protocols (see 10.1) among multiple users of a data link. An organization that has an OUI assigned to it may use its OUI to assign universally unique protocol identifiers to its own protocols, for use in the protocol identification field of SNAP PDUs (see 10.3).

The protocol identifier is five octets (40 bits) in length and follows the LLC header in a frame. The first three octets of the protocol identifier consist of the OUI in exactly the same fashion as in 48-bit LAN MAC addresses. The remaining two octets (16 bits) are administered by the assignee. In the protocol identifier, an example of which is shown in Figure 9, the OUI is contained in octets 0, 1, 2 with octets 3, 4 being assigned by the assignee of the OUI.

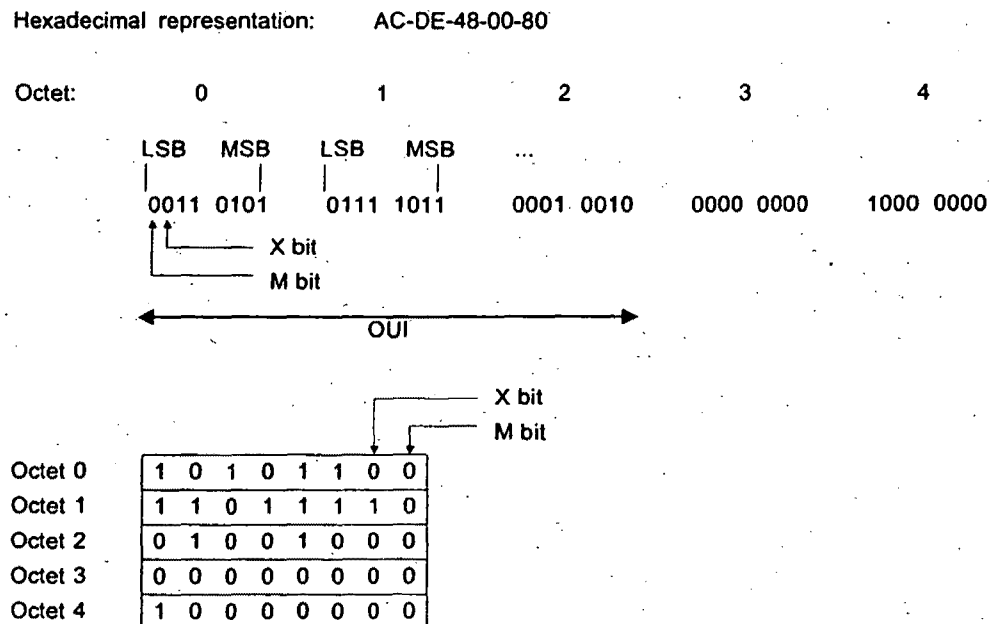


Figure 9—Protocol identifier

The standard representation of a protocol identifier is as a string of five octets, using the hexadecimal representation (3.1.8).

The LSB of the first octet of a protocol identifier is referred to as the M bit. All identifiers derived from OUIs assigned by the IEEE shall have the M bit set to 0. Values with the M bit set to 1 are reserved.

Protocol identifiers may be assigned universally or locally. The X bit of a protocol identifier is the bit of the first octet adjacent to the M bit. All identifiers derived from OUIs assigned by the IEEE will have the X bit set to 0 and are universally assigned. Values with the X bit set to 1 are locally assigned and have no relationship to the IEEE-assigned values. They may be used, but there is no assurance of uniqueness.

#### 9.4 Standard group MAC addresses

The previous subclauses described the assignment of individual and group MAC addresses, and protocol identifiers for public or private use by private organizations. There is also a need for standard group MAC addresses to be used with standard protocols. The administration of these addresses, including the procedure for application and a list of currently assigned values, is defined in ISO/IEC TR 11802-2. These standard group MAC addresses come from a block of universally administered LAN MAC addresses derived from an OUI that has been assigned by the IEEE for this purpose.

ISO/IEC 8802-5 also defines *functional addresses*, for use in Token Ring LAN environments to identify well-known functional entities. These addresses are a subset of the locally administered group MAC addresses, identified by having the 15 address bits that follow the I/G and U/L address bits set to zero. Certain values are used consistently throughout Token Ring LAN environments and, therefore, play a very similar role to standard group MAC addresses; these functional address values are also recorded in ISO/IEC TR 11802-2.

#### 9.5 Bit-ordering and different MACs

NOTE—Throughout this subclause, considerations relating to the order of bit and/or octet transmission refer to the basic bit-serial model of transmission that applies to the representation of MAC frames at the boundary between the MAC sublayer and the Physical layer; see 6.2.3.

##### 9.5.1 General considerations

The transmission of data on IEEE 802.3 and 802.4™ LAN types is represented (6.2.3) as occurring LSB first within each octet. This is true for the entire frame: LAN MAC address fields (source and destination), MAC-specific fields (e.g., length field in IEEE 802.3 LANs), and the MAC Information field. (The MAC Information field is defined to be that part of the frame starting directly after the MAC header and ending immediately before the frame check sequence: e.g., LLC information, such as the Protocol Identification field, is contained in the MAC Information field.)

On some other LAN types, for which IEEE 802.5 is here used as the typical example, each octet of the MAC Information field is represented as being transmitted MSB first. The LAN MAC address fields (source and destination), however, are represented as being transmitted with the LSB of each octet first. Thus, the first bit transmitted is the I/G Address Bit, as on IEEE 802.3 and IEEE 802.4 LANs. For frames that originate within the MAC (e.g., MAC-embedded management frames), the ordering of bits within the MAC Information field is defined by the MAC specification—ISO/IEC 8802-5, etc.

For most purposes, the difference in the bit-orderings used to represent transmission of the octets of the MAC Information field is of no consequence, whether considered within a given MAC type, or across different MAC types. Each octet of user data is mapped to and from the appropriate ordering, symmetrically by the transmitting and receiving MAC entities. An unfortunate exception has occurred, however, where the octets concerned are those of a MAC address that is embedded, as user data, in the MAC Information field.

The consequences particularly affect the use of MAC addresses in mixed environments containing Token Ring LANs and non-Token-Ring LANs.

The following subclauses describe the problem and some of the issues arising from it.

### 9.5.2 Illustrative examples

This subclause illustrates the various bit- and octet-transmission scenarios that can occur, and it is intended as a basis for clarifying the issue of bit ordering for LAN MAC addresses across different MACs. Throughout, the examples make use of the OUI value AC-DE-48, introduced in 9.2.1. This three-octet value is considered in its two possible roles: as the first part of a five-octet protocol identifier, and as the first part of a six-octet LAN MAC address. The consistent representations of the OUI in its role as part of a protocol identifier are contrasted with the sometimes variable representations that apply to its role as part of a MAC address.

NOTE—Protocol identifiers always form part of the normal user data in a MAC Information field; hence, there is nothing special about OUI octets in their protocol identifier role.

For the examples, the bit significance of an OUI in general is defined to be as in Figure 10.

|         | MSB |   |   |   |   |   | LSB |   |
|---------|-----|---|---|---|---|---|-----|---|
| Octet 0 | h   | g | f | e | d | c | b   | a |
| Octet 1 | p   | o | n | m | l | k | j   | i |
| Octet 2 | x   | w | v | u | t | s | r   | q |

When used in LAN MAC addresses:

Bit "a" of the OUI = I/G address bit.

Bit "b" of the OUI = U/L address bit.

When used in protocol identifiers:

Bit "a" of the OUI = M bit.

Bit "b" of the OUI (always zero) = X bit.

**Figure 10—Bit significance of an OUI**

When transmitted on an IEEE 802.3 or IEEE 802.4 LAN (all data octets transmitted LSB first), the OUI portions of a protocol identifier and of a LAN MAC address appear as in Figure 11. When transmitted on an IEEE 802.5 LAN (data octets in the MAC Information field transmitted MSB first), the OUI portions of a protocol identifier, and of a LAN MAC address contained in a MAC Address field, appear as in Figure 12

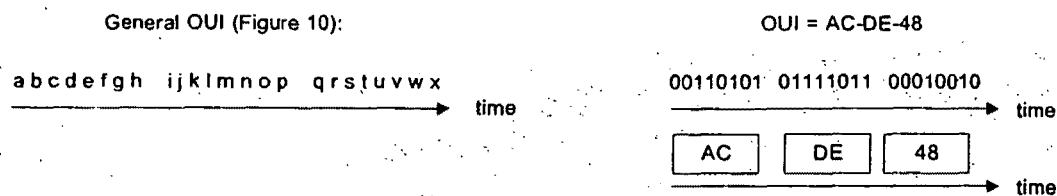
In some circumstances, it is necessary to convey LAN MAC addresses as data within MAC Information fields, e.g., as part of a management protocol or a Network layer routing protocol.

For LAN types in which Figure 11 applies, such as IEEE 802.3, the bit ordering within the octets of a LAN MAC address conveyed as data is the same as both the ordering when the address appears in a MAC address field and the ordering for octets of nonaddress information (see Figure 13).

For LAN types in which Figure 12 applies, such as IEEE 802.5 and FDDI, there appears to be a choice of representations for MAC addresses conveyed as data, as follows:

- The octets of the MAC address can be treated like any other data octets and transmitted with the bit-ordering of Figure 12 (A)
- The bit-ordering of Figure 12 (B) can be treated as a property of the MAC address rather than of the MAC address field as transmitted in MAC frames, and the MAC address octets can be transmitted with the bit-ordering reversed compared with normal data octets

(A) OUI within a protocol identifier (in MAC Information field, as normal data):



(B) OUI within a MAC Address field:

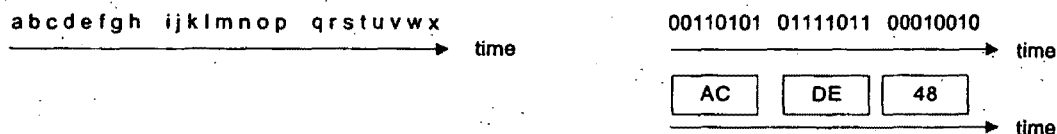
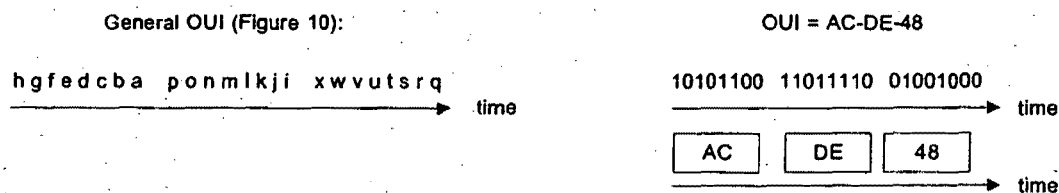


Figure 11—IEEE 802.3, etc., frame: Order of bit and octet transmission for an OUI

(A) OUI within a protocol identifier (in MAC Information field, as normal data):



(B) OUI within a MAC Address field:

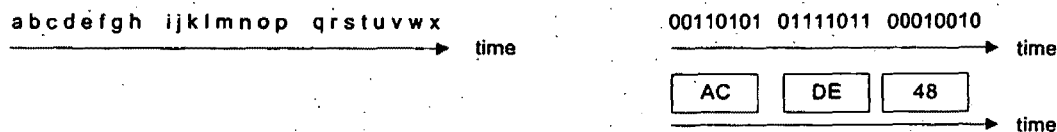


Figure 12—IEEE 802.5, etc., frame: Order of bit and octet transmission for an OUI

OUI within a MAC address contained in the MAC Information field:

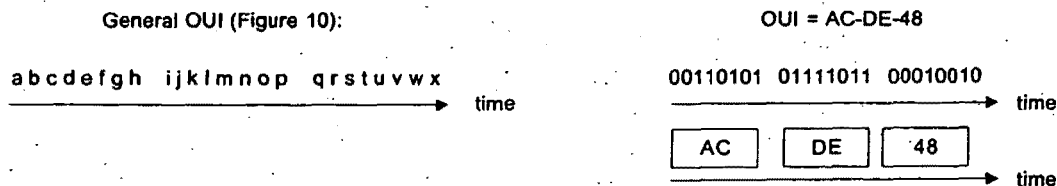


Figure 13—IEEE 802.3, etc., frame: Order of bit and octet transmission for an OUI in a MAC address contained in a MAC Information field

In the case of IEEE 802.5 Token Ring LANs, approach b) was adopted early in the development and deployment of Token Ring technology. This has the unfortunate consequence that applications operating in environments containing a mixture of LAN types have to handle different representations of MAC addresses, according to the environment in which the MAC address is to be used; see Figure 14.

OUI within a bit-reversed MAC address contained in the MAC Information field:

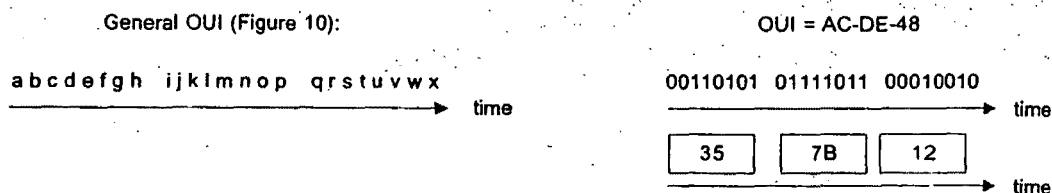


**Figure 14—IEEE 802.5, etc., frame: Order of bit and octet transmission for an OUI in a MAC address contained in a MAC Information field (noncanonical format)**

For other LAN types in which Figure 12 applies, including, in particular, FDDI, approach a) was adopted (Figure 15), at least in environments involving interconnection with IEEE 802.3, and so on, LANs. However, where FDDI LANs are used in an IEEE 802.5 Token Ring environment, approach b) is used for consistency with the interconnected IEEE 802.5 LANs. In a mixed environment of FDDI, IEEE 802.3 and IEEE 802.5 LANs, frames constructed according to both approaches can occur on the FDDI LANs, at least; some care is needed in managing such an installation to avoid confusion between the formats.

OUI within a MAC address contained in the MAC Information field:

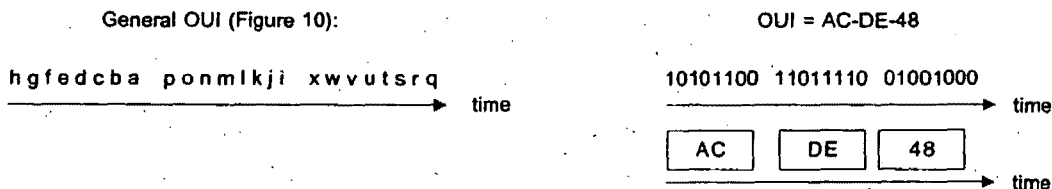


**Figure 15—FDDI frame: Order of bit and octet transmission for an OUI in a MAC address contained in a MAC Information field (canonical format)**

In Figure 11 through Figure 15, it can be seen that the interpretation of OUI bits as octet values is consistent in every case except Figure 14, in which the octet values are bit reversed. This reversal of the bit order applies only to all six octets (not just the OUI) of a MAC address placed in the MAC Information field of a frame by a protocol that uses the Token Ring Bit-reversed view of MAC addresses derived from Figure 12 (B). Frames containing, or possibly containing, such MAC addresses are described as having noncanonical format. Frames (on any LAN or LAN type) that cannot contain such MAC addresses are described as having canonical format.

Note that there is no way of knowing, from MAC layer information only, whether a particular frame is in canonical or noncanonical format. In general, this depends on which higher layer protocols are present in the frame.

### 9.5.3 Recommendation

Designers of protocols that operate above the Data Link layer are strongly recommended to avoid specifying new protocols that result in frames of noncanonical format, except where such a protocol is clearly an extension of existing practice in a strongly Token Ring environment.

## 10. Protocol discrimination above the MAC sublayer: Subnetwork Access Protocol (SNAP) and Ethernet types

### 10.1 Introduction

This clause outlines the mechanisms for the coexistence of multiple standard, public, and private network layer protocols within a single 802 station (10.2). It then describes the functions, features, and protocol format conventions for public and private protocols sharing a single LSAP (10.3). All public and private protocols using the IEEE 802 reserved LLC address assigned for public and private protocol use shall conform to this standard.

This clause further describes Ethernet types used to identify different protocols operating over the alternative Ethernet sublayer (10.4), and it describes the standard encapsulation specified for conveyance of such Ethernet-supported protocols on IEEE 802 LANs that do not intrinsically support an Ethernet sublayer (10.5).

A standard protocol is defined to be a protocol whose specification is published and known to the public but controlled by a standards body. A public protocol is defined to be a protocol whose specification is published and known to the public, but controlled by an organization other than a formal standards body. A private protocol is defined to be a protocol whose use and specification are controlled by a private organization.

By providing for the coexistence of multiple Network layer protocols, the migration of existing LANs to future standard protocols is facilitated, and multiple higher layer protocols are more easily accommodated.

### 10.2 Basic concepts

#### 10.2.1 Coexistence of multiple protocols

Within a given layer, entities can exchange data by a mutually agreed upon protocol mechanism. A pair of entities that do not support a common protocol cannot communicate with each other. For multiple protocols to coexist within a layer, it is necessary to determine which protocol is to be invoked to process a service data unit delivered by the lower layer.

The following subclauses specify mechanisms for use when the LLC sublayer is present above the MAC layer, and when the alternative Ethernet sublayer is present above the MAC sublayer.

#### 10.2.2 Multiple protocols above the LLC sublayer

Standard Network layer protocols have been assigned reserved LLC addresses, as recorded in ISO/IEC TR 11802-1. These addresses permit multiple standard network layer protocols to coexist at a single MAC station. One half of the LLC address space is reserved for such assignment.



Other protocols are accommodated in two ways. One way is by local assignment of LSAPs, for which the other half of the LLC address space is available. Thus, users can agree to use locally assigned LSAPs for either an instance of communication or a type of communication.

The second way is through the use of a particular reserved LLC address value that has been assigned for use in conjunction with the Subnetwork Access Protocol (SNAP, specified in 10.3), which provides for multiplexing and demultiplexing of public and private protocols among multiple users of a data link.

### 10.2.3 Multiple protocols above the Ethernet sublayer

The Ethernet MAC frame format includes a 16-bit type value, whose function is to identify the particular protocol pertaining to the user data contained in the frame. See 10.4 for further details.

## 10.3 Subnetwork Access Protocol

### 10.3.1 SNAP address

The reserved LLC address for use with SNAP is called the SNAP address. It is defined to be the bit pattern (starting with the LSB) Z1010101, in which the symbol Z indicates that either value 0 or 1 can occur, depending on the context in which the address appears (as specified in ISO/IEC 8802-2). The two possible values have Hexadecimal Representation AA and AB.

The SNAP address identifies, at each MSAP, a single LSAP for standard, public, and private protocol usage. To permit multiple public and private network layer protocols to coexist at one MSAP, each public or private protocol using SNAP must employ a protocol identifier that enables SNAP to discriminate among these protocols.

### 10.3.2 SNAP PDU format

Each SNAP PDU shall conform to the format shown in Figure 16 and shall form the entire content of the LLC information field.

In Figure 16, the Protocol Identification field is a five-octet field containing a protocol identifier whose format and administration are as described in 9.3. The Protocol Data field is a field whose length, format, and content are defined by a public or private protocol specification. Each public or private protocol begins its PDU format with the Protocol Identification field, which shall contain the protocol identifier assigned to the protocol.

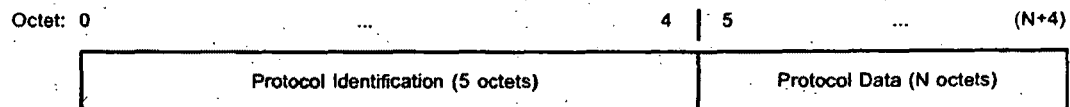


Figure 16—SNAP PDU format

Figure 17 illustrates how a SNAP PDU appears in a complete MAC frame (the IEEE 802.3 MAC format is used for the example). The LLC control field (CTL) is shown for PDU type UI, Unnumbered Information, which is the most commonly used PDU type in this context; however, other information-carrying LLC PDU types may also be used with SNAP.

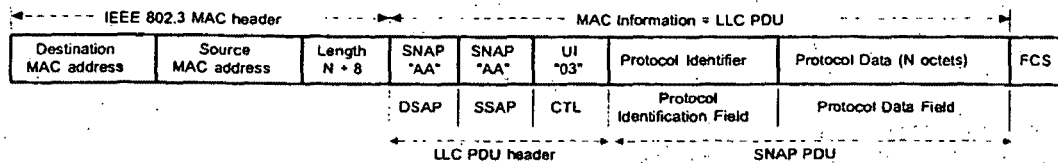


Figure 17—SNAP PDU in IEEE 802.3 MAC frame

#### 10.4 Ethernet types: Format, function, and administration

The IEEE 802.3 MAC frame format is compatible with the alternative Ethernet MAC frame format, in the sense that frames of both formats can be freely intermixed on a given LAN and at a given LAN station. The service provided by use of the Ethernet frame format differs from the ISO/IEC 15802-1 MAC service in that there is a 16-bit type value associated with each frame transferred, and that the minimum amount of MAC-sublayer user data transferred is 64 octets.

An Ethernet type value is a sequence of two octets, interpreted as a 16-bit numeric value with the first octet containing the most significant 8 bits and the second octet containing the least significant 8 bits. Values in the range 0–1535 are not available for use.

The function of the Ethernet type value is to identify the protocol that is to be invoked to process the user data in the frame.

As with OUIs, administration of Ethernet types was originally undertaken by the Xerox Corporation, and it is now the responsibility of the IEEE using procedures defined by the IEEE RAC (see Clause 9). All assignments of Ethernet types made by the predecessor administration remain in effect under the IEEE's administration.

#### 10.5 Encapsulation of Ethernet frames over LLC

This subclause specifies the standard method for conveying Ethernet frames across IEEE 802 LANs that offer only the LLC sublayer, and not the Ethernet sublayer, directly above the MAC sublayer.

An Ethernet frame conveyed on an LLC-only LAN shall be encapsulated in a SNAP PDU contained in an LLC PDU of type UI, as follows (see Figure 18):

- a) The Protocol Identification field of the SNAP PDU shall contain a protocol identifier in which
  - 1) The three OUI octets each take the value zero.
  - 2) The two remaining octets take the values, in the same order, of the two octets of the Ethernet frame's Ethernet type.
- b) The Protocol Data field of the SNAP PDU shall contain the user data octets, in order, of the Ethernet frame.
- c) The values of the Destination MAC Address and Source MAC Address fields of the Ethernet frame shall be used in the Destination MAC Address and Source MAC Address fields, respectively, of the MAC frame in which the SNAP PDU is conveyed.

## NOTES

1—This encapsulation was originally specified in RFC 1042, which contains recommendations relating to its use. Further recommendations are contained in RFC 1390.

2—ISO/IEC TR 11802-5 (IEEE Std 802.1H™-1997) contains recommendations for bridges, addressing the consequences of certain problems that arose from differing interpretations of RFC 1042.

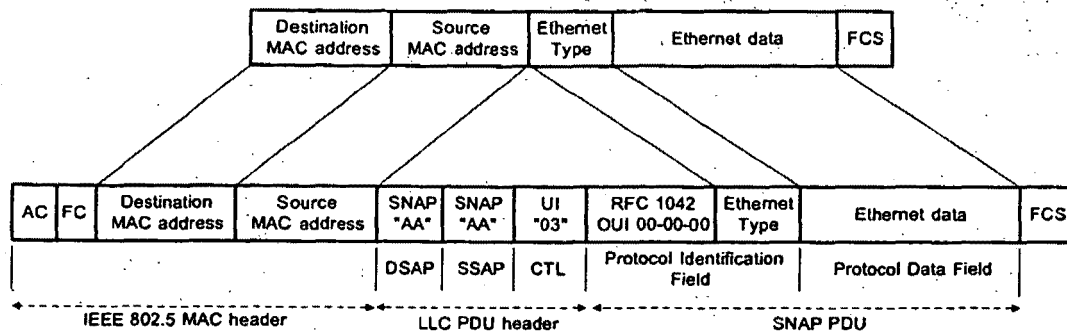


Figure 18—Ethernet frame SNAP-encapsulated in IEEE 802.5 frame

## 11. ISLAN and MAN support for isochronous bearer services

In addition to the mandatory LAN and MAN services described so far, some IEEE 802 LANs and MANs, notably, ISO/IEC 8802-9 and ISO/IEC 8802-6, also make provision for supporting isochronous bearer services. Isochronous bearer services are distinctive relative to packet services such as the MAC service and LLC, in that they maintain a flow of service data units at constant time intervals from a transmitter to a receiver for the duration of a service. In almost all circumstances, such isochronous bearer services are carried over duplex bidirectional connections thereby providing effective and efficient means of supporting the ubiquitous WAN voice telephony services. IEEE 802 ISLANs and MANs provide isochronous bearer services designed to interwork readily with these WAN services as standardized by ITU-T, in particular, as defined in the I series of ITU-T Recommendations.

NOTE—Use of an end-to-end physical-layer isochronous bearer service, which intrinsically delivers data with timing preserved, needs to be distinguished from use of a packet-based service for conveyance of time-sensitive data such as voice or video. The latter approach can be successful, given adequate bandwidth in the LANs and bridges, and provided that bridges do not introduce the possibility of excessive delay for packets carrying the time-sensitive data.

### 11.1 Key concepts

Applications requiring sustained periodic use of end-to-end network bandwidth are common. Two of the IEEE 802 standards address this requirement; both the ISO/IEC 8802-9 ISLAN standard and the optional isochronous service on an ISO/IEC 8802-6 Distributed Queue Dual Bus (DQDB) MAN use synchronously cyclic methods to ensure precise timing of the acceptance, transfer, and delivery of continuous streams of information. This applies whether or not asynchronous packet services are also provided concurrently.

The ISLAN employs a time-division multiplex (TDM) bearer mechanism within the Physical layer. The isochronous service on a DQDB MAN uses a Pre-Arbitrated function to ensure precisely timed access to the media, as distinct from the packet-service Queued Arbitrated function. In each case, this permits the support and delivery of a plurality of transparent isochronous service channels, the provision of an octet alignment signal for these channels, and a facility to provide and accept these precise timing signals. It is the provision of the timing signal that principally distinguishes the isochronous services from the asynchronous packet services that are provided from the ISLAN Physical layer.

Both methods for providing isochronous bearer services require the prior establishment of a connection for each isochronous information flow. For the DQDB MAN isochronous services, the mechanisms used for establishing and clearing connections are left outside of the scope of the IEEE 802 Standard. For ISLAN, see 11.4 below for an overview of the mechanisms used.

## 11.2 Applications

Applications for isochronous bearer services include the following:

- PBX interconnections at DS1 (1.544 Mbit/s) or E1 (2.048 Mbit/s) rates
- Low (384 kbit/s) to medium (44.2097 Mbit/s) bandwidth constant bit-rate compressed video
- Channels with bandwidth in multiples of 56 or 64 kbit/s for conveyance of voice and audio
- Multimedia combinations of these along with data services

Multimedia applications can require simultaneous, integrated use of two or more of these audio/voice, video, text, and graphics information streams. This can require the conveyance over common bearer channels of multiple isochronous and bursty information streams, in distinct channels with specific timing relationships. This provides the main rationale for incorporating isochronous services in LANs and MANs.

The provision of isochronous (TDM bearer) services enables direct interworking with a WAN network such that the access unit or hub (LAN/WAN interworking unit) can forward information in its native form, so that ISLAN terminals and access units do not have to provide gateway functions to transform the user information streams. In addition, the provision of isochronous bearer services greatly reduces the latency as information is queued/dequeued at the Physical service interface. This is of value in meeting established norms of loop delay on end-to-end connections for many human interactive services.

Typical isochronous services include the following:

- Unrestricted 64 kbit/s information transfer
- Restricted 56 kbit/s information transfer
- Synchronous data
- Facsimile data
- Wideband video and image transfer

The ISO/IEC 8802-9 ISLAN is specifically designed to provide concurrent support for LLC conformant packet services and narrowband ITU-T conformant ISDN services, both packet and isochronous, as defined in ITU-T I-series Recommendations.

## 11.3 Isochronous service access points and PhSAPs

The ISLAN and DQDB MAN standards both support concurrent packet and isochronous services within the Physical layer by means of convergence functions. In both cases, there is therefore a need for explicit identification of the distinct packet and isochronous channels provided over the common media supporting the ISLAN or MAN. In addition, both offer support for multiple isochronous bearer channels, and thus, there is a need to distinguish among multiple Physical service connections.

In the ISLAN standard, multiple PhSAPs are used to provide for the plurality of connections at the Physical service boundary, and for access by the user to the Physical-layer services for packet transfer and for

D channel signaling (see Figure 19). For the DQDB MAN isochronous services, Connection Endpoint (CEs) identifiers are used for a similar purpose.

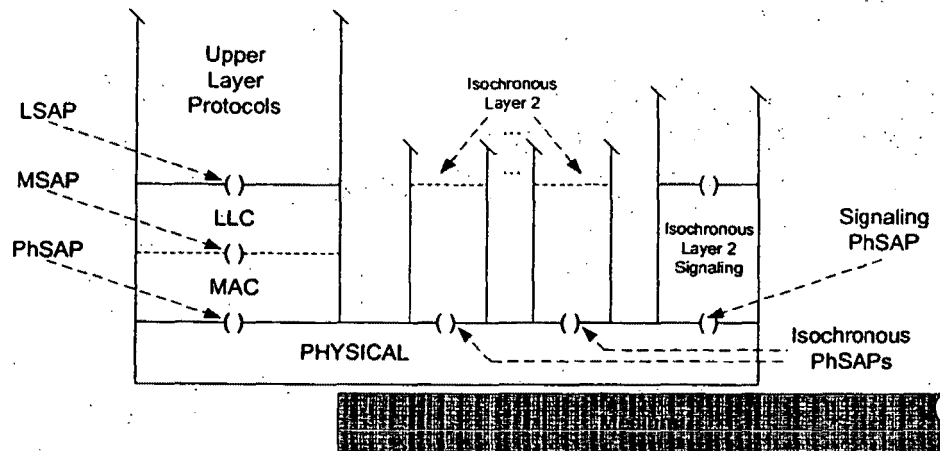


Figure 19—ISLAN RM (end station)

PhSAPs and CEs are the architectural mechanism by which symbol streams are passed to the Physical service provider by the Physical service user, and to the Physical service user by the Physical service provider. The distinction of different PhSAPs at a single ISLAN Physical service boundary is required because that service boundary is used simultaneously to provide both packet-mode and (multiple) circuit-mode Physical services.

It is a function of the layer management of the PHY multiplexing sublayer to provide each Physical service user with both the information stream and a channel identifier that is mapped onto the PhSAP relevant to the service provided to that user.

#### 11.4 ISLAN signaling

The ISLAN standard provides for direct interworking with ITU-T conformant ISDN I-series Recommendations. These require means of establishing, maintaining, and disestablishing end-to-end connections across (in the ISLAN case) both the ISLAN and intervening WAN. To this end, ISO/IEC 8802-9 includes specifications for extensions to the ITU-T I- and Q-series signaling protocols carried in a signaling-specific D channel. This is a packet-based protocol, but to achieve interworking with the ITU-T Recommendations, it is distinct from the LLC packet service provided over ISLAN.

The signaling service provided by the protocols carried in the D channel permits negotiation of end-to-end network resources such that a guaranteed service can be provided to the users of an end-to-end isochronous channel. Thus, the ISLAN management signalling entity is responsible, as a management agent, for performing the following tasks:

- Negotiation of bandwidth (configuration) management, fault management, performance management, and security management of the access link between device and hub
- Negotiation of service provisioning over the local ISLAN interface in order to access the WAN-based ISDN services

The ISLAN signaling message elements are provided in compliance with international (ITU-T) network signaling methods with appropriate protocol extensions.

## Annex A

(informative)

### Bibliography (Additional references for LAN/MAN-related standards)

#### A.1 General LAN/MAN standards and specifications

[B1] *Ethernet Version 2.0, A Local Area Network—Data Link Layer and Physical Layer Specifications*. Digital Equipment Corp., Intel Corp., and Xerox Corp., November 1982.

[B2] IEEE 100™, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.<sup>8</sup>

[B3] IEEE Std 802.10-1992, IEEE Standards for Local and Metropolitan Area Networks: Interoperable LAN/MAN Security (SILS) (includes IEEE Std 802.10b™-1992).<sup>9</sup>

[B4] ISO/IEC TR 8802-1:1997, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Technical reports and guidelines—Part 1: Overview of Local Area Network Standards.

[B5] ISO/IEC 8802-3:1999 (IEEE Std 802.3-1998), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.

[B6] ISO/IEC 8802-4:1990 (IEEE Std 802.4-1990), Information processing systems—Local area networks—Part 4: Token-passing bus access method and physical layer specifications.

[B7] ISO/IEC 8802-5:1998 (IEEE Std 802.5-1998), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 5: Token ring access method and physical layer specifications.

[B8] ISO/IEC 8802-6:1994 (IEEE Std 802.6™-1994), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 6: Distributed Queue Dual Bus (DQDB) access method and physical layer specifications.

[B9] ISO/IEC 8802-9:1996 (IEEE Std 802.9™-1996), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 9: Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers.

[B10] ISO/IEC 8802-11:1999 (IEEE Std 802.11™-1999), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications.

<sup>8</sup>The IEEE standards and products referred to in Annex A are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

<sup>9</sup>IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

[B11] ISO/IEC 8802-12:1998 (IEEE Std 802.12-1998), Information technology — Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 12: Demand-Priority access method, physical layer and repeater specifications.

[B12] ISO 9314-1:1989, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 1: Token Ring Physical Layer Protocol (PHY).

[B13] ISO 9314-2:1989, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 2: Token Ring Media Access Control (MAC).

[B14] ISO 9314-3:1990, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 3: Token Ring Physical Layer Medium Dependent (PMD).

[B15] ISO 9314-6:1989, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 6: Token Ring Station Management (SMT).

[B16] ISO/IEC TR 11802-5:1997 (IEEE Std 802.1H-1997), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Technical reports and guidelines—Part 5: Media Access Control (MAC) Bridging of Ethernet V2.0 in Local Area Networks.

[B17] ISO/IEC 15802-5:1998 (IEEE Std 802.1G™-1998), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 5: Remote Media Access Control (MAC) Bridging.

[B18] RFC 1042, A Standard for the Transmission of IP Datagrams over IEEE 802 Networks. Postel, J., and Reynolds, J., February 1988.<sup>10</sup>

[B19] RFC 1390, Transmission of IP and ARP over FDDI Networks. Katz, D., January 1993.

## A.2 Management

NOTE—Many of the standards listed in Clause 2 and A.1 contain specifications of their managed objects.

[B20] IEEE Std 802.1F-1993, IEEE Standards for Local and Metropolitan Area Networks: Common Definitions and Procedures for IEEE 802 Management Information.

NOTE—Some of the content of IEEE Std 802.1F-1993 is also included in ISO/IEC 10742.

[B21] ISO/IEC 7498-4:1989, Information processing systems—Open Systems Interconnection—Basic Reference Model—Part 4: Management framework.

[B22] ISO/IEC 8824-1:1995, Information technology—Abstract Syntax Notation One (ASN.1)—Specification of basic notation.

[B23] ISO/IEC 8824-2:1995, Information technology—Abstract Syntax Notation One (ASN.1)—Information object specification.

<sup>10</sup>Internet RFCs are available from the Internet Engineering Task Force on the World Wide Web browser at <http://www.ietf.org/rfc/rfcnnnn.txt> (where nnnn is the four-digit RFC number, padded with leading zeros if necessary). For more information, call the IETF secretariat at +1-703-620-8990.

- [B24] ISO/IEC 8824-3:1995, Information technology—Abstract Syntax Notation One (ASN.1)—Constraint specification.
- [B25] ISO/IEC 8824-4:1995, Information technology—Abstract Syntax Notation One (ASN.1)—Parameterization of ASN.1 specifications.
- [B26] ISO/IEC 8825-1:1995, Information technology—ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER).
- [B27] ISO/IEC 9595:1991, Information technology—Open Systems Interconnection—Common management information service definition.
- [B28] ISO/IEC 9596-1:1991, Information technology—Open Systems Interconnection—Common management information protocol—Part 1: Specification
- [B29] ISO/IEC 10040:1992, Information technology—Open Systems Interconnection—Systems management overview.
- [B30] ISO/IEC 10164-1/8:1993, Information technology—Open Systems Interconnection—Systems management: [various functions].
- [B31] ISO/IEC 10165-1:1993, Information technology—Open Systems Interconnection—Structure of management information: Management information model.
- [B32] ISO/IEC 10165-2:1992, Information technology—Open Systems Interconnection—Structure of management information: Definition of management information.
- [B33] ISO/IEC 10165-4:1992, Information technology—Open Systems Interconnection—Structure of management information: Guidelines for the definition of managed objects.
- [B34] ISO/IEC 10742:1994, Information technology—Telecommunications and information exchange between systems—Elements of management information related to OSI Data Link Layer standards.
- [B35] ISO/IEC 15802-2:1995 (IEEE Std 802.1B-1995), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 2: LAN/MAN management, service and protocol.
- [B36] ISO/IEC 15802-4:1994 (IEEE Std 802.1E™-1994), Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 4: System load protocol.
- [B37] RFC 1095, The Common Management Services and Protocol over TCP/IP (CMOT). Warrior, U., and Besaw, L., April 1989.
- [B38] RFC 1155, Structure and Identification of Management Information for TCP/IP-based Internets. Rose, M., and McCloghrie, K., May 1990.
- [B39] RFC 1157, A Simple Network Management Protocol (SNMP). Case, J., Fedor, M., Schoffstall, M., and Davin, J., May 1990.
- [B40] RFC 1212, Concise MIB Definitions. Rose, M., and McCloghrie, K. (Editors), March 1991.
- [B41] RFC 1215, A Convention for Defining Traps for use with the SNMP. Rose, M., March 1991.



[B42] RFC 1493, Definitions of Managed Objects for Bridges. Decker, E., Langille, P., Rijssinghani, A., and McCloghrie, K., July 1993.

[B43] RFC 1643, Definitions of Managed Objects for the Ethernet-like Interface Types. Kastenholz, F., July 1994.

[B44] RFC 1902, Structure of Management information for Version 2 of the Simple Network Management Protocol (SNMPv2). Case, J., McCloghrie, K., Rose, M., and Waldbusser, S., January 1996.

[B45] RFC 1903, Textual Conventions for Version 2 of the Simple Network Management Protocol (SNMPv2). Case, J., McCloghrie, K., Rose, M., and Waldbusser, S., January 1996.

[B46] RFC 1904, Conformance Statements for Version 2 of the Simple Network Management Protocol (SNMPv2). Case, J., McCloghrie, K., Rose, M., and Waldbusser, S., January 1996.

[B47] RFC 1905, Protocol Operations for Version 2 of the Simple Network Management Protocol (SNMPv2). Case, J., McCloghrie, K., Rose, M., and Waldbusser, S., January 1996.

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☐ BLACK BORDERS

☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES

☒ FADED TEXT OR DRAWING

☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING

☐ SKEWED/SLANTED IMAGES

☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS

☐ GRAY SCALE DOCUMENTS

☐ LINES OR MARKS ON ORIGINAL DOCUMENT

☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY

☐ OTHER: \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**

---

## IEEE P802.11 Wireless LANs

---

### WWiSE Proposal: High throughput extension to the 802.11 Standard

---

**Date:** August 13, 2004

**Authors:** PHY: Manoneet Singh, et al.  
Texas Instruments  
165 Gibraltar Ct, Sunnyvale, CA 94089 USA  
Phone: +1 408 543 5337  
Fax: +1 408 541 9910  
email: msingh@ti.com

MAC: Bruce Edwards, et al.  
Broadcom Corporation  
25 Burlington Mall Road, Suite 300, Burlington, MA 01803 USA  
Phone: +1 781 229 7391  
Fax: +1 781 272 3706  
email: bedwards@broadcom.com

---

### Abstract

Changes and additions to IEEE Std. 802.11-1999 (Reaff 2003), as amended by published amendments IEEE802.11a, IEEE802.11g, IEEE802.11h and IEEE802.11i and by IEEE draft standard 802.11e/D9.0 are provided to support a new high throughput physical layer (PHY) for operation in the 2.4 and 5 GHz bands.

---

**Contributors**

|    |                                          |    |                                     |
|----|------------------------------------------|----|-------------------------------------|
| 1  |                                          | 56 | Menzo Wentink, Conexant             |
| 2  |                                          | 57 |                                     |
| 3  | Sean Coffey, Texas Instruments           | 58 | Richard Williams, Texas Instruments |
| 4  |                                          | 59 |                                     |
| 5  | Dennis Connors, Texas Instruments        | 60 | Chris Young, Broadcom               |
| 6  |                                          | 61 |                                     |
| 7  | Gabriella Convertino, STMicroelectronics | 62 |                                     |
| 8  |                                          | 63 |                                     |
| 9  | Bruce Edwards, Broadcom                  | 64 |                                     |
| 10 |                                          | 65 |                                     |
| 11 | Matt Fischer, Broadcom                   | 66 |                                     |
| 12 |                                          | 67 |                                     |
| 13 | James Gardner, Airgo Networks            |    |                                     |
| 14 |                                          |    |                                     |
| 15 | Srikanth Gummadi, Texas Instruments      |    |                                     |
| 16 |                                          |    |                                     |
| 17 | Neil Hamady, Bermai                      |    |                                     |
| 18 |                                          |    |                                     |
| 19 | Chris Hansen, Broadcom                   |    |                                     |
| 20 |                                          |    |                                     |
| 21 | Dave Hedberg, Conexant                   |    |                                     |
| 22 |                                          |    |                                     |
| 23 | VK Jones, Airgo Networks                 |    |                                     |
| 24 |                                          |    |                                     |
| 25 | Young Kim, Bermai                        |    |                                     |
| 26 |                                          |    |                                     |
| 27 | Tushar Moorti, Broadcom                  |    |                                     |
| 28 |                                          |    |                                     |
| 29 | Mike Moreton, STMicroelectronics         |    |                                     |
| 30 |                                          |    |                                     |
| 31 | Fabio Osnato, STMicroelectronics         |    |                                     |
| 32 |                                          |    |                                     |
| 33 | Pratima Pai, STMicroelectronics          |    |                                     |
| 34 |                                          |    |                                     |
| 35 | Steve Pope, Texas Instruments            |    |                                     |
| 36 |                                          |    |                                     |
| 37 | Ali Raissinia, Airgo Networks            |    |                                     |
| 38 |                                          |    |                                     |
| 39 | Vincenzo Scarpa, STMicroelectronics      |    |                                     |
| 40 |                                          |    |                                     |
| 41 | Michael Seals, Conexant                  |    |                                     |
| 42 |                                          |    |                                     |
| 43 | Manoneet Singh, Texas Instruments        |    |                                     |
| 44 |                                          |    |                                     |
| 45 | Massimiliano Siti, STMicroelectronics    |    |                                     |
| 46 |                                          |    |                                     |
| 47 | Jason Trachewsky, Broadcom               |    |                                     |
| 48 |                                          |    |                                     |
| 49 | Richard van Nee, Airgo Networks          |    |                                     |
| 50 |                                          |    |                                     |
| 51 | Allert van Zelst, Airgo Networks         |    |                                     |
| 52 |                                          |    |                                     |
| 53 | George Vlantis, STMicroelectronics       |    |                                     |
| 54 |                                          |    |                                     |
| 55 | Mark Webster, Conexant                   |    |                                     |

# Contents

|    |                                                                               |    |
|----|-------------------------------------------------------------------------------|----|
| 1  | <b>Contents</b>                                                               |    |
| 2  | <u>Abstract</u> .....                                                         | i  |
| 3  | <u>Contributors</u> .....                                                     | ii |
| 4  | <u>3. Definitions</u> .....                                                   | 10 |
| 5  | <u>4. Abbreviations and acronyms</u> .....                                    | 11 |
| 6  | <u>6. MAC Service Definition</u> .....                                        | 11 |
| 7  | <u>6.1 Overview of MAC services</u> .....                                     | 11 |
| 8  | <u>6.1.4 Data service architecture (informative)</u> .....                    | 11 |
| 9  | <u>6.2 Detailed service specification</u> .....                               | 12 |
| 10 | <u>6.2.1 MAC data services</u> .....                                          | 12 |
| 11 | <u>6.2.1.1 MA-UNITDATA.request</u> .....                                      | 12 |
| 12 | <u>7. Frame Formats</u> .....                                                 | 13 |
| 13 | <u>7.1 MAC frame formats</u> .....                                            | 13 |
| 14 | <u>7.1.2 General frame format</u> .....                                       | 13 |
| 15 | <u>7.1.3 Frame fields</u> .....                                               | 13 |
| 16 | <u>7.1.3.5 QoS Control field</u> .....                                        | 13 |
| 17 | <u>7.2 Format of individual frame types</u> .....                             | 13 |
| 18 | <u>7.2.1 Control Frames</u> .....                                             | 13 |
| 19 | <u>7.2.1.7 Block Acknowledgement Request (BlockAckReq) frame format</u> ..... | 13 |
| 20 | <u>7.2.1.8 Block Acknowledgement (BlockAck) frame format</u> .....            | 14 |
| 21 | <u>7.2.2 Data Frames</u> .....                                                | 15 |
| 22 | <u>7.2.3 Management frames</u> .....                                          | 15 |
| 23 | <u>7.2.3.1 Beacon frame format</u> .....                                      | 15 |
| 24 | <u>7.2.3.9 Probe Response frame format</u> .....                              | 16 |
| 25 | <u>7.3 Management frame body components</u> .....                             | 17 |
| 26 | <u>7.3.1 Fixed fields</u> .....                                               | 17 |
| 27 | <u>7.3.1.4 Capability Information field</u> .....                             | 17 |

|    |                                                                  |    |
|----|------------------------------------------------------------------|----|
| 1  | <u>7.3.2 Information Elements</u> .....                          | 17 |
| 2  | <u>7.3.2.13 ERP Information element</u> .....                    | 17 |
| 3  | <u>7.3.2.25 Channel Set</u> .....                                | 20 |
| 4  | <u>9. MAC sublayer functional description</u> .....              | 20 |
| 5  | <u>9.1 MAC architecture</u> .....                                | 20 |
| 6  | <u>9.1.4 MSDU aggregation</u> .....                              | 20 |
| 7  | <u>9.1.6 HTP Burst Transmission overview</u> .....               | 21 |
| 8  | <u>9.2 DCF</u> .....                                             | 21 |
| 9  | <u>9.2.3 Interframe Space (IFS)</u> .....                        | 22 |
| 10 | <u>9.2.3.1 ZIFS</u> .....                                        | 22 |
| 11 | <u>9.2.3.2 RIFS</u> .....                                        | 22 |
| 12 | <u>9.2.12 Determination of PLME aCWmin characteristics</u> ..... | 22 |
| 13 | <u>9.6 Multirate support</u> .....                               | 22 |
| 14 | <u>9.6.1 Modulation Classes</u> .....                            | 23 |
| 15 | <u>9.9 HCF</u> .....                                             | 23 |
| 16 | <u>9.9.1 HCF contention-based channel access (EDCA)</u> .....    | 23 |
| 17 | <u>9.9.1.4 Multiple frame transmission in an EDCA TXOP</u> ..... | 23 |
| 18 | <u>9.9.2 HCF controlled channel access</u> .....                 | 23 |
| 19 | <u>9.9.2.1 HCF controlled channel access procedure</u> .....     | 23 |
| 20 | <u>9.9.2.2 TXOP structure and timing</u> .....                   | 24 |
| 21 | <u>9.10 Block acknowledgment</u> .....                           | 24 |
| 22 | <u>9.10.1 Introduction (Informative)</u> .....                   | 24 |
| 23 | <u>9.10.3 Data and acknowledgement transfer</u> .....            | 24 |
| 24 | <u>9.12 Frame exchange sequences</u> .....                       | 24 |
| 25 | <u>9.13 Protection mechanism</u> .....                           | 24 |
| 26 | <u>9.13.1 OFDM Protection</u> .....                              | 25 |
| 27 | <u>9.14 40 MHz Channel Pairs</u> .....                           | 25 |
| 28 | <u>9.14.1 40 MHz Fundamentals of Operation</u> .....             | 26 |

|    |                                                                                                                |    |
|----|----------------------------------------------------------------------------------------------------------------|----|
| 1  | <u>9.14.2 Coexistence with non High Throughput STAs on the secondary channel</u> .....                         | 26 |
| 2  | <u>9.14.2.1 Secondary Channel Beacon</u> .....                                                                 | 26 |
| 3  | <u>9.14.3 Beacon Transmission</u> .....                                                                        | 26 |
| 4  | <u>9.14.4 Limits on Channel Numbering</u> .....                                                                | 27 |
| 5  | <u>10. Layer management</u> .....                                                                              | 27 |
| 6  | <u>10.4 PLME SAP interface</u> .....                                                                           | 27 |
| 7  | <u>10.4.3 PLME_CHARACTERISTICS.confirm</u> .....                                                               | 27 |
| 8  | <u>10.4.3.2 Semantics of the service primitive</u> .....                                                       | 27 |
| 9  | <u>10.4.4 PLME-DSSSTESTMODE.request</u> .....                                                                  | 27 |
| 10 | <u>10.4.4.2 Semantics of the service primitive</u> .....                                                       | 27 |
| 11 | <u>20. High throughput PHY specification for the 2.4 and 5 GHz bands</u> .....                                 | 28 |
| 12 | <u>20.1 Overview</u> .....                                                                                     | 28 |
| 13 | <u>20.1.1 Introduction</u> .....                                                                               | 28 |
| 14 | <u>20.1.2 Operational Modes</u> .....                                                                          | 28 |
| 15 | <u>20.1.3 Scope</u> .....                                                                                      | 28 |
| 16 | <u>20.1.4 MIMO-OFDM PHY functions</u> .....                                                                    | 28 |
| 17 | <u>20.2 PHY-specific service parameter list</u> .....                                                          | 29 |
| 18 | <u>Table 001—TXVECTOR parameters</u> .....                                                                     | 29 |
| 19 | <u>Table 002—RXVECTOR parameters</u> .....                                                                     | 30 |
| 20 | <u>20.3 MIMO-OFDM PLCP sublayer</u> .....                                                                      | 30 |
| 21 | <u>20.3.1 Introduction</u> .....                                                                               | 30 |
| 22 | <u>20.3.2 PLCP frame format</u> .....                                                                          | 30 |
| 23 | <u>20.3.2.1 Overview of the PPDU encoding process</u> .....                                                    | 33 |
| 24 | <u>20.3.2.2 RATE-dependent parameters</u> .....                                                                | 34 |
| 25 | <u>Table 003—Rate-dependent parameters for 20 MHz, <math>N_{SS} = 2</math> (<math>N_{FS} = 1</math>)</u> ..... | 34 |
| 26 | <u>Table 004—Rate-dependent parameters for 20 MHz, <math>N_{SS} = 3</math> (<math>N_{FS} = 1</math>)</u> ..... | 34 |
| 27 | <u>Table 005—Rate-dependent parameters for 20 MHz, <math>N_{SS} = 4</math> (<math>N_{FS} = 1</math>)</u> ..... | 34 |
| 28 | <u>Table 006—Rate-dependent parameters for 40 MHz, <math>N_{SS} = 1</math> (<math>N_{FS} = 1</math>)</u> ..... | 34 |

|    |                                                                                                                           |    |
|----|---------------------------------------------------------------------------------------------------------------------------|----|
| 1  | <u>Table 007—Rate-dependent parameters for 40 MHz, <math>N_{SS} = 2</math> (<math>N_{ES} = 1</math>)</u> .....            | 35 |
| 2  | <u>Table 008—Rate-dependent parameters for 40 MHz, <math>N_{SS} = 3</math> (<math>N_{ES} = 2</math>)</u> .....            | 35 |
| 3  | <u>Table 009—Rate-dependent parameters for 40 MHz, <math>N_{SS} = 4</math> (<math>N_{ES} = 2</math>)</u> .....            | 35 |
| 4  | <u>20.3.2.3 Timing related parameters</u> .....                                                                           | 35 |
| 5  | <u>Table 010—Timing-related parameters</u> .....                                                                          | 35 |
| 6  | <u>20.3.2.4 Mathematical conventions in the signal descriptions</u> .....                                                 | 36 |
| 7  | <u>20.3.3 PLCP preamble (SYNC)</u> .....                                                                                  | 37 |
| 8  | <u>20.3.4 Signal fields (SIG-N and SIG-MM)</u> .....                                                                      | 40 |
| 9  | <u>Table 011—SIG-N field bit assignment</u> .....                                                                         | 40 |
| 10 | <u>20.3.5 DATA field</u> .....                                                                                            | 41 |
| 11 | <u>20.3.5.1 Service field (SERVICE)</u> .....                                                                             | 41 |
| 12 | <u>20.3.5.2 PPDU tail bits</u> .....                                                                                      | 41 |
| 13 | <u>20.3.5.3 PAD bits</u> .....                                                                                            | 42 |
| 14 | <u>20.3.5.4 PLCP data scrambler and descrambler</u> .....                                                                 | 42 |
| 15 | <u>20.3.5.5 Convolutional encoder</u> .....                                                                               | 42 |
| 16 | <u>20.3.5.6 Interleaver</u> .....                                                                                         | 43 |
| 17 | <u>Table 012—Interleaving parameters</u> .....                                                                            | 43 |
| 18 | <u>20.3.5.7 Low density parity check codes (optional ECC)</u> .....                                                       | 44 |
| 19 | <u>20.3.5.7.1 LDPCC Code Rates and Block Sizes</u> .....                                                                  | 44 |
| 20 | <u>Table 013— LDPCC parameters</u> .....                                                                                  | 44 |
| 21 | <u>20.3.5.7.3 LDPCC PPDU encoding process</u> .....                                                                       | 44 |
| 22 | <u>20.3.5.7.4 LDPCC Encoder</u> .....                                                                                     | 45 |
| 23 | <u>20.3.5.7.5 Parity check matrix</u> .....                                                                               | 46 |
| 24 | <u>20.3.5.8 Subcarrier modulation mapping</u> .....                                                                       | 47 |
| 25 | <u>20.3.5.9 Pilot tones</u> .....                                                                                         | 47 |
| 26 | <u>Table 014—Pilot value sent from <math>m</math>th antenna during <math>n</math>th OFDM symbol in 20 MHz modes</u> ..... | 48 |
| 27 | <u>Table 015—Pilot value sent from <math>m</math>th antenna during <math>n</math>th OFDM symbol in 40 MHz modes</u> ..... | 48 |
| 28 | <u>20.3.5.10 Space-time block coding (STBC)</u> .....                                                                     | 48 |



|    |                                                                                                               |    |
|----|---------------------------------------------------------------------------------------------------------------|----|
| 1  | <u>Table 016—Rate-dependent parameters for 20 MHz, <math>N_{TX} = 2</math>, <math>N_{SS} = 1</math></u> ..... | 48 |
| 2  | <u>20.3.6 Clear channel assessment</u> .....                                                                  | 49 |
| 3  | <u>20.3.7 PLCP data modulation and modulation rate change</u> .....                                           | 49 |
| 4  | <u>20.3.8 PMD operating specifications</u> .....                                                              | 50 |
| 5  | <u>20.3.8.1 TX Block diagram</u> .....                                                                        | 50 |
| 6  | <u>20.3.8.2 Regulatory requirements</u> .....                                                                 | 50 |
| 7  | <u>20.3.8.3 Operating channel frequencies</u> .....                                                           | 50 |
| 8  | <u>20.3.8.4 Spurious emissions</u> .....                                                                      | 50 |
| 9  | <u>20.3.8.5 TX RF delay</u> .....                                                                             | 50 |
| 10 | <u>20.3.8.6 Slot time</u> .....                                                                               | 51 |
| 11 | <u>20.3.8.7 Transmit and receive antenna port impedance</u> .....                                             | 51 |
| 12 | <u>20.3.8.8 Transmit and receive operating temperature range</u> .....                                        | 51 |
| 13 | <u>20.3.9 PMD TX specifications</u> .....                                                                     | 51 |
| 14 | <u>20.3.9.1 TX power levels</u> .....                                                                         | 51 |
| 15 | <u>20.3.9.2 TX spectrum mask</u> .....                                                                        | 51 |
| 16 | <u>20.3.9.3 TX spurious</u> .....                                                                             | 52 |
| 17 | <u>20.3.9.4 TX center frequency tolerance</u> .....                                                           | 52 |
| 18 | <u>20.3.9.5 TX symbol clock frequency tolerance</u> .....                                                     | 52 |
| 19 | <u>20.3.9.6 Modulation accuracy</u> .....                                                                     | 52 |
| 20 | <u>20.3.9.6.1 TX center frequency leakage</u> .....                                                           | 52 |
| 21 | <u>20.3.9.6.2 TX spectral flatness</u> .....                                                                  | 52 |
| 22 | <u>20.3.9.6.3 TX constellation error</u> .....                                                                | 52 |
| 23 | <u>Table 017—Allowed relative constellation error versus constellation type and code rate</u> .....           | 52 |
| 24 | <u>20.3.9.7 TX modulation accuracy (EVM) test</u> .....                                                       | 53 |
| 25 | <u>20.3.10 PMD RX specifications</u> .....                                                                    | 54 |
| 26 | <u>20.3.10.1 RX minimum input level sensitivity</u> .....                                                     | 54 |
| 27 | <u>Table 018—Receiver minimum input level sensitivity</u> .....                                               | 54 |
| 28 | <u>20.3.10.2 RX maximum input level</u> .....                                                                 | 55 |

|    |                                                                       |    |
|----|-----------------------------------------------------------------------|----|
| 1  | <u>20.3.10.3 CCA sensitivity</u> .....                                | 55 |
| 2  | <u>20.3.11 PLCP TX procedure</u> .....                                | 55 |
| 3  | <u>20.3.12 PLCP RX procedure</u> .....                                | 57 |
| 4  | <u>20.4 MIMO-OFDM PMD operating specifications</u> .....              | 61 |
| 5  | <u>20.4.1 PLME_SAP sublayer management primitives</u> .....           | 61 |
| 6  | <u>20.4.2 MIMO-OFDM management information base</u> .....             | 61 |
| 7  | <u>Table 20.4.2T1 MIB attribute default values/ranges</u> .....       | 61 |
| 8  | <u>20.4.3 MIMO-OFDM TXTIME calculation</u> .....                      | 62 |
| 9  | <u>20.4.4 MIMO-OFDM PHY characteristics</u> .....                     | 62 |
| 10 | <u>Table 20.4.4.1—MIMO-OFDM PHY characteristics</u> .....             | 62 |
| 11 | <u>20.5 MIMO-OFDM operating specifications</u> .....                  | 63 |
| 12 | <u>20.5.1 Scope and field of application</u> .....                    | 63 |
| 13 | <u>20.5.2 Overview of service</u> .....                               | 63 |
| 14 | <u>20.5.3 Overview of interactions</u> .....                          | 63 |
| 15 | <u>20.5.4 Basic services and options</u> .....                        | 63 |
| 16 | <u>20.5.4.1 PMD_SAP peer-to-peer service primitives</u> .....         | 63 |
| 17 | <u>Table 20.5.4.1 PMD_SAP peer-to-peer services</u> .....             | 63 |
| 18 | <u>20.5.4.2 PMD_SAP sublayer-to-sublayer service primitives</u> ..... | 63 |
| 19 | <u>Table 19.9.4.2 PMD_SAP sublayer-to-sublayer services</u> .....     | 64 |
| 20 | <u>20.5.4.3 PMD_SAP service primitive parameters</u> .....            | 64 |
| 21 | <u>Table 20.5.4.3 List of parameters for the PMD primitives</u> ..... | 64 |
| 22 | <u>20.5.5 PMD_SAP detailed service specification</u> .....            | 65 |
| 23 | <u>20.5.5.1 PMD_DATA.request</u> .....                                | 65 |
| 24 | <u>20.5.5.2 PMD_DATA.indicate</u> .....                               | 65 |
| 25 | <u>20.5.5.3 PMD_TRANSMISSION_MODE.request</u> .....                   | 65 |
| 26 | <u>20.5.5.4 PMD_TXSTART.request</u> .....                             | 65 |
| 27 | <u>20.5.5.5 PMD_TXEND.request</u> .....                               | 65 |
| 28 | <u>20.5.5.6 PMD_ANTSEL.request</u> .....                              | 65 |

---

|   |                                                |    |
|---|------------------------------------------------|----|
| 1 | <u>20.5.5.7 PMD_TXPRWLVL.request</u> .....     | 66 |
| 2 | <u>20.5.5.8 PMD_DATARATE.request</u> .....     | 66 |
| 3 | <u>20.5.5.9 PMD_RSSI.indicate</u> .....        | 66 |
| 4 | <u>Annex A – LDPC matrix definitions</u> ..... | 67 |
| 5 |                                                |    |

**Draft Amendment to IEEE Standard for Information  
technology-  
Telecommunications and information exchange between  
systems -  
Local and metropolitan area networks -  
Specific Requirements -**

**Part 20: Wireless LAN Medium Access Control  
(MAC) and Physical Layer (PHY) specifications:**

**High throughput extension for the 2.4 GHz and  
5 GHz Bands**

[This amendment is based on IEEE Std 802.11™, 1999 Edition (Reaff 2003), as amended by IEEE Std 802.11a™-1999 and IEEE Std 802.11g™-2003, and Draft Amendment IEEE P802.11e/D9.0]

### **3. Definitions**

*Insert the following new definitions in alphabetical order, renumbering as necessary:*

**20 MHz transmission:** A frame transmission in which the modulation spans only one of the 20 MHz channels of a 40 MHz Channel Pair.

**40 MHz channel pair:** A pair of 20 MHz channels whose centre frequencies are separated by 20 MHz and which can be treated as a single channel for 40 MHz transmissions by a BSS, and where one of the 20 MHz channels will also be used for (non-overlapping) 20 MHz transmissions by the BSS.

**40 MHz transmission:** A frame transmission in which the modulation spans both 20 MHz channels of a 40 MHz channel pair.

**aggregated MSDU (A-MSDU):** A MSDU that encapsulates one or more MSDUs to be transmitted to the same destination.

**aggregated PPDU (A-PPDU):** A PPDU that contains one or more pairs of PLCP headers and PSDUs.

**HTP burst transmission:** A sequence of frames transmitted by a single high-throughput station in a single medium access. The frames may be transmitted as part of an A-PPDU, or with reduced or zero interframe spacing to enhance medium efficiency.

**primary channel:** The channel in a 40 MHz channel pair that will be used for 20 MHz transmissions as well as being part of the 40 MHz channel for 40 MHz transmissions.

**secondary channel:** The channel in a 40 MHz channel pair that is used only as part of the 40 MHz channel for 40 MHz transmissions, and which is not used for 20 MHz transmissions.

**HTP rate group:** A group of rates supported by a HTP PHY that use the same transmit bandwidth, the same number of transmit antennas, and the number of spatial streams.

**MIMO-OFDM:** Multiple input multiple output orthogonal frequency division multiplexing

## 4. Abbreviations and acronyms

*Insert the following acronyms alphabetically in the list in Clause 4:*

|        |                                                                                                  |
|--------|--------------------------------------------------------------------------------------------------|
| A-MSDU | aggregated MSDU                                                                                  |
| A-PPDU | aggregated PPDU                                                                                  |
| ECC    | error correction code                                                                            |
| HT     | high throughput                                                                                  |
| HTP    | high-throughput PHY conforming to Clause 20                                                      |
| LDPCC  | low density parity check code                                                                    |
| MIMO   | multiple input multiple output                                                                   |
| nHTP   | non HTP PHY conforming to Clause 15 or Clause 17 or Clause 18 or Clause 19, but not to Clause 20 |
| RIFS   | reduced interframe space                                                                         |
| STBC   | space time block code                                                                            |
| ZIFS   | zero interframe space                                                                            |

## 6. MAC Service Definition

### 6.1 Overview of MAC services

#### 6.1.4 Data service architecture (informative)

*Change the paragraph in 6.1.4 (.11e) as shown:*

The MAC data plane architecture (i.e., processes that involve transport of all or part of an MSDU) is shown in Figure 11g. During transmission, an MSDU goes through some or all of the following processes: frame delivery deferral during power save mode, aggregation, sequence number assignment, fragmentation, encryption, integrity protection, and frame formatting. IEEE 802.1X may block the MSDU at the Controlled Port. At some point the Data frames that contain all or part of the MSDU are queued per access category/TS. This queuing may be at any of the three points indicated in Figure 11g. During reception, a received data frame goes through processes of MPDU header + cyclic redundancy codecheck (CRC) validation, duplicate removal, possible reordering if the Block Ack mechanism is used, decryption, defragmentation, integrity

checking, de-aggregation, and replay detection. After replay detection (or defragmentation if security is used), the MSDU is delivered to the MAC\_SAP or to the DS. The IEEE 802.1X Controlled/ Uncontrolled Ports discard the MSDU if the Controlled Port is not enabled or if the MSDU does not represent an IEEE 802.1X frame. TKIP and CCMP MPDU frame order enforcement occurs after decryption, but prior to MSDU defragmentation; therefore, defragmentation will fail if MPDUs arrive out of order.

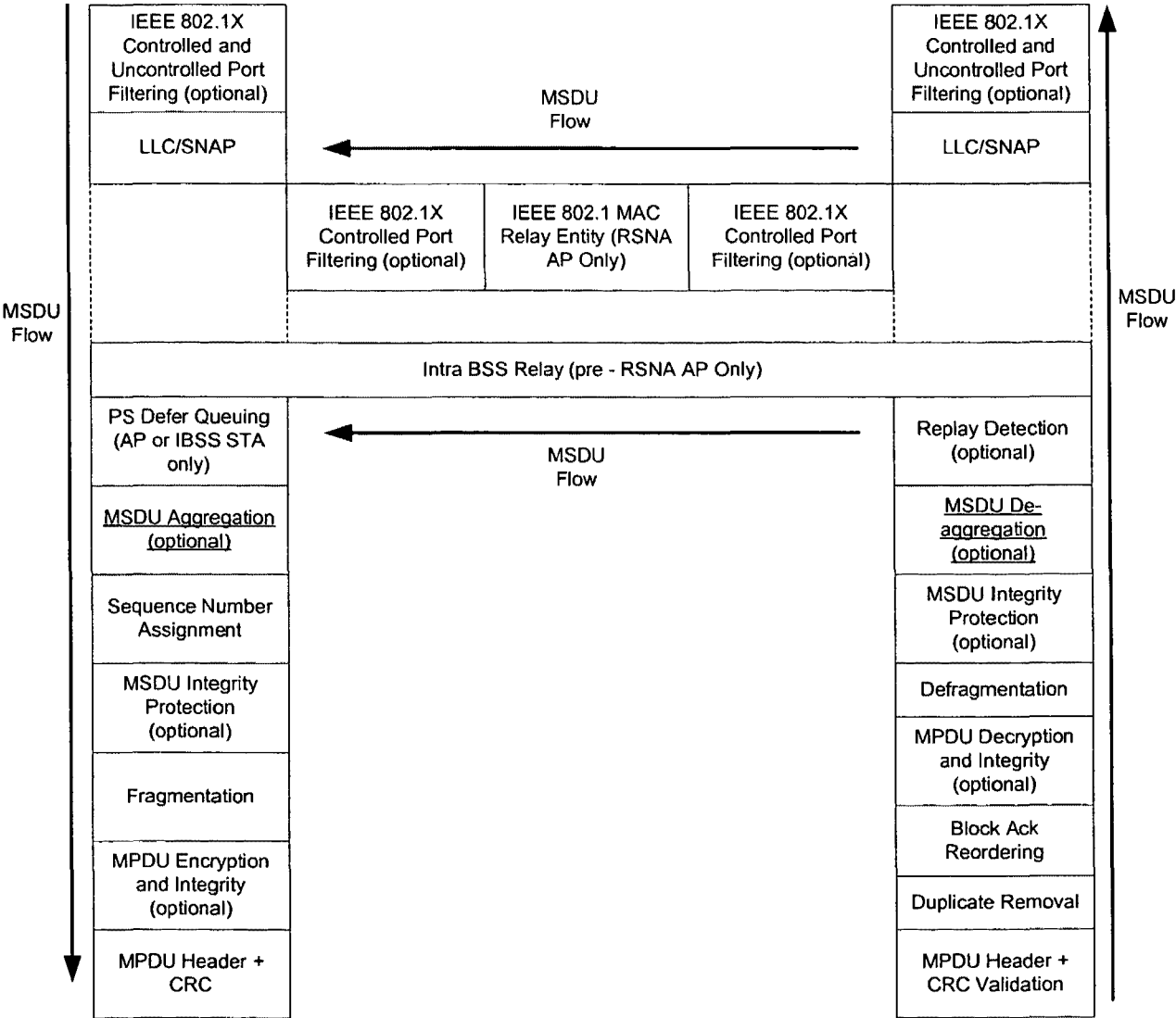


Figure 11g – MAC data plane architecture

## 6.2 Detailed service specification

### 6.2.1 MAC data services

#### 6.2.1.1 MA-UNITDATA.request

##### 6.2.1.1.2 Semantics of the service primitive

*Change the third from the last paragraph as follows:*

The data parameter specifies the MSDU to be transmitted by the MAC sublayer entity. For IEEE 802.11, the length of the MSDU ~~must~~shall be less than or equal to 23048100 octets.

## 7. Frame Formats

### 7.1 MAC frame formats

#### 7.1.2 General frame format

Change Figure 12(.11e) as follows:

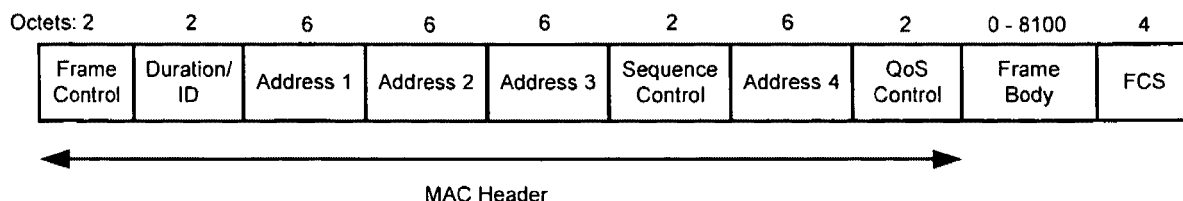


Figure 12 – MAC frame format

### 7.1.3 Frame fields

#### 7.1.3.5 QoS Control field

Change Table 3.1 in 7.1.3.5 (.11e) to appear as follows:

Table 3.1 – QoS Control field

| Applicable Frame (sub) Types                   | Bits 0-3 | Bit 4 | Bit 5-6    | Bit 7                   | Bits 8-15               |
|------------------------------------------------|----------|-------|------------|-------------------------|-------------------------|
| QoS (+)CF-Poll frames sent by HC               | TID      | EOSP  | Ack Policy | Reserved                | TXOP limit              |
| QoS Data and QoS Data+CF-Ack frames sent by HC | TID      | EOSP  | Ack Policy | Aggregated MSDU Present | QAP PS Buffer State     |
| QoS Null, QoS CFAck frames sent by HC          | TID      | EOSP  | Ack Policy | Reserved                | QAP PS Buffer State     |
| QoS data type frames sent by non-AP QSTAs      | TID      | 0     | Ack Policy | Aggregated MSDU Present | TXOP duration requested |
|                                                | TID      | 1     | Ack Policy | Aggregated MSDU Present | Queue size              |

## 7.2 Format of individual frame types

### 7.2.1 Control Frames

#### 7.2.1.7 Block Acknowledgement Request (BlockAckReq) frame format

Change the diagram of the BAR control field of 7.2.1.7 to appear as follows:

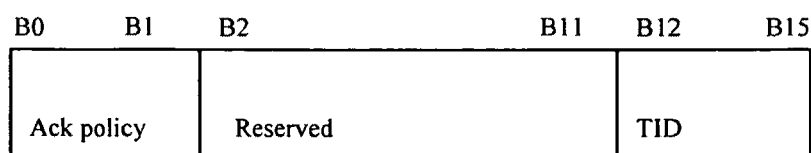


**Figure 21.2– BAR Control Field**

*Insert the following text and table immediately after Figure 21.2 within clause 7.2.1.7:*

The ACK Policy subfield of the BAR Control field contains the ACK policy for the BlockAckReq frame. The ACK policy subfield bits shall have the meaning indicated in table 3.3:

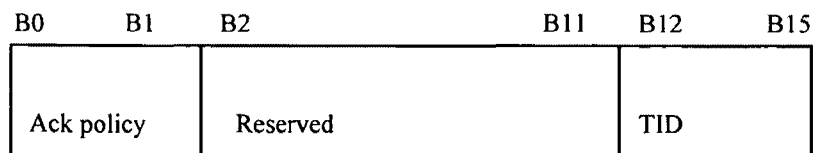
| <b>Bits in BAR Control field</b> | <b>Meaning</b>                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Bit 0 Bit 1</b>               |                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <u>0 0</u>                       | <u>Normal acknowledgement.</u><br><u>The addressed recipient returns an ACK as defined in 9.2.8 or a Block Acknowledgement frame after a SIFS period, according to the previously negotiated block ack policy as described in 11.5. The Ack Policy field is set to this value in all directed Block Ack Request frames in which the sender requires immediate acknowledgement, including those requiring an immediate Block Acknowledgement.</u> |
| <u>1 0</u>                       | <u>No Acknowledgement</u><br><u>The addressed recipient performs no immediate response action upon receipt of the frame. More details are provided in 9.11. The Ack Policy is set to this value in all BlockAckReq frames in which the sender does not require immediate, explicit acknowledgement.</u>                                                                                                                                          |
| <u>0 1</u>                       | <u>Reserved</u>                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <u>1 1</u>                       | <u>Reserved</u>                                                                                                                                                                                                                                                                                                                                                                                                                                  |

**Table 3.3**

### **7.2.1.8 Block Acknowledgement (BlockAck) frame format**

*Change the diagram of the BA control field of 7.2.1.8 to appear as follows:*

The BA control field defined in Figure 21.5 consists of the TID and Ack Policy subfields as shown in figure 21.5.

**Figure 21.5 – BA Control Field**

*Insert the following text and table immediately after Figure 21.5 within clause 7.2.1.8:*

The ACK Policy subfield of the BA Control field contains the ACK policy for the Block Acknowledgement frame. The ACK policy subfield bits shall have the meaning indicated in table 3.4:

| <b>Bits in BAR Control field</b> | <b>Meaning</b> |
|----------------------------------|----------------|
|----------------------------------|----------------|



| Bit 0 | Bit 1 |                                                                                                                                                                                                                                                                                                     |
|-------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0     | 0     | Normal acknowledgement.<br>The addressed recipient returns an ACK as defined in 9.2.8 after a SIFS period. The Ack Policy field is set to this value in all directed Block Acknowledgement frames in which the sender requires immediate acknowledgement.                                           |
| 1     | 0     | No Acknowledgement<br>The addressed recipient performs no immediate response action upon receipt of the frame. More details are provided in 9.11. The Ack Policy is set to this value in all Block Acknowledgement frames in which the sender does not require immediate, explicit acknowledgement. |
| 0     | 1     | Reserved                                                                                                                                                                                                                                                                                            |
| 1     | 1     | Reserved                                                                                                                                                                                                                                                                                            |

Table 3.4

## 7.2.2 Data Frames

Change the text, figures and tables in 7.2.2 (.11e) as shown:

The frame format for a Data frame is dependent on the QoS subfield of the subtype field and is as defined in Figure 22.

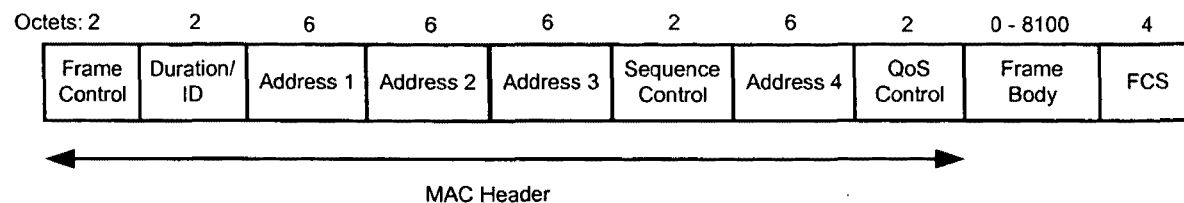


Figure 22 – Data frame

Change the definitions as follows:

The DA is the destination of the A-MSDU or MSDU (or fragment thereof) in the frame body field.

The SA is the address of the MAC entity which initiated the A-MSDU or MSDU (or fragment thereof) in the frame body field.

## 7.2.3 Management frames

### 7.2.3.1 Beacon frame format

Insert the Channel Set entry and change the notes in Table 5(.11g) to read as follows:

| Order | Information      | Notes                                                                                                                                                                                                         |
|-------|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7     | DS Parameter Set | The DS Parameter Set information element is present within Beacon frames generated by STAs using Clause 15, Clause 18 and Clause 19 PHYs and by STAs using Clause 20 PHYs while operating in the 2.4GHz band. |
| 15    | Channel Set      | The Channel Set information element is present within Beacon frames generated by APs using a                                                                                                                  |

|    |                 |                                                                                                                                                     |
|----|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
|    |                 | Clause 20 PHY operating on a 40 MHz channel pair                                                                                                    |
| 19 | ERP Information | The ERP Information element is present within Beacon frames generated by STAs using ERP PHYs and HTP PHYs and is optionally present in other cases. |

*Add a new clause 7.2.3.1.1 immediately after the existing clause 7.2.3.1 "Beacon Frame Format"*

### 7.2.3.1.1 Secondary Channel Beacon Format

An AP with a Clause 20 PHY operating on a 40 MHz channel pair may send a Beacon frame on the secondary channel as described in clause 9.13.2.1. In contrast to the normal sending of Beacon frames, the aim of sending a Beacon frame on the secondary channel is to discourage use of that channel (other than as the secondary channel of the 40 MHz channel pair) and as a result, the required frame body is substantially different.

The contents of the fields of the Beacon frame sent on the secondary channel shall be the same as those of the Beacon frame sent on the primary channel, with the exceptions noted below.

The Supported Rate Set Information Element shall consist of a single Clause 20 rate, marked as a basic rate.

**Table 7.2.3.1.1T1 – Beacon Frame Body when used as a Secondary Channel Beacon**

| Order | Information                   | Notes                                                                 |
|-------|-------------------------------|-----------------------------------------------------------------------|
| 1     | Timestamp                     |                                                                       |
| 2     | Beacon Interval               |                                                                       |
| 3     | Capability                    |                                                                       |
| 4     | Service Set Identifier (SSID) |                                                                       |
| 5     | Supported Rate Set            |                                                                       |
| 6     | CF Parameter Set              | May optionally be included to further discourage use of this channel. |
| 5     | Channel Set                   |                                                                       |

### 7.2.3.9 Probe Response frame format

*Insert the Channel Set entry and change the notes in Table 12(.11g) to read as follows:*

| Order | Information      | Notes                                                                                                                                                                                                                 |
|-------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7     | DS Parameter Set | The DS Parameter Set information element is present within Probe Response frames generated by STAs using Clause 15, Clause 18 and Clause 19 PHYs and by STAs using Clause 20 PHYs while operating in the 2.4GHz band. |
| 11    | Channel Set      | The Channel Set information element is present within Probe Response frames generated by APs using a Clause 20 PHY operating on a 40 MHz Channel Pair                                                                 |
| 18    | ERP Information  | The ERP Information element is present within Probe Response frames generated by STAs using ERP PHYs and HTP PHYs and is                                                                                              |

|                                    |
|------------------------------------|
| optionally present in other cases. |
|------------------------------------|

## 7.3 Management frame body components

### 7.3.1 Fixed fields

#### 7.3.1.4 Capability Information field

*Change the second paragraph in 7.3.1.4(11e) as shown:*

The length of the Capability Information field is 2 octets. The format of the Capability Information field is defined as illustrated in Figure 27. No subfield is supplied for ERP as a STA supports ERP operation if it includes all the clause 19 mandatory rates in its supported rate set. No subfield is supplied for HTP (STAs employing a Clause 20 PHY), as a STA supports HTP operation if it includes all of the Clause 20 mandatory rates in its supported rate set.

### 7.3.2 Information Elements

*Add a new row to Table 20 "Element IDs" as follows, and adjust reserved ids appropriately*

|             |                                                |
|-------------|------------------------------------------------|
| Channel Set | XXX-To be assigned by ANA before letter ballot |
|-------------|------------------------------------------------|

*Add the following text to the end of clause 7.3.2 after the table of Element IDs*

Individual information elements may be extended in length by future versions of this standard by adding new fields to the end of an existing information element. STAs shall ignore any additional information beyond the expected end of an Information Element, and shall treat any such information element as legal.

#### 7.3.2.13 ERP Information element

*Change the text of clause 7.3.2.13(11g) as follows:*

~~The ERP Information element contains information on the presence of Clause 15 or Clause 18 stations in the BSS that are not capable of Clause 19 (ERP-OFDM) data rates. It also contains the requirement of the ERP Information element sender (AP in a BSS or STA in an IBSS) as to the use of protection mechanisms to optimize BSS performance and as to the use of long or short Barker preambles. See Figure 42E for a definition of the frame element.~~

The ERP Information element contains information on:

- a) the presence of Clause 15 or Clause 18 stations in the BSS that are not capable of Clause 19 (ERP-OFDM) data rates
- b) the requirement of the ERP Information element sender (the AP, or in an IBSS a STA) as to the use of protection mechanisms to optimize BSS performance in the presence of STA which have implemented a PHY from Clause 15 or Clause 18 and not including Clause 19 capability
- c) the requirement of the ERP Information element sender (AP in a BSS or STA in an IBSS) as to the use of long or short Barker preambles
- d) the presence of Clause 19 stations in the BSS, when the ERP Information element sender is an HTP STA
- e) the requirement of the ERP Information element sender (AP in a BSS or STA in an IBSS) as to the use of OFDM-protection mechanisms to optimize BSS performance
- f) the presence of Clause 17 stations in the BSS, when the ERP Information element sender is a HTP STA
- g) the presence of Clause 17 stations in the secondary 20 MHz channel which potentially limits the ability of the HTP STA to utilize a 40 MHz wide channel, when the ERP Information element sender is a HTP STA

See Figure 42E for a definition of the ERP Information element.

If one or more NonERP STAs are associated in the BSS, the Use\_Protection bit shall be set to 1 in transmitted ERP Information Elements.

If one or more Clause 19 or Clause 17 STAs are associated in the BSS, then the Use\_OFDM\_Protection bit shall be set to 1 in ERP Information Elements transmitted by HTP STAs and may be set to 1 in ERP Information Elements transmitted by nHTP STAs.

In an IBSS, the setting of the Use\_Protection and Use\_OFDM\_Protection bits is left to the STA. In an IBSS, there is no uniform concept of association; therefore, a typical algorithm for setting the Use\_Protection and Use\_OFDM\_Protection bits will take into account the traffic pattern and history on the network. If a member of an IBSS which is not an HTP STA detects one or more NonERP STAs that are members of the same IBSS, then the Use\_Protection bit should be set to 1 in the ERP Information Element of transmitted Beacon and Probe Response frames. If a member of an IBSS which is a HTP STA detects one or more Clause 19 STAs or one or more Clause 17 STAs that are members of the same IBSS, then the Use\_OFDM\_Protection bit should be set to 1 in the ERP Information Element of transmitted Beacon and Probe Response frames.

The NonERP\_Present bit shall be set to 1 when a NonERP STA is associated with the BSS. Examples of when the NonERP present bit may additionally be set to 1 include, but are not limited to, when:

- a) A NonERP infrastructure or independent BSS is overlapping (a NonERP BSS may be detected by the reception of a Beacon where the supported rates contain only Clause 15 or Clause 18 rates).
- b) In an IBSS, if a Beacon frame is received from one of the IBSS participants where the supported rate set contains only Clause 15 or Clause 18 rates.
- c) A management frame (excluding a Probe Request) is received where the supported rate set includes only Clause 15 or Clause 18 rates.

The OFDM\_PRESENT bit shall be set to 1 in ERP Information Elements transmitted by HTP STA when a Clause 17 or Clause 19 STA is associated with the BSS. Examples of when the OFDM\_PRESENT bit may additionally be set to 1 in an ERP Information Element transmitted by a HTP STA include, but are not limited to, when

- a) A Clause 17 or Clause 19 infrastructure or independent BSS is overlapping. (A Clause 17 BSS may be detected by the reception of a Beacon where the supported rates contain only Clause 17 rates. A Clause 19 BSS may be detected by the reception of a Beacon where the supported rates contain at least one rate from the set of Clause 19 rates.)
- b) In an IBSS, if a Beacon frame is received from one of the IBSS participants where the supported rate set contains only Clause 17 rates or at least one rate from the set of Clause 19 rates.
- c) A management frame (excluding a Probe Request) is received where the supported rate set includes only Clause 17 rates or at least one rate from the set of Clause 19 rates.

The OFDM\_PRESENT bit may optionally be set to 1 in ERP Information Elements transmitted by non-HTP STA.

~~ERP APs and ERP STAs~~ ERP APs, ERP STAs, HTP APs and HTP STAs shall invoke the use of a protection mechanism after transmission or reception of the Use\_Protection bit with a value of 1 in an MMPDU to or from the BSS that the ~~ERP AP or ERP STA~~ ERP AP, ERP STA, HTP AP or HTP STA has joined or started. ~~ERP APs and ERP STAs~~ ERP APs, ERP STAs, HTP APs and HTP STAs may additionally invoke protection mechanism use at other times.

~~ERP APs and ERP STAs~~ ERP APs, ERP STAs, HTP APs and HTP STAs may disable protection mechanism use after transmission or reception of the Use\_Protection bit with a value of 0 in an MMPDU to or from the BSS that the ~~ERP APs or ERP STAs~~ ERP AP, ERP STA, HTP AP or HTP STA has joined or started.

HTP APs and HTP STAs shall invoke the use of an OFDM protection mechanism after transmission or reception of the Use\_OFDM\_Protection bit with a value of 1 in an MMPDU to or from the BSS that the HTP AP or HTP STA has joined or started. HTP APs and HTP STAs may additionally invoke OFDM protection mechanism use at other times.

HTP APs and HTP STAs may disable OFDM protection mechanism use after transmission or reception of the Use\_OFDM\_Protection bit with a value of 0 in an MMPDU to or from the BSS that the HTP AP or HTP STA has joined or started.

When there are no NonERP STAs associated with the BSS and the ERP Information Element sender's dot11ShortPreambleOptionImplemented MIB variable is set to true, then the Barker\_Preamble\_Mode bit may be set to 0. The Barker\_Preamble\_Mode bit shall be set to 1 by the ERP Information Element sender if one or more associated NonERP STAs are not short preamble capable as indicated in their Capability Information field, or if the ERP Information Element senders dot11ShortPreambleOptionImplemented MIB variable is set to false.

If a member of an IBSS detects one or more non-short preamble-capable STAs that are members of the same IBSS, then the Barker\_Preamble\_Mode bit should be set to 1 in the transmitted ERP Information Element.

~~ERP APs and ERP STAs~~ ERP APs, ERP STAs, HTP APs and HTP STAs shall use long preambles when transmitting Clause 15, Clause 18, and Clause 19 frames after transmission or reception of an ERP Information Element with a Barker\_Preamble\_Mode value of 1 in an MMPDU to or from the BSS that the ~~ERP APs or ERP STAs~~ ERP AP, ERP STA, HTP AP or HTP STA has joined or started, regardless of the value of the short preamble capability bit from the same received or transmitted MMPDU that contained the ERP Information Element. ~~ERP APs and ERP STAs~~ ERP APs, ERP STAs, HTP APs and HTP STAs may additionally use long preambles when transmitting Clause 15, Clause 18, and Clause 19 frames at other times. ~~ERP APs and ERP STAs~~ ERP APs, ERP STAs, HTP APs and HTP STAs may use short preambles when transmitting Clause 15, Clause 18, and Clause 19 frames after transmission or reception of an ERP Information Element with a Barker\_Preamble\_Mode value of 0 in an MMPDU to or from the BSS that the ~~ERP APs or ERP STAs~~ ERP AP, ERP STA, HTP AP or HTP STA has joined or started, regardless of the value of the short preamble capability bit from the same received or transmitted MMPDU. ~~NonERP STAs and NonERP APs~~ STAs which are neither ERP nor HTP and APs which are neither ERP nor HTP may also follow the rules given in this paragraph.

The Secondary\_Channel\_Used bit may be set to 0 in ERP Information Elements transmitted by HTP STAs or HTP APs if no frames with a Clause 17 BSSID have been received within the last two seconds on the secondary 20 MHz channel of the BSS that the HTP AP or HTP STA has joined or started, otherwise, the Secondary\_Channel\_Used bit shall be set to 1. nHTP STAs and nHTP APs shall always set the Secondary\_Channel\_Used bit to 0 if they transmit ERP Information elements.

Recommended behavior for setting the Use\_Protection bit is contained in 9.10.

The ERP Information element shall have the form shown in Figure 42E.

| B0-B7     | B0-B7     | B0             | B1             | B2                   | B3           | B4                  | B5                     | B6 | B7 |
|-----------|-----------|----------------|----------------|----------------------|--------------|---------------------|------------------------|----|----|
| ElementID | Length(1) | NonERP Present | Use_protection | Barker preamble mode | OFDM_present | Use_OFDM_Protection | Secondary_Channel_Used | R6 | R7 |

Figure 42E

~~Bits r3 through r7 are reserved, set to 0, and are ignored on reception. Note that the length of this element is flexible and may be expanded in the future.~~

Bits r6 and r7 are reserved, set to 0, and are ignored on reception. Note that the length of this element is flexible and may be expanded in the future.

### 7.3.2.22.1 Basic Report

*Change one of the reserved bits in figure 46a "Map Field Format" to be "Secondary Channel"*

*Add the following after the definition of the "Unmeasured bit"*

- Secondary Channel bit, which shall be set to 1 when at least one valid Secondary Channel Beacon (as described in clause 9.13.2.1) was received during the measurement period from another BSS. Otherwise the Secondary Channel bit shall be set to zero.

*Add the following new clauses as the last sub-clauses of 7.3.2 "Information Elements"*

### 7.3.2.25 Channel Set

The Channel Set information element is used to convey information about the channels from which a 40 MHz Channel Pair are formed. The Primary Channel field shall contain the channel number of the primary channel. The Secondary Channel shall contain the channel number of the secondary channel.

This information element may be extended in later versions of this standard.

See Figure 000n:

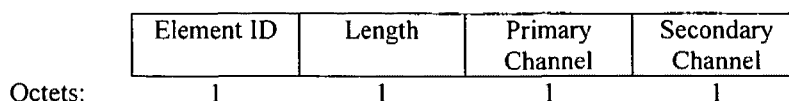


Figure 000n- Channel Set element format

## 9. MAC sublayer functional description

### 9.1 MAC architecture

*Insert the following subclause after clause 9.1.3(.11e) and renumber existing subclauses 9.1.4(.11e) through 9.1.5(.11e) to be subclauses 9.1.5 through 9.1.6*

#### 9.1.4 MSDU aggregation

One or more MSDUs being sent to the same receiver can be aggregated into a single A-MSDU. Aggregation of more than one frame can improve system efficiency as seen at the MAC sub-layer due to the fact that the overheads associated with channel access (e.g. PLCP preamble, MAC header, IFS spacing, etc.) can be amortized over two or more MSDUs. Frames with address types of Broadcast, Multicast, or Unicast frames can be aggregated with other frames of the same address type, but not with frames of different address type due to the requirement to share the receiver address. Aggregation is optional and the process is considered a "sub-process" between MSDU queuing and sequence number assignment in Figure 11g of Clause 6.1.4.

A STA shall only use MSDU aggregation where it knows that the receiver supports MSDU aggregation. A STA shall not aggregate MSDUs that have different values of priority as indicated by the MA-UNITDATA.request primitive. A STA may aggregate MSDUs with different values of destination address as long as they would have the same value in the Address 1 field had they been sent as individual MPDUs.

To form an A-MSDU, two or more MSDUs are aggregated together, separated by a sub-frame header. This is shown in Figure 001n. The resulting A-MSDU is therefore the combination of all MSDUs in the A-MSDU along with a sub-frame header for each constituent MSDU.

The destination address of the A-MSDU is the address of the STA that is the next immediate intended receiver of the aggregated frame. The source address of the A-MSDU is the MAC address of the STA that created the A-MSDU.

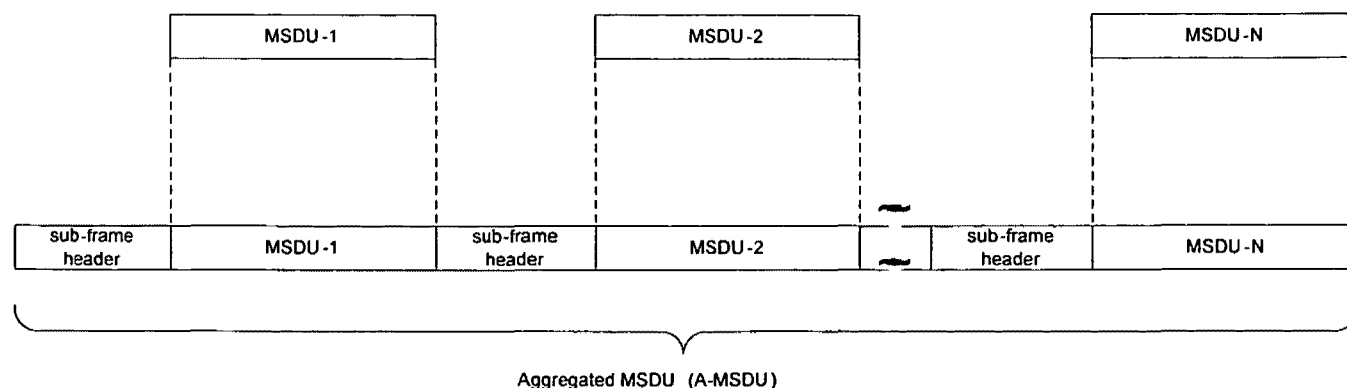
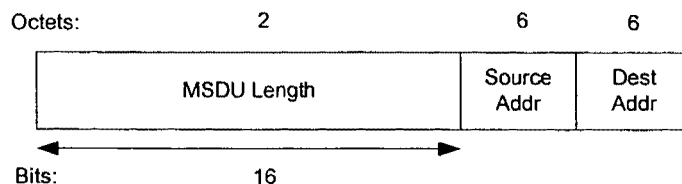


**Figure 001n – Formation of an A-MSDU**

The format for the sub-frame header is given in Figure 002n. The sub-frame header is 14 octets in length and consists of a 16-bit MSDU length field, a 6-octet source address of the constituent MSDU, and a 6-octet destination address of the constituent MSDU. The MSDU length field indicates the length, in octets, of the constituent MSDU.

**Figure 002n – Sub-Frame Header**

A data frame bearing an A-MSDU within its frame body is identified by a '1' in the Aggregated MSDU bit of the QoS Control Field (Clause 7.1.3.5). For data frames containing a non-aggregated MSDU, this bit will be zero.

After aggregation, the procedures for handling an A-MSDU are no different from an MSDU including sequence number assignment, optional MSDU integrity protection, and fragmentation, with the single exception of the Aggregated MSDU bit described above. Once formed, A-MSDUs shall not be un-aggregated by the transmitter, as there are no facilities for individual sequencing or retransmission of the constituent MSDUs.

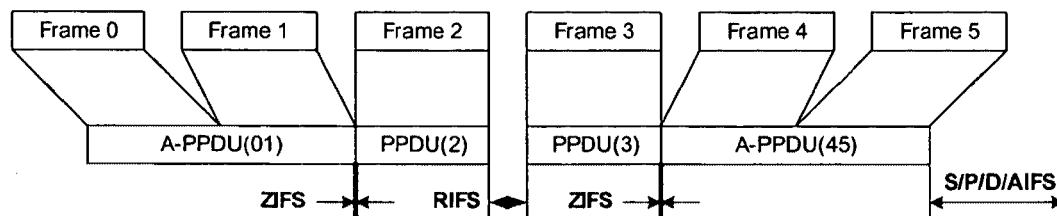
A method for determining when to engage optional MSDU aggregation is out of scope for this standard.

*Insert the following subclause after clause 9.1.3(11e) and renumber existing subclauses 9.1.6(11e) to be subclauses 9.1.7*

### 9.1.6 HTP Burst Transmission overview

The high-throughput PHY defines burst transmission formats that permit more efficient usage of the medium. A HTP burst transmission is performed in a single medium access, and permits frames to be sent to different destination addresses. These formats shall only be used to transmit frames to other HTP STAs, and may be used as part of any kind of TXOP. The medium spacing before and after a HTP burst transmission shall be governed by the rules covering the spacing before and after a non-burst transmission in the TXOP.

A HTP burst transmission consists of a sequence of frames transmitted by a single HTP STA without intervening frames by any other STA. The frames of the HTP burst transmission shall be transmitted using a single HTP rate group as defined in 20.3.2.2. During a HTP burst transmission, the MAC may utilise ZIFS or RIFS and/or instruct the PHY to aggregate multiple frames into a single A-PPDU. These formats are illustrated in Figure 003n.

**Figure 003n – HTP Burst transmission**

Frames may be aggregated into a single A-PPDU, or separated by ZIFS if they are being transmitted at the same TXPWR\_LEVEL. A frame that uses a different TXPWR\_LEVEL as the previous frame in the HTP burst transmission may use RIFS.

## 9.2 DCF

## 9.2.3 Interframe Space (IFS)

*Change the text in clause 9.2.3(11e) as follows*

The time interval between frames is called the IFS. A STA shall determine that the medium is idle through the use of the carrier sense function for the interval specified. Two interframe spaces, ZIFS and RIFS, are defined for use between frames in a HTP burst transmission, and another five IFSs are defined to provide priority levels for access to the wireless media. To obtain access to the medium, a STA shall determine that the medium is idle through the use of the carrier sense function for the interval specified. ~~Five different IFSs are defined to provide priority levels for access to the wireless media; they~~ The interframe spaces are listed in order, from the shortest to the longest except for AIFS. Figure 49 shows some of these relationships.

- a) ZIFS Zero Interframe Space
- b) RIFS Reduced Interframe Space
- c) Short Interframe Space
- d) PIFS Point Coordination Function (PCF) Interframe Space
- e) DIFS Distributed Coordination Function (DCF) Interframe Space
- f) AIFS Arbitration Interframe Space (used by the QoS facility)
- g) EIFS Extended Interframe Space

*Insert the following subclauses after clause 9.2.3(11e) and renumber existing subclauses 9.2.3.1(11e) through 9.2.3.5(11e) to be subclauses 9.2.3.3 through 9.2.3.7.*

### 9.2.3.1 ZIFS

The ZIFS may be used for the second or subsequent frame of a HTP burst transmission if the frame will be transmitted at the same power as the immediately previous frame.

### 9.2.3.2 RIFS

The RIFS may be used for the second or subsequent frame of a HTP burst transmission if the frame will be transmitted at a different power than the immediately previous frame.

## 9.2.12 Determination of PLME aCWmin characteristics

*Modify the first paragraph of clause 9.2.12 as follows:*

In the case of the Clause 19 Extended Rate PHY and Clause 20 High Throughput PHY, the aCWmin value is dependent on the requestor's characteristic rate set. The characteristic rate set is equal to the IBSS's supported rate set when the STA is operating as a member of an IBSS. It is equal to the AP's supported rate set when the STA is associated with an AP. At all other times, it is equal to the STA's mandatory rate set. The MAC variable aCWmin is set to aCWmin(0) if the characteristic rate set includes only rates in the set 1, 2, 5.5, 11 otherwise, aCWmin is set to aCWmin(1). If the returned value for aCWmin is a scalar, then the MAC always sets the variable aCWmin to the returned scalar value of aCWmin.

## 9.6 Multirate support

*Make the following changes to paragraph 7 of clause 9.6(11g) "Multirate Support":*

To allow the transmitting STA to calculate the contents of the Duration/ID field, a STA responding to a received frame shall transmit its Control Response (either CTS or ACK) frames at the highest rate in the BSSBasicRateSet that is less than or equal to the rate of the immediately previous frame in the frame exchange sequence (as defined in 9.7) and that is of the same modulation ~~type~~ class (see Clause 9.6.1) as the received frame. If no rate in the basic rate set meets these conditions, then the control frame sent in response to a received frame shall be transmitted at the highest mandatory rate of the PHY that is less than or equal to the rate of the received frame, and that is of the same modulation ~~type~~ class as the received frame. In addition, the Control Response frame shall be sent using the same PHY options as the received frame, unless they conflict with the requirement to use the BSSBasicRateSet.

*Add new clause 9.6.1 immediately following the existing clause 9.6*



## 9.6.1 Modulation Classes

In order to determine the rules for response frames given in clause 9.6, the following modulation classes are defined. Each row defines a modulation class. Modulation types within the same row have the same modulation class, while modulation types in different rows have different modulation classes.

**Table 9.6.1T Modulation Classes**

| Modulation Class | Description                                                               |
|------------------|---------------------------------------------------------------------------|
| 1                | Clause 16 Infrared PHY                                                    |
| 2                | Clause 14 Frequency Hopping Spread Spectrum PHY                           |
| 3                | Clause 15 DSSS PHY, and Clause 18 High Rate DSSS PHY                      |
| 4                | Clause 19.6 ERP-PBCC PHY                                                  |
| 5                | Clause 19.7 DSSS-OFDM                                                     |
| 6                | Clause 19.5 ERP-OFDM PHY                                                  |
| 7                | Clause 17 Orthogonal Frequency Division Multiplexing PHY in the 5GHz band |
| 8                | Clause 20 High Throughput PHY (20 MHz transmissions)                      |
| 9                | Clause 20 High Throughput PHY (40 MHz transmissions)                      |

## 9.9 HCF

### 9.9.1 HCF contention-based channel access (EDCA)

#### 9.9.1.4 Multiple frame transmission in an EDCA TXOP

*Change the first paragraph of subclause 9.9.1.4(.11e) as follows:*

Multiple frames may be transmitted in an acquired EDCA TXOP following the rules in 9.9.1.3. If there are more than one frame pending in the AC for which the channel has been acquired. However, those frames that are pending in other ACs shall not be transmitted in this EDCA TXOP. If a QSTA has in its transmit queue an additional frame of the same AC as the one just transmitted, and the duration of transmission of that frame plus any expected acknowledgement for that frame is less than the remaining medium occupancy timer value, then the QSTA may commence transmission of that frame at SIFS after the completion of the immediately preceding frame exchange sequence after the completion of the appropriate interframe space from the end of the immediately preceding frame exchange sequence. The intention of using the multiple frame transmission shall be indicated by the QSTA through the setting of the duration/ID values in one of the following two ways (see 7.1.4):

### 9.9.2 HCF controlled channel access

#### 9.9.2.1 HCF controlled channel access procedure

##### 9.9.2.1.2 CAP generation

*Change the second paragraph of subclause 9.9.2.1.2(.11e) as follows*

During a CFP or a TXOP in CP, after each data, QoS data or management type frame with a group address in the Address1 field, the HC shall wait for at least one PIFS period, and shall only continue to transmit if the WM is idle. After the last frame of all other non-final frame exchange sequences (e.g., sequences that convey unicast QoS data or management type frames) during a TXOP, the holder of the current TXOP shall wait for one SIFS period before transmitting the first frame of the next frame exchange sequence, unless the frame exchange is part of a HTP burst transmission when the rules identified in clause

9.1.6 apply. The HC may sense the channel and reclaim the channel after a duration of PIFS after the TXOP, if the channel remains idle. A CAP ends when the HC does not reclaim the channel after a duration of PIFS after the end of a TXOP.

## 9.9.2.2 TXOP structure and timing

*Change the first paragraph of subclause 9.9.2.2(11e) as follows*

Any QoS data type frame of a subclass that includes CF-Poll contains a TXOP limit in its QoS control field. The ensuing polled TXOP is protected by the NAV set by the Duration field of the frame that contained the QoS (+) CF-Poll function, as shown in Figure 62.4. Within a polled TXOP a QSTA may initiate the transmission of one or more frame exchange sequences, with all such sequences being part of a HTP burst transmission, or being nominally separated by a SIFS interval. The QSTA shall not initiate transmission of a frame unless the transmission, and any acknowledgement or other immediate response expected from the peer MAC entity, are able to complete prior to the end of the remaining TXOP duration. All transmissions, including the response frames, within the polled TXOP are considered to be the part of the TXOP and the HC shall account for these when setting the TXOP limit. If the TXOP Limit subfield in the QoS Control field of the QoS data type frame that includes CF-Poll is set to 0, then the QSTA to which the frame is directed to shall respond with either one MPDU or one QoS Null frame.

## 9.10 Block acknowledgment

### 9.10.1 Introduction (Informative)

*Change the first paragraph of subclause 9.9.10.1(11e) as follows*

The Block Acknowledgement (Block Ack) mechanism allows a block of QoS Data MPDUs to be transmitted between two QSTAs without intervening ACK frames each separated by a SIFS period, between two QSTAs. The mechanism is for improving the channel efficiency by aggregating several acknowledgements into one frame. There are two types of Block Ack mechanisms: immediate and delayed. Immediate Block Ack is suitable for high-bandwidth, low latency traffic while the delayed Block Ack is suitable for applications that tolerate moderate latency. In this clause, the QSTA with data to send using the Block Ack mechanism is referred to as the originator and the receiver of that data as the recipient.

### 9.10.3 Data and acknowledgement transfer

*Change the first paragraph of subclause 9.9.10.1(11e) as follows*

After setting up for the Block exchange following the procedure in 9.10.2, the originator may transmit a Block of QoS data type frames ~~separated by SIFS period,~~ with the total number of frames not exceeding the Buffer Size subfield in the associated ADDBA response frame. Each of the frames shall have the Ack policy subfield in the QoS Control set to "Block Acknowledgement". The RA field of the frames shall be the recipient's *unicast* address. The originator requests acknowledgement of outstanding QoS Data type frames by sending a BlockAckReq frame. The recipient shall maintain a Block Ack record for the block.

## 9.12 Frame exchange sequences

*Edit Table 22.1(11e) <HCF sequence> and replace all "=" with "-".*

*Remove definiton 36 from end of Table 22.4(11e) (no PIFS spacing defined anymore).*

*Replace the last sentence of the text in subclause 9.12 as follows(11e) with:*

Individual frames within each of these sequences ~~are separated by a SIFS~~ may be send as part of a HTP burst transmission if the frames meet the rules identified in clause 9.16., otherwise a SIFS separation is used unless an "=" sign appears between frames in the table, in which case, PIFS is used.

## 9.13 Protection mechanism

*Delete two paragraphs from the text of clause 9.13 as follows:*

If a protection mechanism is being used, a fragment sequence may only employ ERP-OFDM modulation for the final fragment and control response.

The rules for calculating RTS/CTS NAV fields are unchanged when using RTS/CTS as a protection mechanism.

*Insert the following new subclause after clause 9.13:*

### 9.13.1 OFDM Protection

The intent of an OFDM protection mechanism is to ensure that an HTP STA does not transmit an MPDU of type Data or an MMPDU, using a Clause 20 rate which is not also a Clause 17 or Clause 19 rate unless it has attempted to update the NAV or cause a PHY-CCA.indicate(status=BUSY) to be elicited by receiving Clause 17 or Clause 19 STAs.

The updated NAV period shall be longer than or equal to the total time required to send the data and any required response frames.

The PHY-CCA.indicate(status=BUSY) shall be longer than or equal to the total time required to send the data and any required response frames.

HTP STAs shall use OFDM protection mechanisms (such as RTS/CTS or CTS-to-self employing a Clause 19 or Clause 17 rate) for Clause 20-only rate MPDUs of type Data or MMPDUs when the Use\_OFDM\_Protection field of transmitted or received ERP Information elements is set to 1 and the BSSID of the frame which contained the ERP Information element is the same as the BSS which the HTP STA has joined or started. Clause 19 rates shall be employed when the BSS is operating in a Clause 19 channel. Clause 17 rates shall be employed when the BSS is operating in a Clause 17 channel.

OFDM Protection mechanism frames shall conform to at least one of the following conditions:

The frame shall be sent using one of the mandatory Clause 19 or Clause 17 rates and using one of the mandatory Clause 17 or Clause 19 waveforms, so that all known ERP or Clause 17 STAs in the BSA will know the duration of the exchange even if they cannot detect the Clause 20 frames using their CCA function

The frame shall be sent using a Clause 17 preamble and signal field (additional, non-clause 17 preamble and signal field may be present following the Clause 17 preamble and signal field)

The frame shall be sent using a Clause 19 preamble and signal field (additional, non-clause 19 preamble and signal field may be present following the Clause 19 preamble and signal field)

In the case of a BSS composed of only HTP STAs, but with knowledge of a neighboring co-channel BSS having nHTP traffic, the AP may require either or both of protection mechanisms and OFDM protection mechanisms to protect the BSSs traffic from interference. This will provide propagation of NAV of PHY-CCA.indicate(status=BUSY) to all associated STAs and all STAs in a neighboring co-channel BSS within range through BSS basic rate set modulated messages. Frames that propagate the NAV throughout the BSS include RTS/CTS/ACK frames, all data frames with the "more fragments" field set to 1, all data frames sent in response to PS-Poll that are not preceded in the frame sequence by a data frame with the "more fragments" field set to 1, Beacon frames with nonzero CF time, +CF-POLL frames, various QOS frames, and CF-End frames. Frames that propagate PHY-CCA.indicate(status=BUSY) throughout the BSS include any frames which commence with an appropriately chosen preamble and signal field.

If any of the rates in the BSSBasicRateSet of the OFDM protection mechanism frame transmitting STAs BSS are Clause 17 or Clause 19 rates, then the OFDM protection mechanism frames shall be sent at one of those Clause 17 or Clause 19 basic rates, unless either condition b) or condition c) from above has been met, in which case, no rate restrictions apply.

OFDM Protection Mechanisms shall not be used where the frame transmission will be protected by the Protection Mechanism defined in clause 9.13

*Insert new clause 9.14 and sub-clauses as follows:*

### 9.14 40 MHz Channel Pairs

Clause 20 defines a mode in which High Throughput PHYs can transmit a frame utilising a 40 MHz channel pair in order to achieve lower frame durations than if a single 20 MHz channel was used. This clause describes the MAC support for this feature in an infrastructure BSS. 40 MHz transmissions shall only be used when the STA has joined or started an Infrastructure BSS.

A 40 MHz channel pair consists of two 20 MHz channels, and a BSS operating on a 40 MHz Channel Pair will make use of one of these channels (called the primary channel) for 20 MHz transmissions. The other channel (called the secondary channel) will not be used by the BSS for 20 MHz transmissions.

### 9.14.1 40 MHz Fundamentals of Operation

A 40 MHz channel pair consists of two 20 MHz channels, on each of which there could be 20 MHz transmissions (from an overlapping BSS on either channel, or from 20 MHz transmissions on the primary channel), and on each of which the Carrier Sense mechanism described in clause 9.2.1 could be run. However, it is not possible to combine two Carrier Sense mechanisms without degrading the effective priority of 40 MHz transmissions to such an extent that they would provide no benefit.

For this reason the MAC models a 40 MHz channel pair as a single 20 MHz channel (the primary channel) in which some transmissions happen to “overflow” into the Secondary Channel. There is no requirement for a STA to consider the state of the Secondary Channel when transmitting.

A STA shall control access to the 40 MHz channel pair through performing the Carrier Sense mechanism on the primary channel. A STA shall not change the transmission time of a frame due to the state of the Carrier Sense mechanism on the secondary channel. A STA may change the transmission rate or modulation class of the frame based on the state of the Carrier Sense mechanism on the secondary channel, where allowed by clause 9.6.

An AP shall indicate that it is operating on a 40 MHz channel pair by including the Channel Set information element in its Beacon frames. An AP shall not change the information contained in the Channel Set information element without invoking the channel move procedure described in clause 11.6.7. A STA that has joined a BSS and that wishes to use 40 MHz transmissions shall check the setting of the Secondary\_Channel\_Used bit in the ERP Information Element in the last valid Beacon frame received from the BSS, and shall not use 40 MHz transmissions where the Secondary\_Channel\_Used bit is set to 1.

A STA shall not send a 20 MHz transmission to a member STA of a BSS on the secondary channel of that BSS. A STA that has joined or started a BSS operating on a 40 MHz channel pair shall discard all 20 MHz transmissions received on the secondary channel. A STA shall not join a BSS on its secondary channel.

### 9.14.2 Coexistence with non High Throughput STAs on the secondary channel

As there is no requirement for a STA to consider the Carrier Sense state of the secondary channel before transmitting, the likelihood of collisions with 20 MHz transmissions from an overlapping BSS in the secondary channel is greatly increased. A STA shall not initiate a frame sequence making use of 40 MHz transmissions if there is significant evidence of collisions on the secondary channel. The algorithm for determining significant evidence of collisions is implementation dependant.

An AP that detects significant evidence of collisions on the secondary channel may invoke the channel move procedure described in clause 11.6.7.

#### 9.14.2.1 Secondary Channel Beacon

In order to reduce the chance of the secondary channel being used by an overlapping BSS, an AP may send a Beacon frame using the secondary channel with contents chosen to discourage use of the secondary channel by other BSSes.

The frame body of such a beacon is shown in Clause 7.2.3.1.1. These beacons contain a rate set consisting of a single clause 20 basic rate, and so should not cause non-clause 20 STAs to attempt to associate with the AP on the secondary channel.

When transmitting a beacon on the secondary channel, the AP may observe the channel access mechanisms described elsewhere in clause 9 for the transmission of Beacon frames, or it may transmit the Beacon frame without consideration of the state of the secondary channel.

### 9.14.3 Beacon Transmission

An AP operating on a 40 MHz channel pair shall send Beacon frames (with the exception of Secondary Channel Beacon frames) on the primary channel using a 20 MHz transmission.

#### 9.14.4 Limits on Channel Numbering

Both the primary and secondary Channels shall be legal 20 MHz channels in the 5GHz band. For a primary channel number “n”, the secondary channel number shall be either “n+4” or “n-4”.

### 10. Layer management

#### 10.4 PLME SAP interface

##### 10.4.3 PLME\_CHARACTERISTICS.confirm

##### 10.4.3.2 Semantics of the service primitive

*Change the primitive description as follows:*

The primitive provides the following parameters:

```
PLME-CHARACTERISTICS.confirm(
    aSlotTime,
    aSIFSTime,
    aRIFSTime,
    aCCATime,
    aRxTxTurnaroundTime,
    aTxPLCPDelay,
    aRxPLCPDelay,
    aRxTxSwitchTime,
    aTxRampOnTime,
    aTxRampOffTime,
    aTxRFDelay,
    aRxRFDelay,
    aAirPropagationTime,
    aMACProcessingDelay,
    aPreambleLength,
    aPLCPHeaderLength,
    aMPDUDurationFactor,
    aMPDUMaxLength,
    aCWmin,
    aCWmax
)
```

*Add the following entry to the table:*

|           |         |                                                                                                                                                          |
|-----------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| aRIFSTime | integer | The minimum time (in microseconds) that the PHY requires between PSDUs that are transmitted with differing TXPWR LEVELs within a HTP burst transmission. |
|-----------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------|

##### 10.4.4 PLME-DSSSTESTMODE.request

##### 10.4.4.2 Semantics of the service primitive

*Change the sixth row in the table in 10.4.4.2 as shown:*

|           |         |                                                                                                      |                                                                                                                                |
|-----------|---------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| DATA_RATE | Integer | 2, 4, 11, 12, 18, 22, 24, 36, 44, 48, 66, 72, <u>73-92</u> , 96, <u>97-106</u> , 108, <u>109-121</u> | Selects among rates <u>and</u> <u>transmission modes</u><br>02 = 1 Mbit/s<br>04 = 2 Mbit/s<br>11 = 5.5 Mbit/s<br>12 = 6 Mbit/s |
|-----------|---------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|

|  |  |  |                                                                                                                                                                                                                                                                                          |
|--|--|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  |  |  | 18 = 9 Mbit/s<br>22 = 11 Mbit/s<br>24 = 12 Mbit/s<br>36 = 18 Mbit/s<br>44 = 22 Mbit/s<br>48 = 24 Mbit/s<br>66 = 33 Mbit/s<br>72 = 36 Mbit/s<br>96 = 48 Mbit/s<br>108 = 54 Mbit/s<br><u>73-92, 97-106, 109-121 =</u><br><u>See Tables 003-009 and</u><br><u>016 in subclause 20.3.2.2</u> |
|--|--|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## 20. High throughput PHY specification for the 2.4 and 5 GHz bands

### 20.1 Overview

This clause specifies the PHY entity for a multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) system and the additions that have to be made to the base standard to accommodate the MIMO-OFDM PHY. The radio frequency LAN system is aimed for both the 2.4 GHz band and the 5 GHz bands, as specified in subclause 20.3.8.3

#### 20.1.1 Introduction

The MIMO-OFDM system provides a wireless LAN with mandatory data payload communication capabilities of up to 135 Mbit/s and with optional modes capable of supporting data rates up to 540 Mbit/s. The MIMO-OFDM PHY draws from the basic OFDM PHY defined in Clause 17, and builds its extensions to two, three, and four transmit antenna modes (hereafter known as 2TX, 3TX, and 4TX, respectively), operating in 20 MHz bandwidth. Additionally, 1TX, 2TX, 3TX, and 4TX modes are also defined for operation in 40 MHz bandwidth.

#### 20.1.2 Operational Modes

The radio portion of all Clause 20 compliant MIMO-OFDM PHY systems shall implement all mandatory and optional data rates defined in Clause 17, all mandatory data rates defined in Clause 19, and all optional data rates of the OFDM-based ERP defined in Clause 19, in their respective bands of operation. In addition, support for transmitting and receiving data using the MIMO-OFDM PHY defined in this Clause is mandatory for all rates specified for the 2TX, 20 MHz mode. Support for 3TX and 4TX modes in 20 MHz, and 1TX, 2TX, 3TX, and 4TX modes in 40 MHz shall be optional.

#### 20.1.3 Scope

This subclause describes the PHY services provided to the IEEE 802.11 wireless LAN MAC by the MIMO-OFDM system. The MIMO-OFDM PHY layer consists of two protocol functions, defined as follows:

- a) A PHY convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the IEEE 802.11 PHY sublayer service data units (PSDU) into a framing format suitable for sending and receiving user data and management information between two or more stations using the associated PMD system.
- b) A PMD system whose function defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more stations, each using the MIMO-OFDM PHY.

#### 20.1.4 MIMO-OFDM PHY functions

The architecture of the MIMO-OFDM PHY is depicted in the ISO/IEC basic reference model shown in Figure 141 of 18.4.1. The MIMO-OFDM PHY contains three functional entities: the PMD function, the PHY convergence function (PLCP), and the layer management function.

The MIMO-OFDM PHY service is provided to the MAC through the PHY service primitives defined in Clause 12. Interoperability is addressed by use of the carrier sense mechanism specified in 9.2.1 and the protection mechanism in 9.10. This mechanism allows non-MIMO-OFDM stations to know of MIMO-OFDM traffic that they cannot demodulate so they may defer the medium to that traffic.

## 20.2 PHY-specific service parameter list

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require PHY-dependent MAC state machines running in the MAC sublayer in order to meet certain PMD requirements. The PHY-dependent MAC state machine resides in a sublayer defined as the MAC sublayer management entity (MLME). In certain PMD implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PMD. This subclause addresses the TXVECTOR and RXVECTOR for the MIMO-OFDM PHY.

The parameters in Table 001 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request service and PLME-TXTIME.request primitives.

**Table 001—TXVECTOR parameters**

| Parameter         | Value                                                                                                                                                                                                                                                                                   |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DATARATE          | The rate used to transmit the PSDU in Mbit/s. Allowed value depends on the values of TRANSMISSION_MODE and NUM_STREAMS parameters<br><br>Values: 6.75, 10.125, 13.5, 20.25, 27, 40.5, 54, 60.75, 81, 108, 121.5, 135, 162, 182.25, 202.5, 216, 243, 270, 324, 364.5, 405, 432, 486, 540 |
| LENGTH            | The length of the PSDU in octets<br><br>Range: 1-8191                                                                                                                                                                                                                                   |
| TRANSMISSION_MODE | The mode used for transmission of the PPDU. Determines the preamble type used.<br><br>Enumerated type: 2TX20GF, 3TX20GF, 4TX20GF, 2TX20MM, 3TX20MM, 4TX20MM, 1TX40GF, 2TX40GF, 3TX40GF, 4TX40GF, 1TX40MM, 2TX40MM, 3TX40MM, 4TX40MM.                                                    |
| NUM_STREAMS       | The number of independent spatial streams transmitted.<br><br>Values: 1, 2, 3, 4.                                                                                                                                                                                                       |
| CODE_TYPE         | Convolutional or LDPC<br><br>Values: 0 (convolutional), 1 (LDPC)                                                                                                                                                                                                                        |
| SERVICE           | The scrambler initialization vector.<br><br>16 null bits                                                                                                                                                                                                                                |
| TXPWR_LEVEL       | The transmit power level. The definition of these levels is up to the implementer.<br><br>Range: 1-8                                                                                                                                                                                    |
| LPI               | Indicates that this is the last PSDU to be aggregated into the current PPDU<br><br>Values: true, false                                                                                                                                                                                  |
| BURST_DURATION    | The length in microseconds of the BURST_DURATION field in the mixed mode preamble. Only used when a mixed mode TRANSMISSION_MODE is selected.<br><br>Range: 0-4095                                                                                                                      |

The parameters in Table 002 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indicate service primitive. When implementations require the use of these vectors, some or all of these parameters may be used in the vectors.

Table 002—RXVECTOR parameters

| Parameter         | Value                                                                                                                                                                                                                                                                                        |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DATARATE          | The rate at which the PSDU was received in Mbit/s. Allowed value depends on the values of TRANSMISSION_MODE and NUM_STREAMS parameters<br><br>Values: 6.75, 10.125, 13.5, 20.25, 27, 40.5, 54, 60.75, 81, 108, 121.5, 135, 162, 182.25, 202.5, 216, 243, 270, 324, 364.5, 405, 432, 486, 540 |
| LENGTH            | The length of the PSDU in octets.<br><br>Range: 1-8191                                                                                                                                                                                                                                       |
| TRANSMISSION_MODE | The transmission type detected during reception of the PPDU<br><br>Enumerated type: 2TX20GF, 3TX20GF, 4TX20GF, 2TX20MM, 3TX20MM, 4TX20MM, 1TX40GF, 2TX40GF, 3TX40GF, 4TX40GF, 1TX40MM, 2TX40MM, 3TX40MM, 4TX40MM.                                                                            |
| NUM_STREAMS       | The number of independent spatial streams transmitted.<br><br>Values: 1,2,3,4.                                                                                                                                                                                                               |
| CODE_TYPE         | Convolutional or LDPC<br><br>Values: 0 (convolutional), 1 (LDPC)                                                                                                                                                                                                                             |
| SERVICE           | Null                                                                                                                                                                                                                                                                                         |
| RSSI              | The RSSI is a measure of the RF energy received by the MIMO-OFDM PHY, averaged across all RX antennas. The 8-bit value is in the range of 0 to RSSI maximum as described in 17.2.3.2.                                                                                                        |
| LPI               | Indicates that this is the last PSDU to be aggregated into the current PPDU<br><br>Values: true, false                                                                                                                                                                                       |
| BURST_DURATION    | The length in microseconds of the BURST_DURATION field in the mixed mode preamble. Only valid when a mixed mode TRANSMISSION_MODE is used.<br><br>Range: 0-4095                                                                                                                              |

## 20.3 MIMO-OFDM PLCP sublayer

### 20.3.1 Introduction

This subclause provides a convergence procedure by which PSDUs are converted to and from PPDU at the transmitter and receiver. During transmission, the PSDU shall be appended with a PLCP preamble and header to create the PPDU. At the receiver, the PLCP preamble and header are processed to aid in the demodulation and delivery of the PSDU.

Stations implementing the MIMO-OFDM PHY shall use one of two methods of access to the medium. The medium may be reserved solely via a MAC mechanism, as defined in subclause 9.13. Alternatively, a special PLCP frame format may be used to cause non-MIMO-OFDM stations to defer the medium to MIMO-OFDM traffic. Hereafter, these two methods of access shall be known as greenfield and mixed-mode, respectively.

### 20.3.2 PLCP frame format

Figure 001 shows the format of the PPDU used with greenfield access in the 1TX mode of operation in 40 MHz and the 2TX modes of operation in both 20 and 40 MHz. The PPDU consists of a MIMO-OFDM PLCP preamble, MIMO-OFDM PLCP header, PSDU, and may consist of appended tail bits and pad bits.

The MIMO-OFDM PLCP preamble is composed of a sequence of short and long training symbols. The format of the PLCP preamble is defined in subclause 20.3.3 for each mode of operation in the MIMO-OFDM PHY.



The MIMO-OFDM PLCP header is composed of the SIGNAL-N field and the SERVICE field. The SIGNAL-N field is defined in 20.3.4 and consists of 54 bits that specify all configuration and length-related parameters associated with PPDU transmission. The SERVICE field is composed of 16 bits and is defined in subclause 20.3.5.1.

The SERVICE field of the PLCP header and the PSDU (with tail and pad bits appended, if necessary) are denoted as DATA and may constitute multiple MIMO-OFDM symbols. These symbols are transmitted according to the configuration parameters specified in the SIGNAL-N field.

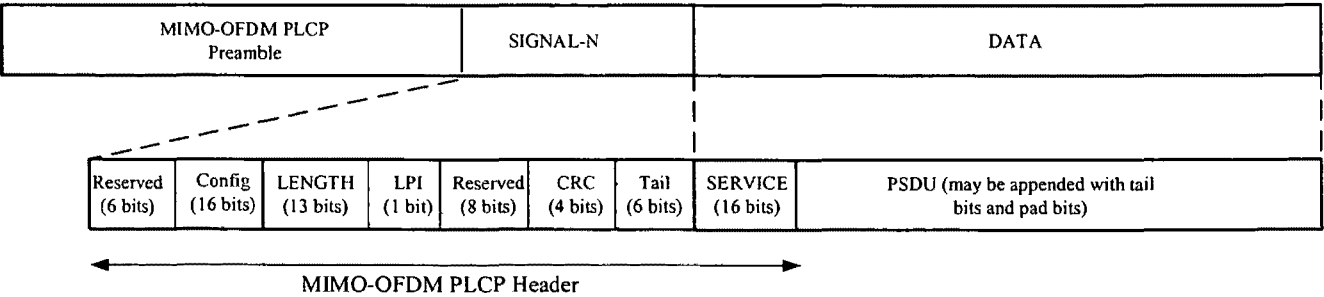


Figure 001 – PPDU frame format: Greenfield access in the 1TX (40 MHz) and 2TX (20 and 40 MHz) modes

Figure 002 shows the format of the PPDU used with greenfield access in the 3TX and 4TX modes of operation in both 20 and 40 MHz. In these modes the MIMO-OFDM PLCP preamble field is extended according to subclause 20.3.3 in order to provide training from the additional transmit antennas.

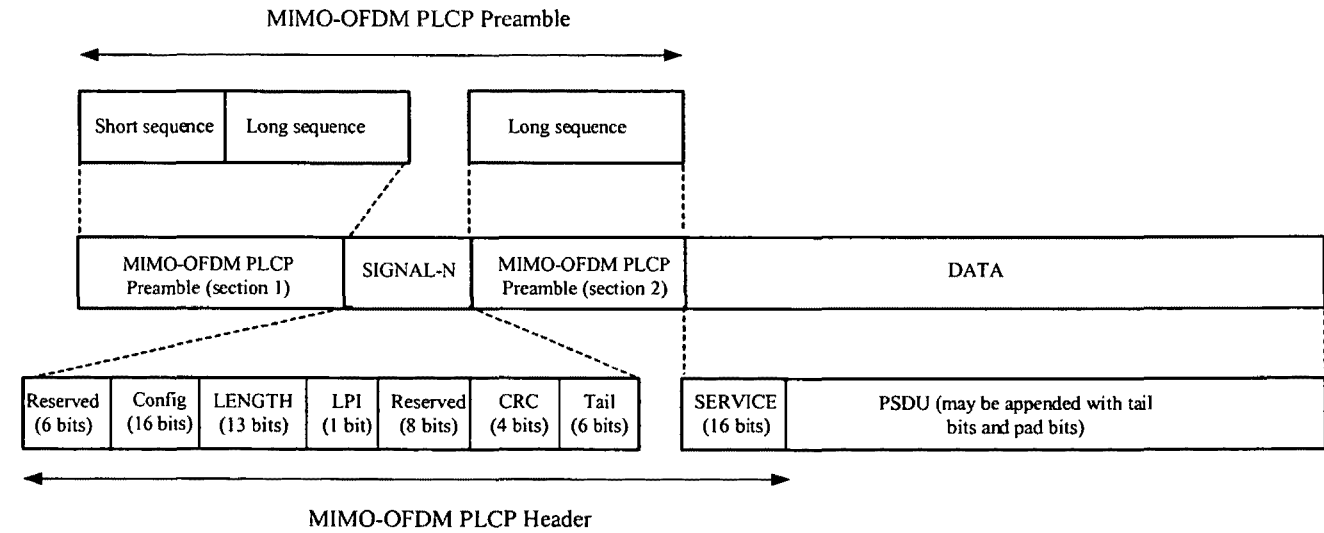


Figure 002 – PPDU frame format: Greenfield access in the 3TX and 4TX modes (20 and 40 MHz)

Figure 003 shows the format of the PPDU used with mixed-mode access in the 1TX mode of operation in 40 MHz and the 2TX modes of operation in both 20 and 40 MHz. The PLCP header in these modes consists of an additional SIGNAL-MM field that conveys information about the MIMO-OFDM PPDU transmission to non-MIMO-OFDM stations, causing them to defer the medium for the duration of the MIMO-OFDM transmission. The SIGNAL-MM field is defined in subclause 20.3.4.

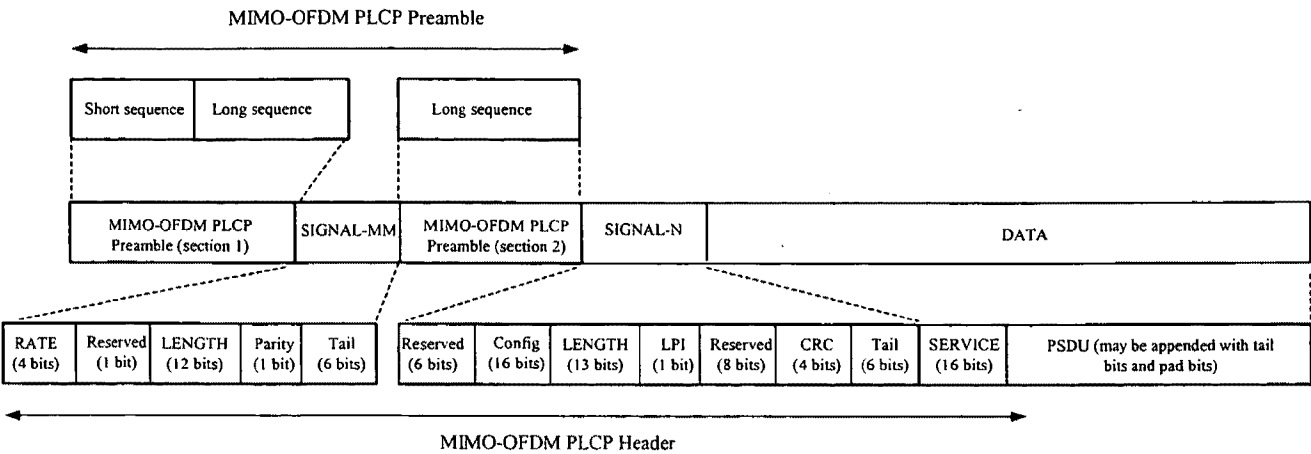


Figure 003 – PPDU frame format: Mixed mode access in the 1TX (40 MHz) and 2TX (20 and 40 MHz) modes

Figures 004 and 005 shows the format of the PPDU used with mixed mode access in the 3TX and 4TX modes, operating in 20 MHz and 40 MHz, respectively.

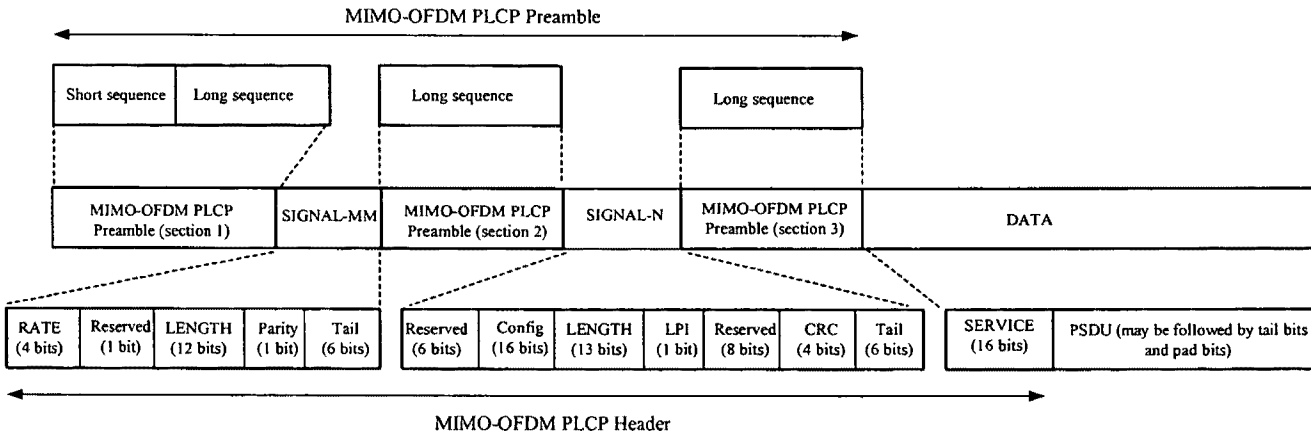


Figure 004– PPDU frame format: Mixed mode access in the 3TX and 4TX modes (20 MHz)

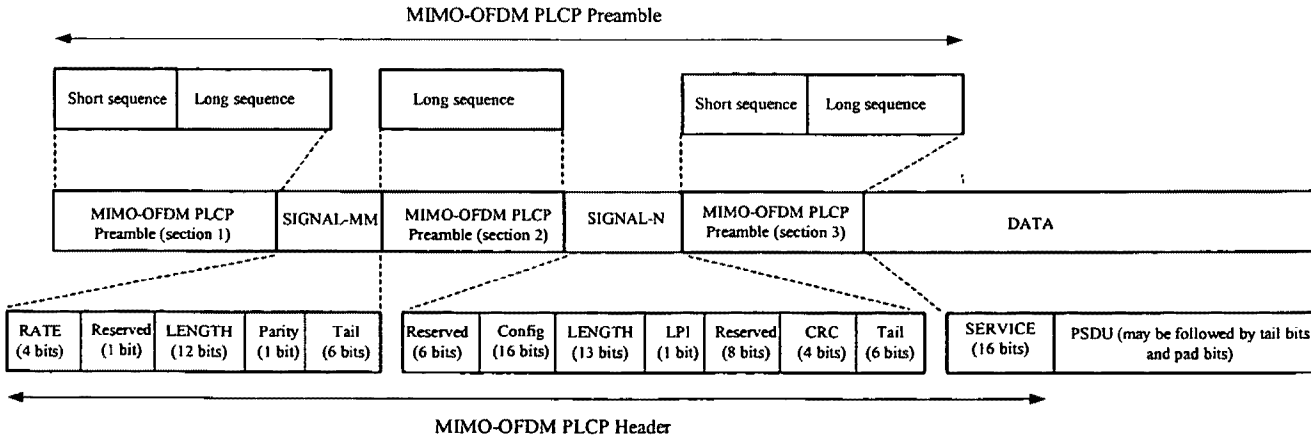


Figure 005– PPDU frame format: Mixed mode access in the 3TX and 4TX modes (40 MHz)

### 20.3.2.1 Overview of the PPDU encoding process

The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details described in these subclauses:

- a) Produce the PLCP preamble fields for each transmit antenna based on the TRANSMISSION\_MODE field of the TXVECTOR. Refer to 20.3.3 for details.
- b) Produce the PLCP header field from the LENGTH, DATARATE, TRANSMISSION\_MODE, NUM\_STREAMS, CODE\_TYPE, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields, as described in subclause 20.3.4 and subclause 20.3.5.1.
- c) Calculate from the DATARATE, TRANSMISSION\_MODE, and NUM\_STREAMS fields of the TXVECTOR, the number of data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ), the coding rate ( $R$ ), the number of bits in each OFDM subcarrier per antenna ( $N_{BPSC}$ ), the number of coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ), the number of spatial streams ( $N_{SS}$ ), and the number of encoding streams ( $N_{ES}$ ).
- d) Extend the data bit string with “zero” bits (at least 6 bits for each encoding stream) so that the resulting length will be a multiple of the number of data bits per OFDM symbol ( $N_{DBPS}$ ).
- e) Initiate the scrambler with a pseudorandom non-zero state; generate a sequence of scrambled data bits as defined in subclause 20.3.5.4.
- f) Demultiplex every other bit of the “data” to the  $N_{ES}$  encoding streams, with bit 0 directed to the first encoder.
- g) Replace the six scrambled “zero” bits following the “data” of each parallel encoding stream with six nonscrambled “zero” bits (These bits return the convolutional encoder to the “zero state” and are denoted as “tail bits.”).
- h) Encode each extended, scrambled parallel encoding stream data string with a convolutional encoder ( $R = 1/2$ ). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate”, as defined in subclause 20.3.5.5.
- i) Divide the parallel encoded bit strings into groups of  $N_{CBPS} / N_{ES}$  bits and multiplex them alternately between the  $N_{ES}$  encoders’ outputs to obtain a single aggregated bit string.
- j) Divide the aggregated bit string into groups of  $N_{CBPS}$  bits. Within each group, perform an “interleaving” (reordering) of the bits according to the rule specified in subclause 20.3.5.6. The interleaving parameters are independent of  $N_{ES}$ .
- k) Divide the resulting coded and interleaved data string into groups of  $N_{BPSC}$  bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables.
- l) Divide the complex number string into groups of  $N_{SD} \times N_{SS}$  complex numbers, where  $N_{SD}$  is the number of data subcarriers per OFDM symbol, and  $N_{SS}$  is the number of spatial streams to be transmitted. Map the complex numbers to antennas and subcarriers, as specified in subclause 20.3.5.8. The first  $N_{SD}$  complex numbers are modulated on the subcarriers of the first transmit antenna.
- m) Insert  $N_{SP}$  subcarriers as pilots on each transmit antenna, according to subclause 20.3.5.9.
- n) For each group of subcarriers, and on each TX antenna, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a guard interval (GI), and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 20.3.2.4 for details.
- o) Append the OFDM symbols for each antenna one after another, starting with the SIGNAL symbols defined in subclause 20.3.4, and with fields of the PLCP preamble inserted in between if necessary. Refer to 20.3.3 for details.
- p) Up-convert the resulting “complex baseband” waveform on each antenna to an RF frequency according to the center frequency of the desired channel and transmit. Refer to 20.3.2.4 and 20.3.8.1 for details.

### 20.3.2.2 RATE-dependent parameters

When the number of transmitted spatial streams  $N_{SS}$  is equal to the number of transmit antennas  $N_{TX}$ , the RATE-dependent modulation parameters shall be set according to the values defined in Tables 003, 004, and 005 respectively for the 2TX, 3TX, and 4TX modes in 20 MHz. The RATE-dependent parameters for the 1TX, 2TX, 3TX, and 4TX modes in 40 MHz shall be set according to the values defined in Tables 006, 007, 008, and 009, respectively.

The number of parallel encoding streams  $N_{ES}$  shall be 2 for all modes in 40 MHz in which the number of spatial streams  $N_{SS}$  is greater than two.  $N_{ES}$  shall be 1 for all other modes.

**Table 003—Rate-dependent parameters for 20 MHz,  $N_{SS} = 2$  ( $N_{ES} = 1$ )**

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier per antenna ( $N_{BPSC}$ ) | Number of data subcarriers ( $N_{SD}$ ) | Number of pilots ( $N_{SP}$ ) | Coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ) | Data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ) | Clause 10.4.4.2 rate code |
|---------------------|------------|-----------------|------------------------------------------------------|-----------------------------------------|-------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------|
| 54                  | 16-QAM     | 1/2             | 4                                                    | 54                                      | 2                             | 432                                            | 216                                           | 73                        |
| 81                  | 16-QAM     | 3/4             | 4                                                    | 54                                      | 2                             | 432                                            | 324                                           | 74                        |
| 108                 | 64-QAM     | 2/3             | 6                                                    | 54                                      | 2                             | 648                                            | 432                                           | 75                        |
| 121.5               | 64-QAM     | 3/4             | 6                                                    | 54                                      | 2                             | 648                                            | 486                                           | 76                        |
| 135                 | 64-QAM     | 5/6             | 6                                                    | 54                                      | 2                             | 648                                            | 540                                           | 77                        |

**Table 004—Rate-dependent parameters for 20 MHz,  $N_{SS} = 3$  ( $N_{ES} = 1$ )**

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier per antenna ( $N_{BPSC}$ ) | Number of data subcarriers ( $N_{SD}$ ) | Number of pilots ( $N_{SP}$ ) | Coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ) | Data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ) | Clause 10.4.4.2 rate code |
|---------------------|------------|-----------------|------------------------------------------------------|-----------------------------------------|-------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------|
| 81                  | 16-QAM     | 1/2             | 4                                                    | 54                                      | 2                             | 648                                            | 324                                           | 78                        |
| 121.5               | 16-QAM     | 3/4             | 4                                                    | 54                                      | 2                             | 648                                            | 486                                           | 79                        |
| 162                 | 64-QAM     | 2/3             | 6                                                    | 54                                      | 2                             | 972                                            | 648                                           | 80                        |
| 182.25              | 64-QAM     | 3/4             | 6                                                    | 54                                      | 2                             | 972                                            | 729                                           | 81                        |
| 202.5               | 64-QAM     | 5/6             | 6                                                    | 54                                      | 2                             | 972                                            | 810                                           | 82                        |

**Table 005—Rate-dependent parameters for 20 MHz,  $N_{SS} = 4$  ( $N_{ES} = 1$ )**

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier per antenna ( $N_{BPSC}$ ) | Number of data subcarriers ( $N_{SD}$ ) | Number of pilots ( $N_{SP}$ ) | Coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ) | Data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ) | Clause 10.4.4.2 rate code |
|---------------------|------------|-----------------|------------------------------------------------------|-----------------------------------------|-------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------|
| 108                 | 16-QAM     | 1/2             | 4                                                    | 54                                      | 2                             | 864                                            | 432                                           | 83                        |
| 162                 | 16-QAM     | 3/4             | 4                                                    | 54                                      | 2                             | 864                                            | 648                                           | 84                        |
| 216                 | 64-QAM     | 2/3             | 6                                                    | 54                                      | 2                             | 1296                                           | 864                                           | 85                        |
| 243                 | 64-QAM     | 3/4             | 6                                                    | 54                                      | 2                             | 1296                                           | 972                                           | 86                        |
| 270                 | 64-QAM     | 5/6             | 6                                                    | 54                                      | 2                             | 1296                                           | 1080                                          | 87                        |

**Table 006—Rate-dependent parameters for 40 MHz,  $N_{SS} = 1$  ( $N_{ES} = 1$ )**

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier per antenna ( $N_{BPSC}$ ) | Number of data subcarriers ( $N_{SD}$ ) | Number of pilots ( $N_{SP}$ ) | Coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ) | Data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ) | Clause 10.4.4.2 rate code |
|---------------------|------------|-----------------|------------------------------------------------------|-----------------------------------------|-------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------|
| 54                  | 16-QAM     | 1/2             | 4                                                    | 108                                     | 4                             | 432                                            | 216                                           | 88                        |

|       |        |     |   |     |   |     |     |    |
|-------|--------|-----|---|-----|---|-----|-----|----|
| 81    | 16-QAM | 3/4 | 4 | 108 | 4 | 432 | 324 | 89 |
| 108   | 64-QAM | 2/3 | 6 | 108 | 4 | 648 | 432 | 90 |
| 121.5 | 64-QAM | 3/4 | 6 | 108 | 4 | 648 | 486 | 91 |
| 135   | 64-QAM | 5/6 | 6 | 108 | 4 | 648 | 540 | 92 |

Table 007—Rate-dependent parameters for 40 MHz,  $N_{SS} = 2$  ( $N_{ES} = 1$ )

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier per antenna ( $N_{BPSC}$ ) | Number of data subcarriers ( $N_{SD}$ ) | Number of pilots ( $N_{SP}$ ) | Coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ) | Data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ) | Clause 10.4.4.2 rate code |
|---------------------|------------|-----------------|------------------------------------------------------|-----------------------------------------|-------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------|
| 108                 | 16-QAM     | 1/2             | 4                                                    | 108                                     | 4                             | 864                                            | 432                                           | 97                        |
| 162                 | 16-QAM     | 3/4             | 4                                                    | 108                                     | 4                             | 864                                            | 648                                           | 98                        |
| 216                 | 64-QAM     | 2/3             | 6                                                    | 108                                     | 4                             | 1296                                           | 864                                           | 99                        |
| 243                 | 64-QAM     | 3/4             | 6                                                    | 108                                     | 4                             | 1296                                           | 972                                           | 100                       |
| 270                 | 64-QAM     | 5/6             | 6                                                    | 108                                     | 4                             | 1296                                           | 1080                                          | 101                       |

Table 008—Rate-dependent parameters for 40 MHz,  $N_{SS} = 3$  ( $N_{ES} = 2$ )

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier per antenna ( $N_{BPSC}$ ) | Number of data subcarriers ( $N_{SD}$ ) | Number of pilots ( $N_{SP}$ ) | Coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ) | Data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ) | Clause 10.4.4.2 rate code |
|---------------------|------------|-----------------|------------------------------------------------------|-----------------------------------------|-------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------|
| 162                 | 16-QAM     | 1/2             | 4                                                    | 108                                     | 4                             | 1296                                           | 648                                           | 102                       |
| 243                 | 16-QAM     | 3/4             | 4                                                    | 108                                     | 4                             | 1296                                           | 972                                           | 103                       |
| 324                 | 64-QAM     | 2/3             | 6                                                    | 108                                     | 4                             | 1944                                           | 1296                                          | 104                       |
| 364.5               | 64-QAM     | 3/4             | 6                                                    | 108                                     | 4                             | 1944                                           | 1458                                          | 105                       |
| 405                 | 64-QAM     | 5/6             | 6                                                    | 108                                     | 4                             | 1944                                           | 1620                                          | 106                       |

Table 009—Rate-dependent parameters for 40 MHz,  $N_{SS} = 4$  ( $N_{ES} = 2$ )

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier per antenna ( $N_{BPSC}$ ) | Number of data subcarriers ( $N_{SD}$ ) | Number of pilots ( $N_{SP}$ ) | Coded bits per MIMO-OFDM symbol ( $N_{CBPS}$ ) | Data bits per MIMO-OFDM symbol ( $N_{DBPS}$ ) | Clause 10.4.4.2 rate code |
|---------------------|------------|-----------------|------------------------------------------------------|-----------------------------------------|-------------------------------|------------------------------------------------|-----------------------------------------------|---------------------------|
| 216                 | 16-QAM     | 1/2             | 4                                                    | 108                                     | 4                             | 1728                                           | 864                                           | 109                       |
| 324                 | 16-QAM     | 3/4             | 4                                                    | 108                                     | 4                             | 1728                                           | 1296                                          | 110                       |
| 432                 | 64-QAM     | 2/3             | 6                                                    | 108                                     | 4                             | 2592                                           | 1728                                          | 111                       |
| 486                 | 64-QAM     | 3/4             | 6                                                    | 108                                     | 4                             | 2592                                           | 1944                                          | 112                       |
| 540                 | 64-QAM     | 5/6             | 6                                                    | 108                                     | 4                             | 2592                                           | 2160                                          | 113                       |

### 20.3.2.3 Timing related parameters

Table 010 is a list of timing parameters associated with the MIMO-OFDM PLCP.

Table 010—Timing-related parameters

| Parameter                                          | Value (20 MHz modes) | Value (40 MHz modes) | Remarks                         |
|----------------------------------------------------|----------------------|----------------------|---------------------------------|
| $N_{SD}$ : Number of data subcarriers              | 54                   | 108                  |                                 |
| $N_{SP}$ : Number of pilot subcarriers             | 2                    | 4                    |                                 |
| $N_{ST}$ : Number of subcarriers, total            | 56                   | 112                  | $N_{ST} = N_{SD} + N_{SP}$      |
| $N_{OT}$ : Index of outermost populated subcarrier | 28                   | 58                   |                                 |
| $N_{TX}$ : Number of transmit antennas             | 2,3,4                | 1,2,3,4              |                                 |
| $\Delta_F$ : Subcarrier frequency spacing          | 0.3125 MHz           | 0.3125 MHz           | $\Delta_F = 20/64 = 40/128$ MHz |

|                                                   |                   |                   |                                    |
|---------------------------------------------------|-------------------|-------------------|------------------------------------|
| $T_{\text{FFT}}$ : IFFT/FFT period                | 3.2 $\mu\text{s}$ | 3.2 $\mu\text{s}$ | $T_{\text{FFT}} = 1/\Delta_F$      |
| $T_{\text{GI}}$ : GI duration                     | 0.8 $\mu\text{s}$ | 0.8 $\mu\text{s}$ | $(T_{\text{FFT}}/4)$               |
| $T_{\text{GI2}}$ : Training symbol guard duration | 1.6 $\mu\text{s}$ | 1.6 $\mu\text{s}$ |                                    |
| $T_{\text{SYM}}$ : Symbol interval                | 4 $\mu\text{s}$   | 4 $\mu\text{s}$   | $(T_{\text{GI}} + T_{\text{FFT}})$ |

#### 20.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signal will be described in a complex baseband signal notation. The RF (radio frequency) signal issued from the antenna is related to the complex baseband signal by the following relation:

$$r_{\text{RF}}(t) = \text{Re}\{r(t) \exp(j2\pi f_c t)\} \quad (1)$$

where  $\text{Re}(\cdot)$  represents the real part of the complex argument, and  $f_c$  denotes the carrier frequency. The actual RF signal over the air is the sum of RF signals emanated from each transmit antenna.

The transmitted baseband signal from any antenna is composed of contributions from several OFDM symbols, including preamble, signal, and data. Each symbol is constructed as an inverse Fourier transform of a set of coefficients  $C_k$ , with  $C_k$  defined later as data, pilots, or training symbols in subclause 20.3.3 through 20.3.5:

$$r_{\text{SYMBOL}}(t) = w_{\text{SYMBOL}}(t) \sum_{k=-N_{\text{OT}}}^{N_{\text{OT}}} C_k \exp(j2\pi k \Delta_F (t - T_{\text{GUARD}})) \quad (2)$$

The parameters  $\Delta_F$  and  $N_{\text{OT}}$  are defined in Table 010. The resulting waveform is periodic with a period of  $T_{\text{FFT}} = 1/\Delta_F$ . Shifting the time by  $T_{\text{GUARD}}$  creates the “cyclic prefix” used in OFDM to avoid ISI from the previous symbol. Three kinds of  $T_{\text{GUARD}}$  are defined: for the short training sequence ( $= 0\mu\text{s}$ ), for the long training sequence ( $= T_{\text{GI2}}$ ), and for data OFDM symbols ( $= T_{\text{GI}}$ ). Informative considerations related to the windowing function  $w_{\text{SYMBOL}}(t)$  and other implementation aspects, as specified in subclause 17.3.2.4, may also apply on a per-antenna basis in the MIMO-OFDM PHY.

The common way to implement the inverse Fourier transform, as shown in Equation (2), is by an inverse Fast Fourier Transform (IFFT) algorithm. If, for example, a 128-point IFFT is used to implement the 40 MHz transmission modes, the coefficients 3 to 58 are mapped to the same numbered IFFT inputs, while the coefficients -58 to -3 are copied into IFFT inputs 70 to 125. The rest of the inputs, 59 to 69, 1, 2, 126, 127, as well as the 0 (dc) input, shall be set to zero. This mapping is illustrated in Figure 006. After performing an IFFT, the output is cyclically extended to the desired length.

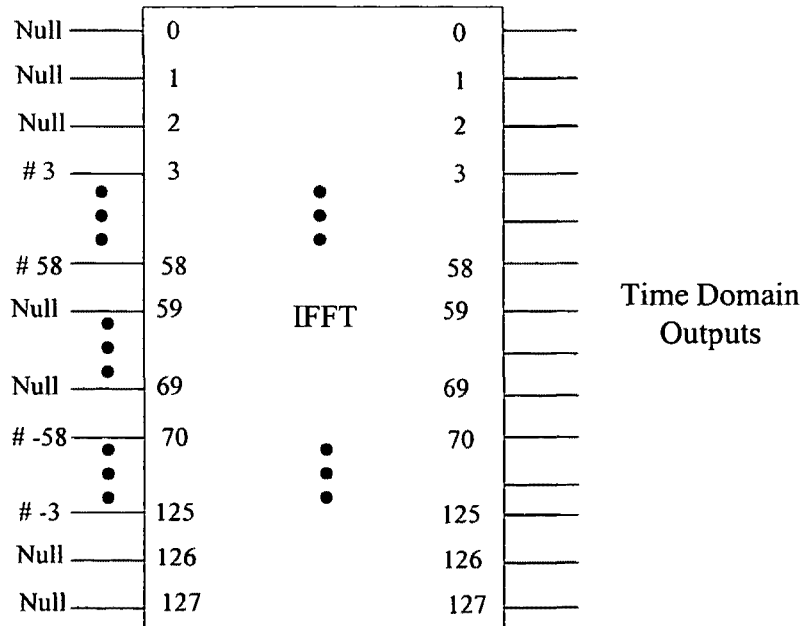


Figure 006– Inputs and outputs of 128-point IDFT for 40 MHz data transmission

### 20.3.3 PLCP preamble (SYNC)

The PLCP preamble field is used for synchronization. It consists of a sequence of short symbols and long symbols that are transmitted simultaneously from all transmit antennas, as described in this subclause.

Figure 007 shows the PLCP preamble format for greenfield 2TX mode in 20 MHz. The PLCP preamble is followed in this mode by the SIGNAL-N field and DATA. The total duration of the training symbols is 16  $\mu$ sec. The short MIMO-OFDM training sequence transmitted from the first antenna consists of 12 subcarriers, which are modulated by elements of the sequence  $SS_{20}$ , given by

$$\text{SS}_{20}[-28,28] = \sqrt{7/3} \times \{0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0\}. \quad (3)$$

The second antenna transmits a cyclically shifted version of the sequence transmitted from the first antenna, such that the first sample of the short sequence transmitted from the second antenna is the sample that is transmitted 400 nsec after the start of the short sequence on the first antenna. This is denoted by “(400 ns cs)” in Figure 007. More generally, an indicator “S (x ns cs)” in Figures 007 through 016 denotes that the transmitted sequence is obtained by cyclically shifting by x nsec, the time-domain sequence corresponding to frequency domain sequence S. The indicator “GI” or “GI2” in these figures denotes respectively the last  $T_{GI}$  or  $T_{GI2}$  duration of waveform of the immediately ensuing OFDM symbol, prepended to the OFDM symbol as a guard interval.

The short sequence is followed by a long OFDM training sequence which is generated by modulating the elements of the sequence

$$\text{LS}_{20}[-28..28] = \{1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, -1\} \quad (4)$$

according to the equation

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} LS_{20}[k] \exp(j2\pi k \Delta_F (t - T_{GI2})) \quad (5)$$

where  $T_{GI2} = 1.6 \mu\text{sec}$ . Two periods of the long symbol are transmitted for improved channel estimation accuracy. The long training sequence is also transmitted simultaneously from both antennas. The second antenna transmits a 1600 nsec cyclically shifted version of the long training symbols transmitted from the first antenna.

The PLCP preamble format for 2TX mixed-mode operation in 20 MHz is shown in Figure 008. The definition of the long and short sequences, as well as relative cyclic shifts between transmit antennas in this mode shall follow the description provided in Figure 008. The first and second TX antennas simultaneously transmit the first and second rows respectively of the MIMO-OFDM training structure shown in the figure.

Figure 009 and 010 define the PLCP preamble format for the 3TX and 4TX modes in 20 MHz, with greenfield access and mixed-mode access respectively. In the 3TX modes, only the first three rows shown in the corresponding MIMO-OFDM training structure are transmitted.

Figures 011, 013, and 015 show the PLCP preamble format for the 1TX, 2 TX, and 3TX/4TX greenfield modes in 40 MHz. The short sequence in these modes are obtained by modulating the elements of the sequence

$$\text{SS}_{40\text{GF}}[-58,58] = \sqrt{2} \times \{0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, \\ 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, \\ 1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 0, 0, \\ -1-j, 0, 0\} \quad (6)$$

on the subcarriers of the OFDM signal. The ensuing long sequence for 40 MHz greenfield operation is defined by the sequence

$$\text{LS}_{40\text{GF}}[-58..58] = \{1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, -1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, 1, 1, -1, -1, -1, -1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1\}. \quad (7)$$

The mixed mode training structures for 1TX, 2TX, and 3TX/4TX modes in 40 MHz are defined in Figure 012, 014, and 016 respectively. The additional short and long sequences used in these modes are defined by the following frequency domain sequences:

$$SS_{40MM}[-58..58] = \sqrt{7/3} \times \{0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0\}, \quad (8)$$

$$\text{LS}_{\text{40MM}}[-58..58] = \{1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, \\ -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, -1, -1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, \\ 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, 1, -1, 1, 1, 1, -1, -1\}. \quad (9)$$

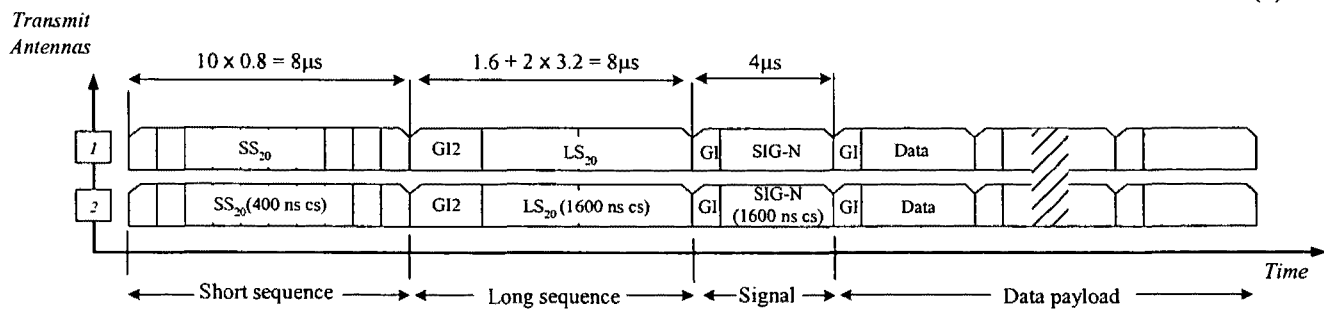


**Figure 007 – MIMO-OFDM Training structure for  $N_{TX} = 2$ , 20 MHz, greenfield operation**

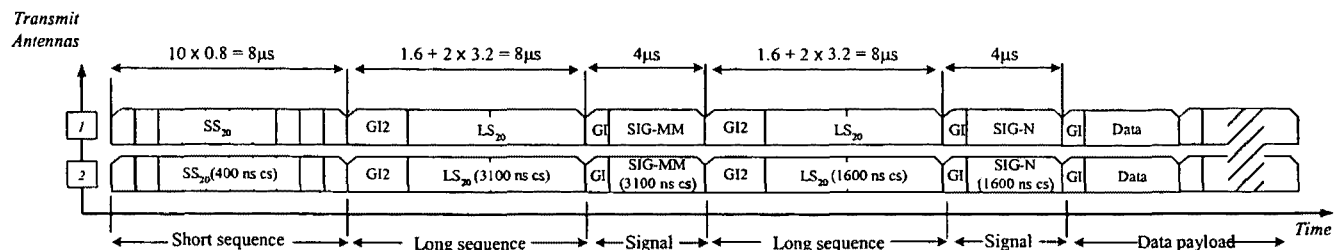


**Figure 008 – MIMO-OFDM Training structure for  $N_{TX} = 2$ , 20 MHz, mixed mode operation**

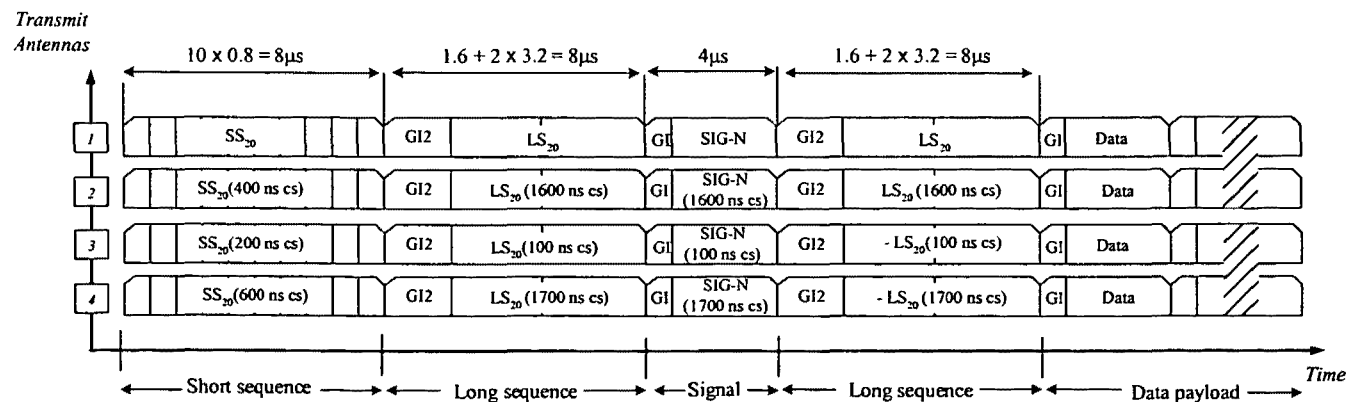
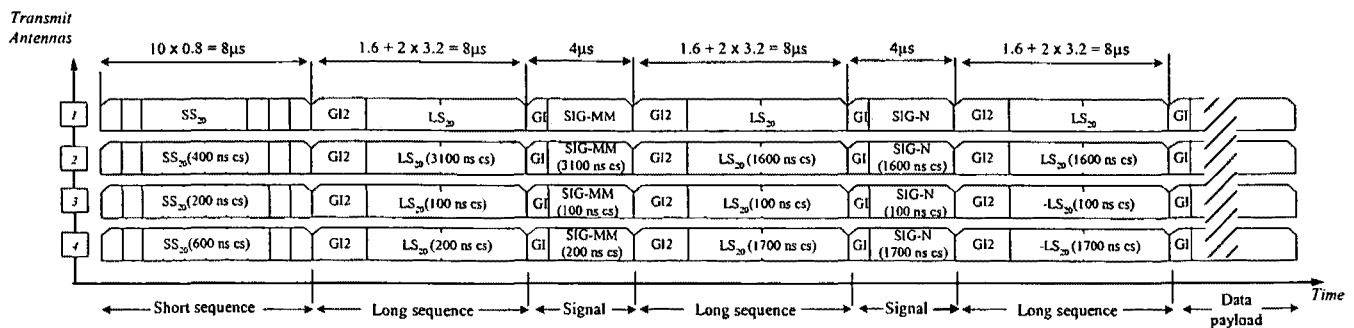
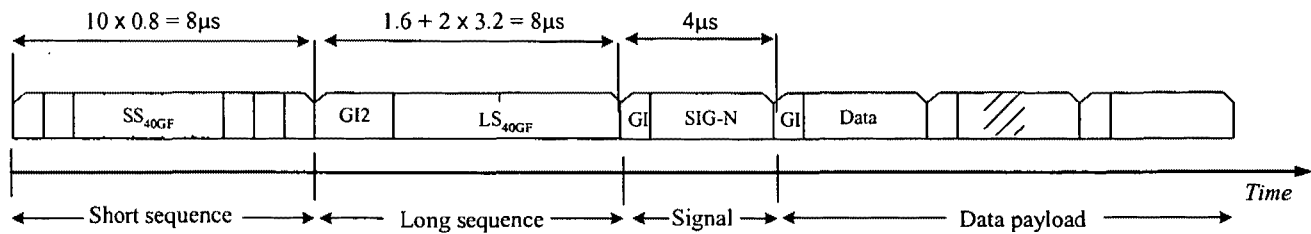
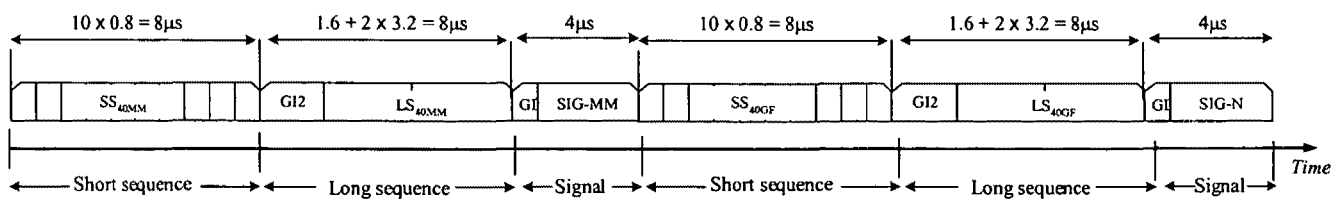
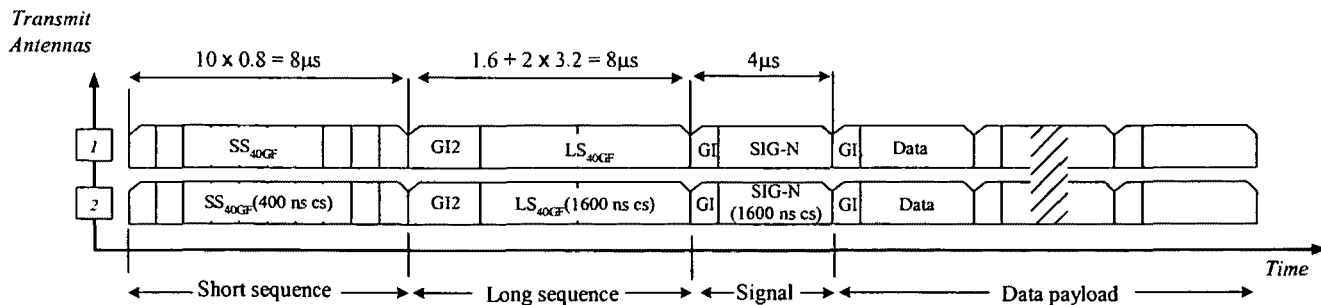


**Figure 009 – MIMO-OFDM Training structure for  $N_{TX} = 3$  and 4, 20 MHz, greenfield operation**





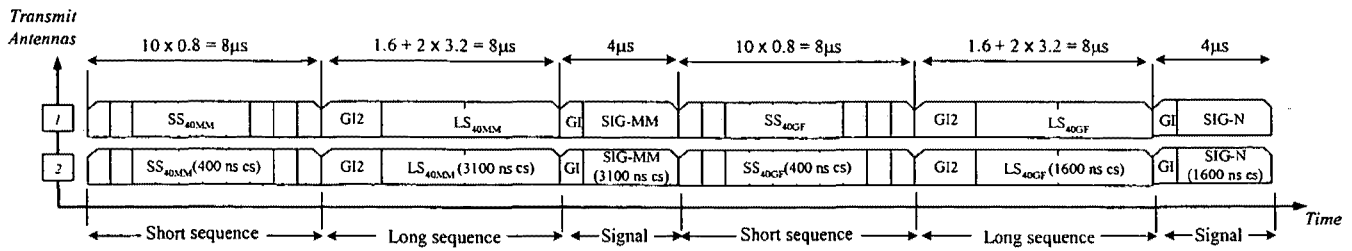


Figure 014 – MIMO-OFDM Training structure for  $N_{TX} = 2$ , 40 MHz, mixed mode operation

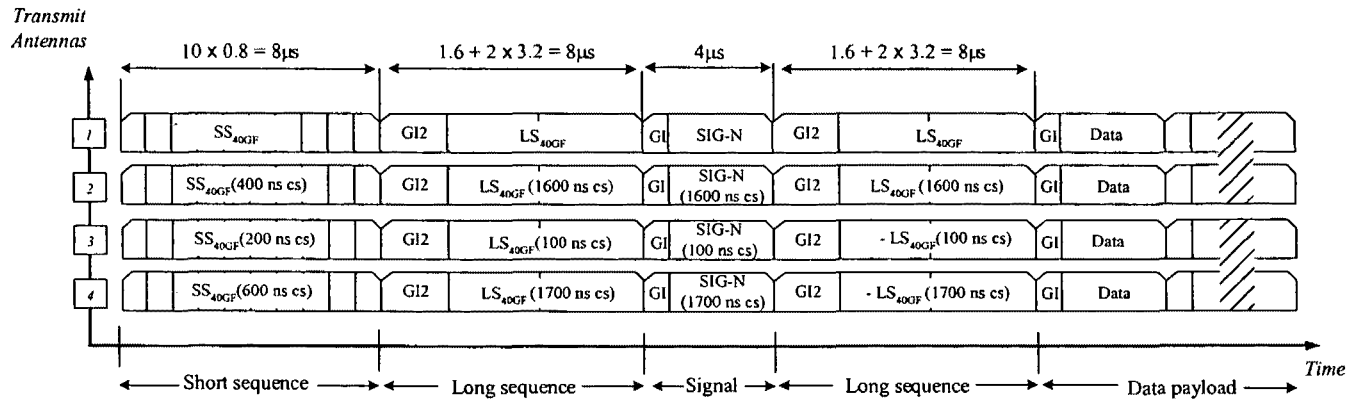


Figure 015 – MIMO-OFDM Training structure for  $N_{TX} = 3$  and 4, 40 MHz, greenfield operation

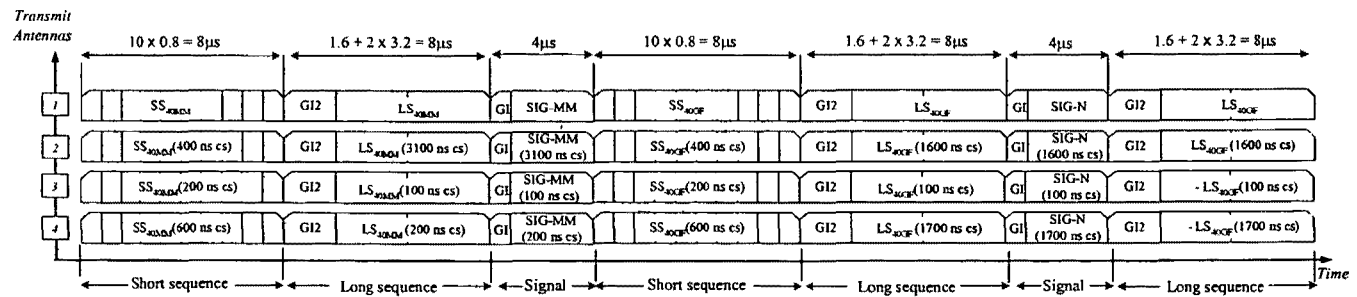


Figure 016 – MIMO-OFDM Training structure for  $N_{TX} = 3, 4$ , 40 MHz, mixed mode operation

### 20.3.4 Signal fields (SIG-N and SIG-MM)

The SIGNAL-N field (SIG-N) is composed of a single MIMO-OFDM symbol that provides all length and configuration parameters associated with a MIMO-OFDM PPDU. The SIGNAL-N field is composed of 54 bits, which shall be interpreted according to the bit assignment specified in Figure 017 and Table 011.

Table 011—SIG-N field bit assignment

| Bits      | Field  | Subfield | Parameter                   | Values                                        |
|-----------|--------|----------|-----------------------------|-----------------------------------------------|
| b0 : b5   | RSVD   |          | Reserved bits               | 111111, Bits shall be ignored at the receiver |
| b6 : b21  | CONFIG |          | Configuration               |                                               |
| b6: b8    |        | NSS      | Number of spatial streams   | 000: 1, 001: 2, 010: 3, 011: 4                |
| b9 : b11  |        | NTX      | Number of transmit antennas | 000: 1, 001: 2, 010: 3, 011: 4                |
| b12 : b13 |        | BW       | Bandwidth                   | 00: 20 MHz, 01: 40 MHz                        |

|           |      |     |                         |                                                                               |
|-----------|------|-----|-------------------------|-------------------------------------------------------------------------------|
| b14 : b16 |      | CR  | Code rate               | 000: 1/2, 001: 2/3, 010: 3/4, 011: 5/6                                        |
| b17 : b18 |      | CT  | ECC type                | 00 : convolutional, 01 : LDPC                                                 |
| b19 : b21 |      | CON | Constellation type      | 000: BPSK, 001: QPSK, 010: 16-QAM, 011: 64-QAM                                |
| b22 : b34 | LEN  |     | Length                  | Number of bytes in the payload                                                |
| b35       | LPI  |     | Last PSDU indicator     | 1 indicates that this is the last PSDU to be aggregated into the current PPDU |
| b36 : b43 | RSVD |     | Reserved                | 00000000, Bits shall be ignored at the receiver                               |
| b44 : b47 | CRC  |     | Cyclic Redundancy Check | CRC calculated on bits 0-43 using generator polynomial $x^4+x+1$              |
| b48 : b53 | TAIL |     |                         | 000000                                                                        |

In all 20 MHz modes, the encoding of the single SIG-N MIMO-OFDM symbol shall be performed with QPSK modulation of the subcarriers of the first antenna and shall use convolutional coding at  $R = 1/2$ . In all 40 MHz modes, the encoding of the single SIG-N MIMO-OFDM symbol shall be performed with BPSK modulation of the subcarriers of the first antenna and shall use convolutional coding at  $R = 1/2$ . The contents of the SIG-N field are not scrambled.

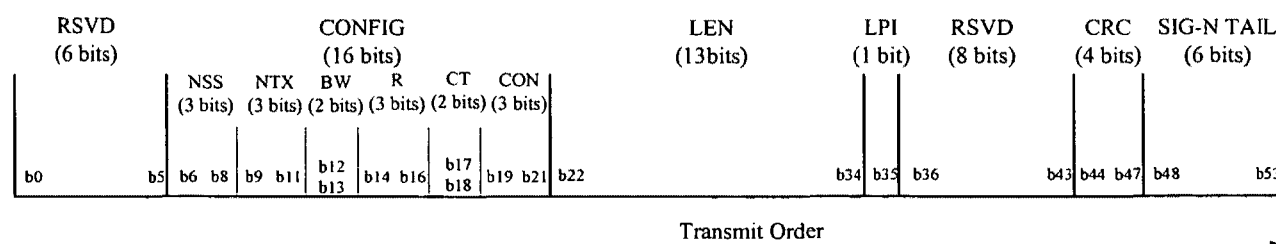


**Figure 017 – SIG-N field bit assignment**

The SIG-N MIMO-OFDM symbol is transmitted simultaneously from all TX antennas in all modes, with the same values of relative cyclic shift between antennas as are used to transmit the long training symbol preceding the SIG-N symbol. The value of the cyclic shift in each operating mode is specified in Figures 007 through 016 in subclause 20.3.3.

With mixed-mode access, another symbol, denoted as SIGNAL-MM (SIG-MM) is sent in the PLCP header. The SIG-MM field is encoded and transmitted from the first antenna as per IEEE 802.11a-1999 subclause 17.3.4. The remaining antennas simultaneously transmit the same OFDM symbol, with relative cyclic shifts defined in subclause 20.3.3. The reserved bit in the SIG-MM field shall be set to signal a MIMO-OFDM PPDU transmission. The duration for which the medium will be used by the MIMO-OFDM PPDU transmission is signaled to non MIMO-OFDM stations via the LENGTH and RATE fields of the SIG-MM symbol.

In 40 MHz mixed-mode operation, the SIG-MM field shall be transmitted such that it can be decoded by non-MIMO-OFDM stations operating in either the upper or the lower 20 MHz band.

### 20.3.5 DATA field

The DATA field contains the SERVICE field, the PSDU, the TAIL bits, and the PAD bits, if needed, as described in 20.3.5.2 and 20.3.5.4. All bits in the DATA field except the TAIL bits are scrambled, as described in 20.3.5.4.

#### 20.3.5.1 Service field (SERVICE)

The IEEE 802.11 SERVICE field has 16 bits, which shall be denoted as bits 0-15. The bit 0 shall be transmitted first in time. The bits 0-6 of the SERVICE field, which are transmitted first, are set to zeros and are used to synchronize the descrambler in the receiver. The remaining 9 bits (7-15) of the SERVICE field shall be reserved for future use. All reserved bits shall be set to zero. Refer to Figure 112, IEEE 802.11a-1999 subclause 17.3.5.1.

#### 20.3.5.2 PPDU tail bits

The PPDU tail bits shall follow IEEE 802.11a-1999 subclause 17.3.5.2.

### 20.3.5.3 PAD bits

The number of bits in the DATA field shall be a multiple of  $N_{CBPS}$ , the number of coded bits in an OFDM symbol. To achieve that, the length of the message is extended so that it becomes a multiple of  $N_{DBPS}$ , the number of data bits per OFDM symbol. At least 6 bits per encoding stream ( $N_{ES}$ ) are appended to the message, in order to accommodate the TAIL bits, as described in 20.3.5.2. The number of MIMO-OFDM symbols,  $N_{SYM}$ ; the number of bits in the DATA field,  $N_{DATA}$ ; and the number of pad bits,  $N_{PAD}$ , are computed from the length of the PSDU (LENGTH) as follows:

$$N_{SYM} = \text{Ceiling}((16 + 8 \times \text{LENGTH} + 6 \times N_{ES})/N_{DBPS}) \quad (10)$$

$$N_{DATA} = N_{SYM} \times N_{DBPS} \quad (11)$$

$$N_{PAD} = N_{DATA} - (16 + 8 \times \text{LENGTH} + 6 \times N_{ES}) \quad (12)$$

The appended bits ("pad bits") are set to "zeros" and are subsequently scrambled with the rest of the bits in the DATA field.

### 20.3.5.4 PLCP data scrambler and descrambler

The PPDU data scrambler and descrambler shall follow IEEE 802.11a-1999 subclause 17.3.5.4.

### 20.3.5.5 Convolutional encoder

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be coded with a convolutional encoder that conforms to IEEE 802.11a-1999 subclause 17.3.5.5 for code rates of  $R = 1/2$ ,  $2/3$ , and  $3/4$ . Additionally, the code rate of  $R = 5/6$  shall be implemented according to the puncturing pattern illustrated in Figure 018.

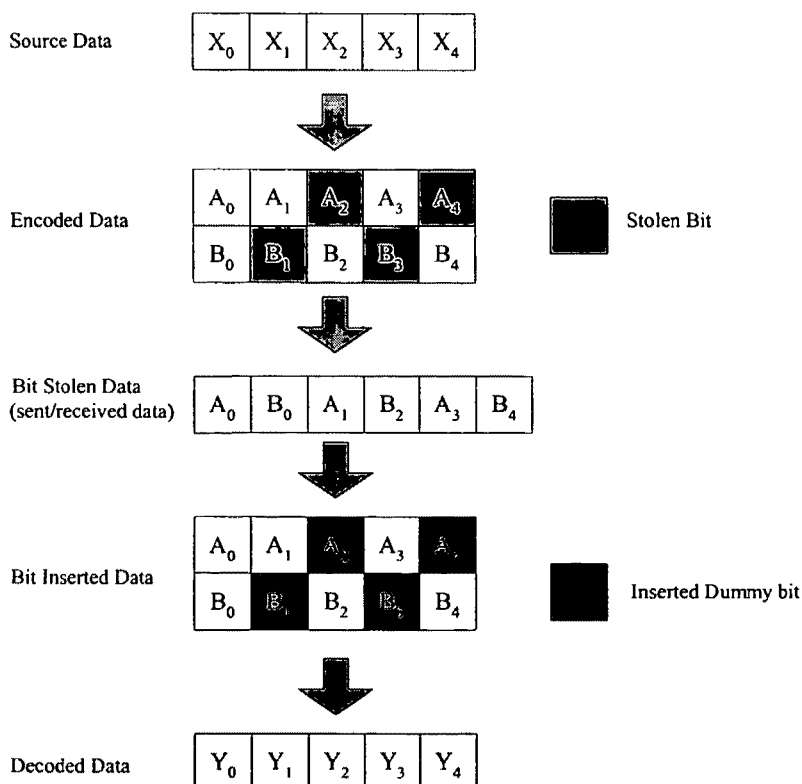


Figure 018 – An illustration of the bit stealing and bit insertion procedure for  $R = 5/6$

### 20.3.5.6 Interleaver

All encoded bits shall be interleaved by a block interleaver with a block size equal to the number of bits in a single MIMO-OFDM symbol,  $N_{CBPS}$ . The interleaver is defined by the following series of permutations.

We shall denote by  $k$  the index of the coded bits before interleaving,  $k = 0, 1 \dots N_{CBPS}-1$ .  $n = 0, 1 \dots N_{SS}-1$  denotes the index of the spatial streams. The bits are first distributed across spatial streams by inputting the bit with index  $k_n \times N_{SS} + n$  into the  $n$ th spatial stream. This is illustrated in Figure 019.

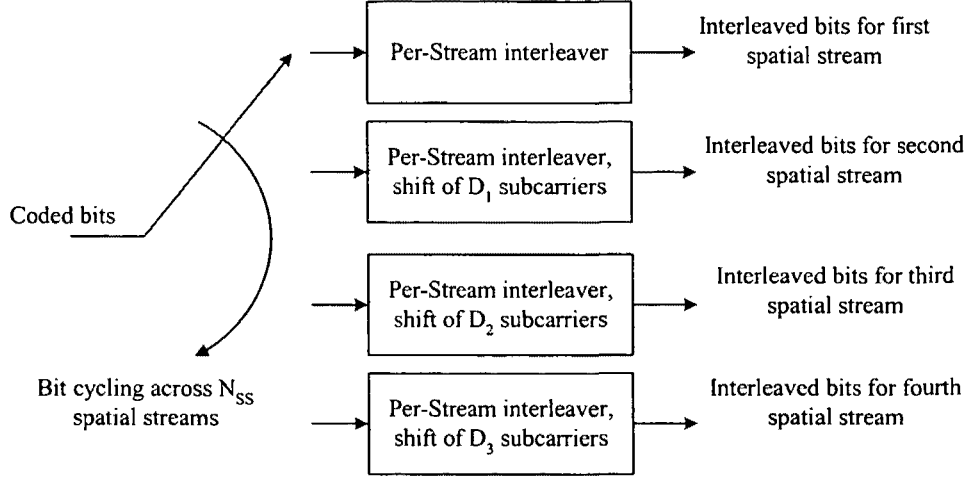


**Figure 019 – Illustration of the interleaver function**

The interleaver for spatial stream  $n$  within its block of  $N_{CBPS}/N_{SS}$  bits is defined by the following relations.

$$\begin{aligned}
 k &= k_n \times N_{SS} + n \\
 i &= ((N_{CBPS}/N_{SS})/I_{DEPTH}) (k_n \bmod I_{DEPTH}) + \text{floor}(k_n/I_{DEPTH}) & k_n = 0, 1 \dots (N_{CBPS}/N_{SS})-1 \\
 j &= s \times \text{floor}(i/s) + (i + N_{CBPS}/N_{SS} - \text{floor}(I_{DEPTH} \times i / (N_{CBPS}/N_{SS}))) \bmod s & s = \max(N_{BPSC}/2, 1) \\
 j_n &= (j + N_{CBPS}/N_{SS} - 2sD_n) \bmod (N_{CBPS}/N_{SS}).
 \end{aligned} \tag{13}$$

The parameter  $D_n$  which denotes the shift in subcarriers for spatial stream  $n$  is given by

$$D_n = 5n. \tag{14}$$

The interleaving depth  $I_{DEPTH}$  shall conform to the values given in Table 012.

**Table 012—Interleaving parameters**

| $N_{SS}$   | $N_{SD}$ | $I_{DEPTH}$ |
|------------|----------|-------------|
| 1, 2, 3, 4 | 54       | 6           |
| 2,3,4      | 108      | 6           |
| 1          | 108      | 12          |

The deinterleaver, which performs the inverse relation, is defined by the following series of permutations.

$$\begin{aligned}
 k_d &= \text{mod}(k_n + N_{CBPS}/N_{SS} + 2sD_n) \bmod (N_{CBPS}/N_{SS}) \\
 i_d &= s \text{ floor}(k_d/s) + (k_d + \text{floor}(I_{DEPTH} \times k_d / (N_{CBPS}/N_{SS}))) \bmod s \\
 j_{dn} &= I_{DEPTH} \times i_d - ((N_{CBPS}/N_{SS}) - 1) \times \text{floor}(I_{DEPTH} \times i_d / (N_{CBPS}/N_{SS})).
 \end{aligned} \tag{15}$$

where  $s$  and  $D_n$  are as defined for the interleaver.

### 20.3.5.7 Low density parity check codes (optional ECC)

This subclause describes the LDPCs to be optionally used in the MIMO-OFDM system as high-performance ECC technique, instead of the convolutional code (20.3.5.5). The rate-dependent parameters in subclause 20.3.2.2 shall still apply.

When this subclause applies, the following clauses are to be considered no more applicable:

20.3.2.1: changes needed, as described in 20.3.5.7.3;

20.3.5.2: not used;

20.3.5.3: replaced by 20.3.5.7.3;

20.3.5.5: replaced by 20.3.5.7.4;

20.3.5.6: not used.

#### 20.3.5.7.1 LDPC Code Rates and Block Sizes

The supported code rates, information block size, and coded block size are described in Table 013.

Table 013— LDPC parameters

| Coding rate (R) | LDPC information bits (bits) | LDPC codeword length (bits) |
|-----------------|------------------------------|-----------------------------|
| 1/2             | 972                          | 1944                        |
| 2/3             | 1296                         | 1944                        |
| 3/4             | 1458                         | 1944                        |
| 5/6             | 1620                         | 1944                        |

#### 20.3.5.7.3 LDPC PPDU encoding process

a) Produce the PLCP preamble fields for each transmit antenna based on the TRANSMISSION\_MODE field of the TXVECTOR. Refer to 20.3.3 for details.

b) Produce the PLCP header field from the LENGTH, DATARATE, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields, as described in subclause 20.3.4 and subclause 20.3.5.1.

c) Compute the integer number of LDPC codewords to be transmitted,  $L_1$ , and the possible remainder  $K_1$ .

$$L_1 = \text{ceil}((\text{LENGTH} \times 8 + 16)/1944/R),$$

$$K_1 = \text{rem}((\text{LENGTH} \times 8 + 16), 1944 \times R). \quad (16)$$

d) If  $K_1 > 0$  compute the number of zeros for padding in order to encode the last codeword as

$$N_{p1} = 1944 \times R - K_1. \quad (17)$$

These bits will not be transmitted nor scrambled. If  $K_1 > 0$ , the last frame has an effective information frame (i.e. information frame excluding padded zeros) of size  $K_1$ , generally less than  $k$ . The last codeword includes a fixed number of parity bits equal to  $p = (1944 - k)$ . This implies the code rate for the last codeword is different from the overall target code rate and is given by:

$$\frac{K_1}{K_1 + (1944 - k)}. \quad (18)$$

e) Compute the number of coded bits to be transmitted (including the shortened codeword) as

$$L_2 = \begin{cases} 1944 \times L_1, & K_1 = 0 \\ 1944 \times L_1 + 1944 \times (1 - R) + K_1, & K_1 \neq 0 \end{cases} \quad (19)$$

f) Compute the integer number of MIMO-OFDM symbols  $N_{S1}$  and the possible reminder  $R_{S1}$ :

$$\begin{aligned} N_{S1} &= \text{ceil}(L_2 / N_{CBPS}), \\ R_{S1} &= \text{rem}(L_2, N_{CBPS}). \end{aligned} \quad (20)$$

g) If  $R_{S1} > 0$  append  $N_{P2}$  zeros to info bits in order to fill an integer number of MIMO-OFDM symbols

$$N_{P2} = N_{CBPS} - R_{S1}. \quad (21)$$

h) The service field at the beginning of the resulting sequence is used to initialize a scrambler, which is then used to scramble the rest of the sequence including the zeros appended in step g).

k) The resulting PSDU is then coded by the LDPC at the proper code rate (R) and block size (i.e. 1944 bits for all frames). The last codeword is encoded extending the info bits with  $N_{P1}$  zeros; these  $N_{P1}$  bits are not transmitted. The last  $N_{P2}$  bits are not encoded.

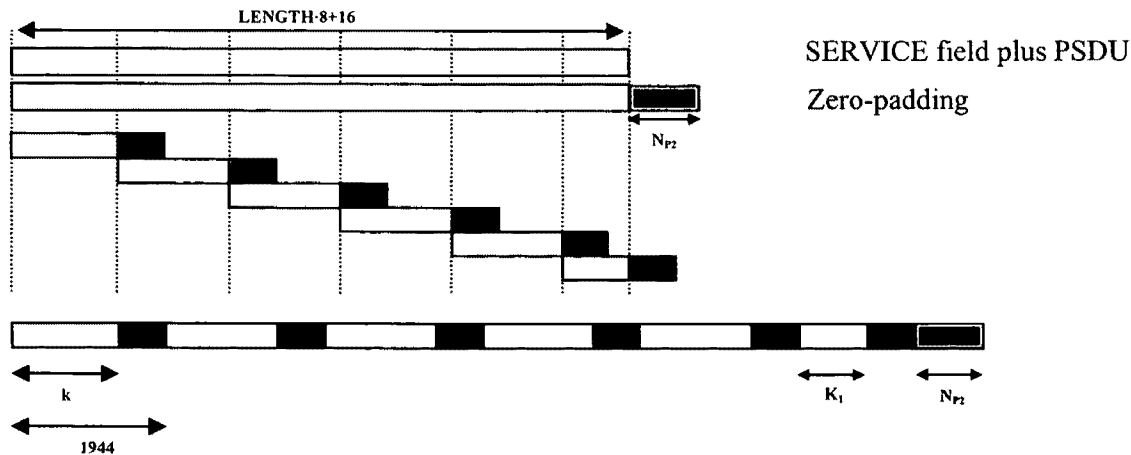


Figure 020 – LDPC PDU encoding

#### 20.3.5.7.4 LDPC Encoder

A characteristic feature of the considered LDPCs is that combining rows of the parity-check matrix (**H**) for the lowest rate code produces **H** for higher rates. This is equivalent to replacing a group of check nodes with a single check node that sums all the edges coming into each of the original check nodes. Direct consequences are that all code rates have the same block length and the same variable node degree distribution.

The LDPC encoder is systematic, i.e. encodes an information block of size  $k$ ,  $I=(i_0, i_1, \dots, i_{(k-1)})$  into a codeword **C** of size  $n$   $C=(i_0, i_1, \dots, i_{(k-1)}, p_0, p_1, \dots, p_{(n-k-1)})$  by adding  $n-k$  parity bits obtained so that  $H \cdot C^T = 0$ .

$k$  and  $n$  are defined in Table 013 according to the selected rate.

The parity check matrix used to generate all the code rates is rate 1/2 (i.e. number of rows  $n-k = 972$ , number of columns  $n = 1944$ ). This belongs to the class of the so-called structured parity check matrices (compared to "random" generated codes). More specifically, the matrix can be partitioned into square sub-blocks of size 27x27 which are either cyclic permutations of the diagonal identity matrix or null sub-matrices. A few of them – specifically 2 in the rate 1/2 matrix described in Table A.1 – may contain two (cyclically shifted) diagonals.

In addition, in order to enable a simple encoding process, the parity-check matrices include a block lower triangular structure at the right-hand side. This allows a linear-complexity encoder (based on back substitution). More precisely, the parity-check matrix is of the type:

$$H_{(n-k) \times n} = [A_{(n-k) \times k} \ B_{(n-k) \times (n-k)}] \quad (22)$$

where  $B$  is block lower triangular, i.e. has the structure reported in Fig. 021.

$$B_{(n-k) \times (n-k)} = \begin{pmatrix} b_{11} & 0 & L & 0 \\ b_{21} & b_{22} & 0 & \\ & b_{32} & O & O & M \\ M & & O & O & 0 \\ & & & O & 0 \\ b_{(n-k)1} & & L & & b_{(n-k)(n-k)} \end{pmatrix},$$

$b_{ij}$  = circulant permutation matrix;  $(i,j)$  sub-matrix indexes.

**Figure 021 – lower triangular part of the parity check matrix**

In order to generate variable rate LDPCs, the following criteria apply:

- Row-combining of rows who do not have a '1' in the same position (this implies a same resulting variable node degree distribution for all the code rates).
- The selection of rows to be summed preserves the lower triangular structure of the right-hand side of the matrix through all the rates.

Taking into account above-mentioned criteria, the code rates are obtained as follows:

- Code rate 2/3:

row  $i$  (the rows are enumerated from top to bottom) is generated by summing row  $i$  of  $\mathbf{H}$  of rate 1/2 code and the row with index  $i+M/2$  where  $M$  is the total number of check equations in rate 1/2 code, for all the rows where  $i < M/3$ .

- Code rate 3/4:

row  $i$  is generated by summing row  $i$  of  $\mathbf{H}$  of rate 1/2 code and the row with index  $i+M/2$  where  $M$  is the total number of  $\mathbf{H}$  rows (i.e. check equations) in rate 1/2 code.

- Code rate 5/6:

Rows are summed three at a time as: row  $i$  plus the row with index  $i+M/3$  plus the row with index  $i+2M/3$ .

The codes are designed to avoid length 4 cycles and to avoid small stopping sets.

#### 20.3.5.7.5 Parity check matrix

In Table A.1 in Annex A the rate 1/2 parity check matrix is reported. All the other rates can be derived by properly combining its rows as explained in 20.3.5.7.4.

The table describes the "matrix prototype", i.e. a structure of size 36x72 where the basic elements are squared sub-matrices whose size is 27x27. Each sub matrix is either a null matrix or a cyclic permutation of the identity matrix (or the lower bidiagonal matrix at the right hand bottom of the matrix).

Figure 022 illustrates some examples (for a 10x10 matrix) of the basic circular permutation matrix  $S_i$ , clarifying how cyclic shift indexes  $i$  are to be interpreted. The last line in Table A.1, indicated as "st", indicates the staircase (or bi-diagonal) structure ( $S_d$  in Fig. 021).



$$S_0 = \begin{bmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & 1 \end{bmatrix} \quad S_3 = \begin{bmatrix} & 1 & & \\ & & 1 & \\ & & & 1 \\ 1 & & & \end{bmatrix} \quad S_7 = \begin{bmatrix} & & 1 & \\ & & & 1 \\ & 1 & & \\ 1 & & & \end{bmatrix} \quad S_d = \begin{bmatrix} 1 & 1 & & \\ & 1 & 1 & \\ & & 1 & 1 \\ & & & 1 & 1 \\ & & & & 1 & 1 \\ & & & & & 1 & 1 \\ & & & & & & 1 & 1 \end{bmatrix}$$

**Figure 022 – Structure of the cyclic permutations of the identity matrix. Matrix  $S_i$  is produced by cyclically shifting the columns of the identity matrix to the right  $i$  places.**

Table A.1 follows the following format: Row number - Column number - Cyclic shift to the right (of columns). Rows are enumerated from top to bottom, columns from left to right.

### 20.3.5.8 Subcarrier modulation mapping

The subcarrier modulation mapping shall follow IEEE 802.11a-1999 clause 17.3.5.7 for each transmit antenna.

### 20.3.5.9 Pilot tones

The subcarriers with index -21 and +21 are dedicated in all 20 MHz modes to transmit pilot signals during each OFDM symbol, in order to increase robustness against frequency offsets and phase noise. In the 40 MHz modes, 4 subcarriers are dedicated to transmitting pilots. These subcarriers have indexes -42, -14, +14, and +42.

The relative polarity of the pilots transmitted from various antennas shall be determined using the following relations. We shall number the MIMO-OFDM symbols transmitted in a PSDU sequentially, with  $n = 0$  denoting the first symbol that follows the PLCP preamble. We shall use  $p_n$  to denote the  $n$ th element of the sequence  $p_{0...126v}$  specified in equation (25) of IEEE 802.11a-1999 subclause 17.3.5.9. We define the following matrices:

$$A = \begin{bmatrix} +1 & +1 & +1 & -1 \\ +1 & -1 & +1 & +1 \end{bmatrix}$$

$$B = \begin{bmatrix} +1 & +1 & -1 & -1 \\ +1 & -1 & +1 & -1 \\ -1 & +1 & +1 & -1 \end{bmatrix}$$

$$C = \begin{bmatrix} +1 & +1 & +1 & -1 \\ +1 & +1 & -1 & +1 \\ +1 & -1 & +1 & +1 \\ -1 & +1 & +1 & +1 \end{bmatrix} \quad (23)$$

Furthermore, we define  $a_{ij}$ ,  $b_{ij}$ , and  $c_{ij}$  as the element on the  $i$ th row and  $j$ th column of the matrices A, B, and C, respectively. For example,  $i = 0, 1, 2; j = 0, 1, 2, 3$  for matrix B. Then the pilot values sent from the  $m$ th antenna ( $m = 1, 2, \dots, 4$ ) during the  $n$ th OFDM symbol in the 20 MHz modes shall be given by the corresponding value in Table 014, multiplied with  $p_{n \bmod 127}$ .

The pilot value in the 40 MHz modes shall be given by the corresponding value in Table 015, multiplied with  $p_{n \bmod 127}$ . The value of the pilot signals sent during the SIG-N symbol defined in 20.3.4 shall be obtained by setting  $n = 0$  in this subclause.

**Table 014—Pilot value sent from  $m$ th antenna during  $n$ th OFDM symbol in 20 MHz modes**

| Subcarrier index | 2TX mode                 | 3TX mode                 | 4TX mode                 |
|------------------|--------------------------|--------------------------|--------------------------|
| -21              | $a_{m-1, n \bmod 2}$     | $b_{m-1, n \bmod 4}$     | $c_{m-1, n \bmod 4}$     |
| +21              | $a_{m-1, (n+1) \bmod 2}$ | $b_{m-1, (n+1) \bmod 4}$ | $c_{m-1, (n+1) \bmod 4}$ |

**Table 015—Pilot value sent from  $m$ th antenna during  $n$ th OFDM symbol in 40 MHz modes**

| Subcarrier index | 1TX mode | 2TX mode                 | 3TX mode                 | 4TX mode                 |
|------------------|----------|--------------------------|--------------------------|--------------------------|
| -42              | +1       | $a_{m-1, n \bmod 4}$     | $b_{m-1, n \bmod 4}$     | $c_{m-1, n \bmod 4}$     |
| -14              | +1       | $a_{m-1, (n+1) \bmod 4}$ | $b_{m-1, (n+1) \bmod 4}$ | $c_{m-1, (n+1) \bmod 4}$ |
| +14              | +1       | $a_{m-1, (n+2) \bmod 4}$ | $b_{m-1, (n+2) \bmod 4}$ | $c_{m-1, (n+2) \bmod 4}$ |
| +42              | -1       | $a_{m-1, (n+3) \bmod 4}$ | $b_{m-1, (n+3) \bmod 4}$ | $c_{m-1, (n+3) \bmod 4}$ |

Figure 023 provides an illustration of the relative polarity of pilot signals transmitted in the 2TX, 20 MHz mode of operation

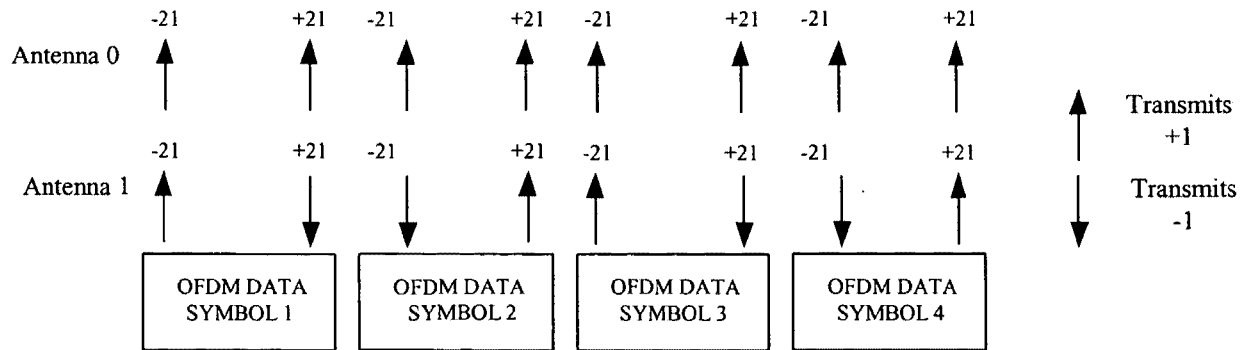


**Figure 023 – An illustration of the relative polarity of pilot signals in the 2TX, 20 MHz mode. “-21” and “+21” indicate the subcarrier indexes on which pilot signals are sent**

#### 20.3.5.10 Space-time block coding (STBC)

This subclause defines a set of robust transmission rates which are applicable when  $N_{TX}$ , the number of TX antennas, is greater than  $N_{SS}$ , the number of transmitted spatial streams. These rates are based on space time block coding.

Implementation of all rates specified in Table 016 for  $N_{TX}=2$ ,  $N_{SS}=1$  in 20 MHz is mandatory. Implementation of all other modes defined in this subclause is optional.

The space time block encoding scheme for  $N_{TX}=2$ ,  $N_{SS}=1$  in 20 MHz and 40 MHz is defined as follows. The bits output from the interleaver of the (single) spatial stream are mapped to the subcarriers of the first antenna, according to subclause 20.3.5.8. We denote the pair of complex numbers transmitted on subcarrier  $k$  from this antenna during the  $j$ -th and  $j$ th OFDM symbol as  $s_{j-1}$  and  $s_j$  respectively. Then the corresponding transmission from the second antenna, on the same subcarrier index and during the same OFDM symbols, shall be  $-s_j^*$  and  $s_{j-1}^*$  where  $*$  denotes complex conjugate. This encoding scheme shall hereafter be referred to as the “STBC encoding rule”.

Since encoding takes place across pairs of MIMO-OFDM symbols in this subclause, the number of pad bits inserted in subclause 20.3.5.3 shall be sufficient to ensure that an even number of MIMO-OFDM symbols are transmitted in the PPDU.

**Table 016—Rate-dependent parameters for 20 MHz,  $N_{TX} = 2$ ,  $N_{SS} = 1$** 

| Data rate (Mbits/s) | Modulation | Coding rate (R) | Coded bits per subcarrier | Number of data subcarriers | Number of pilots | Coded bits per MIMO-OFDM | Data bits per MIMO-OFDM | Clause 10.4.4.2 rate |
|---------------------|------------|-----------------|---------------------------|----------------------------|------------------|--------------------------|-------------------------|----------------------|
|---------------------|------------|-----------------|---------------------------|----------------------------|------------------|--------------------------|-------------------------|----------------------|

|        |        |     | per antenna<br>( $N_{BPSC}$ ) | ( $N_{SD}$ ) | ( $N_{SP}$ ) | symbol<br>( $N_{CBPS}$ ) | symbol<br>( $N_{DBPS}$ ) | code |
|--------|--------|-----|-------------------------------|--------------|--------------|--------------------------|--------------------------|------|
| 6.75   | BPSK   | 1/2 | 1                             | 54           | 2            | 54                       | 27                       | 114  |
| 10.125 | BPSK   | 3/4 | 1                             | 54           | 2            | 54                       | 40.5                     | 115  |
| 13.5   | QPSK   | 1/2 | 2                             | 54           | 2            | 108                      | 54                       | 116  |
| 20.25  | QPSK   | 3/4 | 2                             | 54           | 2            | 108                      | 81                       | 117  |
| 27     | 16-QAM | 1/2 | 4                             | 54           | 2            | 216                      | 108                      | 118  |
| 40.5   | 16-QAM | 3/4 | 4                             | 54           | 2            | 216                      | 162                      | 119  |
| 54     | 64-QAM | 2/3 | 6                             | 54           | 2            | 324                      | 216                      | 120  |
| 60.75  | 64-QAM | 3/4 | 6                             | 54           | 2            | 324                      | 243                      | 121  |

The RATE-dependent parameters for 20 MHz,  $N_{TX} = 3$ ,  $N_{SS} = 2$  are defined in Table 003. In this configuration, the STBC encoding rule shall be applied on the first and second antennas using bits from the first spatial stream. Bits from the second spatial stream shall be mapped to subcarriers of the third transmit antenna, according to subclause 20.3.5.8.

The RATE-dependent parameters for 20 MHz,  $N_{TX} = 4$ ,  $N_{SS} = 2$  are defined in Table 003. In this configuration, the STBC encoding rule shall be applied on the first and second antennas using bits from the first spatial stream, and on the third and fourth antennas using bits from the second spatial stream.

The RATE-dependent parameters for 20 MHz,  $N_{TX} = 4$ ,  $N_{SS} = 3$  are defined in Table 004. In this configuration, the STBC encoding rule shall be applied on the first and second antennas using bits from the first spatial stream. Bits from the second spatial stream shall be mapped to subcarriers of the third transmit antenna, according to subclause 20.3.5.8. Bits from the third spatial stream shall be mapped to subcarriers of the fourth transmit antenna, according to subclause 20.3.5.8.

The RATE-dependent parameters for 40 MHz,  $N_{TX} = 2$ ,  $N_{SS} = 1$  are defined in Table 006. In this configuration, the STBC encoding rule shall be applied on the first and second antennas.

The RATE-dependent parameters for 40 MHz,  $N_{TX} = 3$ ,  $N_{SS} = 2$  are defined in Table 007. In this configuration, the STBC encoding rule shall be applied on the first and second antennas using bits from the first spatial stream. Bits from the second spatial stream shall be mapped to subcarriers of the third transmit antenna, according to subclause 20.3.5.8.

The RATE-dependent parameters for 40 MHz,  $N_{TX} = 4$ ,  $N_{SS} = 2$  are defined in Table 007. In this configuration, the STBC encoding rule shall be applied on the first and second antennas using bits from the first spatial stream, and on the third and fourth antennas using bits from the second spatial stream.

The RATE-dependent parameters for 40 MHz,  $N_{TX} = 4$ ,  $N_{SS} = 3$  are defined in Table 008. In this configuration, the STBC encoding rule shall be applied on the first and second antennas using bits from the first spatial stream. Bits from the second spatial stream shall be mapped to subcarriers of the third transmit antenna, according to subclause 20.3.5.8. Bits from the third spatial stream shall be mapped to subcarriers of the fourth transmit antenna, according to subclause 20.3.5.8.

### 20.3.6 Clear channel assessment

PLCP shall provide the capability to perform CCA and report the result to the MAC. The CCA mechanism shall detect a "medium busy" condition with a performance specified in 20.3.10.5. This medium status report is indicated by the primitive PHY\_CCA.indicate.

### 20.3.7 PLCP data modulation and modulation rate change

The PLCP preamble shall be transmitted using a set of OFDM-modulated fixed waveforms, specified in subclause 20.3.3 for each transmit antenna for each mode of operation defined in the MIMO-OFDM PHY. The SIG-N field, composed of 54 bits, shall indicate the bandwidth, modulation, code rate, code type, number of TX antennas, and number of spatial streams that shall be used to transmit the MPDU. The transmitter (receiver) shall initiate the modulation constellation, code rate, code type, and other configuration parameters according to the CONFIG indicated in the SIG-N field. The MPDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 20.2.

## 20.3.8 PMD operating specifications

Subclauses 20.3.8.1 through 20.3.8.8 provide general specifications for the various modes and options defined in the MIMO-OFDM PMD sublayer. These specifications apply to both the receive and transmit functions and general operation of the MIMO-OFDM PHY.

### 20.3.8.1 TX Block diagram

The general block diagram of the transmitter for the MIMO-OFDM PHY is shown in Figure 024. The blocks that are shaded in the figure may be replicated  $N_{TX}$  times in a MIMO-OFDM system with  $N_{TX}$  transmit antennas.

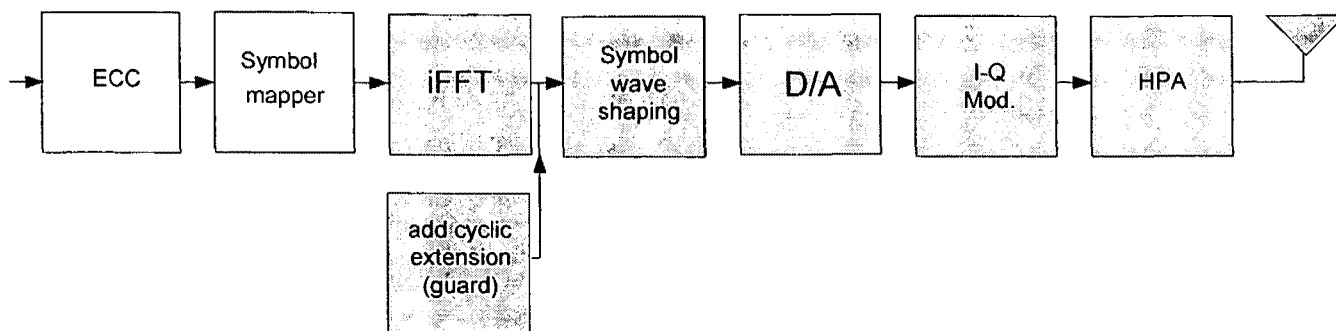


Figure 024 – Transmitter block diagram for the MIMO-OFDM PHY

### 20.3.8.2 Regulatory requirements

All systems shall comply with the local regulatory requirements for operation in the band in which they are implemented. For 2.4 GHz operation, refer to FCC 15.247, 15.249, 15.205, and 15.209 for the USA; ETS 300-328 for Europe; and MPHPT article 49-20 for Japan. For 5 GHz operation in the USA, refer to FCC CFR47, Part 15, sections 15.205 and 15.209; and Subpart E, sections 15.401-15.407.

The documents listed here are provided for information only, and are subject to change or revision at any time.

### 20.3.8.3 Operating channel frequencies

The range of operating frequencies for the MIMO-OFDM PHY shall be 2400-2497 MHz and 4920-5805 MHz. The channel numbering shall be as defined in IEEE 802.11b-1999 clause 18.4.6.2, and clause 17.3.8.3.2 of IEEE P802.11j/D1.5, May 2004. The relationship between center frequency and channel number is given by the following equations:

$$\text{Channel center frequency} = 5000 + (\text{channel number}) \times 5 \text{ (MHz) for center frequency} > 5000 \text{ MHz} \quad (24)$$

$$\text{Channel center frequency} = 4000 + (\text{channel number}) \times 5 \text{ (MHz) for } 4900 \leq \text{center frequency} \leq 5000 \text{ MHz} \quad (25)$$

40 MHz operation shall be restricted to the 5 GHz band only. Each 40 MHz channel shall occupy two 20 MHz channels, with the center frequency of the 40 MHz transmission selected to be midway between the center frequencies of the two occupied 20 MHz channels. For example, if the two occupied 20 MHz channels are centered at channel number 149 and 153, then the 40 MHz transmission shall be centered at channel number 151.

### 20.3.8.4 Spurious emissions

The spurious emissions shall conform to IEEE 802.11a-1999 subclause 17.3.8.4

### 20.3.8.5 TX RF delay

The TX RF delay shall follow IEEE 802.11a-1999 subclause 17.3.8.5.

### 20.3.8.6 Slot time

The slot time shall follow IEEE 802.11a-1999 subclause 17.3.8.6 for 5 GHz bands and IEEE 802.11g-1999 subclause 19.4.4 for 2.4 GHz bands.

### 20.3.8.7 Transmit and receive antenna port impedance

The transmit and receive antenna port impedance for each transmit and receive antenna shall follow IEEE 802.11a-1999 subclause 17.3.8.7.

### 20.3.8.8 Transmit and receive operating temperature range

The transmit and receive temperature range shall follow IEEE 802.11a-1999 subclause 17.3.8.8.

## 20.3.9 PMD TX specifications

Subclauses 20.3.9.1 through 20.3.9.7 describe the transmit specifications associated with the PMD sublayer. In general, these are specified by primitives from the PLCP, and the transmit PMD entity provides the actual means by which the signals required by the PLCP primitives are imposed into the medium.

### 20.3.9.1 TX power levels

The maximum allowable output power shall conform to national regulatory constraints on the maximum radiated power allowed in any frequency band.

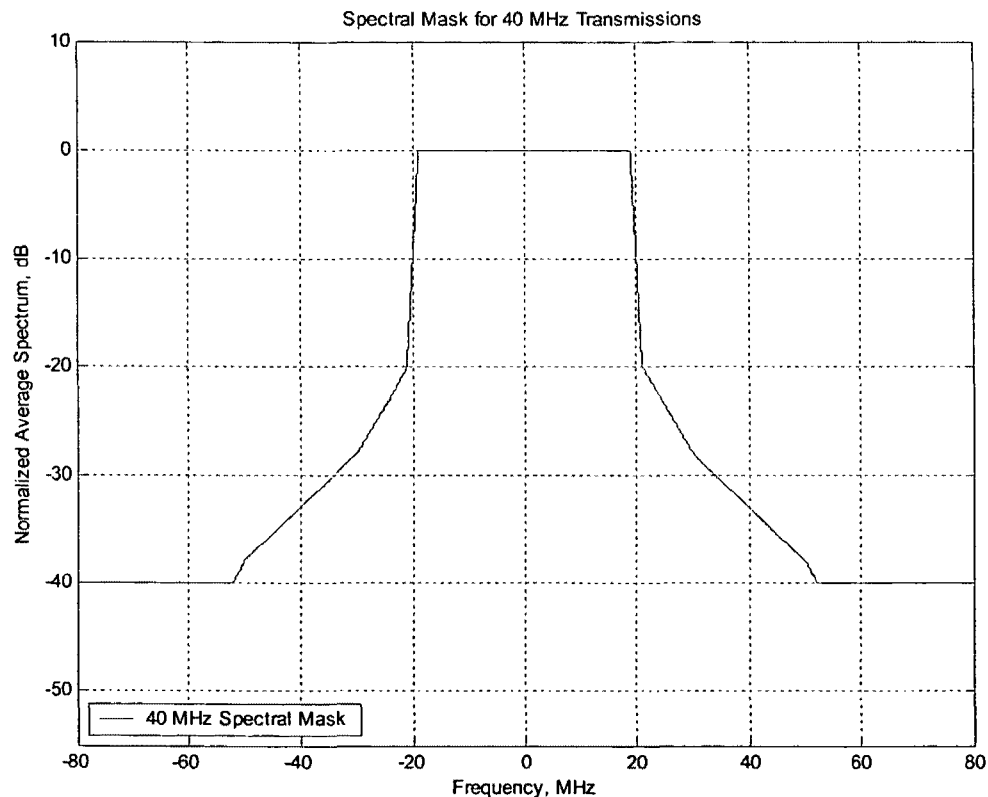


Figure 025 –Transmit spectrum mask for 40 MHz transmissions

### 20.3.9.2 TX spectrum mask

The transmitted spectral density of the transmitted signal shall conform to subclause IEEE 802.11a-1999 17.3.9.2 for all 20 MHz transmissions. The transmitted spectrum for 40 MHz transmissions shall have a 0 dBr bandwidth not exceeding 38 MHz, -20 dBr at 21 MHz frequency offset, -28 dBr at 30 MHz frequency offset, -38 dBr at 50 MHz frequency offset, and -40

dBr at 52 MHz frequency offset and above. The transmitted spectral density of the 40 MHz transmitted signal shall fall within the spectral mask shown in Figure 025. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

### 20.3.9.3 TX spurious

Spurious transmissions from Clause 20 compliant devices shall conform to national regulations.

### 20.3.9.4 TX center frequency tolerance

The transmitted center frequency tolerance shall be  $\pm 20$  ppm maximum for 5 GHz bands and  $\pm 25$  ppm for 2.4 GHz bands. The transmit center frequency and the symbol clock frequency for all transmit antennas shall be derived from the same reference oscillator.

### 20.3.9.5 TX symbol clock frequency tolerance

The symbol clock frequency tolerance shall be  $\pm 20$  ppm maximum for 5 GHz bands and  $\pm 25$  ppm for 2.4 GHz bands. The transmit center frequency and the symbol clock frequency for all transmit antennas shall be derived from the same reference oscillator.

### 20.3.9.6 Modulation accuracy

Transmit modulation accuracy specifications are described in this subclause. The test method is described in 20.3.9.7.

#### 20.3.9.6.1 TX center frequency leakage

TX center frequency leakage shall follow IEEE 802.11a-1999 subclause 17.3.9.6.1 for all 20 MHz modes of transmission. For 40 MHz modes, the center frequency leakage shall not exceed -18 dB relative to overall transmitted power, or, equivalently, +2 dB relative to the average energy of the rest of the subcarriers.

#### 20.3.9.6.2 TX spectral flatness

For 20 MHz transmissions, the average energy of the constellation in each of the spectral lines -16...-1 and +1...+16 will deviate no more than  $\pm 2$  dB of their average energy. The average energy of the constellations in each of the spectral lines -28...-17 and +17...+28 will deviate no more than  $\pm 2/4$  dB from the average energy of the spectral lines -16...-1 and +1...+16.

For 40 MHz transmissions, the average energy of the constellation in each of the spectral lines -32...-3 and +3...+32 will deviate no more than  $\pm 2$  dB of their average energy. The average energy of the constellations in each of the spectral lines -58...-33 and +33...+58 will deviate no more than  $\pm 2/4$  dB from the average energy of the spectral lines -32...-3 and +3...+32.

#### 20.3.9.6.3 TX constellation error

The relative constellation RMS error, averaged over subcarriers, transmit spatial streams, OFDM frames, and packets, shall not exceed a constellation and code rate dependent value according to Table 017 for the all modes in which the number of spatial streams is equal to the number of transmit antennas.

**Table 017—Allowed relative constellation error versus constellation type and code rate**

| Constellation size | Code Rate | Relative constellation error (dB) |
|--------------------|-----------|-----------------------------------|
| 16-QAM             | 1/2       | -17                               |
| 16-QAM             | 3/4       | -20                               |
| 64-QAM             | 2/3       | -24                               |
| 64-QAM             | 3/4       | -26                               |
| 64-QAM             | 5/6       | -27                               |

### 20.3.9.7 TX modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at 20 Msamples/s or more for 20 MHz modes, and 40 Msamples/s or more for 40 MHz modes, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, etc. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signals with a digital oscilloscope and decomposing them digitally into quadrature components.

The test procedure for this requirement is as follows: Matrices  $H_{1TX}$ ,  $H_{2TX}$ ,  $H_{3TX}$ , and  $H_{4TX}$  are defined to give the connections from the transmit antennas to the receive antennas for the 1TX, 2TX, 3TX, and 4TX cases respectively. They are specified as follows:

$$H_{1TX} = \alpha \cdot 1$$

$$H_{2TX} = \alpha \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$H_{3TX} = \alpha \begin{bmatrix} -1 & 2 & 2 \\ 2 & -1 & 2 \\ 2 & 2 & -1 \end{bmatrix}$$

$$H_{4TX} = \alpha \begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix} \quad (25)$$

The elements of the above matrices  $h_{ij}$  specify the connection from the  $j^{\text{th}}$  transmitter to the  $i^{\text{th}}$  receiver, where  $h_{ij}$  is the element of the  $i^{\text{th}}$  row and  $j^{\text{th}}$  column where  $i=1,\dots,N_{RX}$  and  $j=1,\dots,N_{TX}$ . The attenuation  $\alpha$  is chosen to ensure an appropriate received signal power at the test equipment. Figure 026 shows an example test setup for a 2TX mode.

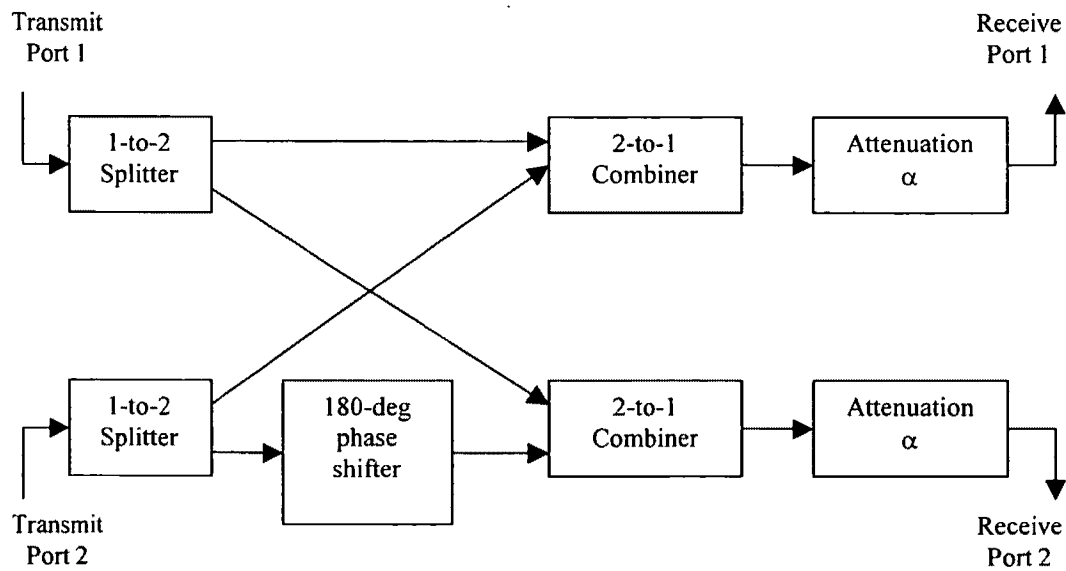


Figure 026 –EVM test setup

The 180 degree phase shifter shall be 180 +/- 10 degrees. The relative amplitudes of the connections  $h_{ij}$  shall be within +/-1 dB of the relative values specified in the H matrices above.

The sampled signals shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

- a) Start of frame shall be detected.
- b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.
- c) Coarse and fine frequency offsets shall be estimated.
- d) The packet shall be derotated according to estimated frequency offset.
- e) The complex channel response coefficients shall be estimated for each of the subcarriers.
- f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and apply an MMSE channel equalizer to each vector of received subcarrier values based on complex estimated channel response coefficients found in (e).
- g) For each data-carrying subcarrier of each transmitted stream, find the closest constellation point and compute the Euclidean distance from it.
- h) Compute the RMS average of all errors in a packet. It is given by:

$$Error_{RMS} = \frac{\sum_{i=1}^{N_f} \sqrt{\frac{\sum_{l=1}^{N_{SS}} \sum_{j=1}^{L_P} \sum_{k=1}^{N_{ST}} \{(I(i, j, k, l) - I_0(i, j, k, l))^2 + (Q(i, j, k, l) - Q_0(i, j, k, l))^2\}}{N_{ST} L_P P_0 N_{SS}}}}{N_f} \quad (26)$$

where

$L_P$  is the length of the packet;

$N_{SS}$  is the number of spatial streams;

$N_f$  is the number of frames for the measurement;

$N_{ST}$  is the total number of subcarriers (data and pilots) per OFDM symbol;

$(I_0(i, j, k, l), Q_0(i, j, k, l))$  denotes the ideal symbol point of the  $i^{\text{th}}$  frame,  $j^{\text{th}}$  OFDM symbol of the frame,  $k^{\text{th}}$  subcarrier, and  $l^{\text{th}}$  spatial stream of the OFDM symbol in the complex plane;

$(I(i, j, k, l), Q(i, j, k, l))$  denotes the observed point of the  $i^{\text{th}}$  frame,  $j^{\text{th}}$  OFDM symbol of the frame,  $k^{\text{th}}$  subcarrier, and  $l^{\text{th}}$  spatial stream of the OFDM symbol in the complex plane;

$P_0$  is the average power of the constellation.

The vector error on a phase plane is shown in Figure 121 in IEEE 802.11a-1999 subclause 17.3.9.7.

The test shall be performed over at least 20 frames ( $N_f$ ), and the RMS average shall be taken. The packets under test shall be at least 16 OFDM symbols long. Random data shall be used for the symbols.

### 20.3.10 PMD RX specifications

Subclauses 20.3.10.1 through 20.3.10.5 describe the receive specifications associated with the PMD sublayer.

#### 20.3.10.1 RX minimum input level sensitivity

The packet error rate (PER) shall be less than 10% at a PSDU length of 1000 bytes for rate-dependent input levels shall be the numbers listed in Table 018 or less. The minimum input levels are measured at the antenna connectors and are referenced as the average power per receive antenna.

**Table 018—Receiver minimum input level sensitivity**

| Constellation size | Code Rate | Minimum sensitivity (dBm) |
|--------------------|-----------|---------------------------|
|--------------------|-----------|---------------------------|



|        |               |     |
|--------|---------------|-----|
| BPSK   | $\frac{1}{2}$ | -82 |
| BPSK   | $\frac{3}{4}$ | -81 |
| QPSK   | $\frac{1}{2}$ | -79 |
| QPSK   | $\frac{3}{4}$ | -77 |
| 16-QAM | $\frac{1}{2}$ | -74 |
| 16-QAM | $\frac{3}{4}$ | -70 |
| 64-QAM | $\frac{2}{3}$ | -66 |
| 64-QAM | $\frac{3}{4}$ | -65 |
| 64-QAM | $\frac{5}{6}$ | -64 |

### 20.3.10.2 RX maximum input level

The RX maximum input level shall be defined as the maximum at any or all antennas, and shall follow IEEE 802.11a-1999 subclause 17.3.10.4 for the 4920-5805 MHz band, and follow IEEE 802.11g-2003 subclause 19.5.3 for the 2400-2497 MHz band.

### 20.3.10.3 CCA sensitivity

The CCA sensitivity of all Clause 20 compliant devices shall conform to IEEE 802.11a-2003 subclause 17.3.10.5.

### 20.3.11 PLCP TX procedure

The transmit PLCP is shown in Figure 029. In order to transmit data, PHY-TXSTART.request shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME. Other transmit parameters, such as DATARATE, TRANSMISSION\_MODE, NUM\_STREAMS, and TXPWR\_LEVEL, are set via the PHY-SAP with the PHY-TXSTART.request(TXVECTOR), as described in 20.2.

A clear channel shall be indicated by PHY-CCA.indicate(IDLE). The MAC considers this indication before issuing the PHY-TXSTART.request. Transmission of the PPDU or A-PPDU shall be initiated after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request are the PLCP header parameters LENGTH, DATARATE, TRANSMISSION\_MODE, NUM\_STREAMS, CODE\_TYPE, SERVICE, LPI, and BURST\_DURATION, and the PMD parameter TXPWR\_LEVEL.

The PLCP shall issue PMD\_TXPWRLVL, PMD\_RATE, PMD\_NUM\_STREAMS, and PMD\_TRANSMISSION\_MODE, primitives to configure the PHY. The PLCP shall then issue a PMD\_TXSTART.request, and transmission of the PLCP preamble and PLCP header, based on the parameters passed in the PHY-TXSTART.request primitive will begin. Once PLCP preamble transmission is started, the PHY entity shall immediately initiate data scrambling and data encoding. The scrambled and encoded data shall then be exchanged between the MAC and the PHY through a series of PHYDATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated from the SERVICE field data of the PLCP header, as described in 20.3.2. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The PLCP header parameter, SERVICE, and PSDU are encoded by the convolutional encoder with the bit-stealing function described in 20.3.5.5. At the PMD layer, the data octets are sent in bit 0-7 order and presented to the PHY through PMD\_DATA.request primitives. In the PMD, the GI shall be inserted in every OFDM symbol as a countermeasure against severe delay spread.

Transmission of a PSDU can be prematurely terminated by the MAC through the primitive PHY-TXEND.request. PHY-TXSTART shall be disabled by the issuance of the PHY-TXEND.request. Normal transmission of a PSDU occurs after the transmission of the final bit of the last PSDU octet, according to the number of bytes supplied in the PLCP header LENGTH.

Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY. If the coded PSDU (C-PSDU) is not multiples of the OFDM symbol, bits shall be stuffed to make the C-PSDU length multiples of the OFDM symbol.

If an aggregated PPDU (A-PPDU) is being transmitted as indicated by the TXVECTOR LPI parameter, the PHY will wait for the next PHY-TXSTART.request from the MAC. The process of transmitting the subsequent MPDUs as part of the A-PPDU is identical to the first MPDU except that the PLCP will not issue PMD primitives to configure the PHY.

Normal termination of the A-PPDU occurs at the termination of the transmission of the last PSDU, indicated by the PHY PLCP header LPI field. A prematurely terminated PSDU transmission from the MAC will prematurely terminate the transmission of the A-PPDU.

The A-PPDU transmission shall be completed and the PHY entity shall enter the receive state (i.e., PHY-TXSTART shall be disabled).

A typical state machine implementation of the transmit PLCP is provided in Figure 027. Requests (.req) and confirmations(.confirm) are issued once with designated states.

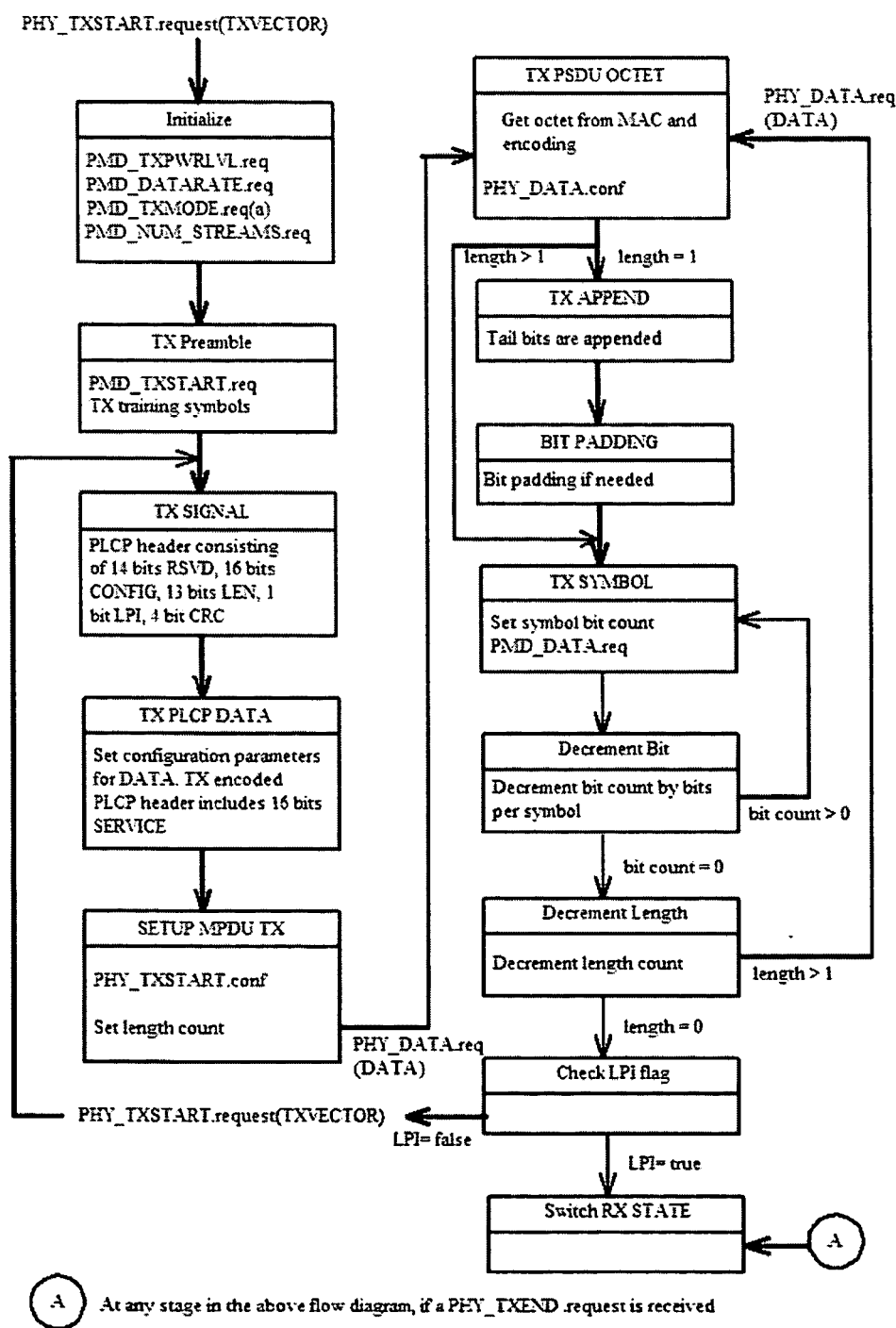


Figure 027 -PLCP transmit state machine

## 20.3.12 PLCP RX procedure

The receive PLCP is shown in Figure 030. In order to receive data, PHY-TXSTART.request shall be disabled so that the PHY entity is in the receive state. Further, through station management (via the PLME) the PHY is set to the appropriate frequency. Other receive parameters, such as RSSI and indicated DATARATE, TRANSMISSION\_MODE, NUM\_STREAMS, CODE\_TYPE, LPI, and BURST\_DURATION may be accessed via the PHY-SAP.

Upon receiving the transmitted PLCP preamble, PMD\_RSSI.indicate shall report a significant received signal strength level to the PLCP. This indicates activity to the MAC via PHY\_CCA.indicate. PHY\_CCA.indicate(BUSY) shall be issued for reception of a signal prior to correct reception of the PLCP frame. The PMD primitive PMD\_RSSI is issued to update the RSSI and parameter reported to the MAC.

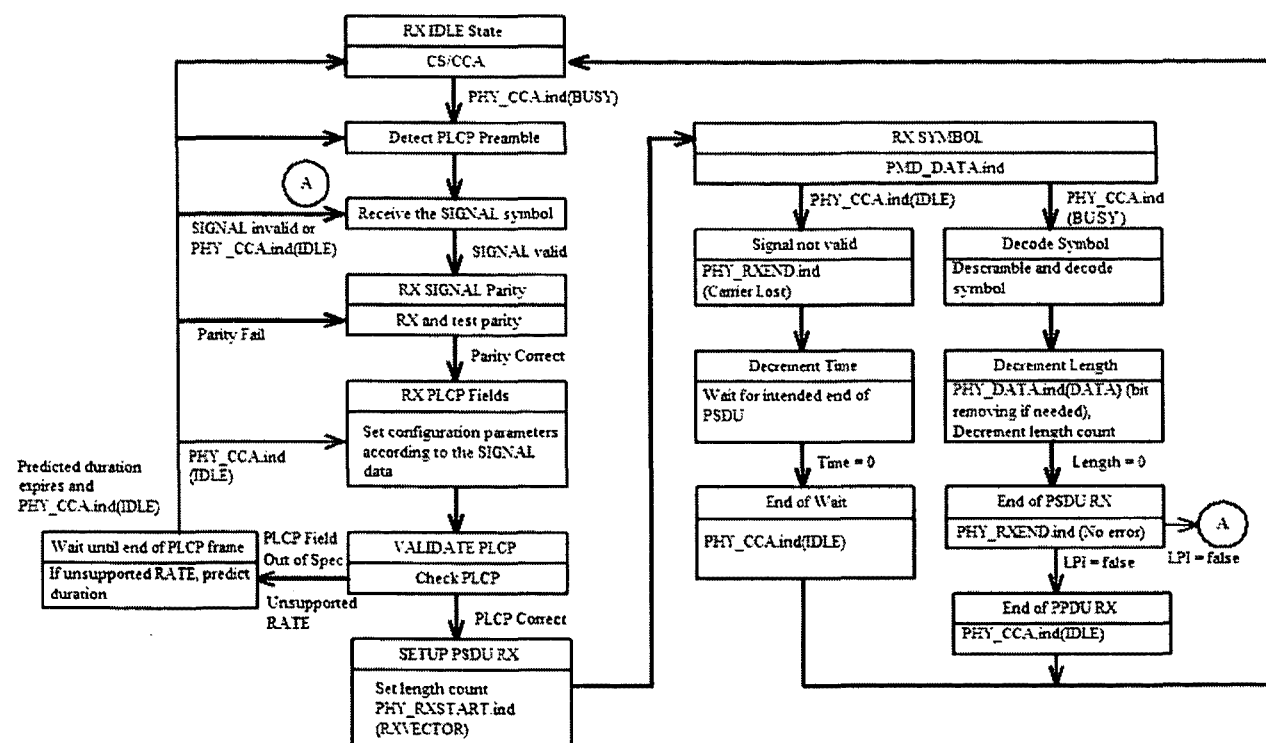


Figure 028 – PLCP receive state machine

After PHY-CCA.indicate is issued, the PHY entity shall begin receiving the training symbols and searching for the SIGNAL in order to set the length of the data stream, the demodulation type, and the decoding rate. Once the SIGNAL is detected without any errors detected by the CRC checker, FEC decode shall be initiated and the PLCP SERVICE fields and data shall be received, and decoded. Should the status of CCA return to the IDLE state during reception prior to completion of the full PLCP processing, the PHY receiver shall return to the RX IDLE state.

If the PLCP header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indicate(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the SIGNAL fields, the SERVICE field, the PSDU length in bytes, and the RSSI. Also, in this case, the HT PHY will ensure that the CCA shall indicate a busy medium for the intended duration of the transmitted frame, as indicated by the LENGTH field. The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indicate(DATA) primitive exchanges. The rate change indicated in the SIGNAL field shall be initiated from the SERVICE field data of the PLCP header, as described in 20.3.2. The PHY shall proceed with PSDU reception. After the reception of the final bit of the last PSDU octet indicated by the PLCP header LENGTH field, the receiver shall transition to the RX IDLE state if LPI is 1 or to the RX SIGNAL state if LPI is 0 in the RXVECTOR associated with this primitive, as shown in Figure 030. If the LPI is 1 in the RXVECTOR, a PHY-RXEND.indicate(NoError) primitive shall also be issued.

In the event that a change in the RSSI causes the status of the CCA to return to the IDLE state before the complete reception of the PSDU, as indicated by the PLCP LENGTH field, the error condition PHYRXEND.indicate(CarrierLost) shall be

1 reported to the MAC. The HT PHY will ensure that the CCA indicates a busy medium for the intended duration of the  
2 transmitted packet. If the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indicate will not be issued.  
3 The PHY shall issue the error condition PHY-RXEND.indicate(UnsupportedRate). If the PLCP header is receivable, but the  
4 FCS check of the PLCP header is not valid, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error  
5 condition PHY-RXEND.indicate(FormatViolation). Any data received after the indicated data length are considered pad bits  
6 (to fill out an OFDM symbol) and should be discarded. A typical state machine implementation of the receive PLCP is given  
7 in Figure 028.  
8  
9

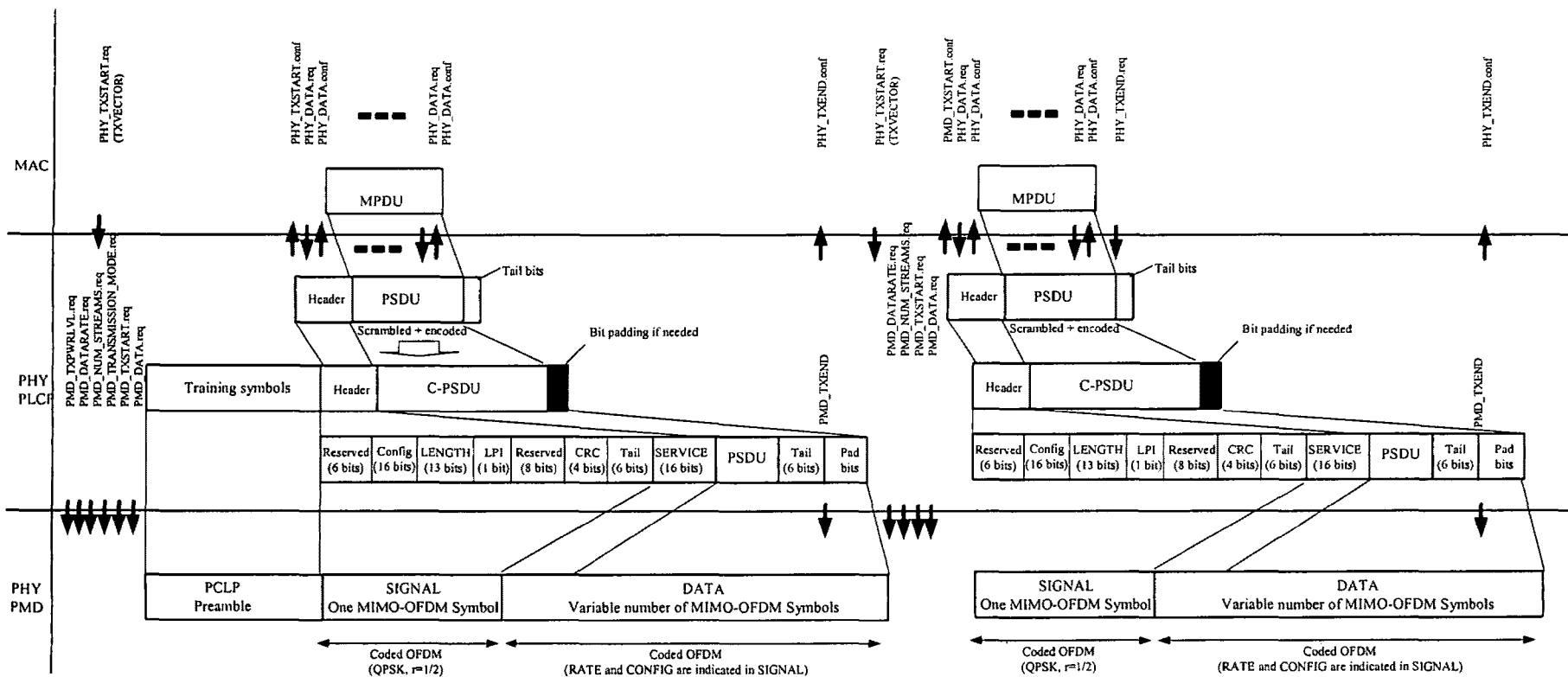


Fig. 029 PLCP transmit procedure for A-PPDU transmission in greenfield 20 MHz modes

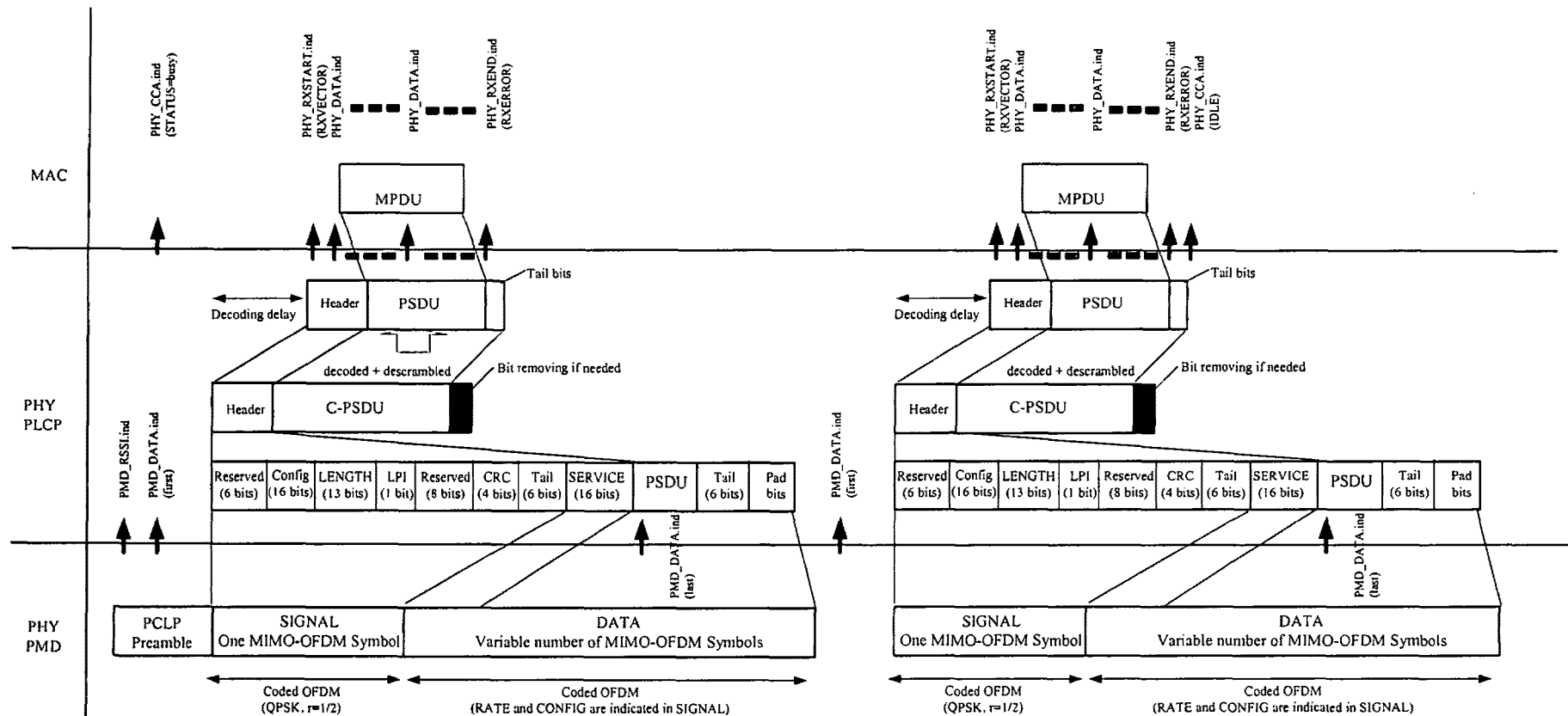


Fig. 030 PLCP receive procedure for A-PPDU reception in greenfield 20 MHz modes

## 20.4 MIMO-OFDM PMD operating specifications

### 20.4.1 PLME\_SAP sublayer management primitives

Table 20.4.2T1 lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 10.4.

### 20.4.2 MIMO-OFDM management information base

All MIMO-OFDM PHY MIB attributes are defined in Clause 13, with specific values defined in Table 20.4.2.T1. The column titled "Operational semantics" in Table 20.4.2.T1 contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

**Table 20.4.2T1 MIB attribute default values/ranges**

| Managed Object                             | Default Value / Range                                                 | Operational Semantics |
|--------------------------------------------|-----------------------------------------------------------------------|-----------------------|
| <b>dot11 PHY Operation Table</b>           |                                                                       |                       |
| dot11PHYtype                               | HTP (Value to be assigned)                                            | Static                |
| dot11CurrentRegDomain                      | Implementation dependent                                              | Static                |
| dot11TempType                              | Implementation dependent                                              | Static                |
| <b>dot11 PHY Antenna Table</b>             |                                                                       |                       |
| dot11CurrentTxAntenna                      | Implementation dependent                                              | Dynamic               |
| dot11DiversitySupport                      | Implementation dependent                                              | Static                |
| dot11CurrentRxAntenna                      | Implementation dependent                                              | Dynamic               |
| <b>Dot11 PHY Tx Power Table</b>            |                                                                       |                       |
| dot11NumberSupportedPowerLevels            | Implementation dependent                                              | Static                |
| dot11TxPowerLevel1                         | Implementation dependent                                              | Static                |
| dot11TxPowerLevel2                         | Implementation dependent                                              | Static                |
| dot11TxPowerLevel3                         | Implementation dependent                                              | Static                |
| dot11TxPowerLevel4                         | Implementation dependent                                              | Static                |
| dot11TxPowerLevel5                         | Implementation dependent                                              | Static                |
| dot11TxPowerLevel6                         | Implementation dependent                                              | Static                |
| dot11TxPowerLevel7                         | Implementation dependent                                              | Static                |
| dot11TxPowerLevel8                         | Implementation dependent                                              | Static                |
| dot11CurrentTxPowerLevel                   | Implementation dependent                                              | Dynamic               |
| <b>dot11 Phy DSSS Table</b>                |                                                                       |                       |
| dot11CurrentChannel                        | Implementation dependent                                              | Dynamic               |
| <b>dot11 Reg Domains Supported Table</b>   |                                                                       |                       |
| dot11RegDomainsSupportedValue(s)           | Implementation dependent                                              | Static                |
| <b>dot11 PHY Antennas List Table</b>       |                                                                       |                       |
| dot11SupportedTxAntenna                    | Implementation dependent                                              | Static                |
| dot11SupportedRxAntenna                    | Implementation dependent                                              | Static                |
| dot11DiversitySelectionRx                  | Implementation dependent                                              | Dynamic               |
| <b>dot11 Supported Data Rates Tx Table</b> |                                                                       |                       |
| dot11SupportedDataRatesTxValue             | See Clause 10.4.4.2 rate code columns of Tables 003-009 and Table 016 | Static                |
| <b>dot11 Supported Data Rates Rx Table</b> |                                                                       |                       |
| dot11SupportedDataRatesRxValue             | See Clause 10.4.4.2 rate code columns of Tables 003-009 and Table 016 | Static                |
| <b>dot11 PHY HTP Table</b>                 |                                                                       |                       |

|                                 |                                                                                                                                                     |         |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| dot11CurrentFrequency           | Implementation dependent                                                                                                                            | Dynamic |
| dot11SupportedTransmissionModes | Assign optional types in TRANSMISSION_MODE of Table 001 to bits in bit mask                                                                         | Static  |
| dot11SupportedNumStreams        | X'0' = Support 1 and 2 streams<br>X'1' = Support 1, 2, and 3 streams<br>X'2' = Support 1, 2, and 4 streams<br>X'3' = Support 1, 2, 3, and 4 streams | Static  |
| dot11SupportedCodeTypes         | X'0' = convolutional only<br>X'1' = convolutional and LDPC                                                                                          | Static  |

### 20.4.3 MIMO-OFDM TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equation:

$$\text{TXTIME} = \text{TXTIME}_{\text{CONV}} \text{ if CODE\_TYPE is convolutional and } \text{TXTIME}_{\text{LDPC}} \text{ if CODE\_TYPE is LDPC}$$

where

$$\text{TXTIME}_{\text{CONV}} = T_{\text{MIXED}} + T_{\text{PREAMBLE}} + T_{\text{SIGNAL}} + T_{\text{SYM}} \cdot \text{Ceiling}((16 + 8 \cdot \text{LENGTH} + 6)/N_{\text{DBPS}})$$

$$\text{TXTIME}_{\text{LDPC}} = T_{\text{MIXED}} + T_{\text{PREAMBLE}} + T_{\text{SIGNAL}} + T_{\text{SYM}} \cdot N_{\text{S1}}$$

$T_{\text{MIXED}}$  is 20 $\mu\text{s}$  if TRANSMISSION\_MODE is a mixed mode and 0 $\mu\text{s}$  if it is a greenfield mode

$T_{\text{PREAMBLE}}$  is 16 $\mu\text{s}$  if TRANSMISSION\_MODE specifies  $N_{\text{TX}} = 2$  and 28 $\mu\text{s}$  if TRANSMISSION\_MODE specifies  $N_{\text{TX}} = 3$  or 4

$T_{\text{SIGNAL}}$  is 4 $\mu\text{s}$

$N_{\text{DBPS}}$  is derived from the DATARATE parameter (Ceiling is a function that returns the smallest integer value greater than or equal to its argument value)

$N_{\text{S1}}$  is defined in subclause 20.3.5.7.3.

### 20.4.4 MIMO-OFDM PHY characteristics

**Table 20.4.4.1—MIMO-OFDM PHY characteristics**

| Characteristic      | Value                                                                                |
|---------------------|--------------------------------------------------------------------------------------|
| aSlotTime           | 9 $\mu\text{s}$                                                                      |
| aSIFSTime           | 16 $\mu\text{s}$                                                                     |
| aRIFSTime           | 2 $\mu\text{s}$                                                                      |
| aCCATime            | <4 $\mu\text{s}$                                                                     |
| aRxTxTurnaroundTime | Implementation dependent as long as the requirements of aSIFSTime are met.           |
| aTxRxTurnaroundTime | Implementation dependent as long as the requirements of aSIFSTime are met.           |
| aTxPLCPDelay        | Implementation dependent as long as the requirements of aRxTxTurnaroundTime are met. |
| aRxPLCPDelay        | Implementation dependent as long as the requirements of                              |



|                     |                                                                                        |
|---------------------|----------------------------------------------------------------------------------------|
|                     | aSIFSTime and aCCATime are met                                                         |
| aRxTxSwitchTime     | Implementation dependent                                                               |
| aTxRampOnTime       | Implementation dependent as long as the requirements of aRxTxTurnaroundTime are met    |
| aTxRampOffTime      | Implementation dependent as long as the requirements of aSIFSTime are met              |
| ATxRFDelay          | Implementation dependent as long as the requirements of aRxTxTurnaroundTime are met    |
| ARxRFDelay          | Implementation dependent as long as the requirements of aSIFSTime and aCCATime are met |
| aAirPropagationTime | $\ll 1 \mu\text{s}$                                                                    |
| aMACProcessingDelay | $< 2 \mu\text{s}$                                                                      |
| aPreambleLength     | $16 \mu\text{s}$                                                                       |
| aPLCPHeaderLength   | $4 \mu\text{s}$                                                                        |
| aMPDUMaxLength      | 8191                                                                                   |
| aCWmin              | 15                                                                                     |
| aCWmax              | 1023                                                                                   |

## 20.5 MIMO-OFDM operating specifications

### 20.5.1 Scope and field of application

This subclause describes the PMD services provided to the PLCP for the MIMO-OFDM PHY.

### 20.5.2 Overview of service

The MIMO-OFDM sublayer accepts PLCP sublayer service primitives and provides the actual means by which data is transmitted or received from the medium. The combined functions of the MIMO-OFDM PMD sublayer primitives and parameters for the receive function result in a data stream, timing information, and associated received signal parameters being delivered to the PLCP sublayer. A similar functionality is provided for data transmission.

### 20.5.3 Overview of interactions

The primitives associated with the PLCP sublayer to the MIMO-OFDM fall into two basic categories

- a) Service primitives that support PLCP peer-to-peer interactions;
- b) Service primitives that have local significance and that support sublayer-to-sublayer interactions.

### 20.5.4 Basic services and options

All of the service primitives described in this subclause are considered mandatory, unless otherwise specified.

#### 20.5.4.1 PMD\_SAP peer-to-peer service primitives

Table 20.5.4.1 indicates the primitives for peer-to-peer interactions.

Table 20.5.4.1 PMD\_SAP peer-to-peer services

| Primitive | Request | Indicate | Confirm | Response |
|-----------|---------|----------|---------|----------|
| PMD_Data  | X       | X        |         |          |

#### 20.5.4.2 PMD\_SAP sublayer-to-sublayer service primitives

Table 19.9.4.2 indicates the primitives for sublayer-to-sublayer interactions.

Table 19.9.4.2 PMD\_SAP sublayer-to-sublayer services

| Primitive             | Request | Indicate | Confirm | Response |
|-----------------------|---------|----------|---------|----------|
| PMD_TXSTART           | X       |          |         |          |
| PMD_TXEND             | X       |          |         |          |
| PMD_ANTSEL            | X       |          |         |          |
| PMD_TXPWRLVL          | X       |          |         |          |
| PMD_TRANSMISSION_MODE | X       |          |         |          |
| PMD_NUM_STREAMS       | X       |          |         |          |
| PMD_DATARATE          | X       |          |         |          |
| PMD_RSSI              |         | X        |         |          |

### 20.5.4.3 PMD\_SAP service primitive parameters

Table 19.9.4.3 shows the parameters used by one or more of the PMD\_SAP service primitives.

Table 20.5.4.3 List of parameters for the PMD primitives

| Parameter         | Associated primitive          | Value                                                                                                                                                                                                                           | Description                                                                                                                                               |
|-------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| TXD_UNIT          | PMD_DATA.request              | 0 to $(2^n)-1$ , where n is the number of bits per symbol for the transmission mode, number of streams, and data rate specified in PMD_TRANSMISSION_MODE.request, PMD_NUM_STREAMS.request, and PMD_DATARATE.request primitives. | This parameter represents a single block of data, which, in turn, is used by the PMD to be encoded into a transmitted symbol.                             |
| RXD_UNIT          | PMD_DATA.indicate             | 0 to $(2^n)-1$ , where n is the number of bits per symbol for the transmission mode, number of streams, and data rate specified in PMD_TRANSMISSION_MODE.request, PMD_NUM_STREAMS.request, and PMD_DATARATE.request primitives. | This parameter represents a single symbol that has been demodulated by the PMD entity.                                                                    |
| TRANSMISSION_MODE | PMD_TRANSMISSION_MODE.request | See Table 001 in 20.2                                                                                                                                                                                                           | This parameter specifies to the PMD layer, which transmission mode is used.                                                                               |
| ANT_STATE         | PMD_ANTSEL.request            | 1 to 256                                                                                                                                                                                                                        | ANT_STATE selects which of the available antennas is used for transmission. The number of available antennas is determined from the MIB table parameters. |
| TXPWR_LEVEL       | PMD_TXPWRLVL.request          | 1-8                                                                                                                                                                                                                             | TXPWR_LEVEL selects which of the optional transmit power levels should be                                                                                 |

|          |                      |                                                                       |                                                                                                                                   |
|----------|----------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
|          |                      |                                                                       | used for the current PPDU transmission. The number of available power levels is determined from the MIB table parameters.         |
| DATARATE | PMD_DATARATE.request | See Clause 10.4.4.2 rate code columns of Tables 003-009 and Table 016 | DATARATE selects which of the data rates is used for PSDU transmission.                                                           |
| RSSI     | PMD_RSSI.indicate    | 8 bits of RSSI (256 levels)                                           | The RSSI is a measure of the RF energy received. Mapping of the RSSI values to actual received power is implementation dependent. |

## 20.5.5 PMD\_SAP detailed service specification

The following subclauses describe the services provided by each PMD primitive.

### 20.5.5.1 PMD\_DATA.request

This primitive is the same as that defined in 17.5.5.1 and 18.4.5.1 except that the parameter TXD\_UNIT is expanded in scope to reflect the supported transmission formats defined in 20.5.4.3.

### 20.5.5.2 PMD\_DATA.indicate

This primitive is the same as that defined in 17.5.5.2 and 18.4.5.2 except that the parameter RXD\_UNIT is expanded in scope to reflect the supported transmission formats defined in 20.5.4.3.

### 20.5.5.3 PMD\_TRANSMISSION\_MODE.request

This primitive is the same as that defined in 18.4.5.3 except that the parameter MODULATION of that section is expanded in scope to reflect the supported transmission formats defined in 20.5.4.3.

### 20.5.5.4 PMD\_TXSTART.request

This primitive is the same as that defined in 17.5.5.3 and 18.4.5.6.

### 20.5.5.5 PMD\_TXEND.request

This primitive is the same as that defined in 17.5.5.4 and 18.4.5.7.

### 20.5.5.6 PMD\_ANTSEL.request

This primitive is the same as that defined in 18.4.5.8, including the definition of the parameter ANT\_STATE.

**20.5.5.7 PMD\_TXPRWLVL.request**

This primitive is the same as that defined in 17.5.5.5, including the definition of the parameter TXPWR\_LEVEL.

**20.5.5.8 PMD\_DATARATE.request**

This primitive is the same as that defined in 17.5.5.6 and 18.4.5.10, except that the parameter DATARATE is expanded in scope to reflect the supported MIMO-OFDM transmission modes as defined in 20.5.4.3.

**20.5.5.9 PMD\_RSSI.indicate**

This primitive is the same as that defined in 17.5.5.7 and 18.4.5.11, including the parameter RSSI. This primitive is used to aid in link optimization algorithms such as roaming decisions.

# Annex A – LDPC matrix definitions

(normative)

**Table A.1 – Description of the  
matrix prototype of the rate  
1/2 parity check matrix**

9

| Row | Col | Shift |
|-----|-----|-------|
| 0   | 3   | 9     |
| 0   | 7   | 15    |
| 0   | 16  | 5     |
| 0   | 22  | 23    |
| 0   | 32  | 6     |
| 0   | 35  | 12    |
| 0   | 36  | 23    |
| 1   | 2   | 12    |
| 1   | 6   | 16    |
| 1   | 10  | 19    |
| 1   | 26  | 12    |
| 1   | 31  | 23    |
| 1   | 36  | 5     |
| 1   | 37  | 24    |
| 2   | 2   | 9     |
| 2   | 9   | 15    |
| 2   | 16  | 2     |
| 2   | 29  | 15    |
| 2   | 37  | 8     |
| 2   | 37  | 9     |
| 2   | 38  | 2     |
| 3   | 1   | 11    |
| 3   | 5   | 15    |
| 3   | 14  | 17    |

|   |    |    |
|---|----|----|
| 3 | 22 | 7  |
| 3 | 36 | 12 |
| 3 | 38 | 19 |
| 3 | 39 | 25 |
| 4 | 4  | 15 |
| 4 | 8  | 3  |
| 4 | 10 | 15 |
| 4 | 26 | 16 |
| 4 | 34 | 6  |
| 4 | 39 | 6  |
| 4 | 40 | 10 |
| 5 | 4  | 20 |
| 5 | 10 | 24 |
| 5 | 11 | 17 |
| 5 | 23 | 4  |
| 5 | 33 | 25 |
| 5 | 40 | 24 |
| 5 | 41 | 15 |
| 6 | 1  | 14 |
| 6 | 5  | 17 |
| 6 | 13 | 0  |
| 6 | 28 | 14 |
| 6 | 35 | 16 |
| 6 | 41 | 24 |
| 6 | 42 | 5  |
| 7 | 1  | 7  |
| 7 | 9  | 7  |
| 7 | 11 | 3  |
| 7 | 21 | 12 |
| 7 | 30 | 18 |
| 7 | 42 | 15 |

|    |    |    |
|----|----|----|
| 7  | 43 | 21 |
| 8  | 2  | 9  |
| 8  | 7  | 25 |
| 8  | 10 | 4  |
| 8  | 18 | 15 |
| 8  | 34 | 15 |
| 8  | 43 | 18 |
| 8  | 44 | 18 |
| 9  | 4  | 13 |
| 9  | 9  | 5  |
| 9  | 18 | 6  |
| 9  | 20 | 3  |
| 9  | 39 | 8  |
| 9  | 44 | 14 |
| 9  | 45 | 15 |
| 10 | 0  | 3  |
| 10 | 7  | 11 |
| 10 | 11 | 10 |
| 10 | 23 | 21 |
| 10 | 33 | 17 |
| 10 | 45 | 13 |
| 10 | 46 | 12 |
| 11 | 1  | 11 |
| 11 | 9  | 9  |
| 11 | 11 | 15 |
| 11 | 29 | 6  |
| 11 | 38 | 11 |
| 11 | 46 | 9  |
| 11 | 47 | 5  |
| 12 | 5  | 16 |
| 12 | 5  | 22 |

|    |    |    |
|----|----|----|
| 12 | 10 | 9  |
| 12 | 24 | 0  |
| 12 | 45 | 5  |
| 12 | 47 | 7  |
| 12 | 48 | 10 |
| 13 | 3  | 13 |
| 13 | 10 | 0  |
| 13 | 13 | 20 |
| 13 | 20 | 23 |
| 13 | 42 | 7  |
| 13 | 48 | 21 |
| 13 | 49 | 14 |
| 14 | 3  | 8  |
| 14 | 7  | 1  |
| 14 | 11 | 3  |
| 14 | 25 | 24 |
| 14 | 46 | 3  |
| 14 | 49 | 3  |
| 14 | 50 | 7  |
| 15 | 0  | 8  |
| 15 | 9  | 0  |
| 15 | 11 | 5  |
| 15 | 19 | 26 |
| 15 | 31 | 8  |
| 15 | 50 | 5  |
| 15 | 51 | 2  |
| 16 | 4  | 4  |
| 16 | 8  | 6  |
| 16 | 15 | 4  |
| 16 | 19 | 11 |
| 16 | 43 | 20 |

|    |    |    |
|----|----|----|
| 16 | 51 | 5  |
| 16 | 52 | 16 |
| 17 | 1  | 10 |
| 17 | 5  | 24 |
| 17 | 10 | 13 |
| 17 | 27 | 3  |
| 17 | 32 | 26 |
| 17 | 52 | 7  |
| 17 | 53 | 24 |
| 18 | 4  | 10 |
| 18 | 8  | 8  |
| 18 | 12 | 10 |
| 18 | 30 | 21 |
| 18 | 48 | 7  |
| 18 | 53 | 16 |
| 18 | 54 | 17 |
| 19 | 4  | 23 |
| 19 | 6  | 15 |
| 19 | 14 | 14 |
| 19 | 28 | 4  |
| 19 | 50 | 5  |
| 19 | 54 | 13 |
| 19 | 55 | 11 |
| 20 | 3  | 9  |
| 20 | 6  | 18 |
| 20 | 15 | 16 |
| 20 | 25 | 5  |
| 20 | 40 | 0  |
| 20 | 55 | 12 |
| 20 | 56 | 8  |
| 21 | 0  | 4  |

|    |    |    |
|----|----|----|
| 21 | 6  | 20 |
| 21 | 11 | 6  |
| 21 | 24 | 9  |
| 21 | 55 | 20 |
| 21 | 56 | 24 |
| 21 | 57 | 12 |
| 22 | 2  | 10 |
| 22 | 8  | 12 |
| 22 | 12 | 12 |
| 22 | 27 | 4  |
| 22 | 53 | 3  |
| 22 | 57 | 0  |
| 22 | 58 | 19 |
| 23 | 0  | 2  |
| 23 | 9  | 17 |
| 23 | 17 | 17 |
| 23 | 21 | 9  |
| 23 | 49 | 14 |
| 23 | 58 | 22 |
| 23 | 59 | 23 |
| 24 | 1  | 16 |
| 24 | 7  | 5  |
| 24 | 17 | 7  |
| 24 | 29 | 12 |
| 24 | 56 | 19 |
| 24 | 59 | 23 |
| 24 | 60 | 4  |
| 25 | 0  | 8  |
| 25 | 8  | 13 |
| 25 | 18 | 1  |
| 25 | 28 | 25 |

|    |    |    |
|----|----|----|
| 25 | 44 | 1  |
| 25 | 60 | 26 |
| 25 | 61 | 13 |
| 26 | 4  | 1  |
| 26 | 9  | 1  |
| 26 | 21 | 10 |
| 26 | 26 | 12 |
| 26 | 52 | 3  |
| 26 | 61 | 6  |
| 26 | 62 | 18 |
| 27 | 3  | 21 |
| 27 | 5  | 8  |
| 27 | 22 | 13 |
| 27 | 27 | 17 |
| 27 | 59 | 21 |
| 27 | 62 | 21 |
| 27 | 63 | 12 |
| 28 | 1  | 13 |
| 28 | 8  | 26 |
| 28 | 20 | 18 |
| 28 | 32 | 11 |
| 28 | 58 | 21 |
| 28 | 63 | 23 |
| 28 | 64 | 3  |
| 29 | 2  | 16 |
| 29 | 5  | 6  |
| 29 | 19 | 10 |
| 29 | 25 | 17 |
| 29 | 54 | 20 |
| 29 | 64 | 16 |
| 29 | 65 | 8  |

|    |    |    |
|----|----|----|
| 30 | 3  | 16 |
| 30 | 7  | 15 |
| 30 | 16 | 1  |
| 30 | 31 | 0  |
| 30 | 41 | 13 |
| 30 | 65 | 15 |
| 30 | 66 | 17 |
| 31 | 0  | 20 |
| 31 | 6  | 8  |
| 31 | 15 | 4  |
| 31 | 34 | 1  |
| 31 | 51 | 22 |
| 31 | 66 | 4  |
| 31 | 67 | 8  |
| 32 | 2  | 11 |
| 32 | 7  | 17 |
| 32 | 13 | 3  |
| 32 | 33 | 12 |
| 32 | 57 | 20 |
| 32 | 67 | 7  |
| 32 | 68 | 3  |
| 33 | 0  | 19 |
| 33 | 6  | 22 |
| 33 | 14 | 8  |
| 33 | 30 | 14 |
| 33 | 35 | 18 |
| 33 | 68 | 16 |
| 33 | 69 | 0  |
| 34 | 3  | 6  |
| 34 | 6  | 0  |
| 34 | 17 | 16 |

|    |    |    |
|----|----|----|
| 34 | 24 | 19 |
| 34 | 47 | 12 |
| 34 | 69 | 1  |
| 34 | 70 | 21 |
| 35 | 2  | 22 |
| 35 | 8  | 22 |
| 35 | 12 | 26 |
| 35 | 23 | 1  |
| 35 | 70 | 5  |
| 35 | 71 | st |

1

2 Table A.2 – Description of the  
3 matrix prototype of the rate  
4 2/3 parity check matrix

| Row | Col | Shift |
|-----|-----|-------|
| 0   | 5   | 16    |
| 0   | 5   | 22    |
| 0   | 10  | 9     |
| 0   | 24  | 0     |
| 0   | 45  | 5     |
| 0   | 47  | 7     |
| 0   | 48  | 10    |
| 1   | 3   | 13    |
| 1   | 10  | 0     |
| 1   | 13  | 20    |
| 1   | 20  | 23    |
| 1   | 42  | 7     |
| 1   | 48  | 21    |
| 1   | 49  | 14    |
| 2   | 3   | 8     |
| 2   | 7   | 1     |
| 2   | 11  | 3     |
| 2   | 25  | 24    |
| 2   | 46  | 3     |
| 2   | 49  | 3     |
| 2   | 50  | 7     |
| 3   | 0   | 8     |
| 3   | 9   | 0     |
| 3   | 11  | 5     |
| 3   | 19  | 26    |
| 3   | 31  | 8     |
| 3   | 50  | 5     |
| 3   | 51  | 2     |

|   |    |    |
|---|----|----|
| 4 | 4  | 4  |
| 4 | 8  | 6  |
| 4 | 15 | 4  |
| 4 | 19 | 11 |
| 4 | 43 | 20 |
| 4 | 51 | 5  |
| 4 | 52 | 16 |
| 5 | 1  | 10 |
| 5 | 5  | 24 |
| 5 | 10 | 13 |
| 5 | 27 | 3  |
| 5 | 32 | 26 |
| 5 | 52 | 7  |
| 5 | 53 | 24 |
| 6 | 3  | 9  |
| 6 | 4  | 10 |
| 6 | 7  | 15 |
| 6 | 8  | 8  |
| 6 | 12 | 10 |
| 6 | 16 | 5  |
| 6 | 22 | 23 |
| 6 | 30 | 21 |
| 6 | 32 | 6  |
| 6 | 35 | 12 |
| 6 | 36 | 23 |
| 6 | 48 | 7  |
| 6 | 53 | 16 |
| 6 | 54 | 17 |
| 7 | 2  | 12 |
| 7 | 4  | 23 |
| 7 | 6  | 15 |
| 7 | 6  | 16 |
| 7 | 10 | 19 |
| 7 | 14 | 14 |
| 7 | 26 | 12 |
| 7 | 28 | 4  |
| 7 | 31 | 23 |
| 7 | 36 | 5  |
| 7 | 37 | 24 |
| 7 | 50 | 5  |
| 7 | 54 | 13 |
| 7 | 55 | 11 |
| 8 | 2  | 9  |
| 8 | 3  | 9  |
| 8 | 6  | 18 |
| 8 | 9  | 15 |
| 8 | 15 | 16 |
| 8 | 16 | 2  |
| 8 | 25 | 5  |
| 8 | 29 | 15 |
| 8 | 37 | 8  |
| 8 | 37 | 9  |
| 8 | 38 | 2  |
| 8 | 40 | 0  |
| 8 | 55 | 12 |
| 8 | 56 | 8  |

|    |    |    |
|----|----|----|
| 9  | 0  | 4  |
| 9  | 1  | 11 |
| 9  | 5  | 15 |
| 9  | 6  | 20 |
| 9  | 11 | 6  |
| 9  | 14 | 17 |
| 9  | 22 | 7  |
| 9  | 24 | 9  |
| 9  | 36 | 12 |
| 9  | 38 | 19 |
| 9  | 39 | 25 |
| 9  | 55 | 20 |
| 9  | 56 | 24 |
| 9  | 57 | 12 |
| 10 | 2  | 10 |
| 10 | 4  | 15 |
| 10 | 8  | 3  |
| 10 | 8  | 12 |
| 10 | 10 | 15 |
| 10 | 12 | 12 |
| 10 | 26 | 16 |
| 10 | 27 | 4  |
| 10 | 34 | 6  |
| 10 | 39 | 6  |
| 10 | 40 | 10 |
| 10 | 53 | 3  |
| 10 | 57 | 0  |
| 10 | 58 | 19 |
| 11 | 0  | 2  |
| 11 | 4  | 20 |
| 11 | 9  | 17 |
| 11 | 10 | 24 |
| 11 | 11 | 17 |
| 11 | 17 | 17 |
| 11 | 21 | 9  |
| 11 | 23 | 4  |
| 11 | 33 | 25 |
| 11 | 40 | 24 |
| 11 | 41 | 15 |
| 11 | 49 | 14 |
| 11 | 58 | 22 |
| 11 | 59 | 23 |
| 12 | 1  | 14 |
| 12 | 1  | 16 |
| 12 | 5  | 17 |
| 12 | 7  | 5  |
| 12 | 13 | 0  |
| 12 | 17 | 7  |
| 12 | 28 | 14 |
| 12 | 29 | 12 |
| 12 | 35 | 16 |
| 12 | 41 | 24 |
| 12 | 42 | 5  |
| 12 | 56 | 19 |
| 12 | 59 | 23 |
| 12 | 60 | 4  |

|    |    |    |
|----|----|----|
| 13 | 0  | 8  |
| 13 | 1  | 7  |
| 13 | 8  | 13 |
| 13 | 9  | 7  |
| 13 | 11 | 3  |
| 13 | 18 | 1  |
| 13 | 21 | 12 |
| 13 | 28 | 25 |
| 13 | 30 | 18 |
| 13 | 42 | 15 |
| 13 | 43 | 21 |
| 13 | 44 | 1  |
| 13 | 60 | 26 |
| 13 | 61 | 13 |
| 14 | 2  | 9  |
| 14 | 4  | 1  |
| 14 | 7  | 25 |
| 14 | 9  | 1  |
| 14 | 10 | 4  |
| 14 | 18 | 15 |
| 14 | 21 | 10 |
| 14 | 26 | 12 |
| 14 | 34 | 15 |
| 14 | 43 | 18 |
| 14 | 44 | 18 |
| 14 | 52 | 3  |
| 14 | 61 | 6  |
| 14 | 62 | 18 |
| 15 | 3  | 21 |
| 15 | 4  | 13 |
| 15 | 5  | 8  |
| 15 | 9  | 5  |
| 15 | 18 | 6  |
| 15 | 20 | 3  |
| 15 | 22 | 13 |
| 15 | 27 | 17 |
| 15 | 39 | 8  |
| 15 | 44 | 14 |
| 15 | 45 | 15 |
| 15 | 59 | 21 |
| 15 | 62 | 21 |
| 15 | 63 | 12 |
| 16 | 0  | 3  |
| 16 | 1  | 13 |
| 16 | 7  | 11 |
| 16 | 8  | 26 |
| 16 | 11 | 10 |
| 16 | 20 | 18 |
| 16 | 23 | 21 |
| 16 | 32 | 11 |
| 16 | 33 | 17 |
| 16 | 45 | 13 |
| 16 | 46 | 12 |
| 16 | 58 | 21 |
| 16 | 63 | 23 |
| 16 | 64 | 3  |



|    |    |    |
|----|----|----|
| 17 | 1  | 11 |
| 17 | 2  | 16 |
| 17 | 5  | 6  |
| 17 | 9  | 9  |
| 17 | 11 | 15 |
| 17 | 19 | 10 |
| 17 | 25 | 17 |
| 17 | 29 | 6  |
| 17 | 38 | 11 |
| 17 | 46 | 9  |
| 17 | 47 | 5  |
| 17 | 54 | 20 |
| 17 | 64 | 16 |
| 17 | 65 | 8  |
| 18 | 3  | 16 |
| 18 | 7  | 15 |
| 18 | 16 | 1  |
| 18 | 31 | 0  |
| 18 | 41 | 13 |
| 18 | 65 | 15 |
| 18 | 66 | 17 |
| 19 | 0  | 20 |
| 19 | 6  | 8  |
| 19 | 15 | 4  |
| 19 | 34 | 1  |
| 19 | 51 | 22 |
| 19 | 66 | 4  |
| 19 | 67 | 8  |
| 20 | 2  | 11 |
| 20 | 7  | 17 |
| 20 | 13 | 3  |
| 20 | 33 | 12 |
| 20 | 57 | 20 |
| 20 | 67 | 7  |
| 20 | 68 | 3  |
| 21 | 0  | 19 |
| 21 | 6  | 22 |
| 21 | 14 | 8  |
| 21 | 30 | 14 |
| 21 | 35 | 18 |
| 21 | 68 | 16 |
| 21 | 69 | 0  |
| 22 | 3  | 6  |
| 22 | 6  | 0  |
| 22 | 17 | 16 |
| 22 | 24 | 19 |
| 22 | 47 | 12 |
| 22 | 69 | 1  |
| 22 | 70 | 21 |
| 23 | 2  | 22 |
| 23 | 8  | 22 |
| 23 | 12 | 26 |
| 23 | 23 | 1  |
| 23 | 70 | 5  |
| 23 | 71 | st |

2 Table A.3 – Description of the  
3 matrix prototype of the rate  
4 3/4 parity check matrix

| Row | Col | Shift |
|-----|-----|-------|
| 0   | 3   | 9     |
| 0   | 4   | 10    |
| 0   | 7   | 15    |
| 0   | 8   | 8     |
| 0   | 12  | 10    |
| 0   | 16  | 5     |
| 0   | 22  | 23    |
| 0   | 30  | 21    |
| 0   | 32  | 6     |
| 0   | 35  | 12    |
| 0   | 36  | 23    |
| 0   | 48  | 7     |
| 0   | 53  | 16    |
| 0   | 54  | 17    |
| 1   | 2   | 12    |
| 1   | 4   | 23    |
| 1   | 6   | 15    |
| 1   | 6   | 16    |
| 1   | 10  | 19    |
| 1   | 14  | 14    |
| 1   | 26  | 12    |
| 1   | 28  | 4     |
| 1   | 31  | 23    |
| 1   | 36  | 5     |
| 1   | 37  | 24    |
| 1   | 50  | 5     |
| 1   | 54  | 13    |
| 1   | 55  | 11    |
| 2   | 2   | 9     |
| 2   | 3   | 9     |
| 2   | 6   | 18    |
| 2   | 9   | 15    |
| 2   | 15  | 16    |
| 2   | 16  | 2     |
| 2   | 25  | 5     |
| 2   | 29  | 15    |
| 2   | 37  | 8     |
| 2   | 37  | 9     |
| 2   | 38  | 2     |
| 2   | 40  | 0     |
| 2   | 55  | 12    |
| 2   | 56  | 8     |
| 3   | 0   | 4     |
| 3   | 1   | 11    |
| 3   | 5   | 15    |
| 3   | 6   | 20    |
| 3   | 11  | 6     |
| 3   | 14  | 17    |
| 3   | 22  | 7     |
| 3   | 24  | 9     |
| 3   | 36  | 12    |

|   |    |    |
|---|----|----|
| 3 | 38 | 19 |
| 3 | 39 | 25 |
| 3 | 55 | 20 |
| 3 | 56 | 24 |
| 3 | 57 | 12 |
| 4 | 2  | 10 |
| 4 | 4  | 15 |
| 4 | 8  | 3  |
| 4 | 8  | 12 |
| 4 | 10 | 15 |
| 4 | 12 | 12 |
| 4 | 26 | 16 |
| 4 | 27 | 4  |
| 4 | 34 | 6  |
| 4 | 39 | 6  |
| 4 | 40 | 10 |
| 4 | 53 | 3  |
| 4 | 57 | 0  |
| 4 | 58 | 19 |
| 5 | 0  | 2  |
| 5 | 4  | 20 |
| 5 | 9  | 17 |
| 5 | 10 | 24 |
| 5 | 11 | 17 |
| 5 | 17 | 17 |
| 5 | 21 | 9  |
| 5 | 23 | 4  |
| 5 | 33 | 25 |
| 5 | 40 | 24 |
| 5 | 41 | 15 |
| 5 | 49 | 14 |
| 5 | 58 | 22 |
| 5 | 59 | 23 |
| 6 | 1  | 14 |
| 6 | 1  | 16 |
| 6 | 5  | 17 |
| 6 | 7  | 5  |
| 6 | 13 | 0  |
| 6 | 17 | 7  |
| 6 | 28 | 14 |
| 6 | 29 | 12 |
| 6 | 35 | 16 |
| 6 | 41 | 24 |
| 6 | 42 | 5  |
| 6 | 56 | 19 |
| 6 | 59 | 23 |
| 6 | 60 | 4  |
| 7 | 0  | 8  |
| 7 | 1  | 7  |
| 7 | 8  | 13 |
| 7 | 9  | 7  |
| 7 | 11 | 3  |
| 7 | 18 | 1  |
| 7 | 21 | 12 |
| 7 | 28 | 25 |
| 7 | 30 | 18 |

|    |    |    |
|----|----|----|
| 7  | 42 | 15 |
| 7  | 43 | 21 |
| 7  | 44 | 1  |
| 7  | 60 | 26 |
| 7  | 61 | 13 |
| 8  | 2  | 9  |
| 8  | 4  | 1  |
| 8  | 7  | 25 |
| 8  | 9  | 1  |
| 8  | 10 | 4  |
| 8  | 18 | 15 |
| 8  | 21 | 10 |
| 8  | 26 | 12 |
| 8  | 34 | 15 |
| 8  | 43 | 18 |
| 8  | 44 | 18 |
| 8  | 52 | 3  |
| 8  | 61 | 6  |
| 8  | 62 | 18 |
| 9  | 3  | 21 |
| 9  | 4  | 13 |
| 9  | 5  | 8  |
| 9  | 9  | 5  |
| 9  | 18 | 6  |
| 9  | 20 | 3  |
| 9  | 22 | 13 |
| 9  | 27 | 17 |
| 9  | 39 | 8  |
| 9  | 44 | 14 |
| 9  | 45 | 15 |
| 9  | 59 | 21 |
| 9  | 62 | 21 |
| 9  | 63 | 12 |
| 10 | 0  | 3  |
| 10 | 1  | 13 |
| 10 | 7  | 11 |
| 10 | 8  | 26 |
| 10 | 11 | 10 |
| 10 | 20 | 18 |
| 10 | 23 | 21 |
| 10 | 32 | 11 |
| 10 | 33 | 17 |
| 10 | 45 | 13 |
| 10 | 46 | 12 |
| 10 | 58 | 21 |
| 10 | 63 | 23 |
| 10 | 64 | 3  |
| 11 | 1  | 11 |
| 11 | 2  | 16 |
| 11 | 5  | 6  |
| 11 | 9  | 9  |
| 11 | 11 | 15 |
| 11 | 19 | 10 |
| 11 | 25 | 17 |
| 11 | 29 | 6  |
| 11 | 38 | 11 |

|    |    |    |
|----|----|----|
| 11 | 46 | 9  |
| 11 | 47 | 5  |
| 11 | 54 | 20 |
| 11 | 64 | 16 |
| 11 | 65 | 8  |
| 12 | 3  | 16 |
| 12 | 5  | 16 |
| 12 | 5  | 22 |
| 12 | 7  | 15 |
| 12 | 10 | 9  |
| 12 | 16 | 1  |
| 12 | 24 | 0  |
| 12 | 31 | 0  |
| 12 | 41 | 13 |
| 12 | 45 | 5  |
| 12 | 47 | 7  |
| 12 | 48 | 10 |
| 12 | 65 | 15 |
| 12 | 66 | 17 |
| 13 | 0  | 20 |
| 13 | 3  | 13 |
| 13 | 6  | 8  |
| 13 | 10 | 0  |
| 13 | 13 | 20 |
| 13 | 15 | 4  |
| 13 | 20 | 23 |
| 13 | 34 | 1  |
| 13 | 42 | 7  |
| 13 | 48 | 21 |
| 13 | 49 | 14 |
| 13 | 51 | 22 |
| 13 | 66 | 4  |
| 13 | 67 | 8  |
| 14 | 2  | 11 |
| 14 | 3  | 8  |
| 14 | 7  | 1  |
| 14 | 7  | 17 |
| 14 | 11 | 3  |
| 14 | 13 | 3  |
| 14 | 25 | 24 |
| 14 | 33 | 12 |
| 14 | 46 | 3  |
| 14 | 49 | 3  |
| 14 | 50 | 7  |
| 14 | 57 | 20 |
| 14 | 67 | 7  |
| 14 | 68 | 3  |
| 15 | 0  | 8  |
| 15 | 0  | 19 |
| 15 | 6  | 22 |
| 15 | 9  | 0  |
| 15 | 11 | 5  |
| 15 | 14 | 8  |
| 15 | 19 | 26 |
| 15 | 30 | 14 |
| 15 | 31 | 8  |

|    |    |    |
|----|----|----|
| 15 | 35 | 18 |
| 15 | 50 | 5  |
| 15 | 51 | 2  |
| 15 | 68 | 16 |
| 15 | 69 | 0  |
| 16 | 3  | 6  |
| 16 | 4  | 4  |
| 16 | 6  | 0  |
| 16 | 8  | 6  |
| 16 | 15 | 4  |
| 16 | 17 | 16 |
| 16 | 19 | 11 |
| 16 | 24 | 19 |
| 16 | 43 | 20 |
| 16 | 47 | 12 |
| 16 | 51 | 5  |
| 16 | 52 | 16 |
| 16 | 69 | 1  |
| 16 | 70 | 21 |
| 17 | 1  | 10 |
| 17 | 2  | 22 |
| 17 | 5  | 24 |
| 17 | 8  | 22 |
| 17 | 10 | 13 |
| 17 | 12 | 26 |
| 17 | 23 | 1  |
| 17 | 27 | 3  |
| 17 | 32 | 26 |
| 17 | 52 | 7  |
| 17 | 53 | 24 |
| 17 | 70 | 5  |
| 17 | 71 | st |

1

2 Table A.4 – Description of the  
3 matrix prototype of the rate  
4 5/6 parity check matrix

| Row | Col | Shift |
|-----|-----|-------|
| 0   | 1   | 16    |
| 0   | 3   | 9     |
| 0   | 5   | 16    |
| 0   | 5   | 22    |
| 0   | 7   | 5     |
| 0   | 7   | 15    |
| 0   | 10  | 9     |
| 0   | 16  | 5     |
| 0   | 17  | 7     |
| 0   | 22  | 23    |
| 0   | 24  | 0     |
| 0   | 29  | 12    |
| 0   | 32  | 6     |
| 0   | 35  | 12    |
| 0   | 36  | 23    |
| 0   | 45  | 5     |

|   |    |    |
|---|----|----|
| 0 | 47 | 7  |
| 0 | 48 | 10 |
| 0 | 56 | 19 |
| 0 | 59 | 23 |
| 0 | 60 | 4  |
| 1 | 0  | 8  |
| 1 | 2  | 12 |
| 1 | 3  | 13 |
| 1 | 6  | 16 |
| 1 | 8  | 13 |
| 1 | 10 | 0  |
| 1 | 10 | 19 |
| 1 | 13 | 20 |
| 1 | 18 | 1  |
| 1 | 20 | 23 |
| 1 | 26 | 12 |
| 1 | 28 | 25 |
| 1 | 31 | 23 |
| 1 | 36 | 5  |
| 1 | 37 | 24 |
| 1 | 42 | 7  |
| 1 | 44 | 1  |
| 1 | 48 | 21 |
| 1 | 49 | 14 |
| 1 | 60 | 26 |
| 1 | 61 | 13 |
| 2 | 2  | 9  |
| 2 | 3  | 8  |
| 2 | 4  | 1  |
| 2 | 7  | 1  |
| 2 | 9  | 1  |
| 2 | 9  | 15 |
| 2 | 11 | 3  |
| 2 | 16 | 2  |
| 2 | 21 | 10 |
| 2 | 25 | 24 |
| 2 | 26 | 12 |
| 2 | 29 | 15 |
| 2 | 37 | 8  |
| 2 | 37 | 9  |
| 2 | 38 | 2  |
| 2 | 46 | 3  |
| 2 | 49 | 3  |
| 2 | 50 | 7  |
| 2 | 52 | 3  |
| 2 | 61 | 6  |
| 2 | 62 | 18 |
| 3 | 0  | 8  |
| 3 | 1  | 11 |
| 3 | 3  | 21 |
| 3 | 5  | 8  |
| 3 | 5  | 15 |
| 3 | 9  | 0  |
| 3 | 11 | 5  |
| 3 | 14 | 17 |
| 3 | 19 | 26 |

|   |    |    |
|---|----|----|
| 3 | 22 | 7  |
| 3 | 22 | 13 |
| 3 | 27 | 17 |
| 3 | 31 | 8  |
| 3 | 36 | 12 |
| 3 | 38 | 19 |
| 3 | 39 | 25 |
| 3 | 50 | 5  |
| 3 | 51 | 2  |
| 3 | 59 | 21 |
| 3 | 62 | 21 |
| 3 | 63 | 12 |
| 4 | 1  | 13 |
| 4 | 4  | 4  |
| 4 | 4  | 15 |
| 4 | 8  | 3  |
| 4 | 8  | 6  |
| 4 | 8  | 26 |
| 4 | 10 | 15 |
| 4 | 15 | 4  |
| 4 | 19 | 11 |
| 4 | 20 | 18 |
| 4 | 26 | 16 |
| 4 | 32 | 11 |
| 4 | 34 | 6  |
| 4 | 39 | 6  |
| 4 | 40 | 10 |
| 4 | 43 | 20 |
| 4 | 51 | 5  |
| 4 | 52 | 16 |
| 4 | 58 | 21 |
| 4 | 63 | 23 |
| 4 | 64 | 3  |
| 5 | 1  | 10 |
| 5 | 2  | 16 |
| 5 | 4  | 20 |
| 5 | 5  | 6  |
| 5 | 5  | 24 |
| 5 | 10 | 13 |
| 5 | 10 | 24 |
| 5 | 11 | 17 |
| 5 | 19 | 10 |
| 5 | 23 | 4  |
| 5 | 25 | 17 |
| 5 | 27 | 3  |
| 5 | 32 | 26 |
| 5 | 33 | 25 |
| 5 | 40 | 24 |
| 5 | 41 | 15 |
| 5 | 52 | 7  |
| 5 | 53 | 24 |
| 5 | 54 | 20 |
| 5 | 64 | 16 |
| 5 | 65 | 8  |
| 6 | 1  | 14 |
| 6 | 3  | 16 |

|   |    |    |
|---|----|----|
| 6 | 4  | 10 |
| 6 | 5  | 17 |
| 6 | 7  | 15 |
| 6 | 8  | 8  |
| 6 | 12 | 10 |
| 6 | 13 | 0  |
| 6 | 16 | 1  |
| 6 | 28 | 14 |
| 6 | 30 | 21 |
| 6 | 31 | 0  |
| 6 | 35 | 16 |
| 6 | 41 | 13 |
| 6 | 41 | 24 |
| 6 | 42 | 5  |
| 6 | 48 | 7  |
| 6 | 53 | 16 |
| 6 | 54 | 17 |
| 6 | 65 | 15 |
| 6 | 66 | 17 |
| 7 | 0  | 20 |
| 7 | 1  | 7  |
| 7 | 4  | 23 |
| 7 | 6  | 8  |
| 7 | 6  | 15 |
| 7 | 9  | 7  |
| 7 | 11 | 3  |
| 7 | 14 | 14 |
| 7 | 15 | 4  |
| 7 | 21 | 12 |
| 7 | 28 | 4  |
| 7 | 30 | 18 |
| 7 | 34 | 1  |
| 7 | 42 | 15 |
| 7 | 43 | 21 |
| 7 | 50 | 5  |
| 7 | 51 | 22 |
| 7 | 54 | 13 |
| 7 | 55 | 11 |
| 7 | 66 | 4  |
| 7 | 67 | 8  |
| 8 | 2  | 9  |
| 8 | 2  | 11 |
| 8 | 3  | 9  |
| 8 | 6  | 18 |
| 8 | 7  | 17 |
| 8 | 7  | 25 |
| 8 | 10 | 4  |
| 8 | 13 | 3  |
| 8 | 15 | 16 |
| 8 | 18 | 15 |
| 8 | 25 | 5  |
| 8 | 33 | 12 |
| 8 | 34 | 15 |
| 8 | 40 | 0  |
| 8 | 43 | 18 |
| 8 | 44 | 18 |

|    |    |    |
|----|----|----|
| 8  | 55 | 12 |
| 8  | 56 | 8  |
| 8  | 57 | 20 |
| 8  | 67 | 7  |
| 8  | 68 | 3  |
| 9  | 0  | 4  |
| 9  | 0  | 19 |
| 9  | 4  | 13 |
| 9  | 6  | 20 |
| 9  | 6  | 22 |
| 9  | 9  | 5  |
| 9  | 11 | 6  |
| 9  | 14 | 8  |
| 9  | 18 | 6  |
| 9  | 20 | 3  |
| 9  | 24 | 9  |
| 9  | 30 | 14 |
| 9  | 35 | 18 |
| 9  | 39 | 8  |
| 9  | 44 | 14 |
| 9  | 45 | 15 |
| 9  | 55 | 20 |
| 9  | 56 | 24 |
| 9  | 57 | 12 |
| 9  | 68 | 16 |
| 9  | 69 | 0  |
| 10 | 0  | 3  |
| 10 | 2  | 10 |
| 10 | 3  | 6  |
| 10 | 6  | 0  |
| 10 | 7  | 11 |
| 10 | 8  | 12 |
| 10 | 11 | 10 |
| 10 | 12 | 12 |
| 10 | 17 | 16 |
| 10 | 23 | 21 |
| 10 | 24 | 19 |
| 10 | 27 | 4  |
| 10 | 33 | 17 |
| 10 | 45 | 13 |
| 10 | 46 | 12 |
| 10 | 47 | 12 |
| 10 | 53 | 3  |
| 10 | 57 | 0  |
| 10 | 58 | 19 |
| 10 | 69 | 1  |
| 10 | 70 | 21 |
| 11 | 0  | 2  |
| 11 | 1  | 11 |
| 11 | 2  | 22 |
| 11 | 8  | 22 |
| 11 | 9  | 9  |
| 11 | 9  | 17 |
| 11 | 11 | 15 |
| 11 | 12 | 26 |
| 11 | 17 | 17 |

1

|    |    |    |
|----|----|----|
| 11 | 21 | 9  |
| 11 | 23 | 1  |
| 11 | 29 | 6  |
| 11 | 38 | 11 |
| 11 | 46 | 9  |
| 11 | 47 | 5  |
| 11 | 49 | 14 |
| 11 | 58 | 22 |
| 11 | 59 | 23 |
| 11 | 70 | 5  |
| 11 | 71 | st |

**IEEE P802.11**  
**Wireless LANs**

**TGn Sync Proposal Technical Specification**

**Date:** August 13, 2004

**Author:** Syed Aon Mujtaba  
Agere Systems, Inc  
555 Union Boulevard  
Allentown, Pennsylvania 18109, U.S.A.  
Phone: +1 610 712 6616  
Mobile: +1 908 342 5251  
e-Mail: mujtaba@agere.com

**Abstract**

This document presents the technical specification for the  
MAC and the PHY layer of the TGn Sync proposal to IEEE 802.11 TGn.

**Contributors:**

Adrian P Stephens ([adrian.p.stephens@intel.com](mailto:adrian.p.stephens@intel.com))

Brian Hart ([brianh@cisco.com](mailto:brianh@cisco.com))

Daisuke Takeda ([daisuke.takeda@toshiba.co.jp](mailto:daisuke.takeda@toshiba.co.jp))

Darren McNamara ([Darren.McNamara@toshiba-trel.com](mailto:Darren.McNamara@toshiba-trel.com))

Dongjun Lee ([djthekid.lee@samsung.com](mailto:djthekid.lee@samsung.com))

Eldad Perahia ([eperahia@cisco.com](mailto:eperahia@cisco.com))

Huanchun Ye ([hcy@atheros.com](mailto:hcy@atheros.com))

Jan Boer ([janboer@agere.com](mailto:janboer@agere.com))

Jari Jokela ([jari.jokela@nokia.com](mailto:jari.jokela@nokia.com))

Jeffrey Gilbert ([gilbertj@atheros.com](mailto:gilbertj@atheros.com))

Job Oostveen ([job.oostveen@philips.com](mailto:job.oostveen@philips.com))

Jörg Habetha ([joerg.habetha@philips.com](mailto:joerg.habetha@philips.com))

John Sadowsky ([john.sadowsky@intel.com](mailto:john.sadowsky@intel.com))

Luke Qian ([lchia@cisco.com](mailto:lchia@cisco.com))

Masahiro Takagi ([masahiro3.takagi@toshiba.co.jp](mailto:masahiro3.takagi@toshiba.co.jp))

Monisha Ghosh ([monisha.ghosh@philips.com](mailto:monisha.ghosh@philips.com))

Pen C. Li ([pen.li@philips.com](mailto:pen.li@philips.com))

Pieter-Paul Giesberts ([pgiesberts@agere.com](mailto:pgiesberts@agere.com))

Richard van Leeuwen ([rleeuwen@agere.com](mailto:rleeuwen@agere.com))

Ronald Rietman ([ronald.rietman@philips.com](mailto:ronald.rietman@philips.com))

Stephen Shellhammer ([Stephen.j.shellhammer@intel.com](mailto:Stephen.j.shellhammer@intel.com))

Tomoko Adachi ([tomo.adachi@toshiba.co.jp](mailto:tomo.adachi@toshiba.co.jp))

Tomoya Yamaura ([yamaura@wcs.sony.co.jp](mailto:yamaura@wcs.sony.co.jp))

Tsuguhide Aoki ([tsuguhide.aoki@toshiba.co.jp](mailto:tsuguhide.aoki@toshiba.co.jp))

Won-Joon Choi ([wjchoi@atheros.com](mailto:wjchoi@atheros.com))

Xiaowen Wang ([xiaowenw@agere.com](mailto:xiaowenw@agere.com))

Yasuhiko Tanabe ([yasuhiko.tanabe@toshiba.co.jp](mailto:yasuhiko.tanabe@toshiba.co.jp))

Youngsoo Kim ([KimYoungsoo@samsung.com](mailto:KimYoungsoo@samsung.com))

Yuichi Morioka ([morioka@wcs.sony.co.jp](mailto:morioka@wcs.sony.co.jp))

# 1. Executive Summary

The TGn Sync team respectfully submits its complete proposal. The team is comprised of 802.11 WG participants whose companies represent a broad range of markets, including, PC, Enterprise, Consumer Electronics, Handset, Semiconductor and Public Access. Since these companies are based in the US, Europe and the Pacific Rim, the team has had the benefit of a worldwide perspective, both in terms of perceived market demand as well as regulatory concerns (including channel bandwidth limitations, limited channel access, restricted transmission times, etc.).

Our goal has been to align (or “sync” with) 802.11n members to a single set of core positions prior to the TGn down selection phase. By aligning before entrenched positions form, we hope to increase the possibility of a more rapid introduction of an 802.11n standard.

The team has worked as a technical group for many months to develop a TGn proposal, recognizing that whatever decisions were made had to ultimately survive the TGn process and therefore be based solely on technical merit. There were no signed agreements involved in joining the TGn Sync team. There was no attempt to develop joint IP and each company was expected to abide by the same reasonable and non-discriminatory terms that the IEEE bylaws require.

The technical approach of our proposal balances complexity with performance, recognizing both market expectations and design practicality. The solution is a robust, scalable architecture targeting low complexity. In fact, the basic configuration delivers 243 Mbps using only two antennas. This rate is consistent with the historical trend of 5x with each generation of 802.11 (802.11/2Mbps, 802.11b/11Mbps, and finally 802.11a/ 54Mbps). The proposal also incorporates options for higher rates beyond 600 Mbps. This choice of higher peak data rates was seen as critical for future proofing this next generation of WLAN.

The PHY techniques used to achieve the higher data rates involve a MIMO evolution of 802.11 OFDM PHY with spatial division multiplexing of spatial streams, and wider bandwidth options (either 20MHz or 40MHz, but not required in regulatory domains where prohibited). Additionally, optional enhancements include advanced FEC coding techniques (Reed-Solomon and LDPC), transmit beamforming with negligible additional cost in the receiving client device, shortened guard interval and up to 7/8 coding. The TGn Sync proposal also offers seamless interoperability with 802.11 legacy devices. This interoperability is achieved with an enhanced 802.11 preamble design and efficient PHY and MAC level mechanisms, which also provide robustness and cost-effectiveness.

The features, added to improve MAC efficiency for higher throughput and overall system performance, include frame aggregation, bi-directional data flow, power management (to reduce power consumption), channel management (including a receiver assisted channel training protocol) and feedback mechanisms that enable rate adaptation. Protection mechanisms are also

added to achieve the seamless interoperability and coexistence with legacy devices mentioned above. The approach supports 802.11e and proposes new features for further enhancement.

The MAC and PHY sections that follow identify the baseline TGn Sync technical approach, which consists of the sum of all mandatory features. Together, they define a system that achieves the throughput, the robustness and the efficiency that satisfy market expectations while also insuring low design complexity. Each section also identifies optional features that address specific needs of burgeoning WLAN markets (VoIP, A/V applications, robust public access, etc.) and extensibility for growth in the future.

## 1.1 Proposal Structure

The TGn Sync complete proposal meets the IEEE 802.11n PAR, meets all functional requirements, and addresses all mandatory requirements of the comparison criteria.

This document contains a technical specification of the proposed MAC and PHY enhancements.

[4] contains a summary presentation (in power point format) giving the highlights of the proposal. [5] is a longer version containing more detail.

[6] contains a statement of compliance to the IEEE 802.11 TGn FRCC requirements.

[7] and [8] contain FRCC results (and others) for the PHY and MAC respectively.

[9] and [10] are Excel spreadsheets containing detailed FRCC results from MAC simulations, and [11] describes the methodology used in these simulations.



|    |                                                                       |    |
|----|-----------------------------------------------------------------------|----|
| 1  | <b>Table of Contents</b>                                              |    |
| 2  | 1. <u>Executive Summary</u> .....                                     | 3  |
| 3  | 1.1 <u>Proposal Structure</u> .....                                   | 4  |
| 4  | 2. <u>References</u> .....                                            | 11 |
| 5  | 3. <u>Definitions</u> .....                                           | 11 |
| 6  | 4. <u>Abbreviations and acronyms</u> .....                            | 13 |
| 7  | 5. <u>Introduction</u> .....                                          | 16 |
| 8  | 5.1 <u>Purpose</u> .....                                              | 16 |
| 9  | 5.2 <u>General description of MAC enhancements</u> .....              | 16 |
| 10 | 5.3 <u>General description of PHY enhancements</u> .....              | 17 |
| 11 | 6. <u>Frame Formats</u> .....                                         | 19 |
| 12 | 6.1 <u>Control frames</u> .....                                       | 19 |
| 13 | 6.1.1 <u>Initiator Aggregation Control (IAC) MPDU</u> .....           | 19 |
| 14 | 6.1.2 <u>Responder Aggregation Control (RAC) MPDU</u> .....           | 23 |
| 15 | 6.1.3 <u>Multiple Receiver Aggregate Descriptor (MRAD) MPDU</u> ..... | 25 |
| 16 | 6.1.4 <u>Increase Channel Bandwidth (ICB) MPDU</u> .....              | 26 |
| 17 | 6.1.5 <u>Decrease Channel Bandwidth (DCB) MPDU</u> .....              | 27 |
| 18 | 6.2 <u>Data frames</u> .....                                          | 27 |
| 19 | 6.2.1 <u>MAC Header (MHDR) MPDU</u> .....                             | 27 |
| 20 | 6.2.2 <u>Compressed Header Data (CHDATA) MPDU</u> .....               | 28 |
| 21 | 6.3 <u>Management frame formats</u> .....                             | 29 |
| 22 | 6.3.1 <u>Capabilities</u> .....                                       | 29 |
| 23 | 6.3.2 <u>Information Elements</u> .....                               | 30 |
| 24 | 6.3.3 <u>TRMS Update Action Frame</u> .....                           | 32 |
| 25 | 6.3.4 <u>TSPEC Modifications</u> .....                                | 33 |
| 26 | 6.4 <u>Frame aggregation format</u> .....                             | 34 |
| 27 | 6.4.1 <u>Introduction to Aggregation (Informative)</u> .....          | 34 |
| 28 | 6.4.2 <u>Aggregated PSDU format</u> .....                             | 35 |
| 29 | 6.4.3 <u>Single receiver frame aggregation format</u> .....           | 36 |
| 30 | 6.4.4 <u>Multiple receiver frame aggregation format</u> .....         | 37 |
| 31 | 7. <u>MAC sublayer functional description</u> .....                   | 40 |
| 32 | 7.1 <u>Aggregation Exchange Sequences and related rules</u> .....     | 40 |
| 33 | 7.1.1 <u>IAC/RAC Exchange Rules</u> .....                             | 40 |

|    |                                                                                        |    |
|----|----------------------------------------------------------------------------------------|----|
| 1  | <u>7.1.2 Non-aggregate IAC/RAC Rate selection Rules</u> .....                          | 40 |
| 2  | <u>7.1.3 Response Period Scheduling</u> .....                                          | 41 |
| 3  | <u>7.1.4 Responder Rules</u> .....                                                     | 41 |
| 4  | <u>7.1.5 Response PPDU Contents</u> .....                                              | 41 |
| 5  | <u>7.1.6 Power-saving at the receiver of an aggregate PPDU</u> .....                   | 42 |
| 6  | <u>7.1.7 Protection mechanisms</u> .....                                               | 42 |
| 7  | <u>7.1.8 MAC support for closed loop modes</u> .....                                   | 46 |
| 8  | <u>7.1.9 Aggregated Single Directional frame transfer</u> .....                        | 47 |
| 9  | <u>7.1.10 Bi-directional data transfer</u> .....                                       | 52 |
| 10 | <u>7.1.11 Single receiver aggregationMultiple receiver aggregation (MRA)</u> .....     | 55 |
| 11 | <u>7.2 MAC Header Compression</u> .....                                                | 60 |
| 12 | <u>7.2.1 Introduction (informative)</u> .....                                          | 60 |
| 13 | <u>7.2.2 Functional description</u> .....                                              | 61 |
| 14 | <u>7.2.3 Ordering constraints for MHDR and CHDATA MPDUs</u> .....                      | 62 |
| 15 | <u>7.2.4 Multiple receiver aggregates</u> .....                                        | 62 |
| 16 | <u>7.3 Multirate support</u> .....                                                     | 62 |
| 17 | <u>7.4 QoS enhancements</u> .....                                                      | 62 |
| 18 | <u>7.4.1 802.11e Requirement</u> .....                                                 | 62 |
| 19 | <u>7.4.2 Interactions with 802.11e TSPEC (Informative)</u> .....                       | 63 |
| 20 | <u>7.4.3 TSPEC renegotiation</u> .....                                                 | 63 |
| 21 | <u>7.4.4 TSPEC Packet Loss Priority (PLP)</u> .....                                    | 64 |
| 22 | <u>7.5 Scheduling (Informative)</u> .....                                              | 65 |
| 23 | <u>7.5.1 Introduction</u> .....                                                        | 65 |
| 24 | <u>7.5.2 Scheduler 1</u> .....                                                         | 65 |
| 25 | <u>7.5.3 Scheduler 2</u> .....                                                         | 66 |
| 26 | <u>7.5.4 Retransmissions and Allocation of Time</u> .....                              | 66 |
| 27 | <u>7.5.5 Selecting RDL/RDG values</u> .....                                            | 67 |
| 28 | <u>8. MAC sublayer management</u> .....                                                | 69 |
| 29 | <u>8.1 Coexistence management</u> .....                                                | 69 |
| 30 | <u>8.1.1 Operating Modes</u> .....                                                     | 69 |
| 31 | <u>8.1.2 Receiver capabilities wrt legacy operation in the extension channel</u> ..... | 69 |
| 32 | <u>8.1.3 Infrastructure BSS Operation</u> .....                                        | 70 |
| 33 | <u>8.1.4 IBSS Operation</u> .....                                                      | 76 |
| 34 | <u>8.2 Channel management</u> .....                                                    | 77 |
| 35 | <u>8.2.1 Channel Management at the AP</u> .....                                        | 77 |
| 36 | <u>8.2.2 Channel Management at the STA</u> .....                                       | 77 |

|    |        |                                                     |     |
|----|--------|-----------------------------------------------------|-----|
| 1  | 8.2.3  | Channel Selection Methods                           | 78  |
| 2  | 8.3    | TRMS Power-Saving Management                        | 80  |
| 3  | 8.3.1  | BSS Association, DLP Setup and Mode Changes         | 80  |
| 4  | 8.3.2  | TRMS Operation                                      | 81  |
| 5  | 8.3.3  | Performance Impact of using TRMS mode (Informative) | 82  |
| 6  | 9.     | Background to Protection Mechanisms (Informative)   | 84  |
| 7  | 9.1    | Introduction to Protection Mechanisms               | 84  |
| 8  | 9.2    | Effect of Spoofing                                  | 84  |
| 9  | 9.3    | Pairwise spoofing                                   | 85  |
| 10 | 9.4    | Selecting between Pairwise Spoofing and LongNAV     | 86  |
| 11 | 9.5    | HT PPDU Format with Legacy Protection               | 87  |
| 12 | 9.5.1  | Interpretation by a Legacy Node                     | 87  |
| 13 | 9.5.2  | Interpretation by an HT Node                        | 88  |
| 14 | 9.6    | Protection mechanisms for MRA                       | 89  |
| 15 | 9.6.1  | How to choose between LongNAV and spoofing in MRA   | 89  |
| 16 | 9.6.2  | Protection from Third Party HT Nodes                | 90  |
| 17 | 9.6.3  | Protection from Hidden Nodes                        | 90  |
| 18 | 9.6.4  | Protection from Legacy Nodes                        | 90  |
| 19 | 10.    | PHY-SAP service specification                       | 92  |
| 20 | 10.1   | PHY Specific Service Parameter List                 | 92  |
| 21 | 10.1.1 | TXVECTOR                                            | 92  |
| 22 | 10.1.2 | RXVECTOR                                            | 96  |
| 23 | 11.    | MIMO-OFDM HT PHY specification                      | 99  |
| 24 | 11.1   | Overview                                            | 99  |
| 25 | 11.1.1 | Introduction (Informative)                          | 99  |
| 26 | 11.1.2 | Timing related parameters                           | 108 |
| 27 | 11.1.3 | Mathematical conventions in signal descriptions     | 108 |
| 28 | 11.2   | PLCP sublayer                                       | 109 |
| 29 | 11.2.1 | Basic MIMO Mode                                     | 109 |
| 30 | 11.2.2 | Basic Transmit Beamforming (Optional Mode)          | 137 |
| 31 | 11.2.3 | Advanced Transmit Beamforming (Optional Mode)       | 141 |
| 32 | 11.2.4 | Options for Advanced Coding                         | 145 |
| 33 |        |                                                     |     |

|    |                                                                                 |     |
|----|---------------------------------------------------------------------------------|-----|
| 1  | <b>List of Figures</b>                                                          |     |
| 2  | <u>Figure 1 – IAC MPDU</u>                                                      | 20  |
| 3  | <u>Figure 2 – RAC MPDU</u>                                                      | 24  |
| 4  | <u>Figure 3 – MRAD MPDU</u>                                                     | 25  |
| 5  | <u>Figure 4 – ICB MPDU</u>                                                      | 26  |
| 6  | <u>Figure 5 – DCB MPDU</u>                                                      | 27  |
| 7  | <u>Figure 6 – MHDR MPDU</u>                                                     | 28  |
| 8  | <u>Figure 7 – CHDATA MPDU</u>                                                   | 28  |
| 9  | <u>Figure 8 – HT Capability element format</u>                                  | 30  |
| 10 | <u>Figure 9 – HT Capabilities Info field</u>                                    | 30  |
| 11 | <u>Figure 10 – TRMS element format</u>                                          | 32  |
| 12 | <u>Figure 11 – Aggregated PSDU format</u>                                       | 35  |
| 13 | <u>Figure 12 – Example of TXOP Truncation</u>                                   | 43  |
| 14 | <u>Figure 13 – Basic Operation of Pairwise Spoofing</u>                         | 45  |
| 15 | <u>Figure 14 – Basic Operation of Single Ended Spoofing</u>                     | 46  |
| 16 | <u>Figure 15 – LongNAV, untrained unidirectional exchange</u>                   | 48  |
| 17 | <u>Figure 16 – LongNAV, untrained unidirectional showing aggregate response</u> | 49  |
| 18 | <u>Figure 17 – LongNAV, trained unidirectional showing aggregate response</u>   | 50  |
| 19 | <u>Figure 18 – Pairwise Spoofing, Untrained Unidirectional Exchange</u>         | 51  |
| 20 | <u>Figure 19 – Pairwise Spoofing, Trained Unidirectional Exchange</u>           | 52  |
| 21 | <u>Figure 20 – LongNAV Bi-Directional Example</u>                               | 54  |
| 22 | <u>Figure 21 – Pairwise Spoofing, Trained BiDirectional</u>                     | 55  |
| 23 | <u>Figure 22 – Example of MRA response scheduling with 3 responders</u>         | 56  |
| 24 | <u>Figure 23 – MRMRA Example for Periodic Traffic</u>                           | 59  |
| 25 | <u>Figure 24 – MRMRA Example for Aperiodic Traffic</u>                          | 60  |
| 26 | <u>Figure 25 – Flowchart of PLP mechanism</u>                                   | 65  |
| 27 | <u>Figure 26 – 20 MHz-Base Managed Mixed Mode</u>                               | 73  |
| 28 | <u>Figure 27 – Data transfer example with timed receive mode switching</u>      | 81  |
| 29 | <u>Figure 28 – Standard Virtual Carrier Sense</u>                               | 85  |
| 30 | <u>Figure 29 – Pairwise Spoofing Mechanism</u>                                  | 86  |
| 31 | <u>Figure 30 – PPDU Format with Legacy Protection</u>                           | 87  |
| 32 | <u>Figure 31 – When Received by a Legacy Node</u>                               | 87  |
| 33 | <u>Figure 32 – HT Signal Field BPSK Constellation</u>                           | 88  |
| 34 | <u>Figure 33 – When Received by an HT Node but MPDU is not Decodable</u>        | 89  |
| 35 | <u>Figure 34 – When Received by an HT Node and the MPDU is Decodable</u>        | 89  |
| 36 | <u>Figure 35: Transmitter Datapath for 2-antenna MIMO in 20MHz</u>              | 101 |

|    |                                                                                                                            |     |
|----|----------------------------------------------------------------------------------------------------------------------------|-----|
| 1  | <u>Figure 36: Transmitter datapath for 2-antenna MIMO in 40MHz</u> .....                                                   | 101 |
| 2  | <u>Figure 37: PPDU Format for 2x20 Mandatory Basic MIMO Transmission</u> .....                                             | 102 |
| 3  | <u>Figure 38: Upper and Lower sub-channel specification in 40MHz</u> .....                                                 | 102 |
| 4  | <u>Figure 39: PPDU Format for 2x40 Mandatory Basic MIMO Transmission</u> .....                                             | 102 |
| 5  | <u>Figure 40: HT Preamble format</u> .....                                                                                 | 103 |
| 6  | <u>Figure 41: Transmitter configuration for 6Mbps in 40MHz</u> .....                                                       | 105 |
| 7  | <u>Figure 42: PPDU format for 6Mbps duplicate mode</u> .....                                                               | 105 |
| 8  | <u>Figure 43: Transmitter Datapath with option to perform spatial shaping</u> .....                                        | 106 |
| 9  | <u>Figure 44: Timing boundaries for subframes in a HT transmission</u> .....                                               | 109 |
| 10 | <u>Figure 45: PPDU Format for <math>N_{TX}</math> antennas</u> .....                                                       | 110 |
| 11 | <u>Figure 46: PPDU format leveraging CDD transmission</u> .....                                                            | 111 |
| 12 | <u>Figure 47: HT-LTF pattern for 2 antennas (2 spatial streams)</u> .....                                                  | 117 |
| 13 | <u>Figure 48: HT-LTF pattern for 3 antennas (3 spatial streams)</u> .....                                                  | 118 |
| 14 | <u>Figure 49: HT-LTF pattern for 4 antennas (4 spatial streams)</u> .....                                                  | 119 |
| 15 | <u>Figure 50: Constellation specification for LSIG and HTSIG</u> .....                                                     | 120 |
| 16 | <u>Figure 51: SIGNAL field bit assignment</u> .....                                                                        | 120 |
| 17 | <u>Figure 52: HT SIGNAL FIELD (HTSIG1 and HTSIG2) bit assignment</u> .....                                                 | 123 |
| 18 | <u>Figure 53: Generation of CRC bits</u> .....                                                                             | 127 |
| 19 | <u>Figure 54: Puncturing pattern for code rate = 7/8</u> .....                                                             | 129 |
| 20 | <u>Figure 55: Tone Format for Fat Channel at 40MHz</u> .....                                                               | 132 |
| 21 | <u>Figure 56 Inputs and Outputs of IFFT for a 40 MHz channel</u> .....                                                     | 133 |
| 22 | <u>Figure 57: Transmit Spectrum Mask for 20MHz channelization</u> .....                                                    | 136 |
| 23 | <u>Figure 58: Transmit spectrum mask for 40MHz channelization</u> .....                                                    | 137 |
| 24 | <u>Figure 59: Transmitter architecture for TX Beamforming for <math>N_{ss}=2</math>, and <math>N_{TX} = 3</math></u> ..... | 140 |
| 25 | <u>Figure 60: Transmit Datapath Architecture for ABF-MIMO mode</u> .....                                                   | 144 |
| 26 | <u>Figure 61: LDPC inclusion in the transmit datapath architecture</u> .....                                               | 147 |
| 27 | <u>Figure 62: Concatenated RS and Convolutional encoding</u> .....                                                         | 147 |
| 28 |                                                                                                                            |     |
| 29 | <b>List of Tables</b>                                                                                                      |     |
| 30 | <u>Table 1 – Additional HT Capabilities</u> .....                                                                          | 29  |
| 31 | <u>Table 2 – Additional HT Information Elements</u> .....                                                                  | 30  |
| 32 | <u>Table 3 – Additional HT TSPEC Fields</u> .....                                                                          | 33  |
| 33 | <u>Table 4 – MPDU delimiter Fields</u> .....                                                                               | 35  |
| 34 | <u>Table 5 Single Receiver Aggregation MPDUs</u> .....                                                                     | 36  |
| 35 | <u>Table 6: Multiple Receiver Aggregation MPDUs</u> .....                                                                  | 37  |
| 36 | <u>Table 7 No Response Receiver Group MPDUs</u> .....                                                                      | 38  |

|    |                                                                           |     |
|----|---------------------------------------------------------------------------|-----|
| 1  | <u>Table 8 MRA Aggregate MPDUs</u> .....                                  | 38  |
| 2  | <u>Table 9 – AP Mode Definitions</u> .....                                | 70  |
| 3  | <u>Table 10 – IBSS Mode Definitions</u> .....                             | 76  |
| 4  | <u>Table 11 – Beacon Elements for HT Channel Management</u> .....         | 77  |
| 5  | <u>Table 12: Table of parameters for the TX Vector</u> .....              | 93  |
| 6  | <u>Table 13: Table of parameters for the RX Vector</u> .....              | 96  |
| 7  | <u>Table 14: Options for Throughput Enhancement</u> .....                 | 100 |
| 8  | <u>Table 15: Feedback Mechanisms</u> .....                                | 107 |
| 9  | <u>Table 16: MIMO Transmission options</u> .....                          | 107 |
| 10 | <u>Table 17: Timing Related Paramters</u> .....                           | 108 |
| 11 | <u>Table 18: List of HT Long Training Fields</u> .....                    | 115 |
| 12 | <u>Table 19: Content of the legacy SIGNAL field</u> .....                 | 121 |
| 13 | <u>Table 20: MCS field content for the basic mode</u> .....               | 124 |
| 14 | <u>Table 21: ADVCODING Field Content</u> .....                            | 125 |
| 15 | <u>Table 22: Interleaver Parameters</u> .....                             | 130 |
| 16 | <u>Table 23: Extended MCS set for ABF-MIMO</u> .....                      | 142 |
| 17 | <u>Table 24: Constellation Mapping for 256-QAM in ABF-MIMO Mode</u> ..... | 144 |
| 18 |                                                                           |     |

## 2. References

- [1] IEEE Std 802.11®-1999 (Reaff 2003)  
Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
- [2] IEEE P802.11e/D8.0, February 2004  
(Draft Amendment to IEEE Std 802.11, 1999 Edition (Reaff 2003))  
Medium Access Control (MAC) Enhancements for Quality of Service (QoS)
- [3] Project Authorization Request for IEEE 802.11n.  
11-02-798r7-HT-SG-Draft-PAR.doc
- [4] IEEE 802.11-04/887, "TGnSync Proposal Summary"
- [5] IEEE 802.11-04/888, "TGnSync Proposal"
- [6] IEEE 802.11-04/890, "TGnSync Proposal FRCC Compliance"
- [7] IEEE 802.11-04/891, "TGnSync Proposal PHY Results"
- [8] IEEE 802.11-04/892, "TGnSync Proposal MAC Results"
- [9] IEEE 802.11-04/893, "TGnSync Proposal MAC1 Simulation Results"
- [10] IEEE 802.11-04/894, "TGnSync Proposal MAC2 Simulation Results"
- [11] IEEE 802.11-04/895, "TGnSync Proposal MAC Simulation Methodology"

## 3. Definitions

**Aggregate:** A PSDU transported by the PHY with an aggregate attribute indicating that it contains multiple MPDUs.

**Initiator:** A STA that holds a TXOP and transmits the first frame in a frame exchange sequence including aggregate PPDU's and/or aggregate control frames (IAC/RAC/MRAD).

**LongNAV:** A MAC-layer protection mechanism that protects multiple PPDU's exchanged within a TXOP

**Mixed Mode:** A mode of operation of an HT BSS in which there are co-channel legacy devices present.

**OFDM Format:** Definition of subcarrier frequencies relative to the channel center frequency, and specification of data bearing and pilot subcarriers.

**Originator:** A QSTA that sends data using the Block ACK mechanism.

1  
2 **Pairwise Spoofing:** A PHY layer protection mechanism described in 7.1.7.3.

3  
4 **Preamble: short and long:** Portions of the 802.11 HT PPDU used for PHY synchronization and  
5 channel estimation.

6  
7 **Pure Mode:** A mode of operation of a BSS in which there are no legacy devices.

8  
9 **Receiver:** Any STA receiving the current PPDU.

10  
11 **Recipient:** A QSTA that receives data using the Block ACK mechanism.

12  
13 **Responder:** A STA that responds to an initiator in a frame exchange sequence including  
14 aggregate PPDUs and/or aggregate control frames (IAC/RAC/MRAD).

15  
16 **SIGNAL FIELD:** Portion of the 802.11 HT PHY PPDU that contains “Rate” and “Duration”,  
17 part of the PLCP header.

18  
19 **Symbol:** Typically refers to an OFDM symbol, which is a collection of sub-carriers (or tones)



## 4. Abbreviations and acronyms

| Term     | Description                                                                                                        |
|----------|--------------------------------------------------------------------------------------------------------------------|
| ABF-MIMO | Advanced Beamforming MIMO (Transmit Beamforming with Spatial water filling techniques on Multiple Spatial Streams) |
| ACK      | Acknowledgement                                                                                                    |
| AGC      | Automatic Gain Control                                                                                             |
| AP       | Access Point                                                                                                       |
| ATOC     | Aggregate Table Of Contents                                                                                        |
| BF-MIMO  | Beamforming MIMO (Basic Transmit Beamforming on Multiple Spatial Streams)                                          |
| CAP      | Controlled Access Phase                                                                                            |
| CDD      | Cyclic Delay Diversity                                                                                             |
| CHDATA   | Compressed Header Data MPDU                                                                                        |
| CRC      | Cyclic Redundancy Check                                                                                            |
| CSI      | Channel State Information                                                                                          |
| CSIT     | Channel State Information at the Transmitter                                                                       |
| CTS      | Clear to Send                                                                                                      |
| DLP      | Direct Link Protocol                                                                                               |
| DCB      | Decrease Channel Bandwidth MPDU                                                                                    |
| ERP      | Extended Rate PHY                                                                                                  |
| FCS      | Frame Check Sequence                                                                                               |
| FPD      | Following Packet Descriptor                                                                                        |
| HC       | Hybrid Controller                                                                                                  |
| HID      | Header Identity                                                                                                    |
| HT       | High Throughput                                                                                                    |
| HT-LTF   | High Throughput Long Training Field                                                                                |
| HT-SIG   | High Throughput Signal Field                                                                                       |
| HT-STF   | High Throughput Short Training Field                                                                               |
| IAC      | Initiator Aggregate Control                                                                                        |
| ICB      | Increase Channel Bandwidth MPDU                                                                                    |
| IE       | Information Element                                                                                                |
| LLC      | Logical Link Control                                                                                               |
| L-LTF    | Legacy Long Training Field                                                                                         |
| L-SIG    | Legacy signal field                                                                                                |

|                 |                                                                                                                                                              |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| L-STF           | Legacy Short Training Field                                                                                                                                  |
| MAC             | Medium Access Controller                                                                                                                                     |
| MCS             | Modulation Coding Scheme – includes modulation order (BPSK, QPSK, etc.), FEC code and code rate, number of spatial streams (MIMO) and number of TX antennas. |
| MFB             | MCS Feedback                                                                                                                                                 |
| MHDR            | MAC Header MPDU                                                                                                                                              |
| MIMO            | Multiple input, multiple output (Both transmitter and receiver have multiple antennas for signaling over a point-to-point link)                              |
| MISO            | Multiple input, single output (transmitter has multiple antennas but receiver has a single antenna)                                                          |
| MPDU            | MAC protocol data unit                                                                                                                                       |
| MRA             | Multiple Receiver Aggregate – an aggregate that contains MPDUs for multiple receiver addresses.                                                              |
| MRAD            | Multiple Receiver Aggregate Descriptor                                                                                                                       |
| MRC             | Maximum Ratio Combining (a technique to maximize received SNR using antenna signal combining).                                                               |
| MRMRA           | Multi-response Aggregate – an MRA with multiple responses from its multiple receivers                                                                        |
| MRQ             | MCS Request                                                                                                                                                  |
| MSDU            | MAC service data unit                                                                                                                                        |
| NAV             | Network Allocation Vector (a MAC-level carrier-sense)                                                                                                        |
| N <sub>TX</sub> | Total Number of Transmit Antennas                                                                                                                            |
| OFDM            | Orthogonal Frequency Division Multiplexing                                                                                                                   |
| PHY             | Physical Layer                                                                                                                                               |
| PLCP            | PHY layer convergence protocol                                                                                                                               |
| PPDU            | PHY protocol data unit                                                                                                                                       |
| PSDU            | PHY service data unit                                                                                                                                        |
| Pure Mode       | A mode of operation of a BSS in which there are no legacy devices                                                                                            |
| QAP             | QoS access point                                                                                                                                             |
| QoS             | Quality of service                                                                                                                                           |
| QSTA            | QoS station                                                                                                                                                  |
| RAC             | Royal Automobile Club                                                                                                                                        |
| RDG             | Reverse Direction Grant                                                                                                                                      |
| RDL             | Reverse Direction Limit                                                                                                                                      |
| RDR             | Reverse Direction Request                                                                                                                                    |
| RDTID           | Reverse Direction Traffic Identifier                                                                                                                         |
| RPO             | Response Period Offset                                                                                                                                       |

|       |                                                                                                  |
|-------|--------------------------------------------------------------------------------------------------|
| RR    | Rate Recommendation                                                                              |
| RSSI  | Receive Signal Strength Indicator                                                                |
| RTS   | Request to send                                                                                  |
| RX    | Receiver                                                                                         |
| SAP   | Service Access Point                                                                             |
|       |                                                                                                  |
| SF    | Signal Field                                                                                     |
| SIFS  | Short inter-frame spacing                                                                        |
| SIMO  | Single input, multiple output (transmitter has a single antenna, receiver has multiple antennas) |
| SISO  | Single input, single output (both transmitter and receiver have a single antenna)                |
| SoP   | Start of Packet (i.e. PPDU Packet)                                                               |
| SRA   | Single Receiver Aggregate – an aggregate that contains MPDUs for a single receiver address.      |
| STA   | Station                                                                                          |
| SVD   | Singular Value Decomposition: For an arbitrary matrix $A = USV^H$                                |
| TBC   | To be confirmed – need to check this definition                                                  |
| TBD   | To be determined                                                                                 |
| TC    | Traffic Category                                                                                 |
| TGe   | 802.11 Task Group e - Quality of Service                                                         |
| TGn   | 802.11 Task Group n - Enhancements for Higher Throughput                                         |
| TRMS  | Timed Receive Mode Switching                                                                     |
| TRQ   | Training Request                                                                                 |
| TS    | Traffic Stream                                                                                   |
| TSID  | Traffic Stream Identifier                                                                        |
| TSPEC | Traffic specification                                                                            |
| TX    | Transmitter                                                                                      |
| TXOP  | Transmission opportunity                                                                         |

## 5. Introduction

### 5.1 Purpose

This document defines proposed Enhancements for Higher Throughput within the scope of the Project Authorization Request (PAR) [3] formulated for IEEE 802.11 Task Group n.

### 5.2 General description of MAC enhancements

The proposed MAC enhancements assume a baseline specification defined by IEEE 802.11 standard [1] and its later amendments, including the draft IEEE 802.11e amendment [2]. The purpose of the enhancements is to significantly improve throughput, providing a maximum throughput of at least 100Mbps, as measured at the MAC data service access point (SAP).

The features supported by this TGn Sync MAC proposal are as follows:

- A Frame Aggregation format that allows aggregation of multiple Data and Control MPDUs in one PPDU. Note, an aggregate can also include a single management frame, in addition to multiple data and control frames per unicast receiver address.
- New Control MPDUs and (aggregate) frame exchange rules that control the exchange of multiple MPDUs per PPDU between a single initiating STA and potentially multiple responding STAs.
- MAC header compression that allows more efficient medium usage when multiple Data MPDUs are aggregated in a single PPDU.
- A receiver assisted channel training protocol.
- A reverse direction data protocol that allows efficient channel access for single and multiple responders within a frame exchange sequence.
- Protection of the new frame exchange sequences may be provided through one of two mechanisms: a MAC-level mechanism based on NAV reservations, and a PHY-level mechanism based on spoofing the legacy PLCP rate/length information.
- QoS enhancements for TSPEC renegotiation and prioritized discarding of QoS MSDUs according to an application-defined loss priority labeling.

- Mechanisms to manage coexistence of legacy and HT devices.
- Channel management and channel selection methods.
- Power saving mechanism to reduce power consumption by only enabling a single receive chain during periods of inactivity.

### 5.3 General description of PHY enhancements

With the aim to increase the maximum PHY layer data rate, our proposal introduces two primary techniques:

- Transmission of Multiple Spatial Streams via Multiple Transmit Antennas. Our recommendation is to make 2 antennas mandatory, with the option to scale to 4 antennas. Our proposal is a MIMO evolution of the 802.11a PHY.
- Extended Bandwidth signaling. 20MHz channelization shall be mandatory worldwide. Our recommendation is to support 40MHz channelization in regulatory domains that will permit wider bandwidth operation

We have also introduced several secondary techniques for increasing throughput. These include:

- A reduced guard interval of 400ns, channel dispersion permitting (e.g. TGn channel model B)
- Higher channel coding rate of 7/8
- 256-QAM in certain advanced transmission modes

Due to the susceptibility of a wireless channel to multipath fading, especially with multiple antennas (and multiple spatial streams), our proposal also introduces several techniques for improving the robustness of the link between the transmitter and the receiver, with the aim to keep the client (station) configuration low-cost and low-power:

- Transmitter beamforming (with the understanding that Access Points will be able to support more than 2 antennas, while the client stations would be restricted to 2 antennas).
- Advanced channel coding (such as LDPC). Such codes have a larger minimum free distance compared to the existing 802.11a convolutional code, and hence, are able to better exploit the frequency and spatial diversity in the MIMO channel.

- Advanced Transmitter beamforming techniques. These include water-filling concepts in the spatial domain, such as unequal power ratios and different choice of modulation-coding schemes on the various spatial streams.

Our proposal support full backwards compatibility with existing 802.11a/b/g standards. Our preamble design support PHY layer interoperability with the OFDM preamble from 802.11a/g, while providing a robust mechanism for synchronization of the high throughput data.

## 6. Frame Formats

This clause specifies the format of new HT frames.

Reserved fields and subfields shall be transmitted as zeroes and shall be ignored by an HT receiver

### 6.1 Control frames

#### 6.1.1 Initiator Aggregation Control (IAC) MPDU

##### 6.1.1.1 Introduction

This MPDU provides control of the MCS, size, duration, training and any reverse flow of aggregates in an exchange of aggregates between STAs. It is sent by the initiator STA of an aggregate exchange.

There are a number of groups of fields (IAC elements), which perform specific purposes within the MPDU as described below:

| Element Name                      | Purpose of item                                                                                                                                                                                                                                           |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| RTS – Request to Send             | Detects collisions at the receiver<br>Tests state of NAV in the receiver<br>Sets NAV reservation near Transmitter (LongNAV)                                                                                                                               |
| TRQ – MIMO training request       | Request to train the channel<br>Used for MIMO with implicit Feedback.                                                                                                                                                                                     |
| MRQ – MCS request                 | Indicates a request for MCS feedback                                                                                                                                                                                                                      |
| MFB – Use this MCS selection      | Closed loop channel adaptation feedback<br>Contains values from which the MCS, which will be used for the next PPDU, may be derived deterministically.<br>Note, when combined with an RDG, the RDG duration is adjusted as appropriate to this MCS value. |
| FPD – Following packet descriptor | Provides size and default MCS for the next PPDU to be sent by this STA so that its peer can properly set a Pairwise Spoofing value                                                                                                                        |
| RDL – Reverse direction limit     | Indicates a duration that is a limit on the amount of reverse direction that will be granted<br>Used for Bi-directional frame transfer as defined in section 7.1.10                                                                                       |
| RDG – Reverse direction grant     | Grants a specified duration to be used for a reverse direction PPDU                                                                                                                                                                                       |

|  |                                                                     |
|--|---------------------------------------------------------------------|
|  | Used for Bi-directional frame transfer as defined in section 7.1.10 |
|--|---------------------------------------------------------------------|

Note, although described as "elements", the structure of the IAC MPDU containing these elements is fixed.

### 6.1.1.2 Format of IAC MPDU

This section defines the format of the IAC MPDU.

The IAC MPDU has a fixed structure. Fields that are not used are present, but reserved.

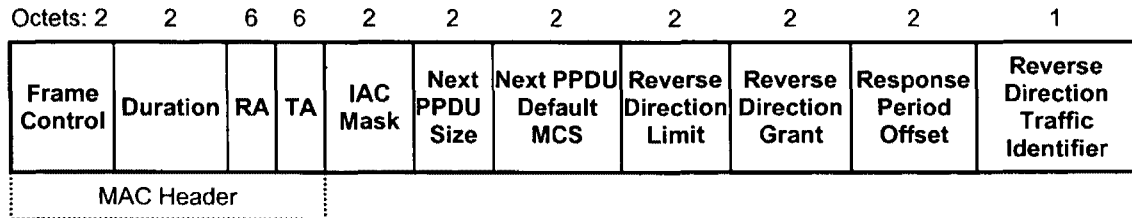
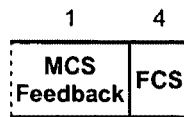


Figure 1 – IAC MPDU

| Field                 | Size (bytes) | Purpose                                                                                                                                                                                                                                     |
|-----------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Frame Control         | 2            |                                                                                                                                                                                                                                             |
| Duration              | 2            |                                                                                                                                                                                                                                             |
| Receiver Address      | 6            |                                                                                                                                                                                                                                             |
| Transmitter Address   | 6            |                                                                                                                                                                                                                                             |
| IAC Mask              | 2            | A bitmask indicating which IAC elements are present in the packet.                                                                                                                                                                          |
| Next PPDU Size        | 2            | Size in bytes of following PPDU that will be sent by this STA (FPD).<br><br>This is interpreted along with the Next PPDU default MCS to determine the duration of the next PPDU.<br><br>Present when FPD is indicated, otherwise undefined. |
| Next PPDU Default MCS | 2            | Default MCS that will be used in the absence of any updated training information to send next PPDU.                                                                                                                                         |



|                                              |   |                                                                                                                                                                                                                                                                                               |
|----------------------------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                              |   | Present when FPD is indicated, otherwise undefined.                                                                                                                                                                                                                                           |
| Reverse direction limit                      | 2 | Indicates the amount of time in microseconds that is the maximum amount of time that will be granted in a RDG.<br><br>Present when RDL is indicated the IAC mask field, otherwise undefined.                                                                                                  |
| Reverse direction grant                      | 2 | Indicates the amount of time in microseconds that is available for a reverse direction PPDU including any expected response MPDUs and an RAC MPDU.<br><br>Present when RDG is indicated, otherwise undefined.                                                                                 |
| Response Period Offset (RPO)                 | 2 | Indicates the delay in microseconds between the end of the PPDU containing the IAC MPDU and the start of the response PPDU.<br><br>This value shall be no less than SIFS.<br><br>Present when RDG is indicated, otherwise undefined.                                                          |
| Reverse Direction Traffic Identifier (RDTID) | 1 | Indicates one of: <ul style="list-style-type: none"> <li>• An AC for which reverse direction grant is valid</li> <li>• A TSID indicating a specific TS for which the reverse direction grant is valid</li> <li>• Unconstrained</li> </ul> Present when RDG is indicated, otherwise undefined. |
| MCS Feedback                                 | 1 | Contains a recommended MCS value.<br><br>Present when MFB is indicated, otherwise undefined.                                                                                                                                                                                                  |
| FCS                                          | 4 |                                                                                                                                                                                                                                                                                               |

1

2

3 **6.1.1.2.1 IAC Mask Field**

4 This field indicates which logical elements are carried in the MPDU.

| IAC Mask Field bit | Position | Description                                             |
|--------------------|----------|---------------------------------------------------------|
| RTS                | B0       | When set, indicates this is an RTS. The receiver should |

|     |    |                                                                                                                                                                         |
|-----|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |    | not generate any response if its NAV is non-zero.                                                                                                                       |
| TRQ | B1 | When set, indicates a request to train the channel.<br>Used for MIMO with implicit Feedback.                                                                            |
| MRQ | B2 | When set, indicates a request for MCS feedback.                                                                                                                         |
| MFB | B3 | When set, indicates an MFB training response is present as defined by the MCS Feedback field.                                                                           |
| FPD | B4 | When set, indicates that the next PPDU duration may be determined from the next PPDU length and default MCS fields. FPD is set only when using Pairwise Spoofing rules. |
| RDG | B5 | When set, indicates a reverse direction grant is present.                                                                                                               |

1

2 **6.1.1.2.2 MCS Feedback Field**

3 This contains an MCS value containing a recommended MCS value.

4 MCS values are defined in section 11.2.1.4.2.2.

5

6 **6.1.1.3 Use of IAC elements according to context**

7 This section defines what IAC elements are valid in the following three contexts:

- 8 • Within an SRA
- 9 • Within an MRA, when a response is permitted for that receiver
- 10 • Within an MRA, when no response is permitted for that receiver

11

| Element Name                      | SRA Context                             | MRA Context<br>(response) | MRA Context<br>(non-response) |
|-----------------------------------|-----------------------------------------|---------------------------|-------------------------------|
| RTS – Request to Send             | Valid                                   | Valid (see note below)    | Not Valid                     |
| TRQ – MIMO training request       | Valid                                   | Valid                     | Not Valid                     |
| MRQ – MCS request                 | Valid                                   | Valid                     | Not Valid                     |
| MFB – Use this MCS selection      | Valid                                   | Valid                     | Valid                         |
| FPD – Following packet descriptor | Valid – implies Pairwise Spoofing rules | Not Valid                 | Not Valid                     |
| RDL – Reverse direction limit     | Valid                                   | Valid                     | Not Valid                     |
| RDG – Reverse                     | Valid                                   | Valid                     | Not Valid                     |

|                 |  |  |  |
|-----------------|--|--|--|
| direction grant |  |  |  |
|-----------------|--|--|--|

Note – the RTS element may be included in an MRA. For this to be useful, the initiator should aggregate together an IAC (RTS) for each responder and send these as an aggregate. These IACs should contain a short RDG to collect RAC (CTS) responses. The responder will interpret this as a request to check its NAV is idle during its scheduled response period. If the NAV is idle, a response is sent. Using this method, the initiator can test the NAV state of multiple STAs.

## 6.1.2 Responder Aggregation Control (RAC) MPDU

### 6.1.2.1 Introduction

This MPDU provides control of the MCS, size, duration, training and any reverse flow of aggregates in an exchange of aggregates between STAs. It is sent by the responder STA of an aggregate exchange.

There are a number of groups of fields (RAC elements), which perform specific purposes within the MPDU as described below:

| RAC Element Name                | Purpose of item                                                                                                                                                                                                                                        |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CTS – yes the channel is clear  | Response to RTS                                                                                                                                                                                                                                        |
| TRQ – MIMO training request     | Request to train the channel<br>Used for MIMO with implicit Feedback.                                                                                                                                                                                  |
| MRQ – MCS request               | Indicates a request for MCS feedback                                                                                                                                                                                                                   |
| MFB – Use this MCS selection    | Closed loop channel adaptation feedback<br>Contains values from which the MCS, which will be used for the next PPDU, may be derived deterministically.<br>Note, when combined with an RDG, the RDG duration is adjusted appropriate to this MCS value. |
| RDR – Reverse direction request | Request for a reverse direction data flow<br>Contains requested total data MPDU length (bytes) and default MCS                                                                                                                                         |

Because the training response data may be large, a variable structure is defined to hold it.

### 6.1.2.2 Format of RAC MPDU

This section defines the format of the RAC MPDU.

The RAC MPDU has a fixed structure. Fields that are not used are present, but reserved.

|           |   |   |   |   |   |   |   |   |
|-----------|---|---|---|---|---|---|---|---|
| Octets: 2 | 2 | 6 | 6 | 2 | 2 | 2 | 1 | 4 |
|-----------|---|---|---|---|---|---|---|---|

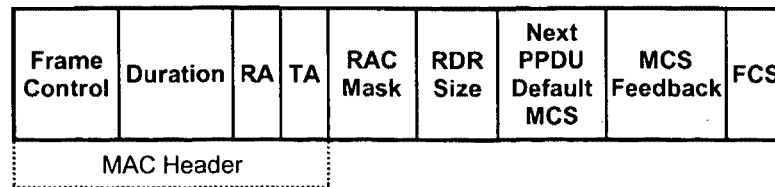


Figure 2 – RAC MPDU

| Field                | Size (bytes) | Purpose                                                                                                                                                                                                                 |
|----------------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Frame Control        | 2            |                                                                                                                                                                                                                         |
| Duration             | 2            |                                                                                                                                                                                                                         |
| Receiver Address     | 6            |                                                                                                                                                                                                                         |
| Transmitter Address  | 6            |                                                                                                                                                                                                                         |
| RAC Mask             | 2            | A bitmask indicating which RAC elements are present in the packet.                                                                                                                                                      |
| RDR Size             | 2            | Size in bytes of requested reverse direction flow.<br><br>This is interpreted along with the Next PDU default MCS to determine the duration of the next PDU.<br><br>Present when RDR is indicated, otherwise undefined. |
| Next PDU Default MCS | 2            | Default MCS that will be used in the absence of any updated training information to send next PDU<br><br>Present when RDR is indicated, otherwise undefined.                                                            |
| MCS Feedback         | 1            | Contains a recommended RCS value..<br><br>Present when MFB is indicated, otherwise undefined.                                                                                                                           |
| FCS                  | 4            |                                                                                                                                                                                                                         |

#### 6.1.2.2.1 RAC Mask Field

This field indicates which logical RAC elements are carried in the MPDU.

| RAC Mask Field bit | Position | Description                                                                                  |
|--------------------|----------|----------------------------------------------------------------------------------------------|
| CTS                | B0       | When set, indicates this is a CTS.                                                           |
| TRQ                | B1       | When set, indicates a request to train the channel.<br>Used for MIMO with implicit Feedback. |
| MRQ                | B2       | When set, indicates a request for MCS feedback.                                              |

|     |    |                                                                                                                                         |
|-----|----|-----------------------------------------------------------------------------------------------------------------------------------------|
| MFB | B3 | When set, indicates an MFB training response is present as defined by the MCS Feedback field.                                           |
| RDR | B4 | When set, indicates a request for reverse direction data-flow is present as described by the RDR Size and Next PPDU Default MCS fields. |

1

2 **6.1.2.2 MCS Feedback Field**

3 As defined in IAC MPDU.

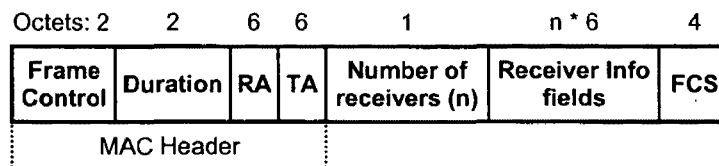
4 **6.1.3 Multiple Receiver Aggregate Descriptor (MRAD) MPDU**5 **6.1.3.1 Introduction**

6 The MRAD MPDU is the first frame inside a MRA aggregate. It contains an overview of the  
 7 contents of the aggregate. The MRAD may be used by a receiving STA to save power. Based on  
 8 the contents of the MRAD, the receiving STA may disable its receiver after it has received any  
 9 broadcast frames or frames addressed to its unicast address.

10 **6.1.3.2 Format of MRAD MPDU**

11 This section defines the format of the MRAD MPDU.

12



13

Figure 3 – MRAD MPDU

14

| Field                | Size (bytes) | Purpose                                                                            |
|----------------------|--------------|------------------------------------------------------------------------------------|
| Frame Control        | 2            | Frame type is Control.                                                             |
| Duration             | 2            |                                                                                    |
| Receiver Address     | 6            | The RA field is the broadcast group address.                                       |
| Transmitter Address  | 6            | The TA field is the address of the STA transmitting the MRA aggregate.             |
| Number of receivers  | 1            | The number of receivers (n) for which MPDUs are included inside the MRA aggregate. |
| Receiver Info fields | n * 6        | n Receiver Info fields, one for each Receiver Address in the MRA aggregate.        |
| FCS                  | 4            |                                                                                    |

15 The order of the Receiver Info fields is equal to the order in which MPDUs for the corresponding  
 16 receivers appear in the MRA aggregate.

### 6.1.3.2.1 Receiver Info field

The format of the Receiver Info field is as described below.

| Field            | Size (bytes) | Description                         |
|------------------|--------------|-------------------------------------|
| Receiver Address | 6            | Contains the receiver's MAC address |

## 6.1.4 Increase Channel Bandwidth (ICB) MPDU

### 6.1.4.1 Introduction

The ICB frame is sent by an HT AP to start a 40 MHz period in 20 MHz-base managed mixed mode. When 40 MHz HT STAs operating in 20 MHz receive this frame, they shift to 40 MHz analogue mode.

### 6.1.4.2 Format of ICB MPDU

The frame format for the ICB frame is defined as is in Figure 4.

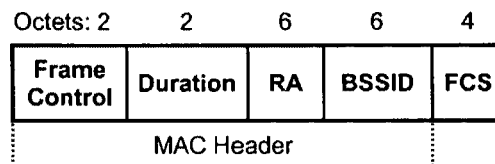


**Figure 4 – ICB MPDU**

| Field            | Size (bytes) | Purpose                                                        |
|------------------|--------------|----------------------------------------------------------------|
| Frame Control    | 2            | Frame type is Control.                                         |
| Duration         | 2            |                                                                |
| Receiver Address | 6            | The RA field is the broadcast group address.                   |
| BSSID            | 6            | The BSSID field is the address of the STA contained in the AP. |
| FCS              | 4            |                                                                |

This frame is used in the 20 MHz-base managed mixed mode and sent by the HT AP. When switching to 40 MHz channel, the Duration field will be set to cover the 40 MHz phase plus the transition periods between 20 and 40 MHz operation. This is to have HT STAs switch back to 20 MHz channel even if they do not receive the DCB frame at the end of the 40 MHz period.

## 6.1.5 Decrease Channel Bandwidth (DCB) MPDU

### 6.1.5.1 Introduction

The DCB frame is sent by an HT AP to end a 40 MHz period in 20 MHz-base managed mixed mode. When 40 MHz HT STAs operating in 40 MHz receive this frame, they shift to 20 MHz analogue mode.

### 6.1.5.2 Format of DCB MPDU

The frame format for the DCB frame is defined as is in Figure 4.

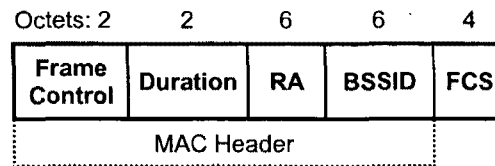


Figure 5 – DCB MPDU

| Field            | Size (bytes) | Purpose                                                        |
|------------------|--------------|----------------------------------------------------------------|
| Frame Control    | 2            | Frame type is Control.                                         |
| Duration         | 2            |                                                                |
| Receiver Address | 6            | The RA field is the broadcast group address.                   |
| BSSID            | 6            | The BSSID field is the address of the STA contained in the AP. |
| FCS              | 4            |                                                                |

This frame is used in the 20 MHz-base managed mixed mode and sent by the HT AP.

When switching back to the 20 MHz channel, the Duration field will at least cover up to the start of the next 40 MHz period. The Duration field in the DCB frame is giving this duration in TUs.

## 6.2 Data frames

To allow for MAC header compression two new MPDUs are defined: MAC Header (MHDR) MPDU and Compressed Header Data (CHDATA) MPDU.

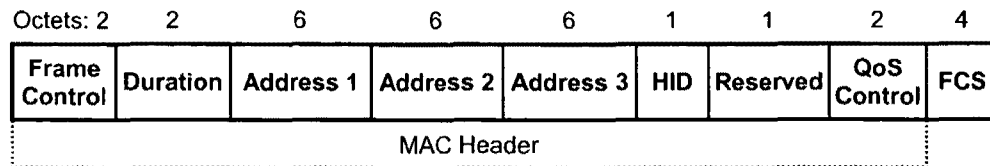
### 6.2.1 MAC Header (MHDR) MPDU

#### 6.2.1.1 Introduction

This MPDU provides the MAC header for subsequent CHDATA MPDUs.

**6.2.1.2 Format of MHDR MPDU**

This section defines the format of the MHDR MPDU.

**Figure 6 – MHDR MPDU**

Note, the MHDR MPDU contains no data.

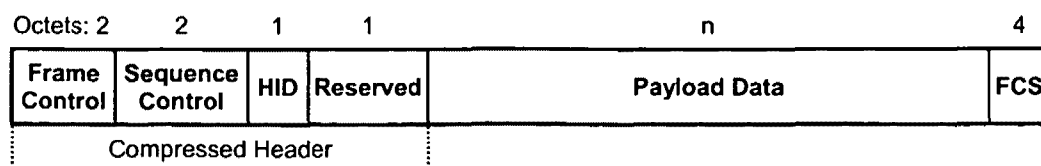
| Field         | Size (bytes) | Purpose                                                                      |
|---------------|--------------|------------------------------------------------------------------------------|
| Frame Control | 2            | Frame type is Data.                                                          |
| Duration      | 2            |                                                                              |
| Address 1     | 6            |                                                                              |
| Address 2     | 6            |                                                                              |
| Address 3     | 6            |                                                                              |
| HID           | 1            | The Header ID field that links the MHDR MPDU with corresponding CHDATA MPDUs |
| Reserved      | 1            |                                                                              |
| QoS Control   | 2            |                                                                              |
| FCS           | 4            |                                                                              |

**6.2.2 Compressed Header Data (CHDATA) MPDU****6.2.2.1 Introduction**

This MPDU contains the actual data and a (compressed) header that refers to a MHDR MPDU for full MAC header information.

**6.2.2.2 Format of CHDATA MPDU**

This section defines the format of the CHDATA MPDU.

**Figure 7 – CHDATA MPDU**



| Field            | Size (bytes) | Purpose                                                                     |
|------------------|--------------|-----------------------------------------------------------------------------|
| Frame Control    | 2            | Frame type is Data..                                                        |
| Sequence Control | 2            |                                                                             |
| HID              | 1            | The Header ID field that links the CHDATA MPDU with corresponding MHDR MPDU |
| Reserved         | 1            |                                                                             |
| FCS              | 4            |                                                                             |

## 6.3 Management frame formats

### 6.3.1 Capabilities

Support for any optional features or behavior will be declared through a STA's capabilities or management elements.

**Table 1 – Additional HT Capabilities**

| Capability                        | Contents                                                                                                                                                                                                                           |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HT Supported                      | Indicates that the device is an HT device, supporting all the mandatory features of this document                                                                                                                                  |
| Number of Rx Antennas             | Indicates the number of Rx Antennas                                                                                                                                                                                                |
| Max number of Rx spatial channels | Max number of spatial channels the device can receive: in the range 1 to 4.                                                                                                                                                        |
| Supported MCS set                 | Defines the MCS values supported by a STA. An MCS set contains a bitmap of size 128 bits. Bit 0 maps to MCS 0. A bit is set to indicate support for that MCS.<br>See section 11.2.1.4.2.2 for a list of MCSs.                      |
| Advanced Coding Capability        | Advanced Coding Capability Indicates support for advanced coding.<br>This field has the same format as the advanced coding field defined in section 10.1.1.8, where a bit set as one indicates that that coding type is supported. |
| Supported Channel Width Set       | Contains:<br>{20} for a device only capable of 20MHz operation<br>{20, 40} for a device capable of both 20MHz and 40MHz operation.                                                                                                 |

AP Capabilities are determined by a STA through listening to beacons or performing a directed or broadcast probe request.

STA Capabilities are determined by an AP when the STA performs an association request.

STA Capabilities may be determined by a STA using a directed probe request to generate a probe response.

### 6.3.1.1 HT Capability element

The HT Capability element contains a number of subfields that are used to advertise optional HT capabilities at an HT device. The HT Capability element is present in beacons, association and re-association request frames and in probe response frames. The presence of the HT Capability element indicates that the device is an HT device. The HT Capability element is defined in Figure 8.

|                            |                        |                             |                          |
|----------------------------|------------------------|-----------------------------|--------------------------|
| Octets: 1                  | 1                      | 2                           | 16                       |
| <b>Element ID<br/>(??)</b> | <b>Length<br/>(18)</b> | <b>HT Capabilities Info</b> | <b>Supported MCS set</b> |

**Figure 8 – HT Capability element format**

The HT Capabilities Info field is 2 octets in length, and contains capability information bits as defined in Figure 9.

|                                  |                                                  |                 |                                           |                                              |
|----------------------------------|--------------------------------------------------|-----------------|-------------------------------------------|----------------------------------------------|
| B0 B1                            | B2 B3                                            | B4 B5           | B6 B7                                     | B8 B15                                       |
| <b>Number of<br/>Rx antennas</b> | <b>Max number<br/>of rx spatial<br/>channels</b> | <b>Reserved</b> | <b>Supported<br/>modulation<br/>types</b> | <b>Supported training<br/>exchange types</b> |

**Figure 9 – HT Capabilities Info field**

Note: All APs and STAs support TRMS operation in other STAs with a zero stay-awake time.

### 6.3.2 Information Elements

The AP will signal information in new information elements to manage the BSS.

This information is defined in the table below.

**Table 2 – Additional HT Information Elements**

| <b>Name</b>              | <b>Description</b>                                                                                                                        | <b>Use</b>                                                                                                                                                |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Control Channel          | Channel number of the control 20MHz channel                                                                                               | In a mixed mode, all broadcast and unaggregated control frames are sent so that they can be received by a legacy device operating on the control channel. |
| Extension Channel Offset | Values: -1, 1 indicate offset of the extension channel from the control channel.<br>Value of 0 indicates no extension channel is present. | To locate the 40MHz channel in combination with the control channel                                                                                       |
| Permitted Width Set      | Defines the channel widths that may be used in the BSS.<br>Values: {20} or {20,40}                                                        | A STA can use any channel width in transmitting a unicast non-control frame supported by the destination STA, and present in the permitted width set.     |

|                                  |                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                          |
|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operating Mode                   | <p>Either:</p> <p>Mixed: (there are legacy devices co-channel)</p> <p>Pure: (there are no legacy devices co-channel or the AP is operating internally in managed mixed mode)</p> <p>Base-20 Managed mixed: (there may be legacy devices in both the control and the extension channel, see section 8.1.3.4)</p> <p>Mixed-Capable IBSS</p> | <p>Used to control the use of protection mechanisms (see section 7.1.7).</p> <p>Also selects between legacy beacon and HT beacon generation in an IBSS network (see section 8.1.3.2).</p>                                                                |
| Channel Extension Indication     | <p>Values: 0,1</p> <p>1 means that 40 MHz capable HT STAs in the BSS should extend their channel bandwidth to 40 MHz according to the information from the Extension Channel Offset information element.</p>                                                                                                                              | <p>Present in Beacon frames in CFP when 20 MHz-base managed mixed mode is used. It indicates that transition to a 40 MHz period will start in the current CFP after the reception of the Beacon.</p>                                                     |
| Extension Channel Access Timeout | <p>Integer <math>\geq 1</math></p> <p>Specifies a time limit (in TU) after which the AP gives up the transition to 40 MHz and the 40 MHz capable HT STA switches back to 20 MHz if it has not received CTS-to-self or Beacon on the extension channel.</p>                                                                                | <p>Present in Beacon/Probe Response frames when 20 MHz-base managed mixed mode is used.</p> <p>Note: The AP sets the local extension channel access timer to the Extension Channel Access Timeout minus the duration of CTS-to-self or Beacon frame.</p> |
| Basic MCS set                    | <p>An MCS set contains a bitmap of size 128 bits. Bit 0 maps to MCS 0. A bit is set to indicate support for that MCS.</p>                                                                                                                                                                                                                 | <p>Present in Beacon/Probe Response frames to indicate what MCS values shall be supported by all devices in the BSS.</p>                                                                                                                                 |
| Duplicate Legacy Beacon          | <p>Indicates that this beacon is a duplicate transmitted as part of managed mixed mode operation.</p> <p>HT STAs should ignore duplicate legacy beacons regardless of BSSID.</p>                                                                                                                                                          | <p>Present in legacy beacons transmitted by a HT AP during managed mixed mode operation.</p> <p>(See section 8.1.3.3.)</p>                                                                                                                               |

1

2 **6.3.2.1 TRMS Information Element**

3 The TRMS feature is managed by the TRMS information element defined below.

The TRMS Information Element (IE) may be included in association and reassociation request frames, DLP request and response frames and TRMS Update action frames. This IE includes the following fields:

| Field        | Description                                                                                                                                                                                                                                                                       | Use                                                                                                                                                                                                                                                                                                              |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRMS active  | Indicates whether or not TRMS operation is active                                                                                                                                                                                                                                 | If TRMS is active, a STA transmitting to this STA shall operate the procedures defined in section 8.3.                                                                                                                                                                                                           |
| Hold-on time | The amount of time in 100s of milliseconds that the STA operates with full receive capability after transmitting a frame. A value of zero indicates that it retains full receive capability for 1 slot time (+ SIFS) after transmitting a frame for which a response is expected. | A hold-on time of zero indicates that the STA wishes to reduce receive capability on completing a sequence exchange.<br><br>All APs and STAs support TRMS operation in other STAs with a hold-on time of zero.<br><br>It is an option of a STA to support TRMS tracking for non-zero values of the hold-in time. |

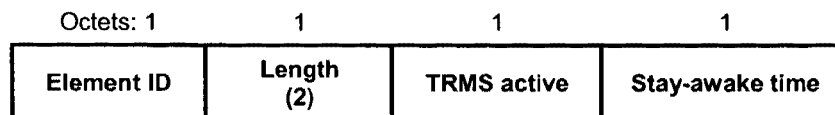


**Figure 10 – TRMS element format**

### 6.3.3 TRMS Update Action Frame

The TRMS Update Action frame provides a mechanism for the STA to notify the AP and its peers of changes in its operating mode. This frame includes the TRMS IE defined in section 6.3.2.1.

This frame is an action frame using the 802.11e Action frame format. A Category code needs to be defined for HT and an action code for this frame.

The frame body of the TRMS update contains the information shown in the table below:

| Order | Information  |
|-------|--------------|
| 1     | Category     |
| 2     | Action       |
| 3     | Dialog Token |
| 4     | Status Code  |
| 5     | TRMS IE      |

All fields except the TRMS IE are defined in 802.11e [2].

### 6.3.4 TSPEC Modifications

In order to support modified behavior defined in section 7.4, the TSPEC is modified to carry the following additional items.

**Table 3 – Additional HT TSPEC Fields**

| Item                        | Type        | Description                                                                                                                                                                                                                                                                                          |
|-----------------------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| QAP Renegotiation upwards   | Flag        | If set, this flag permits the QAP to initiate TSPEC parameter negotiation to give the QSTA increased resources as they become available                                                                                                                                                              |
| QAP Renegotiation downwards | Flag        | If set, this flag permits the QAP to initiate TSPEC parameter negotiation to give the QSTA decreased resources according to the reasons defined below.                                                                                                                                               |
| Renegotiation reason        | Enumeration | Reason for renegotiation:<br>Increased resources are available<br>The QSTA cannot maintain its negotiated minimum PHY rate<br>The QAP cannot gain access to the medium to service this TSPEC<br>Bandwidth is required for some other TSPEC                                                           |
| Renegotiation response      | Enumeration | Response to renegotiation request:<br>Accepted<br>Counter proposal. Only valid if the counter proposal consumes less resources than the proposal.<br>Rejected. Valid for all upward negotiations. Valid for a downward negotiation only if the reason is bandwidth is required for some other TSPEC. |
| PLR Enabled                 | Flag        | When enabled, indicates that MSDUs may be discarded from this TS based on their packet loss priority value as defined in section 7.4.4.                                                                                                                                                              |

#### 6.3.4.1 Periodic RDR

##### 6.3.4.1.1 Introduction (Informative)

Periodic RDR is a new type of traffic specification (TSPEC) that results in the HC seeing a periodic reverse direction request for data associated with that TSPEC.

In a conventional periodic uplink TXOP, the HC delivers a polled TXOP for a known duration during a known service period to a QSTA. The QSTA can then use this TXOP for any purpose it chooses. It can send MPDUs to the HC or any other QSTA using DLP. It is responsible for retrying any transmission failures.

A periodic RDR is much more constrained. The HC will deliver an RDG of duration to collect the first transmissions of data during a known service period. The HC also allows in the

scheduling of the service period enough time to send subsequent RDG to collect retransmissions of failed data.

The HC can service multiple QSTAs during the same service period. In practice it is likely to group together into a composite service period RDG for QSTAs with similar TSPECs (i.e. service interval and delay limit) and possibly PHY parameters. How it does this is outside the scope of the standard.

#### 6.3.4.1.2 TSPEC Element Modifications for Periodic RDR

Add a new field to the TSPEC Info Field called Periodic RDR.

This field takes values 0 and 1.

When 1, the TSID is associated with a Periodic RDR. This is valid only with TSPECs indicating periodic uplink. This is interpreted by the HC as meaning that, instead of delivering a QoS CF-Poll to the STA, it periodically delivers an IAC containing an RDG for the specified TSPEC.

#### 6.3.4.1.3 Meaning of Service Period with Periodic RDR

When a STA creates a TSPEC using periodic RDR, the AP shall create a service period during which the STA shall be awake to receive data and RDGs.

The AP may add TSPEC requests from multiple STAs into a composite service period during which it will service the STA. This allows it to use MRMRA.

Note, as STAs are added to or removed from the composite service period, the AP may need to update the service period notification by transmitting an updated service period element to the STAs.

The AP ensures that any IAC transmissions intended to service the periodic RDR traffic stream lie wholly within the service period.

A STA that receives data during an MRMRA sequence may go to sleep as soon as it has correctly received and acknowledged all data sent to it by the initiator, and may go to sleep as soon as it has received acknowledgement for all data it has sent.

## 6.4 Frame aggregation format

### 6.4.1 Introduction to Aggregation (Informative)

Aggregation is described in here as a MAC layer function.

The MAC interprets the PSDU as a single MPDU, or a sequence of MPDUs according to the *Aggregate* TXVECTOR/RXVECTOR parameter, that is robustly transported in the PLCP header.

The MAC separates the MPDUs of an aggregate PSDU using a robust MPDU delimiter. It is robust in the sense that loss of a single delimiter does not necessarily cause loss of multiple MPDUs in an aggregate.

Note, MPDUs are separately protected by a CRC. Loss of an individual MPDU does not imply loss of all MPDUs in a PPDU.

The MAC Header Duration fields of all MPDUs in an aggregate carry the same value.

#### 6.4.2 Aggregated PSDU format

An aggregate PSDU consists of a number of MPDU delimiters each followed by an MPDU.

Except when it is the last MPDU, padding octets are appended (if needed) to make it a multiple of 4 octets in length.

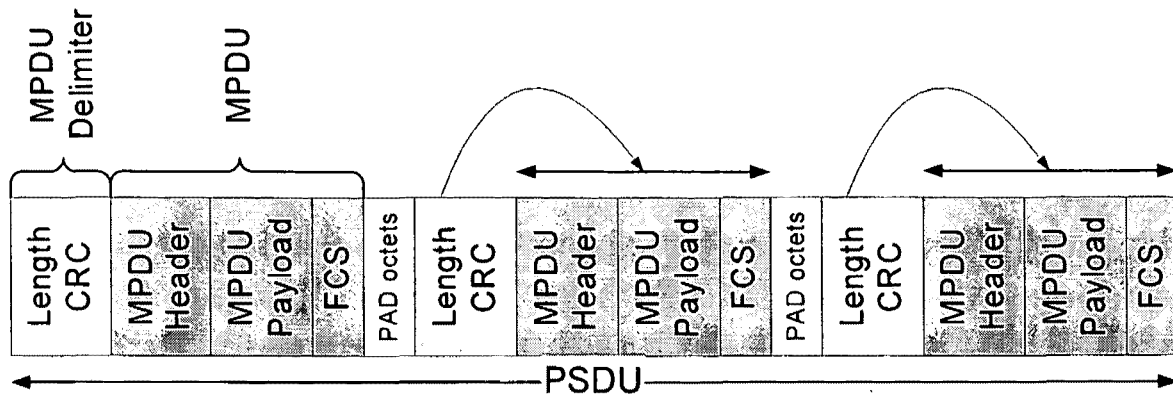


Figure 11 – Aggregated PSDU format

The MPDU delimiter is 4 octets in length and contains the fields defined below:

Table 4 – MPDU delimiter Fields

| MPDU delimiter Field | Size (bits) | Description                                                                                                                          |
|----------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------|
| Reserved             | 4           | -                                                                                                                                    |
| MPDU length          | 12          | Length of the MPDU in octets                                                                                                         |
| CRC                  | 8           | 8-bit CRC of the preceding 16-bits.<br>As defined in IEEE 802.11 section 14.3.2.2.3                                                  |
| Unique pattern       | 8           | Unique pattern that may be used to detect an MPDU delimiter when scanning for a delimiter. Set to the ASCII value for character 'N'. |

The purpose of the MPDU delimiter is to robustly delimit the MPDUs within the aggregate. Robust in this case means that the structure of the aggregate can usually be recovered when one or more MPDU delimiters are received with errors. Individual delimiters have the same BER as the surrounding MPDUs, and so can be lost.

##### 6.4.2.1 Deaggregation (Informative)

The receiver checks the MPDU delimiter for validity based on the CRC. It can also check that the length indicated is within the PSDU HT length indicated in RXVECTOR. If the MPDU

delimiter is not valid, it skips forward 4 octets and checks to see if the new location contains a valid MPDU delimiter. It continues until a valid delimiter is found, or the end of the PSDU is reached based on the RXVECTOR PSDU HT length field.<sup>1</sup>

If the MPDU delimiter is valid, the MPDU is received. Until the end of the PPDU is reached, the next MPDU delimiter is expected at the first multiple of 4 octets immediately after the current MPDU.

This algorithm is expressed in the following pseudo-code (note, this is not optimized for efficiency):

```

ParsePSDU(length)
{
    Int offset = 0;    /* Byte offset from start of PPDU */
    While (offset+4 < length)
    {
        If valid_MPDU_delimiter(offset) &&
           get_MPDU_length(offset) <= 2346 &&
           get_MPDU_length(offset) <= (length - (offset+4))
        {
            /* Valid delimiter */
            Receive_MPDU(offset+4, get_MPDU_length(offset));
            /* advance multiple of 4 bytes */
            offset += 4 + 4*((get_MPDU_length(offset)+3)/4);
        }
        Else
        {
            /* delimiter invalid, advance 4 bytes and try again */
            offset += 4;
        }
    }
}

```

Note: the unique pattern can be used to reduce computation required while scanning for a valid delimiter. This is not shown in the pseudo-code above.

### 6.4.3 Single receiver frame aggregation format

An aggregate is a sequence of MPDUs carried in a single PPDU carrying the aggregate attribute.

In a single-receiver aggregate, all MPDUs are addressed to the same receiver address.

The aggregate shall contain the following MPDUs in the order defined below.

**Table 5 Single Receiver Aggregation MPDUs**

| MPDU       | Multiplicity | Description                                                                                                                  |
|------------|--------------|------------------------------------------------------------------------------------------------------------------------------|
| IAC or RAC | At most one  | Initiator or responder aggregate control.<br>Used when it is necessary to include a logical element as described in sections |

<sup>1</sup> This procedure will occasionally wrongly interpret a random bit-pattern as a valid delimiter. When this happens, the MAC will attempt to interpret a random MPDU. The MAC will discard it based on a bad MAC CRC check. The overall effect may be to lose one or more MPDUs from the aggregate very infrequently.



|                                          |                                                                                                                                                                                               |                                                                                                                                                                                                                                                                     |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                          |                                                                                                                                                                                               | 6.1.1 and 6.1.2                                                                                                                                                                                                                                                     |
| ACK                                      | At most one                                                                                                                                                                                   | Contains an acknowledgement of at most one MPDU in the previous aggregate that required immediate acknowledgement.                                                                                                                                                  |
| BA                                       | At most one per Block ACK agreement in the appropriate direction                                                                                                                              | Block ACK MPDUs                                                                                                                                                                                                                                                     |
| QoS Data                                 | No limit, except as constrained by Block ACK protocol and TXOP duration<br><br>When MAC Header compression is applied the aggregate shall include at least one MHDR MPDU per TC and receiver. | Data MPDUs sent under Block-ACK policy. These MPDUs can come from multiple TCs, provided that they comply with the TC policy of the current TXOP.<br><br>Apart from regular Data MPDUs the aggregate may also contain MHDR- and CHDATA MPDUs (both of Type 'Data'). |
| BAR                                      | At most one per Block ACK agreement (immediate Block ACK).                                                                                                                                    | Immediate Block ACK Requests                                                                                                                                                                                                                                        |
| Any MPDU requiring an immediate response | At most one                                                                                                                                                                                   | At most one MPDU that requires an Ack MPDU response may be transmitted.<br><br>This includes BAR sent under delayed Block ACK policy, Data MPDU (including non-QoS), Management MPDU.                                                                               |

- 1 At most one single Block ACK Request using the delayed Block ACK policy is permitted. This  
2 is acknowledged by an acknowledgement MPDU in the following aggregate.

#### 3 6.4.4 Multiple receiver frame aggregation format

4 A multiple-receiver aggregate contains MPDUs that are addressed to multiple receivers.

5 The multiple receiver aggregate (MRA) is distinguished by the presence of the MRAD MPDU  
6 which lists the receiver addresses referenced in the aggregate. The MRA contains a MRAD  
7 MPDU, followed by one or more groups of MPDUs organized by receiver address.

8 Each group is either a response group or a non-response group. The rules for contents of the two  
9 groups are similar, except that the response group contains an IAC that defines a response  
10 period.

11 A Broadcast/Multicast Data Group shall contain the following MPDUs in the order defined  
12 below.

13 **Table 6: Multiple Receiver Aggregation MPDUs**

| MPDU                    | Multiplicity                                     | Description                                                                            |
|-------------------------|--------------------------------------------------|----------------------------------------------------------------------------------------|
| Data or management MPDU | No limit, except as constrained by TXOP duration | Data or management MPDUs with the broadcast or the same multicast destination address. |

14

- 1 A Scheduled Response Receiver Group shall contain the same MPDUs as a Single Receiver  
 2 Aggregate (see section 6.4.3), addressed to the same receiver, in the order defined in Table 5.  
 3  
 4 A No Response Receiver Group shall contain the following MPDUs, addressed to the same  
 5 receiver, in the order defined below.

6 **Table 7 No Response Receiver Group MPDUs**

| MPDU     | Multiplicity                                                                                                                                                                                  | Description                                                                                                                                                                                                                                                         |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IAC      | At most one                                                                                                                                                                                   | Initiator aggregate control MPDU<br>Note this cannot contain an RDG.                                                                                                                                                                                                |
| ACK      | At most one                                                                                                                                                                                   | Contains an acknowledgement of at most one MPDU in the previous aggregate that required immediate acknowledgement.                                                                                                                                                  |
| BA       | At most one per Block ACK agreement in the appropriate direction                                                                                                                              | Block ACK MPDUs                                                                                                                                                                                                                                                     |
| QoS Data | No limit, except as constrained by Block ACK protocol and TXOP duration<br><br>When MAC Header compression is applied the aggregate shall include at least one MHDR MPDU per TC and receiver. | Data MPDUs sent under Block-ACK policy. These MPDUs can come from multiple TCs, provided that they comply with the TC policy of the current TXOP.<br><br>Apart from regular Data MPDUs the aggregate may also contain MHDR- and CHDATA MPDUs (both of Type 'Data'). |

- 7  
 8 The MRA aggregate shall contain the following (groups of) MPDUs in the order defined below.

9 **Table 8 MRA Aggregate MPDUs**

| MPDU                                                                  | Multiplicity                                                                                                  |
|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| MRAD                                                                  | One                                                                                                           |
| Broadcast/Multicast Data Group                                        | One per broadcast or multicast destination address.<br>Only permitted when the BSS is operating in pure mode. |
| Scheduled Response Receiver Group<br>or<br>No Response Receiver Group | One per receiver address.                                                                                     |

- 10  
 11 Scheduled Response Receiver Groups and No Response Receiver Groups may be mixed in any  
 12 order.

- 1 Data MPDUs can come from multiple TCs, provided that they comply with the TC policy of the
- 2 current TXOP.
- 3 Data MPDUs with the same receiver address are included in consecutive locations in the MRA
- 4 aggregate. The order of (groups of) Data MPDUs for different receiver addresses is equal to the
- 5 order of the Receiver Info fields in the MRAD MPDU.

## 7. MAC sublayer functional description

### 7.1 Aggregation Exchange Sequences and related rules

#### 7.1.1 IAC/RAC Exchange Rules

This section describes how IAC/RAC MPDUs are used in a bi-directional exchange.

An exchange protected using LongNAV rules shall start with the exchange of unaggregated IAC and RAC MPDUs at a basic rate. An RTS/CTS exchange may be substituted for an IAC/RAC exchange if none of the features of the IAC/RAC are required by the initiator. Control frames required to modify the NAV (IAC, RAC, CF-End, SCB) are sent at the rate that would be selected for RTS/CTS under existing rules.

A STA shall respond to a PPDU carrying an unaggregated IAC MPDU with an unaggregated RAC response MPDU.

Note, in this case the IAC MPDU does not include an RDG value. The response RAC is generated regardless of the absence of the RDG.

Following the initial exchange, for all PPDUs for which a response is permitted, the initiator may include an IAC in the aggregate containing the permitted response grant.

An HT STA may also generate a response containing only the response MPDUs implied by receipt of an aggregate if it knows itself to be the first (or only) responder. The purpose of this is to allow an HT STA that knows a response is expected to send a response, even if it has not received the IAC. This avoids delaying the BA response in the case that an IAC was lost. It also allows an HT initiator to not send the IAC and allow the HT STA to infer the presence of a response.

It knows itself to be the first (of many), if it correctly receives an MRAD in which it is the first unicast address.

It knows itself to be the only if it receives an aggregate containing a unicast MPDU addressed to it in the first position (change to current protocol at sender), or it receives an MPDU of size equal to IAC in the first position, followed by a unicast frame correctly received and addressed to it in the second position.

When the initiator schedules a response, the initiator shall allow enough RDG time for a response RAC and any requested BAs. The responder does not need to include an RAC if no elements of the RAC need to be transmitted. If the response is a single MPDU (i.e. a Block Ack), the responder may send this as an aggregate or non-aggregate.

Note: under LongNAV rules, the initiator can re-use any time not used by the responder in its response. Under pairwise spoofing rules, this is not the case.

#### 7.1.2 Non-aggregate IAC/RAC Rate selection Rules

An initiator that needs to set the NAV in its locality (i.e. LongNAV rules for initial exchange) shall use a basic rate. In a mixed BSS, it shall use a basic legacy rate and PPDU format.

A responder responding to an IAC with an RAC MPDU assumes that it is required to set the NAV in its locality. It shall use a basic rate. In a mixed BSS, it shall use a basic legacy rate and legacy compatible PPDU format.

### 7.1.3 Response Period Scheduling

The initiator may grant reverse direction to:

- Respond to an RDR contained in the previous PPDU received from this STA
- Respond to a periodic RDR TSPEC at the start of its service period
- Respond to a transmission failure in the previous PPDU received from this STA
- Allow for an RAC MPDU
- Allow for a BA response to any BAR it is transmitting to the STA in its current PPDU.
- Allow for an Ack response to any MPDU it is transmitting that requires an ACK response.

The grant is in units of time and should use the latest MCS value for that STA to convert the known amount of data to grant value. This MCS value is the latest value either sent to the STA (as an MFB element, including one in the current PPDU) or received from the STA (as a default MCS).

#### 7.1.3.1 Retransmission Rules

When transmitting an MRA containing periodic RDR, or when transmitting a SRA under the Pairwise Spoofing rules, the initiator shall allocate in its next RDG sent to a receiver during the current frame exchange sequence a grant for MPDUs transmitted by the responder that were not received successfully at the initiator.

### 7.1.4 Responder Rules

An HT STA that receives an IAC containing an RDG shall, in response, transmit a single unaggregated MPDU or a single receiver aggregate PPDU addressed to the initiating HT STA. This response shall begin no earlier than the schedule response period and end no later than the end of the scheduled response period. If the IAC contained an RTS element, the responder shall generate no response if its NAV is non-zero at the start of the response period, otherwise the responder shall respond with an RAC containing a CTS element.

A responder should always respond to the MRA initiator at the starting time of its granted response period, even if it is receiving frames or is physically sensing the medium busy at the starting time of its RDG. This is necessary if an HT STA overhears activity in an adjacent BSS - for example it is currently receiving a Data frame addressed to some STA in that BSS and it had previously received an IAC containing a scheduled response.

### 7.1.5 Response PPDU Contents

When sending a response PPDU, the IAC's Reverse Direction Traffic Identifier (RDTID) constrains what Data MPDUs are eligible to be transmitted.

When the RDTID contains a TSID, only MPDUs of this traffic stream may be transmitted. This is typically used with a periodic TSPEC to gather uplink MPDUs for that TSPEC.

When the RDTID contains an AC, only MPDUs of the specified access category may be transmitted. This is typically used by an initiator that gained access to the channel using EDCA to ensure that only MPDUs of that AC are sent by a responder.

When the RDTID contains the value "unconstrained", MPDUs of any traffic stream or user priority may be transmitted.

#### **7.1.6 Power-saving at the receiver of an aggregate PPDU**

An HT STA may sleep through part of the aggregate PPDU under the following conditions:

- It correctly received an initial MPDU that was not a MRAD, and was addressed to another receiver
- It correctly received an initial MPDU that was a MRAD that did not contain its receiver address or broadcast address

If the HT STA correctly receives a MRAD that caused it to remain awake because it contained the broadcast address, the HT STA may sleep as soon as it decodes a unicast receiver address in the aggregate.

If the HT STA correctly receives a MRAD that caused it to remain awake because it contained its address, the HT STA may sleep once it has decoded an MPDU containing its receiver address followed by one that contains a different receiver address.

#### **7.1.7 Protection mechanisms**

##### **7.1.7.1 MAC layer protection**

The following techniques may be used to achieve protection using a MAC layer technique:

- A contention-free-period of a beacon containing a CF parameter set.
- The HC may deliver a polled TXOP to an HT STA. The whole of the TXOP may be protected by the duration field in the QoS CF-poll.
- The HC uses its privileged channel access (after a PIFS) and starts a CAP with transmission of a CTS-to-self MPDU.
- A TXOP may be started with an RTS/CTS or IAC/RAC exchange, providing NAV protection of the duration specified in these control MPDUs.

##### **7.1.7.1.1 Long NAV**

When a STA has a TXOP, and is using a MAC-layer protection, it generally protects multiple PPDUs using a single protection exchange.

The STA may be able to accurately predict the duration of these PPDUs, in which case it can set the duration values in the preceding protection exchange accurately.

However, it may not be able to predict the duration accurately. This allows it to respond to the following events:

- Retries of failed transmissions in the current exchange

- Adaptation of transmit parameters by training feedback during the current exchange
- Transmission of MSDUs arriving at the MAC Data SAP during the current exchange

LongNAV protection is defined as selecting a duration value, limited by the remaining duration in the current TXOP and setting the NAV to this value using one of the MAC layer protection techniques.

#### 7.1.7.1.2 Truncation of TXOP

In the case that a STA gains access to the channel using EDCA and uses LongNAV to protect a duration value, and then runs out of MPDUs to transmit, the STA may transmit a CF-End provided that the remaining duration is long enough to transmit this MPDU.

This shall be interpreted by HT STAs and is interpreted by legacy STAs as a NAV reset – i.e. they reset their NAV timer to zero at the end of the PPDU containing this MPDU.

Note, the transmission of a single CF-End MPDU by the initiator resets the NAV of devices hearing the initiator. There may be devices that could hear the responder that had set their NAV that do not hear this NAV reset. Those devices will be prevented from contending for the medium until the original NAV reservation expires.

Note: an alternative mechanism considering a two-phase NAV reset would address this issue, but also increases overhead. At this point, it is considered preferable to limit overhead.

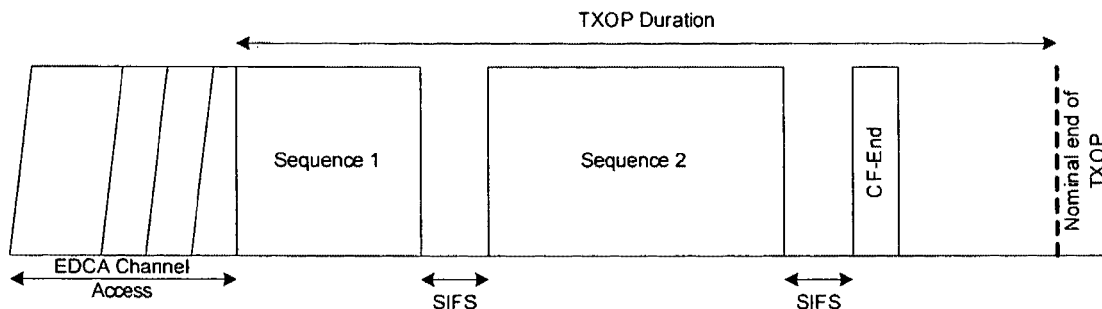


**Figure 12 – Example of TXOP Truncation**

In the example above the device accesses the medium using EDCA channel access and then engages in two sequences of PPDU in the initiator role (these could be to the same receiver address, or different receiver addresses). Each sequence may include multiple PPDU sent and received.

At the end of the second sequence, the initiator has not more data that it can send that fits within the TXOP, and so truncates the TXOP by transmitting a CF-End MPDU.

HT STAs and legacy STAs that receive this MPDU reset their NAV and can start contending for the medium immediately after this MPDU.

#### 7.1.7.2 PHY layer protection – Spoofing

##### 7.1.7.2.1 Method

The Spoofed NAV Duration is virtually set in the PHY Header by using the Length and Rate Field of the SIGNAL Field.

1 Originally, the Rate field declares the Rate that the packet is coded in after the PHY Header, and  
2 the Length field declares the Length of the packet (after the PHY header) in Bytes. When a  
3 legacy node receives this SIGNAL Field, it starts to decode the rest of the packet in the specified  
4 rate and will continue to do so until the end of Length / Rate time.

5 The Spoofed NAV uses this characteristic of the Length and Rate Fields, so that the Length /  
6 Rate – (EIFS – DIFS) is equivalent to the intended NAV Duration. A legacy node that is  
7 spoofed by these two fields will continue reception for that Length / Rate – (EIFS – DIFS) time,  
8 preventing it to start transmission during that period. This way transmission control can be  
9 achieved without altering the mechanism of the legacy nodes.

#### 10 **7.1.7.2.2 HT Device NAV and EIFS Rules**

11 An HT device that receives a PPDU examines the legacy and HT rate and length fields from  
12 which it calculates legacy and HT durations.

13 It determines that spoofing is in operation if the legacy duration is not equal to the HT duration.

14 If spoofing is in operation, it shall set its NAV to the value of legacy duration + (EIFS – DIFS) –  
15 HT duration at the end of the received PPDU, unless the NAV has been set by reception of a  
16 duration field value within the PPDU.

17 Note: EIFS is of less value in an HT network than a legacy network. It is difficult to define  
18 exactly what duration should be protected. Also use of spoofing and LongNAV provides NAV  
19 protection throughout aggregate exchanges containing MPDUs that a 3rd party HT STA is  
20 unlikely to be able to hear. 3rd party HT STAs should not use EIFS at the end of an aggregate  
21 exchange because that would unfairly benefit the two peer STAs involved in the exchange.

22 The following rule defines EIFS selection for an HT STA:

23 An HT STA that receives an MPDU with a bad CRC shall only use EIFS if its NAV is zero at  
24 the start of the PPDU containing the MPDU. The condition is never true during an aggregate  
25 exchange, but is true for isolated Data/ACK.

#### 26 **7.1.7.3 Pairwise Spoofing**

27 Pairwise Spoofing works as follows.



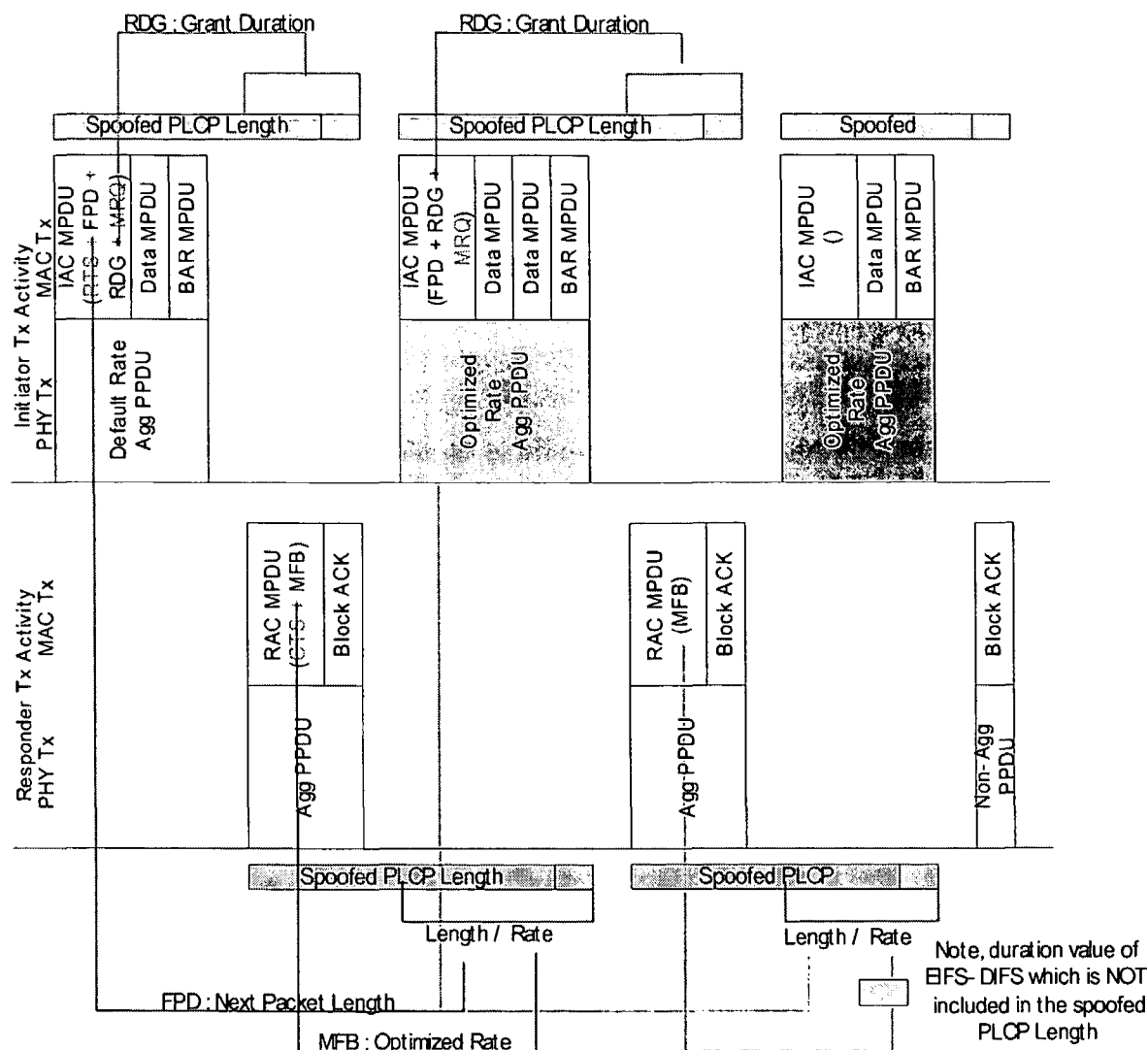


**Figure 13 – Basic Operation of Pairwise Spoofing**

The transmitter of a Data packet informs the recipient of the length of the packet it intends to transmit by indicating the FPD (Following Packet Descriptor) or RDR (Reverse Direction Request) field. When a STA receives an FPD or an RDR, it will calculate the length, in time, it will take to receive that packet by dividing the length by the rate that the packet will be sent at. The MCS of the packet may be specified by the recipient using an MFB (MCS Feed Back) field for optimization purposes, otherwise it uses the default MCS notified in the FPD / RDR Field.

**7.1.7.4 The STA shall add to the length of the packet indicated in the FPD or RDR the length of any response MPDUs (e.g. RAC, BA, Ack) implied by its own transmission in determining the duration to spoof.**

Single Ended Spoofing works as follows.

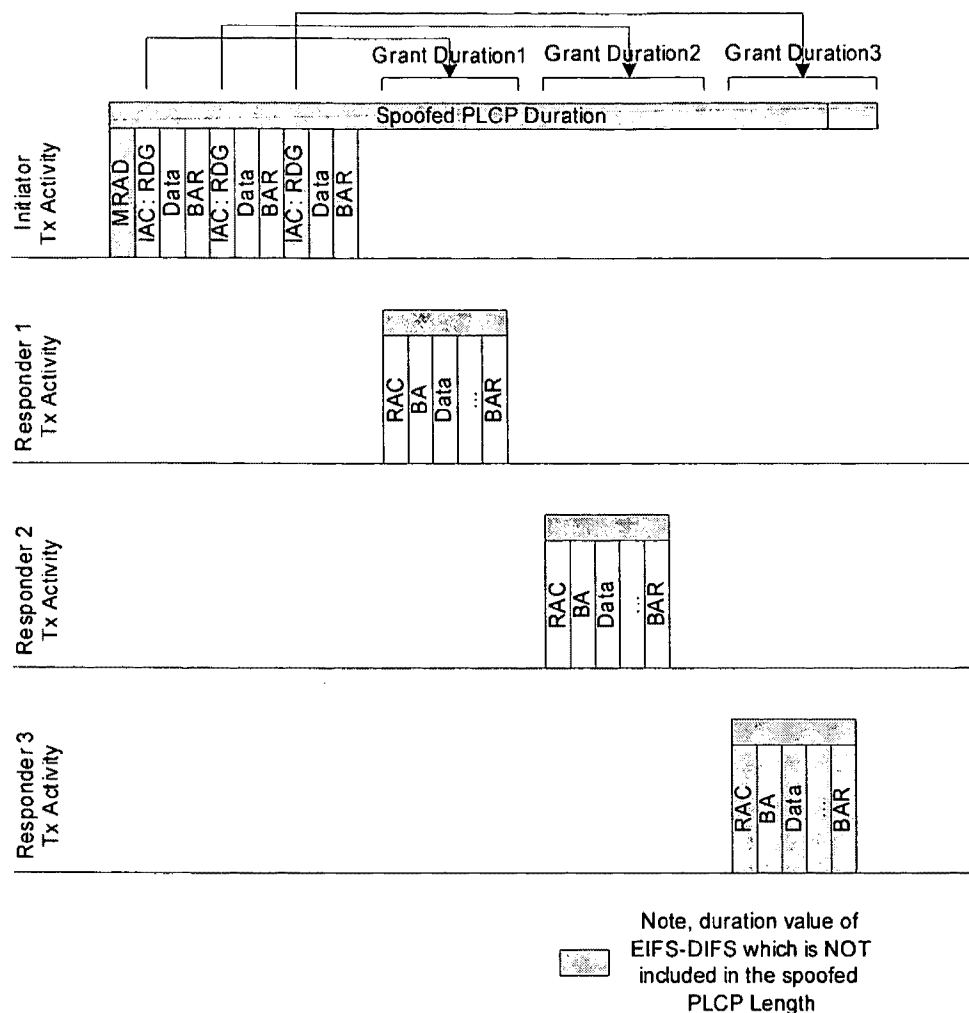


**Figure 14 – Basic Operation of Single Ended Spoofing**

In the case where single ended spoofing is used, an initiator should set its spoofed duration according to the duration it grants to responses using the RDG field. The spoofed duration should be set so that it covers from the start of the initiator's frame to the end of the last grant duration minus (EIFS – DIFS).

In the figure above, single ended spoofing is used to protect responses to an MRMRA packet. The use of single ended spoofing is not limited to just MRMRA but may also be used for protection of an SRA sequence.

### 7.1.8 MAC support for closed loop modes

#### 7.1.8.1 Closed-loop MCS training

Support for closed-loop MCS adaptation is provided by the exchange of MRQ (MCS Request) and MFB (MCS Feedback) elements carried in IAC/RAC control frames.

An MCS Request can be included in any IAC or RAC. Its purpose is to request the peer STA to measure the characteristics of the link and return information in an MFB that allows the link to be used more effectively.

1 There are three types of MCS training exchange: normal, unsolicited and unanswered.

2 There is no negotiation or indication about which type of training exchange will take place. The  
3 peer initiating the exchange shall be prepared for a normal or missing response. It shall also  
4 respect unsolicited MFB.

5 A STA receiving an MFB should use the information contained in it to adapt its transmission  
6 parameters. A STA using the Pairwise Spoofing mechanism shall use the information received in  
7 the MFB to define the transmission parameters of the next PPDU to be transmitted in the current  
8 exchange sequence to that peer.

#### 9 **7.1.8.1.1 Normal Adaptation**

10 In a normal training exchange, an MFB element is present in the next aggregate sent by the  
11 receiver of the MRQ element, and the aggregates are separated by a SIFS interval.

#### 12 **7.1.8.1.2 Unsolicited Adaptation**

13 In an unsolicited exchange, a STA may send an MFB element without any matching MRQ  
14 element at any stage of an exchange.

#### 15 **7.1.8.1.3 Unanswered Training Exchange**

16 In an unanswered training exchange, a STA ignores an MRQ element and refuses to provide an  
17 MFB element. In the case of pairwise spoofing, the STA that has sent the ignored MRQ  
18 element, shall use the default MCS defined in the FPD / RDR element.

#### 19 **7.1.8.2 Closed-loop MIMO training**

20 Support for closed-loop MIMO adaptation is provided by the exchange of a TRQ (MIMO  
21 Training Request) element carried in IAC/RAC control frames and an HT sounding PPDU.

22 A TRQ can be included in any IAC or RAC. Its purpose is to request the peer STA to return an  
23 HT sounding PPDU that allows the requesting STA to use better parameters for subsequent  
24 transmissions to the peer STA.

25 Use of Closed-loop MIMO training is an option of the STA sending the TRQ. A STA that does  
26 not support closed-loop MIMO will never send an IAC or RAC with the TRQ flag set. All STAs  
27 support the creation of an HT sounding PPDU.

28 A STA that receives a PPDU carrying a TRQ element should ensure that its response PPDU is  
29 sent with the TXVECTOR SOUNDING parameter set to 1.

#### 31 **7.1.9 Aggregated Single Directional frame transfer**

32 In order to use aggregation, protection or legacy protection is required as defined by the  
33 operating mode.

34 In the LongNAV case, protection is achieved by the exchange of a pair of frames using an  
35 appropriate rate such that all devices can receive these frames. These frames may be RTS/CTS if  
36 none of the IAC elements (apart from RTS) is required. Otherwise they shall be IAC/RAC.

After this, there occurs a sequence of PPDUs. The PPDUs transmitted by the initiator shall be aggregate PPDUs. The PPDUs transmitted by the responder may be aggregate or non-aggregate may carry only response MPDUs and training feedback. These response PPDUs do not include any Data or Block ACK Request MPDUs.

The initiator prevents reverse direction data flow by defining an RDG big enough only for the expected response control MPDUs: an RAC, one or more BAs and up to one ACK.

7.1.9.1 LongNAV examples

The first example shows use of LongNAV, unidirectional.

A pair of IAC/RAC MPDUs establishes NAV protection of the TXOP.

There then follows a sequence of aggregates and reverse direction Block ACK responses. The responder responds with a non-aggregate PPDUs containing a Block ACK. No RAC MPDUs are present in the response PPDUs because none of the logical elements are required to manage the exchange.

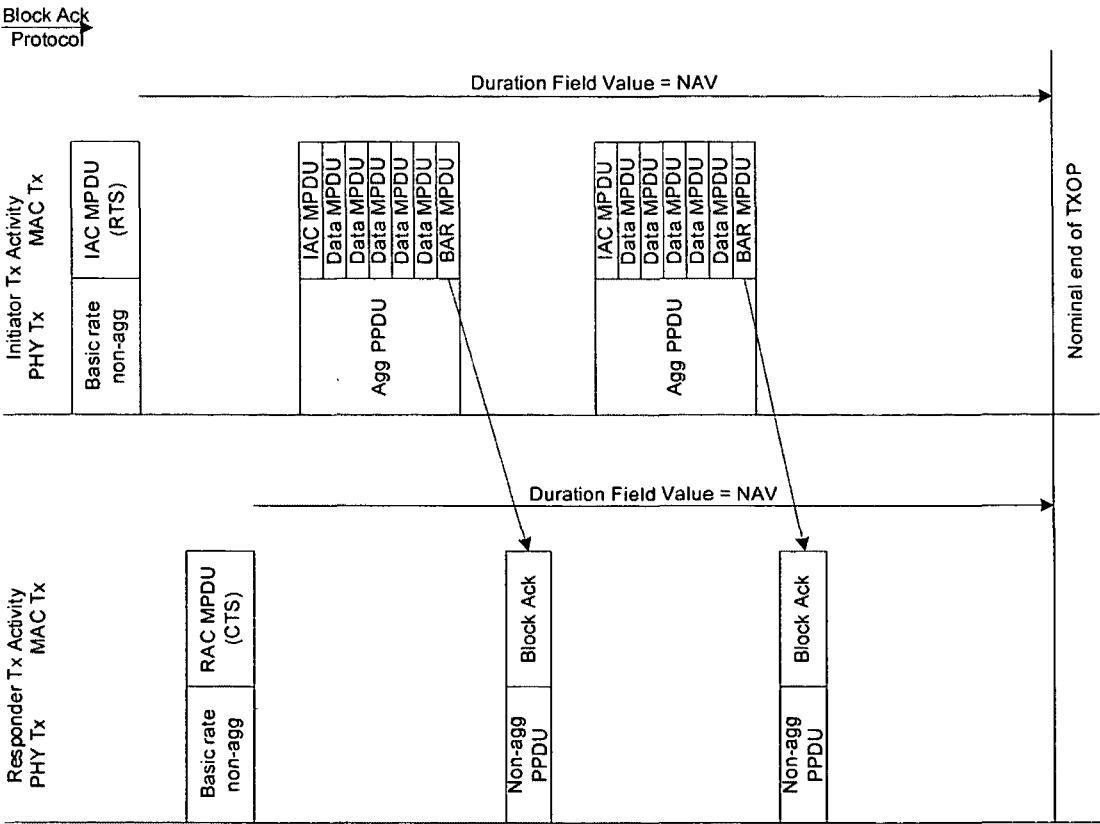
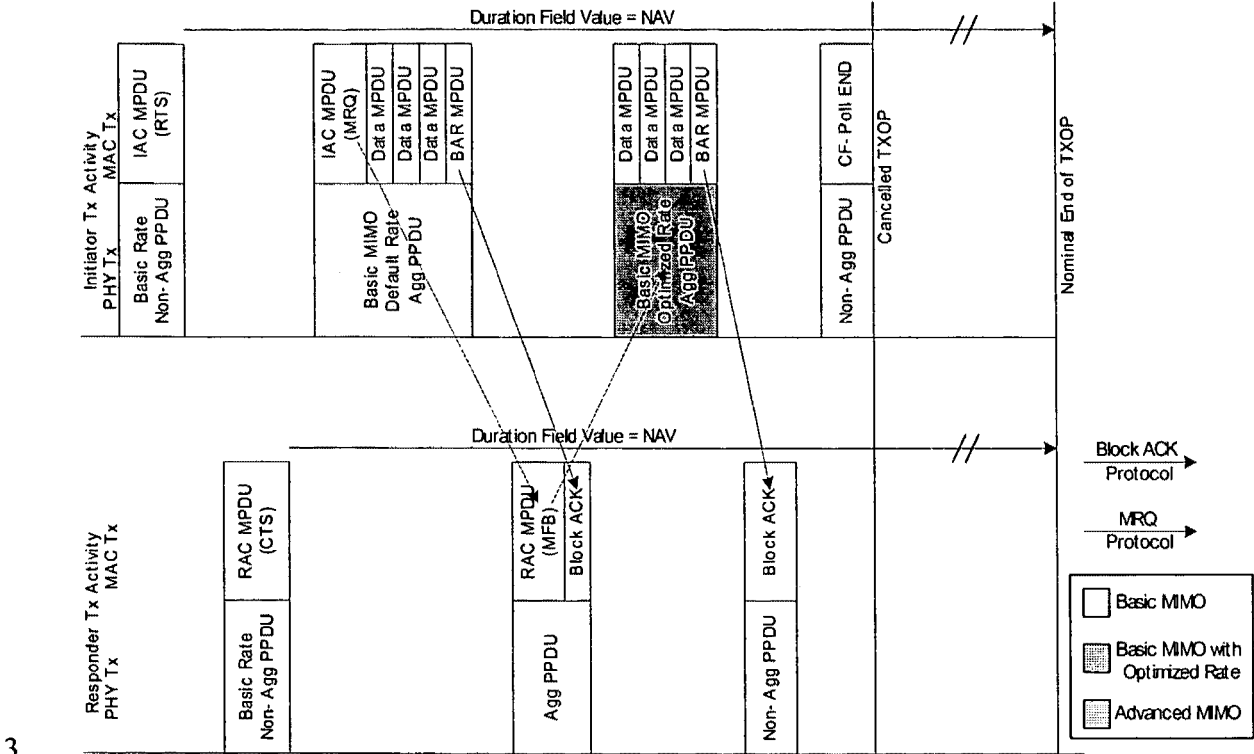


Figure 15 – LongNAV, untrained unidirectional exchange

The responder may want to request some reverse direction, or to send a training response in addition to sending a BA. In this case, it uses an aggregate to collect together this information.

Note: The initiator does not know which of these the responder will elect to do, and so provides an RDG that supports the transmission of the longest response.

- 1 In the example below, the responder uses an aggregate to return a MFB(MCS Feedback) plus a  
2 Block ACK, in response to a MRQ(MCS Request) in the IAC and a BAR(Block ACK Request).



5 **Figure 16 – LongNAV, untrained unidirectional showing aggregate response**

- 6 The next diagram shows an example when training is involved.
- 7 First, a pair of IAC/RAC packets are sent at a basic rate (SISO mode), so that any third party
- 8 nodes, including legacy nodes can set its NAV correctly. In the next IAC packet, the TRQ
- 9 (Training Request) element is indicated to show that the following packet will be sent at an
- 10 “Advanced MIMO Mode (MIMO with implicit Feedback)”. In response to the TRQ, the responder will send its response PPDU with the TXVECTOR SOUNDING parameter set to 1.
- 11 Also, in the second IAC, the MRQ (MCS Request) element is indicated to request a MCS
- 12 Feedback, so that the modulation scheme may be selected by the responder.
- 13 When the initiator chooses to end the TXOP before the nominal end of the intended TXOP, it
- 14 sends a CF-Poll End packet at a Basic Rate to cancel the TXOP.

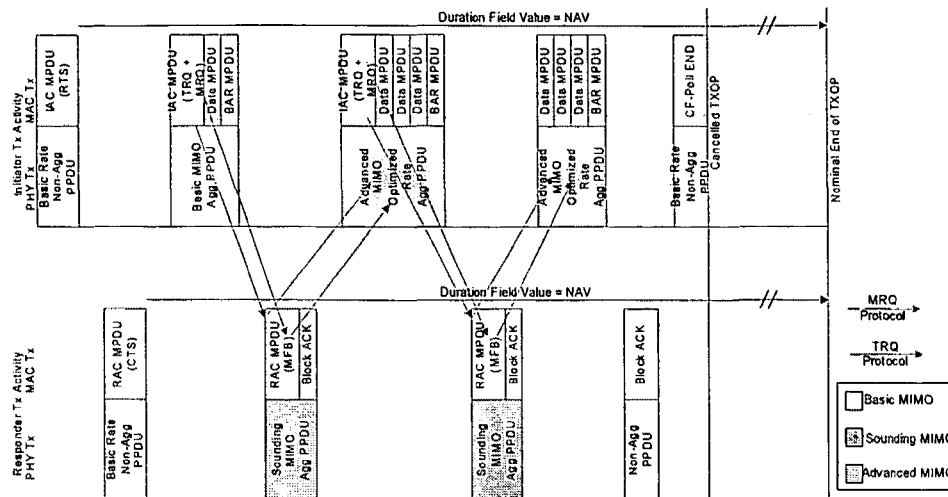


**Figure 17 – LongNAV, trained unidirectional showing aggregate response**

### 7.1.9.2 Pairwise Spoofing example

The next set of examples shows uses of Pairwise Spoofing, unidirectional.

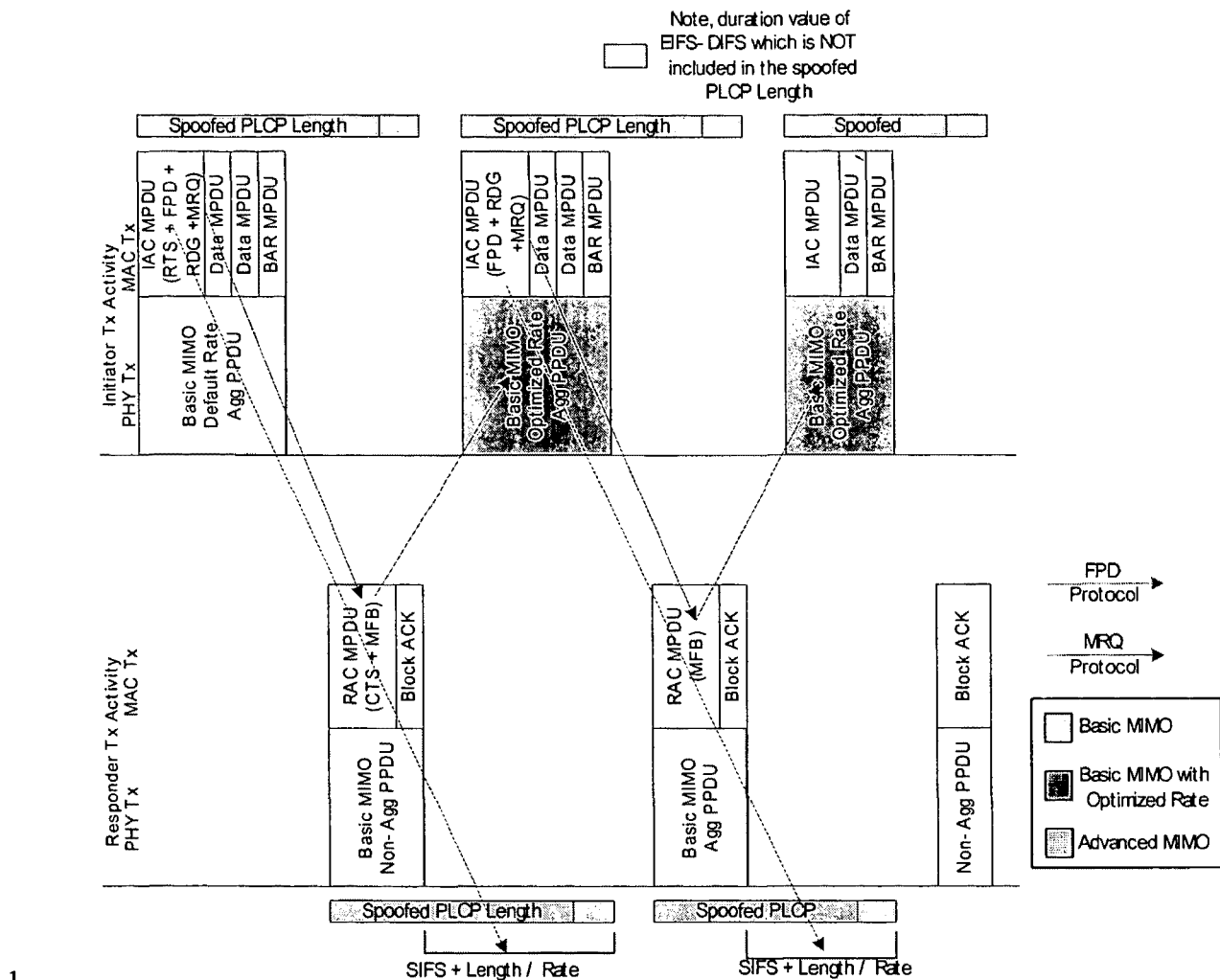


**Figure 18 – Pairwise Spoofing, Untrained Unidirectional Exchange**

An initiator starts with an IAC MPDU containing an FPD (Following Packet Descriptor) and an RDG big enough to hold the RAC response PPDU. Also, an MRQ is present to request MCS selection by the responder. The PPDU carrying the IAC MPDU will have a spoofed duration, set by the Rate and Length Field of the SIGNAL, which protects the RAC MPDU and Block ACK MPDU of known size.

The Responder answers with a RAC MPDU containing an MFB (MCS Feed Back) element. The MFB species the MCS at which it expects to receive the next PPDU from the initiator. When this MFB Field is not present, the Initiator will send its next PPDU at the default MCS specified in the FPD Field. The PPDU containing the RAC MPDU will have a spoofed duration of Length (in the FPD Field) divided by the Rate (either the default MCS or the MCS selected in the MFB) minus (EIFS – DIFS). For details on Spoofed NAV, see section 8.1.7.1.

After receiving the RAC MPDU, the initiator will send its aggregated MPDU at the MCS specified by the MFB Field. This aggregated MPDU will have a spoofed duration, which protects the fixed sized RAC MPDU and the expected response from the BAR (Block Acknowledgment Request) that it has sent.

This process will continue until the expiry of Initiator's TXOP or when the Initiator has no more packets to send.

The following example considers what happens when there is training involved.

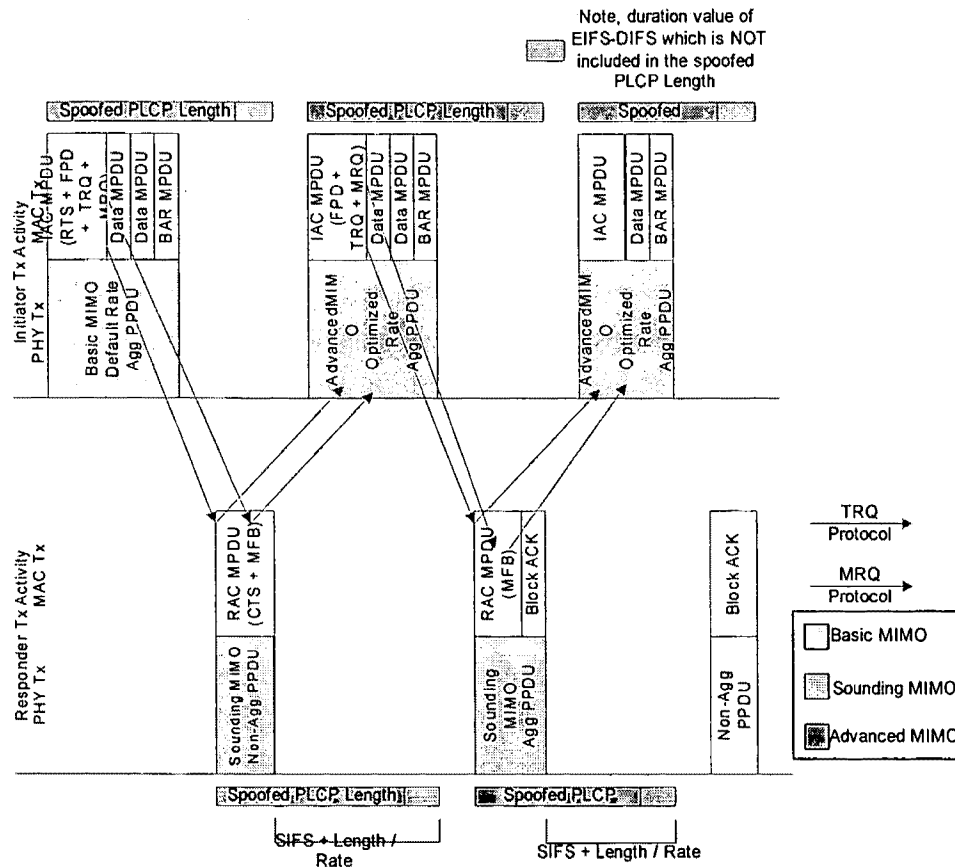


Figure 19 – Pairwise Spoofing, Trained Unidirectional Exchange

In the example shown above, the Initiator's MRQ element is used to optimize MCS selection at the responder. This optimized MCS is carried in the RAC MPDU.

Also, the TRQ (Training Request) element is present to show that the following packet will be sent at an "Advanced MIMO Mode (MIMO with implicit Feedback)". In response to the TRQ, the responder will send its response PPDU with the TXVECTOR SOUNDING parameter set to 1.

#### 7.1.10 Bi-directional data transfer

##### 7.1.10.1 RDL/RDR/RDG Rules

A STA that is an initiator may advertise willingness to provide reverse direction data flow by including a RDL element in its IAC.

A STA that is a responder may request reverse direction using an RDR element. This contains the length of data in the PPDU it would like to send, plus a default MCS. An MFB element may accompany the RDR, and the initiator may determine an updated MCS based on their contents.



1 In determining an RDR value, a STA shall only consider eligible for transmission those MPDUs  
2 that meet any RDTID constraint contained in the previous IAC.

3  
4 The initiator receiving the RDR information (and possibly augmented by the MFB) calculates a  
5 duration request. Its next IAC contains an RDG element containing the allocation for reverse  
6 direction data, plus any additional grants as defined in section 7.1.3.

7  
8 The initiator is free to grant any RDG it wishes (compliant with the TXOP rules) including: no  
9 duration, the exact duration implied by the RDR, or any other duration it likes. Under pairwise  
10 spoofing rules an initiator should not grant an RDG that is longer than the RDR (plus additional  
11 duration as described in section 7.1.3), otherwise it may cause the channel to be used  
12 inefficiently.

### 13 **7.1.10.2 TXOP and RDG**

14 An initiator that grants one or more response periods using RDG shall ensure that that its current  
15 PPDU and any scheduled response periods all fit entirely within the current TXOP.

16 It is up to the initiator to decide whether to also allow for any response it might have to make to  
17 the frame described by the RDG. For example, the PPDU sent next by the responder may  
18 include multiple BAR MPDUs.

19 The initiator can either allow for these responses it may have to make in making its RDG  
20 allocation, in which case it will have time to transmit a response before the end of the TXOP, or  
21 it may decide not to allow for its own responses. In this case, the responder may send a BAR,  
22 but there might be no time to send the BA in the current TXOP. The responder will assume that  
23 the BAR was not received and will retry it subsequently.

7.1.10.3 LongNAV Bi-Directional Example

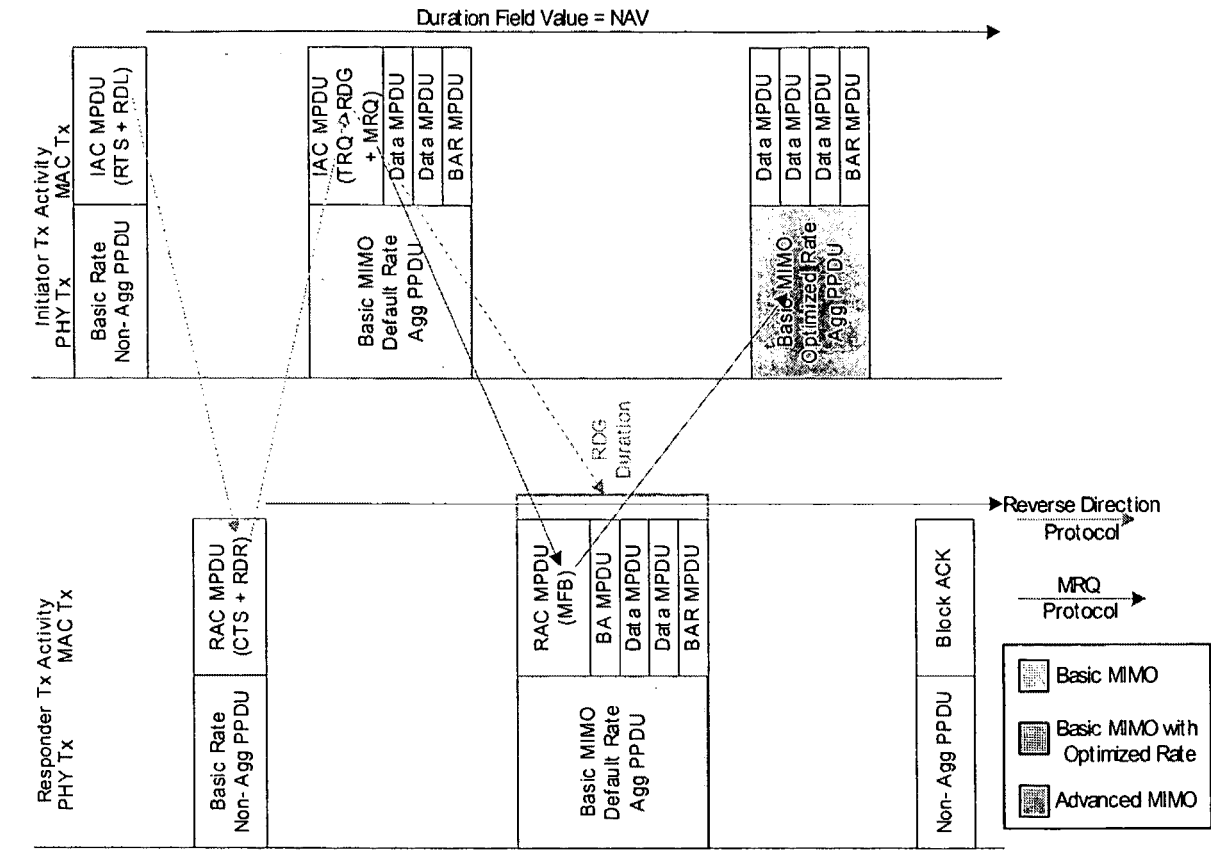


Figure 20 – LongNAV Bi-Directional Example

Initiator sets the granted RDG duration long enough to include any expected response (e.g. RAC + BAs).

The granted RDG duration includes the duration of reverse data plus any expected responses (RAC + BAs). This duration for reverse data may be less than the requested duration, in which case the responder must reduce the amount of data it sends. The responder can also itself reduce the amount of reverse data it sends. Any response PPDU duration no longer than the RDG duration is valid.

If no response is necessary, the responder does not need to send a PPDU, and the initiator can continue after a PIFS with no start of frame detected.

There is no need for a responder to send an RAC unless one or more of its logical elements need to be signaled.

7.1.10.4 Pairwise Spoofing Example



2

3

6

7

## 8

## 9

10

11

13

15

1 The initiator schedules the response periods according to local policy, except as specified here.  
 2 The first response period shall start no less than a SIFS after the end of the MRA PPDU.  
 3 Typically the initiator will arrange that response periods are separated by SIFS, but there is no  
 4 normative requirement for this to be the case.  
 5 An example of the scheduling scheme is shown in Figure 22, where the MRA addresses 3 HT  
 6 clients.

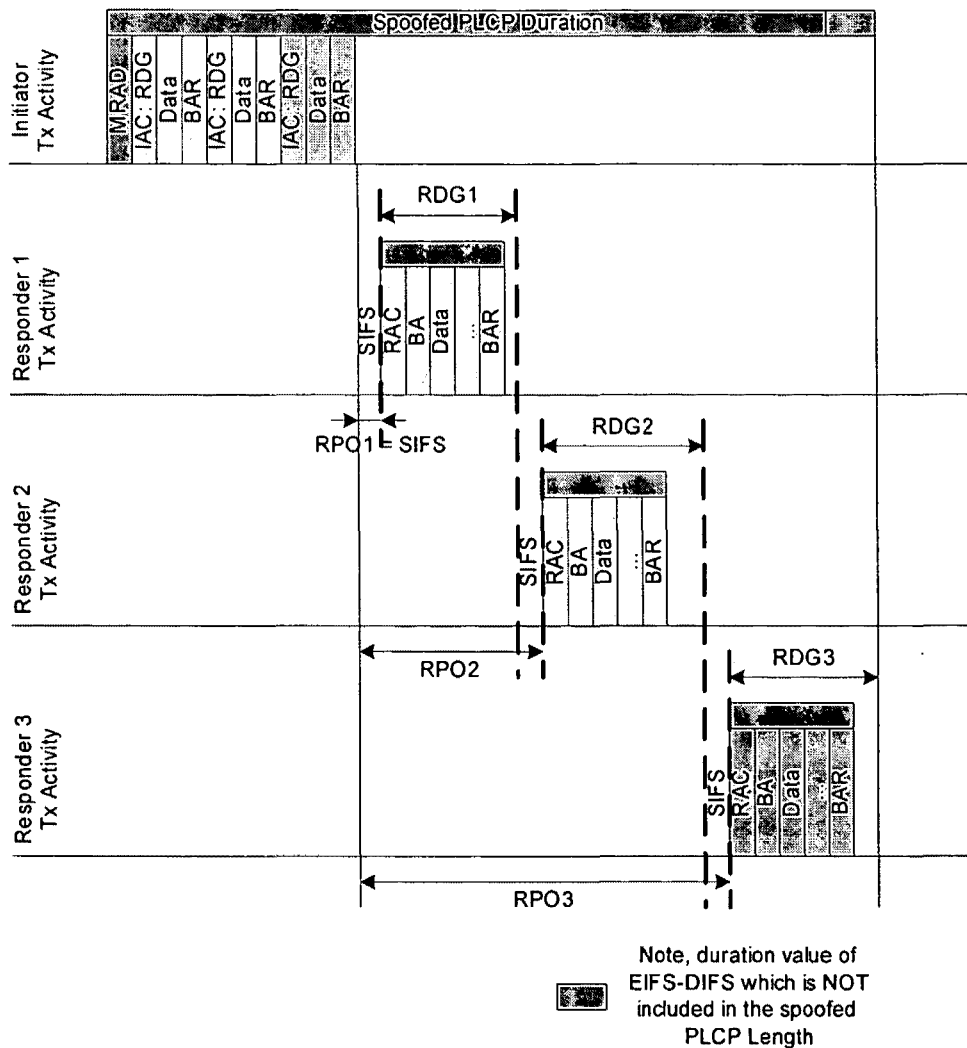


**Figure 22 – Example of MRA response scheduling with 3 responders**

#### 7.1.11.1.1 Scheduling heuristics for MRA (Informative)

When creating an MRA, the HT AP may select receiver addresses so as to optimize throughput. Typically, if clients are sending small amounts of data, the benefits of MRA aggregation should outweigh any reduction in transmit rate. Above a certain data duration, this may no longer hold true. The HT AP can, in principle consider sending to an HT STA separately using its known transmit parameter versus including it in an existing MRA in order to determine which is the more effective use of the channel.

When using spoofing protection, the length of spoofed length field in the PLCP header imposes a limit of the total duration of a MRA and its multiple immediate ACKs/BAs plus data.

#### 7.1.11.1.2 Mixture of periodic and aperiodic traffic

The HT AP may also mix periodic and aperiodic behavior within the same MRA sequence. It can mix periodic and aperiodic transmissions but it cannot mix periodic and aperiodic RDG to a single HT STA in the same response period because these would require different RDTID values within the same IAC.

Within the same sequence of aggregates, the HT AP may change the RDTID type to a particular receiver. So, an HT AP could service a periodic RDR TS and transition to servicing best effort traffic to the same HT STA in a later PPDU.

#### 7.1.11.2 Protection Rules for MRA

An MRA exchange may be protected using either LongNAV or single-ended spoofing.

In the LongNAV case the NAV of all devices that can hear the initiator has already been robustly set by transmission of a previous MPDU. In this case, the MRA PPDU should not carry a spoofed duration because it limits the ability of the initiator to recover unused RDG at the end of the response period. The single-ended spoofing case is applicable when there is no apriori NAV setting. In this case, the initiator sets the spoofed duration of the MRA PPDU to include from the start of this PPDU up to the end of the last scheduled response period as indicated by the IAC MPDUs within the aggregate.

In this spoofing case, the initiator does not generate FPD elements in its IAC MPDUs, and so the responders do not generate a spoofed duration for their response PPDUs.

In the case of LongNAV protection, the initiator may continue with a transmission a SIFS after the actual end of the last response PPDU. In the case of spoofing protection, the initiator may continue its transmission a SIFS after the end of the last response period, regardless of the actual length of the response.

#### 7.1.11.3 Rate Selection

When a STA transmits a MRA to multiple receivers, it shall ensure that the MRA is sent using transmit parameters that should make the PPDU receivable by all receivers in the MRAD.

It has to respect their receiver capabilities (e.g. supported MCS values, number of rx antennas, optional coding capabilities) and select a "lowest common" set of parameters that should be consistent with reception at all these STAs.

If it contains multicast/broadcast Data, the rate is further constrained so a rate in the basic MCS set.

**7.1.11.4 Interaction of MRA and TRQ+MFB (Informative)**

Consider the two possible uses:

1. Periodic
2. Best Effort

In the periodic case, if the shelf-life of the training information is longer than the interval between service periods, the initial MRA can contain training requests for multiple STAs. The STAs can generate forward direction rate feedback and a reverse direction training request in their responses. The initiator can then generate a final MRA containing the reverse direction rate feedback. So at the end of each cycle, rate feedback has been exchanged in both directions for use in the next service period.

In the best effort case, the initial MRA contains the training requests (and RDL values). The responses contain the rate feedback (and RDR). After the first MRA and responses, the forward direction is now trained, so an MRA containing data can be transmitted and also containing rate feedback and RDG for the reverse direction.

**7.1.11.5 Examples of MRMRA frame transfer**

The examples below for MRMRA frame exchanges are illustrative rather than restrictive.

**7.1.11.5.1 Periodic Traffic**

To support periodic RDR TSs, the AP periodically sends an IAC containing a response period specific to that TS. These IACs may be aggregated into an MRA.

The PPDU is then followed by one or more response periods during which the responder sends any RAC, any BA, its data for the specified TS and a BAR.

At the end of the responses, the initiator then sends an aggregate containing Block ACKs. It may also contain IACs scheduling response grants for any transmissions from responders that were not correctly received as well as retransmissions of data that were not acknowledged.

The cycle of MRA followed by responses terminates when either there is no more time in the service period, or when all data to and from the initiator has been successfully received.

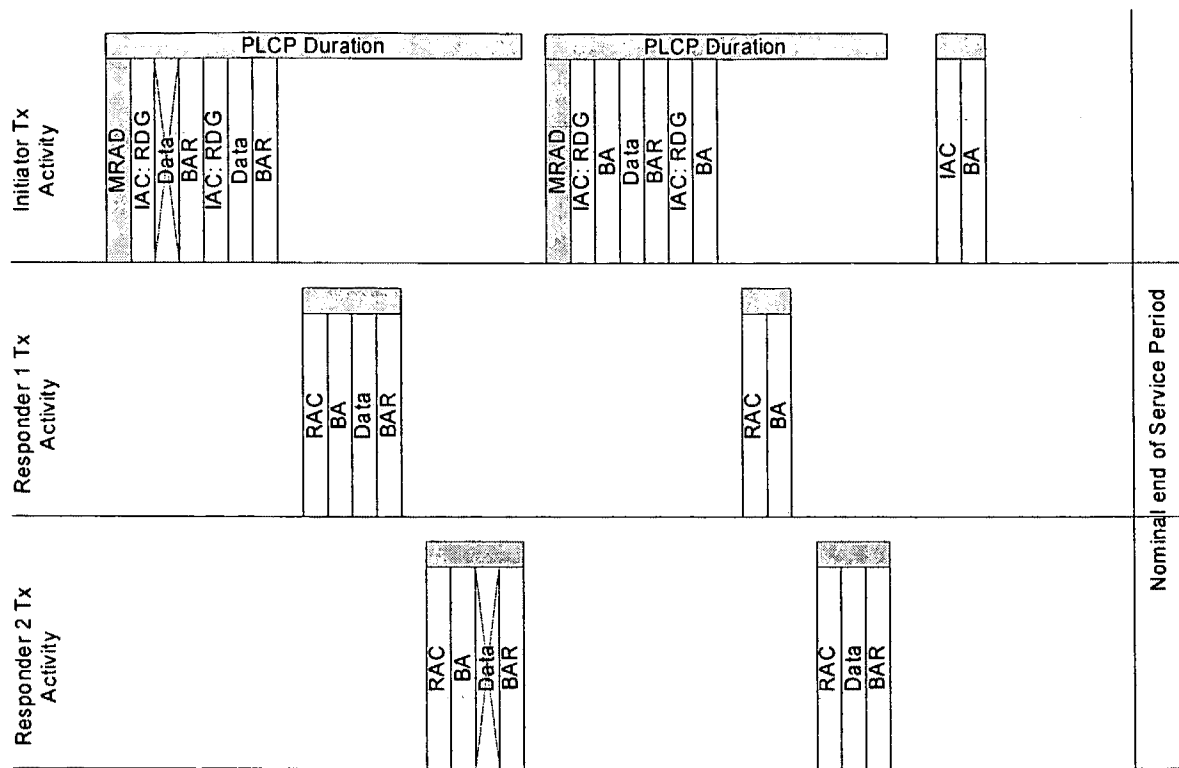


**Figure 23 – MRMRA Example for Periodic Traffic**

In the example shown above, an AP has two STAs with established periodic RDR in the uplink direction (the downlink is also periodic, and part of the same composite schedule).

The first PPDU is an MRA containing a MRAD that lists the two responders. For each responder there is an IAC containing a grant for its uplink data (plus RAC, BA, BAR), some data and a BAR. The spoofed duration of the first PPDU includes the MRA and the two response periods.

The first responder generates a response PPDU containing an RAC (not strictly necessary), BA, Data, BAR. Because it didn't receive the data properly the BA says this.

The second responder generates a response PPDU containing an RAC (not strictly necessary), BA, Data, BAR. In this case because it received the data correctly the BA indicates this.

The initiator generates a PPDU containing the retried data to responder 1 and grants to both responders. The grant to the first responder is because it has transmitted a BAR and wants the BA. The grant to the second responder is because it did not correctly receive all of the uplink data and is scheduling an opportunity to retransmit.

The responder 1 then sends the BA, and the responder 2 successfully transmits data and BAR.

The initiator needs to respond to the BAR and sends an aggregate containing the BA. Because this is sent to a single receiver, this aggregate does not contain a MRAD. Strictly, the IAC is not necessary, and the response could be sent in a non-aggregate PPDU.

### 7.1.11.5.2 Aperiodic Traffic

The MRA may also be used with aperiodic traffic. Aperiodic traffic has no implicit RDR at the start of the sequence. In this case, the initiator sends an MRA containing one or more IACs containing a scheduled response period big enough to contain an RAC and any expected BA MPDUs.

The initiator advertises its willingness to allow aperiodic traffic in an MRA response by including an RDL value and specifying an RDTID that does not correspond to a periodic RDR TSID.

The responder can also, at this point, generate an RDR to request additional response duration for its data transmissions to the initiator.

Note, from the receiver's point of view, this sequence is exactly the same as for a LongNAV bidirectional single-receiver sequence – except for the absence of the initial RTS/CTS and timing of the response period.

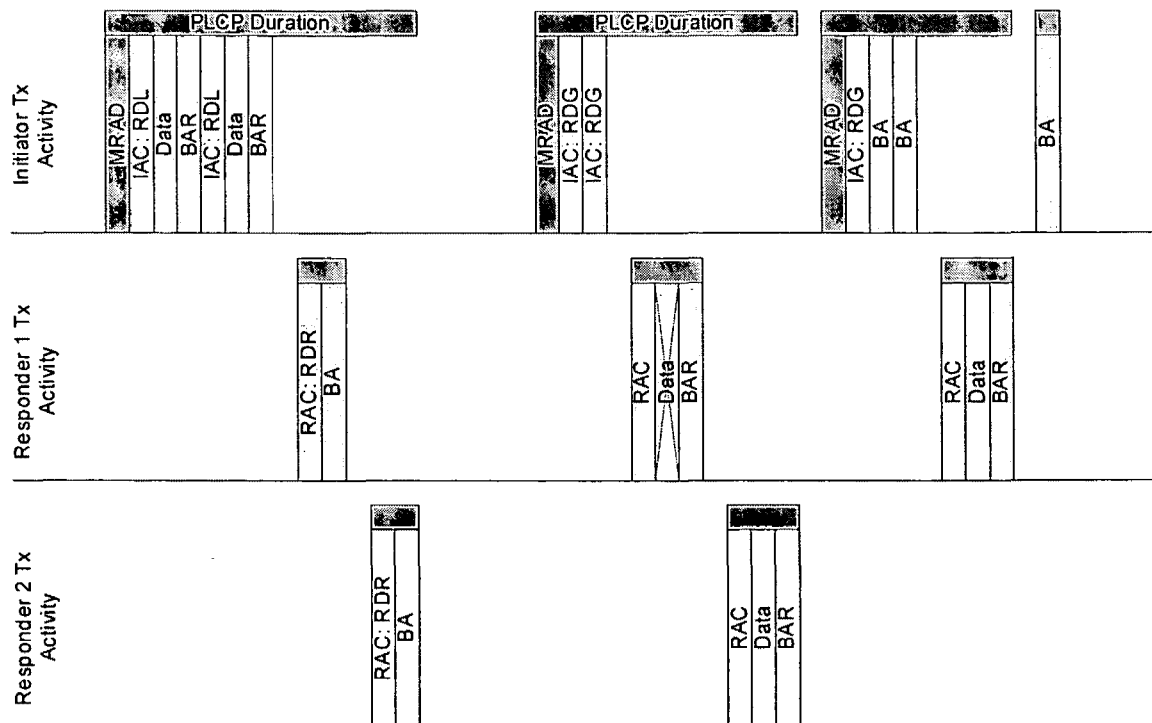


Figure 24 – MRMRA Example for Aperiodic Traffic

## 7.2 MAC Header Compression

### 7.2.1 Introduction (informative)

Frame aggregates can contain multiple Data MPDUs with similar MAC Headers. MAC Header Compression reduces the overhead associated with the MAC Headers of these MPDUs. The efficiency gain of MAC Header Compression depends on the number and size of the Data MPDUs in the frame aggregate.



A transmitting STA or AP includes a MAC Header (MHDR) MPDU in an aggregate frame. This MPDU then provides MAC header information to multiple Compressed Header Data (CHDATA) MPDUs. Both MPDUs include a Header Identity (HID) to relate a CHDATA MPDU to the corresponding MHDR MPDU for MAC header information.

### 7.2.2 Functional description

MAC Header compression is limited to the boundaries of a frame aggregate, i.e. only Data MPDUs within a single aggregate are compressed using MAC Header compression. As a consequence MAC Header (MHDR) MPDUs and Compressed Header Data (CHDATA) MPDUs are not present outside the boundaries of a frame aggregate.

The following functionalities apply to a transmitting- and receiving STA or AP in an 802.11n network:

- It is optional for a transmitting STA or AP to use MAC Header compression in a frame aggregate.
- It is mandatory for a receiving STA or AP to handle compressed MAC MPDUs in a frame aggregate.

#### 7.2.2.1 Transmitting side

When the transmitting STA or AP uses MAC Header compression it includes a MAC Header (MHDR) MPDU, identified by a Header Identity (HID), in the aggregate.

The transmitting STA or AP includes one or multiple Compressed Header Data (CHDATA) MPDUs, each having the same HID as the corresponding MHDR MPDU.

The transmitting STA or AP may include multiple copies of MHDR MPDUs to increase robustness in case of loss of a MHDR MPDU. These MHDR MPDUs may be located anywhere within the sequence of CHDATA MPDUs subject to the constraints specified in section 7.2.3.

The transmitting STA or AP performs MAC Header compression per destination and per Traffic Class separately.

Retransmissions of CHDATA MPDUs may be as either uncompressed Data or CHDATA MPDUs.

#### 7.2.2.2 Receiving side

A receiving STA or AP determines whether MAC Header compression has been used based on the Type and Subtype definitions in the received MPDUs.

A receiving STA or AP uses the fields from the MAC Header (MHDR) MPDU to replace the missing fields of the Compressed Header Data (CHDATA) MPDUs, having the same HID value, to recreate full Data MPDUs.

MHDR MPDUs are not acknowledged by the receiving STA or AP.

The acknowledgement policy of CHDATA MPDUs is defined in the QoS field as present in the corresponding MHDR MPDU. When acknowledgements of CHDATA MPDUs are required, the existing Block Acknowledgement scheme is used. Retransmissions of corrupt or non-received CHDATA MPDUs by the transmitting STA or AP are supported by the presence of standard sequence numbers in these MPDUs.

CHDATA MPDUs for which no corresponding MHDR MPDU is found in the frame aggregate, are discarded.

### 7.2.3 Ordering constraints for MHDR and CHDATA MPDUs

Only a single MHDR needs to be stored by a receiver in order to fully reconstruct an aggregate containing CHDATA MPDUs.

A CHDATA MPDU for a particular HID must be preceded by at least one MHDR MPDU for the same HID. No MHDR for a different HID may occur between a CHDATA and its matching MHDR MPDU(s).

Within an aggregate, MHDR MPDUs that are not identical shall have different HID values.

### 7.2.4 Multiple receiver aggregates

The Header Identity (HID) ensures a unique link between a single MAC Header MPDU and a CHDATA MPDU. For each receiver address in a Multi Receiver Aggregate, a MHDR MPDU is included in the aggregate with a unique HID. The subsequent CHDATA MPDUs include the HID for the corresponding MHDR MPDU.

## 7.3 Multirate support

The Supported MCS Set (6.3.1) and Basic MCS Set (6.3.2) indicate MCS values for HT format PPDU only.

The existing basic rate and supported rate sets indicate rate selections for legacy format PPDU only.

Rate selection for control frames:

A control frame that needs to be received by legacy devices (i.e. to set the NAV) shall be selected from basic rates in the BSS's basic rate set, and transmitted using the legacy PPDU format.

Multicast/broadcast frames in pure mode and control frames that need to be received by HT devices only shall be selected from the Basic MCS set.

Control frames that need to be received by a single HT device only may be sent at any rate supported by the intended receiver. An example of this is a single Ack/BlockAck by a responder within a sequence protected by LongNAV.

Under pairwise and single-ended spoofing rules, it is not necessary for any third part HT STA to be able to receive MPDUs, so aggregate PPDU may use any MCS supported by the intended receiver(s).

## 7.4 QoS enhancements

### 7.4.1 802.11e Requirement

An HT device shall support the mandatory features of an 802.11e QSTA.

An HT device shall support the use of the Block ACK mechanism introduced in 802.11e.

The default TXOP limit is 3.008 ms for Best Effort (BE) traffic. This value needs to be validated by simulation in order to determine the effect of this value on bandwidth differentiation between Best Effort and Video (VI) traffic. This value should be considered to be a place-holder.

A TXOP limit of zero is considered to allow an Aggregate exchange sequence containing the transfer of at most a single MSDU or MMPDU, which may be fragmented and acknowledged using the block Ack protocol.

#### 7.4.2 Interactions with 802.11e TSPEC (Informative)

Because our PHY rates cover a much wider range than legacy PHYs (and also potentially very much faster changes too), this increased variability interacts with the TSPEC mechanism that attempts to guarantee some agreed level of service.

In 802.11, providing an application with a guaranteed service level is difficult because:

There is no guarantee that the channel is sufficiently idle to provide this service level (the effect of interference or competing channel access).

If one or both peers of the link (or indeed, anything in its environment) are mobile, the channel between the peers may change so that the desired data rate cannot be achieved.

While the problem is not specific to 802.11n, the problem is worse in 802.11n because the PHY can adapt to the channel capacity quickly and accurately using a training exchange resulting in a very wide range of effective PHY rates that changes rapidly.

802.11e provides a mechanism that allows a traffic specification (TSPEC) to be negotiated between client and AP. The methods described here extend these mechanisms to address these issues.

Two main adaptation methods (and some variants) are described below. These are not mutually exclusive; each may be more appropriate depending on the application. The adaptation method to be used can be negotiated when the TSPEC is created.

Method 1 relies on renegotiation between the MAC and application. Method 2 relies on discarding application packets when the going gets tough. One or both methods may be used, and their use is negotiated when a TSPEC is first created.

#### 7.4.3 TSPEC renegotiation

A QSTA negotiates with a QAP to provide a specific level of service using a TSPEC request (current behavior). Critical to this scheme is that it includes a minimum PHY rate parameter and a data rate. (It may include multiple data rates, such as mean and peak, but this is not important here).

We add two new types of negotiation: upward (an improvement in service) and downward (a reduction in service).

An upward negotiation is initiated by the QAP when one of the following occurs:

- An observation by the QAP that the channel load is less than some threshold. In evaluating the channel load, the QAP should replace the observed load taken by each TSPEC with its maximum committed value.

- An observation that the actual PHY rate used by a TSPEC is significantly higher than the minimum PHY rate negotiated in the TSPEC. The actual rate can be averaged over some period of time. The QAP can avoid repeated refused renegotiations by recording the "last offered minimum PHY rate" and only attempting a renegotiation if the actual rate is higher than this as well. "Significantly" can mean, for example, a fixed threshold above the current values.
- Deletion of some other TSPEC, thereby making additional capacity available.

A downward negotiation can be triggered by:

- An observation that the actual PHY rate (either instantaneously, or averaged over some period) is less than the minimum PHY rate specified in the TSPEC.
- An observation that the channel free time is not enough to service existing TSPEC commitments. This might arise, for example, if a nearby co-channel BSS starts operation, or due to non-802.11 interference.
- A request to create a new TSPEC or modify an existing TSPEC is received at the QAP from this QSTA, or some other QSTAs.

Renegotiation is started by the QAP, which sends a TSPEC proposal to the QSTA containing the proposed new service parameters and the reason for the renegotiation.

The QSTA can accept the proposal as specified or modify it to some lower level of service (for example, to match a specific application traffic profile). In the case of upward negotiations the QSTA can refuse the suggestion – meaning that it has no use for the additional resources. In the case of downward negotiations, the QSTA can also refuse the suggestion, but only if the reason for the reduction is to admit some other TSPEC. In other cases, the QSTA must either accept the suggestion, or make a reduced suggestion, or delete the TSPEC.

#### 7.4.4 TSPEC Packet Loss Priority (PLP)

The QSTA may negotiate use of packet loss priority (PLP) when a TSPEC is set up, or subsequently.

A QSTA with a PLP-enabled TSPEC adapts, potentially per transmission opportunity (TXOP), to the amount of available time and the channel conditions by discarding "less important" parts of the application traffic (such as the higher-numbered MPEG-4 FGS layers). This is operated at the source end of a TSPEC – either QAP or QSTA.

PLP requires that the application generate separate packets that are marked with a "packet loss priority" value. A zero value of packet loss priority means that the packet is very important (should not be discarded). High values mean that the packet is unimportant (can be discarded).

The TSPEC shall contain a delay bound. The operation of the PLP mechanism ensures that packets are not delayed in the transmitting MAC any longer than this value.

The TSPEC shall be associated with a Block ACK agreement. This is necessary because MSDUs are transmitted out of order with the "most important" ones first.

When a QSTA gets a transmit opportunity, it transmits together all buffered packets of the lowest buffered packet loss priority, gets a selective acknowledgement and performs any necessary

retries until these are all successfully transmitted, their expiry time is reached or the transmission opportunity ends. This is then repeated until the buffer is empty or the transmission opportunity ends.

The transmitting MAC shall ensure that packets that have been successfully transmitted are delivered to the LLC before their delay bound is reached. This can be achieved by transmitting a Block ACK to move the starting sequence number in order to flush received packets.

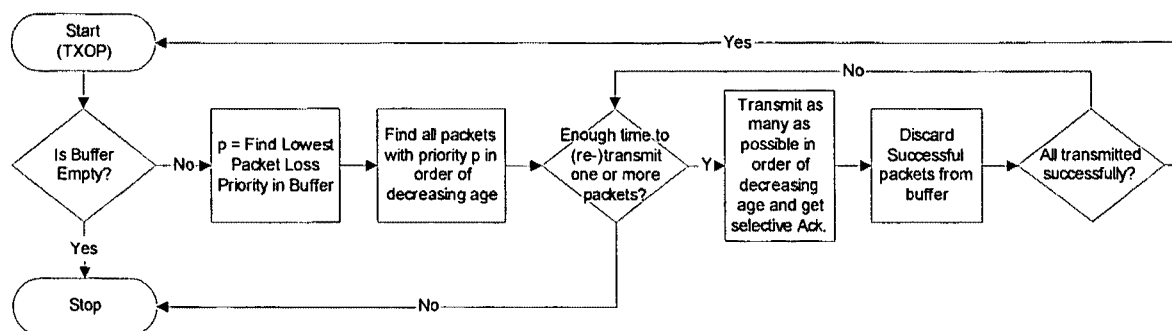


Figure 25 – Flowchart of PLP mechanism

## 7.5 Scheduling (Informative)

### 7.5.1 Introduction

A data transfer sequence may contain multiple MSDUs carried in one or more aggregate PPDUs.

The best throughput performance is gained when the length of the aggregate is maximized and the number of PPDUs is minimized. However, this maximum throughput is potentially gained at the expense of increased transport delay.

Apart from the effects of power-saving and 802.11e prioritization, a legacy 802.11 STA normally transmits MSDUs in the order that they are received at its MAC SAP.

Keeping this constraint on 802.11 HT would make throughput strongly dependent on the application traffic pattern at the MAC SAP. Therefore we allow a STA to reorder and delay transmission in the hope of building longer aggregates and using the medium more effectively.

Note: these schedulers are specific to single-receiver aggregates.

### 7.5.2 Scheduler 1

A STA keeps a queue per access category of Data MPDUs for transmission.

The STA starts its channel access attempt as soon as any queue is non-empty.

When a TXOP is gained, the STA selects one of its transmit queues according to HCF rules. The MPDU at the head of this queue defines the receiver address. The STA then scans its transmit queues for more MPDUs addressed to the same receiver. These are available for transmission during the aggregate exchange.

For a sequence using embedded training, the rate may be modified when rate feedback is received. After an initial IAC/RAC training exchange, the STA can calculate how many of the MPDUs addressed to this receiver can fit in the available TXOP and transmits one or more aggregates containing these MPDUs.

### 7.5.3 Scheduler 2

In scheduler 1, the identity of the receiver is selected by HCF channel access, and is always defined by an MPDU at the top of an access category transmit queue. Furthermore, when an access category is not empty, a channel access attempt is active.

Scheduler 2 changes these two properties.

It delays EDCA channel access until:

- There is an aggregate to send exceeding some threshold length, or
- An MPDU has been delayed more than a certain threshold time in a transmit queue.

Once channel access is gained, the STA selects a receiver address as follows:

- If any MPDUs have exceeded the delay threshold, select the oldest one, or
- Select the receiver with the most buffered data

The effect of this algorithm is that an application flow (i.e. point-point link) that is saturated sees low delay and high throughput. Aggregate throughput is maximized because the scheduler prefers the longest aggregate.

An application flow that is low-rate and isochronous sees additional delay, because it never exceeds the length threshold, so it gets transmitted only when its delay threshold has been exceeded.<sup>2</sup>

### 7.5.4 Retransmissions and Allocation of Time

The strategy that maximizes throughput is to maximize the duration of aggregates, and minimize the number of PPDU's.

According to this strategy, a STA with a fully backlogged transmit queue will generate an aggregate that, together with the expected response, just fills the TXOP.

Any MPDUs that were not correctly received in the TXOP will have to wait for a subsequent channel access for retransmission.

An alternative strategy can be used that trades throughput for average channel access delay. This can be particularly useful with data for which a traffic specification (TSPEC) exists that specifies a delay bound.

In this case, the STA monitors or predicts the PER<sup>3</sup> From this, it can predict the number of failures in an aggregate, and leave enough room for retransmissions.

---

<sup>2</sup> Note, do not confuse this threshold with an MSDU lifetime limit. The delay threshold is the delay below which no channel access attempt need be made. The MSDU lifetime limit is the delay after which delivery is useless, which is hopefully a bigger number!

<sup>3</sup> How it does this is not relevant here.

One way of allocating enough room is to require that the aggregate ( $N_{\text{aggregate}}$ ) and its retries ( $N_{\text{retries}}$ ) are expected to fit within the TXOP with some defined probability – known here as a confidence limit.

For any defined aggregate length and PER, the space to reserve for retries can be determined by inspecting a cumulative distribution function (Prob errors < N vs N) at the required confidence limit. If the packet errors are independent, a cumulative binomial distribution can be used.

## 7.5.5 Selecting RDL/RDG values

### 7.5.5.1 Scheduling decisions for RDL/RDG (Informative)

In a bi-directional data sequence, the initiator can control the amount of time spent by the responder in response (aggregate) PPDU through use of the RDG element. There are two scheduling decisions to be made:

- How much of the time to offer to the responder (RDL and RDG)
- How to use the offered time at the responder

The bi-directional data sequence is designed to allow trained data to flow in both directions, sharing the overhead of channel access and training exchange.

The mechanism was designed specifically to allow a TCP link to "piggyback" TCP ack collection onto TCP data transmission. In the ideal mode of operation, the TCP data downlink for a half congestion window of data collect the TCP ack uplink for the previous half congestion window's worth of data.

In this mode, the transmissions by the responder are short TCP ACK MSDUs.

Assuming that the Block ACK protocol is being used to allow the use of aggregate PPDU, there is some limited opportunity for the responder to select Data MPDUs from its transmit buffer, subject to Block ACK windowing constraints so as to use the offered response duration.

### 7.5.5.2 Simple RDL/RDG heuristic

This section contains an initial recommended heuristic.

The initiator will normally try and fill the TXOP with its own data. Aggregate throughput is maximized by maximizing the length of the data in a TXOP. This is best achieved with known data rather than potential response data.

If there is an excess of data buffered for the chosen receiver address, the initiator does not advertise any reverse direction (RDL=0).

If there is room in a TXOP after delivering all its own data, the initiator can send an aggregate containing a non-zero RDL indicating the remaining TXOP duration. If the responder does not respond with a request (i.e. RDR=0), the sequence terminates.

If, on winning a TXOP, the initiator has less data than will clearly fill the TXOP, it can advertise some fraction of the TXOP in its initial IAC, thereby allowing possible reverse direction data flow early in the sequence, and maximizing throughput.

The responder uses any offered response duration for its data of the same user priority or access category, without any intentional reordering of data packets within the access category. This

- 1 recommendation is based on the understanding that if there are no large packets in the
- 2 responder's buffer, any TCP ACKs will get sent. But if there are, the responder's TCP ACKs
- 3 can be sent as part of a later data exchange sequence it initiates, and that good efficiency will be
- 4 achieved due to the presence of the large packets.
- 5 This proposed mechanism does not seek to achieve low TCP RTT, but only good utilization of
- 6 the medium.



## 8. MAC sublayer management

### 8.1 Coexistence management

#### 8.1.1 Operating Modes

The operating modes of an HT BSS are defined in the following table. These modes are used to control the format of beacon transmission and what kind of protection must be used for HT transmissions.

| Topology             | BSS Mode Name             | Definition of Mode                                                                                                                                                                                                                                                                                                       |
|----------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Infrastructure       | Pure                      | No co-channel legacy devices are present                                                                                                                                                                                                                                                                                 |
|                      | Mixed Capable             | No co-channel legacy devices are present, but the HT AP is able to accept association from a legacy device that discovers this BSS (e.g. through receiving its legacy beacon) and decides to associate.                                                                                                                  |
|                      | Managed Mixed             | Legacy and HT devices are present co-channel. Access to the medium is managed by an AP.<br><br>Note: time divided between contention period for HT and one for legacy stations (by selectively setting the NAV)                                                                                                          |
|                      | Unmanaged Mixed           | BSS contains both legacy and HT devices or there are co-channel legacy devices of a different BSS present                                                                                                                                                                                                                |
|                      | 20 MHz-Base Managed Mixed | BSS contains both legacy and HT devices. There may be legacy devices of overlapping BSS in either or both of the channels. Legacy and HT devices associate to the AP's BSS in the control channel. The AP manages the generation of 40 MHz mode periods, during which 40 MHz HT devices are allowed to access in 40 MHz. |
| Independent (ad-hoc) | Discoverable IBSS         | No co-channel legacy devices. The IBSS may be discovered by a legacy device.                                                                                                                                                                                                                                             |
|                      | Mixed IBSS                | There are legacy devices co-channel                                                                                                                                                                                                                                                                                      |

#### 8.1.2 Receiver capabilities wrt legacy operation in the extension channel

An HT AP or IBSS STA should be able to detect activity in the extension channel without necessarily being able to receive legacy MPDUs in it. On detecting what may be a legacy MPDU, the STA should enable itself to receive in that extension channel (not necessarily simultaneous with supporting operation of the BSS in the control channel) in order to determine if a legacy BSS has arrived on the extension channel.

## 8.1.3 Infrastructure BSS Operation

### 8.1.3.1 At the AP

**Table 9 – AP Mode Definitions**

| AP Mode                   | Beacon Transmission                                                              | Indicated STA operation |
|---------------------------|----------------------------------------------------------------------------------|-------------------------|
| Pure                      | Pure                                                                             | Pure                    |
| Mixed Capable             | Legacy                                                                           | Mixed                   |
| Managed Mixed             | Dual (see below)                                                                 | Pure                    |
| Unmanaged Mixed           | Legacy                                                                           | Mixed                   |
| 20 MHz-Base Managed Mixed | Legacy<br>mandatory in the control channel,<br>optional in the extension channel | Mixed                   |

The AP controls the operating mode of its STA through an information element in the beacon.

In pure mode, the AP will ignore any probe requests sent by legacy STAs and any legacy beacons sent by overlapping co-channel legacy devices. The AP transmits its beacon using a normal HT PPDU type. The beacon contains an HT management element that requires pure mode operation of its STAs. Note, use of pure mode at the AP is only suitable for managed installations where it is not permitted that legacy APs may share the same channels as HT APs.

In the mixed-capable mode, the AP transmits its beacon using a legacy PPDU. The beacons contain an HT management element that indicates this is an HT AP<sup>4</sup>.

An HT STA shall operate in pure mode except for communicating with a legacy STA on a Direct Link. An HT STA shall switch to legacy mode for communication with a legacy STA on a Direct Link.

In mixed-capable mode, the AP may receive association and probe requests from legacy STAs. It shall respond to a legacy probe request with a legacy probe response. It shall respond to a legacy association request with a legacy association response. The AP may choose to accept or deny the association response. If the AP sends an association response with status = OK, it shall enter either managed, unmanaged or 20 MHz-base managed mixed mode operation, and stay there while it has any associated legacy STA. The AP monitors its channel for a legacy co-channel BSS, and if it detects one, transitions into mixed mode, or attempts to find an alternative channel using the procedures defined in section 8.2.

In the Unmanaged mixed mode, the AP transmits its beacon using the legacy PPDU type. The beacon contains an HT management element that requires mixed mode operation of its STAs.

In the 20 MHz-base managed mixed mode, the AP transmits its beacon using the legacy PPDU type. It is sent in the control channel but for the purpose of reliability of reserving the extension channel, implementers may decide to send beacons also in the extension channel. Beacons in the

<sup>4</sup> This will stop other co-channel mixed-capable APs from considering the AP to be a legacy AP.

1 extension channel might induce legacy STAs to try association but the HT AP will refuse  
2 association or may ignore those requests. The beacon contains an HT management element that  
3 requires mixed mode operation of its STAs.

#### 4 **8.1.3.2 At the STA**

5 An infrastructure HT STA supports three possible modes of operation: legacy, mixed and pure.<sup>5</sup>

6 In pure mode, there are no overlapping legacy STAs. Protection of HT frames from legacy  
7 devices is not required.

8 In mixed mode, the HT STA is operating in the presence of legacy STAs co-channel on the  
9 control channel and/or the extension channel. These STAs may be part of the same BSS, or may  
10 be associated with an overlapping legacy BSS. In mixed mode, use of a legacy protection  
11 mechanism is required (see section 7.1.6). An HT STA shall operate in pure mode except for  
12 communicating with a legacy STA on a Direct Link. An HT STA shall switch to legacy mode for  
13 communication with a legacy STA on a Direct Link. A 40 MHz capable HT STA, whose  
14 permitted width set is 20 and 40 MHz, shall switch to 20 MHz mode for communication with a  
15 20 MHz HT STA. A 20 MHz HT STA is the one whose permitted width set is limited to 20  
16 MHz.

17 In 20 MHz-base managed mixed mode, a 40 MHz capable HT STA is enabled to communicate  
18 in 40 MHz mode during the 40 MHz period. In case a 40 MHz capable HT STA wishes to  
19 communicate with a 20 MHz mode HT STA or with a legacy STA, it shall do so in the 20 MHz  
20 period.

21 In legacy mode, the HT STA operates exactly as a legacy device, with the exception that it may  
22 switch from legacy mode to mixed or pure modes while scanning in order to detect an HT AP.

#### 23 **8.1.3.3 Managed Mixed Mode Operation (Informative)**

24 This section describes a coexistence mechanism that permits a legacy network and an 802.11 HT  
25 network to operate co-channel without requiring the 802.11 HT devices to be able to  
26 communicate directly with the legacy devices.

27 The mode is operated by an HT AP in managed mixed mode that has both legacy and HT STAs  
28 associated with it. Its HT STAs operate in pure mode.

29 In this mode, the AP manages coexistence of legacy devices in its control channel with HT  
30 devices occupying the HT channel, which may be 20 or 40MHz wide depending on the operating  
31 mode of the AP.

32 The case of a 40MHz channel where both 20MHz halves are overlapped by legacy devices is  
33 managed using the 20 MHz-base managed mixed mode which is described in section 8.1.3.4.

#### 34 **8.1.3.3.1 Assumptions**

35 It is assumed that the legacy devices cannot receive HT PPDU's and cannot interpret MAC  
36 duration values. The managed mode avoids the need for individual STA to provide legacy  
37 protection, and thereby potentially reduces overhead.

---

<sup>5</sup> The STA cannot distinguish between the AP's managed mixed mode and pure mode.

### 8.1.3.3.2 Mechanism

The AP provides managed mixed mode operation.

This AP divides time between legacy and HT phases of operation. In the legacy phase it ensures that the NAV of all HT devices is set, and *vice versa*.

One way to do this is for the AP to periodically transmit a legacy CTS-to-self to start the HT phase and an HT CTS to start the legacy phase. Alternatively, the AP may combine setting the NAV with transmission of a beacon that contains a contention-free period element, and transmission of a matching CF-end at the end of the phase.

The legacy beacon transmitted by an HT AP in managed mixed mode contains an element which causes any HT STA scanning for a network to ignore the duplicate legacy beacon.

HT devices in pure mode should ignore legacy PPDU's they may receive, so they do not receive NAV reservations intended for legacy devices.

### 8.1.3.4 20 MHz-Base Managed Mixed Mode Operation

This section describes a coexistence mechanism where a BSS operates in 20 MHz mode and switches to a 40 MHz capable phase under the control of an HT AP. Both legacy and HT STAs may be associated in the BSS. An HT STA may be either a 40 MHz capable HT STA or a 20 MHz HT STA. STAs associate with the HT AP on the control channel.

The 20 MHz-base managed mixed mode allows overlapping BSS containing legacy STAs in both control and extension channels. Due to the protection of the 40 MHz period in both channels, it is tolerant of overlapping BSSs. If the overlapping BSS is a QBSS, access to the channel may experience longer latencies in the order of the TXOP duration of the QBSS. Similarly, channel access delays will be long when operating with an 802.11b BSS, which may use substantially lower data rates.

The AP, before it selects a control channel and extension channel and operating mode may take into account the likely performance benefits of using the 20MHz base mode operation. The AP should try to avoid overlapping 802.11e or 802.11b STA, particularly on the extension channel.

#### 8.1.3.4.1 Assumptions

Legacy STAs and HT STAs may coexist in the 20 MHz-base managed mixed mode. Two types of STAs may coexist with the 40 MHz capable HT STAs in the 20 MHz-base managed mixed mode: legacy STAs and 20 MHz HT STAs. It is assumed that the legacy STAs cannot receive HT PPDU's and cannot interpret MAC duration values. The 20 MHz HT STAs are assumed not to be able to receive 40 MHz mode HT PPDU's and to interpret their MAC duration values. An HT AP in the 20 MHz-base managed mode provides legacy protection against legacy STAs and 20 MHz HT STAs.

#### 8.1.3.4.2 Mechanism

The 40 MHz capable HT AP may operate in the 20 MHz-base managed mixed mode. It divides time into 20 MHz and 40 MHz periods. In a 20 MHz period, it ensures that the NAV of 40 MHz mode operation in 40 MHz capable HT STAs is set. In the 40 MHz period, the NAV of legacy STAs and 20 MHz HT STAs is set.

The basic period is the one in which operation is strictly in the 20 MHz control channel. To start a 40 MHz period, the HT AP first reserves the control channel by setting NAV of legacy and 20 MHz HT STAs with a legacy Beacon frame or an ICB frame. The transmission rate of the SCB frame shall be selected from the BSSBasicRateSet. Due to the range of the Duration/ID field in the MAC header, the ICB frame cannot be used to start a 40 MHz period longer than 32767  $\mu$ s. Then, the HT AP shifts to the extension channel for its reservation. The extension channel is reserved by a transmission of a CTS-to-self or a legacy Beacon frame after an appropriate channel access is performed in the extension channel.

The Beacon frame sent to reserve the control channel includes the channel extension indication information element. When a 40 MHz capable HT STA associated with the HT AP receives the Beacon frame, it extends its channel bandwidth to 40 MHz according to the information in the Extension Channel Offset information element. The 40 MHz capable HT STAs act in the same way when receiving an ICB control frame.

After setting the NAV in the extension channel is completed, the HT AP resets the NAV of 40 MHz capable HT STAs by sending a CF-end frame. Thereby the 40 MHz period is started, during which HT STAs can communicate in 40 MHz mode using EDCA.

The AP can also support operation using HCCA by polling HT STA during the 40 MHz period before allowing the 40MHz devices to contend using EDCA.

To end the 40 MHz period, the HT AP first sets the NAV of 40 MHz mode operation in 40 MHz capable HT STAs by transmitting an DCB frame. The 40 MHz capable HT STAs will switch back to the control channel in 20 MHz. Then the AP resets the NAV in the extension channel by transmitting a CF-End frame. The AP may reset the NAV in the control channel by a CF-End frame but it may also continue the CFP that was set in the last Beacon frame on the control channel. At this point the AP and all its STAs are operating on the control channel using 20MHz channel width. The process may e.g. be repeated periodically, such as related to the beacon interval. The superframe thus created is divided into a phase for communication on the 40 MHz channel and phases for communication on the 20 MHz channels. One cycle of the process is illustrated in Figure 26.

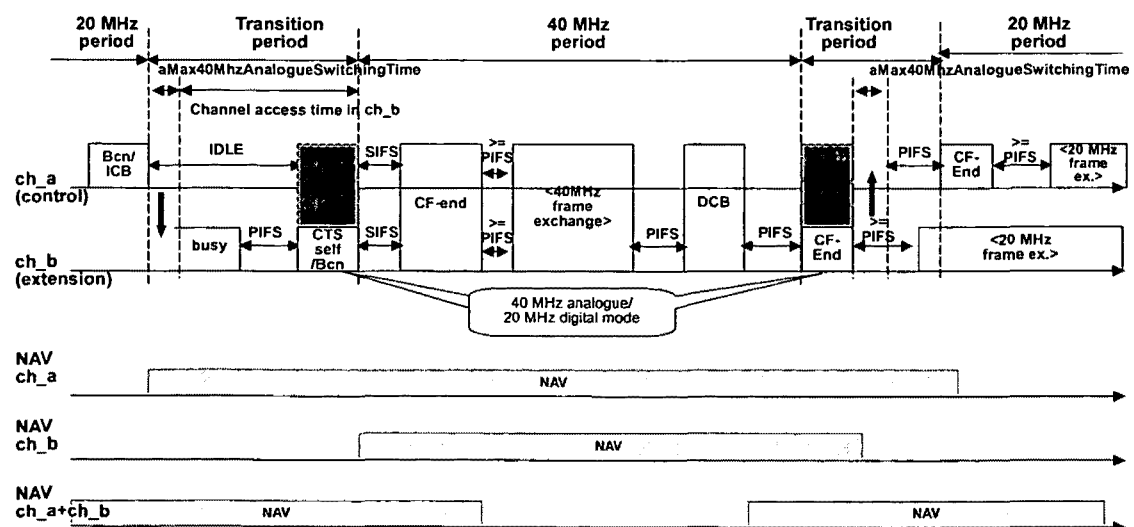


Figure 26 – 20 MHz-Base Managed Mixed Mode

#### 8.1.3.4.3 Operation at HT AP

To start the 40 MHz period, the HT AP transmits a legacy Beacon frame or an ICB frame in the control channel to acquire the control channel and define a CAP to block the channel by setting the NAV of the legacy STAs and 20 MHz HT STAs on the control channel. The CFP of the Beacon or Duration field of the ICB frame will be set to cover the 40 MHz phase plus the transition periods between 20 and 40 MHz operation.

The HT AP announces the "extension channel access timeout" value in its Beacon and Probe Response frames to limit the maximum transition time to the 40 MHz period. When the HT AP transmits the Beacon frame or CTS-to-self frame on the control channel, it starts a timer of a duration, which is "Extension Channel Access Timeout" minus the duration of the Beacon or CTS-to-self frame. The "Extension Channel Access Timeout" is the maximum time, after which the STAs shall have received the Beacon or CTS-to-self on the extension channel. One reason why the AP might not be able to send the Beacon or CTS-to-self frame within "Extension Channel Access Timeout" time could be a busy medium on the extension channel.

After setting the NAV in the control channel, the AP may switch to 40 MHz analogue and 20 MHz digital mode and shall listen to both the control channel and the extension channel. As the control channel is supposed to be reserved by the previous operation, this phase is mainly given to wait for the extension channel to be idle. However, it shall be noted that while waiting for the extension channel to become idle, the control channel will be left without any activity and the STAs which did not receive the Beacon or ICB frame in the control channel may interfere with the reservation. The purpose of the mode transition to 40 MHz analogue and 20 MHz digital is to omit an analogue channel switch at the beginning of the transmission phase in the 40 MHz channel. If the extension channel becomes idle the AP shall transmit a CTS-to-self or legacy Beacon in the extension channel a PIFS after it has become idle. The CTS-to-self or Beacon shall block the channel by setting the NAV of the legacy STAs on the extension channel. The NAV shall cover the intended duration of the 40 MHz period and the transition times between 20 MHz period and 40 MHz period.

If the "extension channel access timeout" timer at the AP expires while attempting to transmit CTS-to-self or Beacon, the AP shall give up switching to the 40 MHz bandwidth and may try again at a later time. The AP shall furthermore transmit a CF-end frame on the 20 MHz control channel in order to re-set the NAV of the legacy STAs on the control channel. HT STAs will have started an "Extension Channel Access Timeout" timer themselves after having received the first Beacon or ICB frame on the control channel and do therefore not have to be notified by the AP about the expiration of the timer.

The NAV setting in the extension channel is done through CTS-to-self or Beacon. CTS-to-self would give less overhead, however, the Beacon in the extension channel may avoid other BSSs being created, since other STAs will detect the presence of the HT BSS. Furthermore, the duration of the NAV that can be signaled by a CTS-to-self is limited. Therefore, for long periods setting the NAV by a Beacon frame will be required. According to this analysis, implementers may decide to send Beacons in the extension channel.

If the "Extension Channel Access Timeout" timer has not yet expired, the AP shall transmit a 40 MHz mode CF-end to signal to the HT STAs that the 40 MHz channel is available. The CF-end frame shall be transmitted at least `aMax40MhzAnalogueSwitchingTime` after the end of the first Beacon or ICB frame on the control channel. `aMax40MhzAnalogueSwitchingTime` is the maximum allowed time for the STAs and the AP to carry out an analogue channel switch from 40 MHz to 20 MHz and vice versa. The AP has to wait at least

1 aMax40MhzAnalogueSwitchingTime before starting the 40 MHz phase in order to account for  
2 the STA with the slowest possible switching time. If aMax40MhzAnalogueSwitchingTime time  
3 has already expired since the end of the Beacon or ICB frame on the control channel, the AP  
4 shall send the CF-end or QoS CF-Poll frame a SIFS after the CTS-to-self or Beacon on the  
5 extension channel.

6 After the 40 MHz frame exchanges, the AP shall set the NAV of the 40 MHz HT STAs until the  
7 intended end of the 20 MHz period by means of a DCB frame. Then the AP shall free the  
8 extension channel and the control channel for communication in 20 MHz mode by transmitting  
9 CF-End frames in both channels. The CF-End frame in the control channel is not required if the  
10 AP wishes to continue the CFP. The CF-End frame on the control channel shall not be sent  
11 earlier than aMax40MhzAnalogueSwitchingTime after the CF-End on the extension channel.  
12 The first CF-End frame in the extension channel may be transmitted in 40 MHz analogue and 20  
13 MHz digital mode in order to avoid an additional analogue channel switch. After the first CF-  
14 End frame the AP switches to the control channel in 20 MHz analogue mode and transmits the  
15 second CF-End frame.

16  
17 The ratio between the 40 MHz and 20 MHz period should be adjusted according to types of  
18 traffic and priority. Whether frames are sent in the 40 MHz or 20 MHz period shall be scheduled  
19 depending on their traffic types.

20 Note that in scenarios with heavy interference between control and extension channel the AP  
21 may choose to switch to a different 40 MHz channel, on which no time-sharing with legacy  
22 STAs might be required. The selection of channels affects the performance and efficiency for the  
23 20 MHz-base managed mixed mode. Not only the initial channel selection but also monitoring  
24 the channels while operating in 20MHz-base mixed mode is necessary to cope with condition  
25 changes.

#### 26 8.1.3.4.4 Operation at 40 MHz capable HT STAs

27 A 40 MHz capable HT STA is allowed to operate in 20 MHz mode on the control channel or in  
28 40 MHz mode on both channels. It is not allowed to operate in 20 MHz mode on the extension  
29 channel.

30 40 MHz capable HT STAs shall store the "extension channel access timeout" value contained in  
31 Beacon or Probe Response frames sent by an HT AP.

32 When a HT STA receives a Beacon or ICB frame with channel extension indication information  
33 element set, it shall start an associated timer of duration "Extension Channel Access Timeout"  
34 and wait in the 40 MHz analogue mode for the HT AP to reset its NAV by a CF-End frame.  
35 Furthermore, upon reception of the Beacon or ICB frame in the control channel, a 40 MHz  
36 capable HT STA shall start the timer included in the Duration/ID field of the ICB frame or the  
37 CFP Parameter Set element in the Beacon frame. If the HT STA operates in the 20 MHz mode, it  
38 shall shift to 40 MHz analogue mode by the reception of the Beacon or the ICB frame on the  
39 control channel. A HT STA shall switch to 40 MHz analogue mode within at least  
40 aMax40MhzAnalogueSwitchingTime time.

41 In case the "extension channel access timeout" timer expires before receiving the CTS-to-self or  
42 Beacon on the extension channel, a 40 MHz capable HT STA leaves the waiting state. It shall  
43 switch back to 20 MHz mode on the control channel depending on the operation mode of the AP.

When a 40 MHz capable HT STA receives a CF-end frame, its NAV for the 40 MHz channel will be reset and it becomes free to access in 40 MHz mode. The 40 MHz capable HT STA switches back to 20 MHz mode on the control channel if the timer runs out before it receives the DCB frame which indicates the end of the 40 MHz period.

The HT STA may send frames not only in EDCA but also in HCCA, which is enabled by QoS CF-Poll to it. A 40 MHz capable HT STA which is granted TXOP may only transmit frames to the AP or other 40 MHz capable HT STAs.

By the reception of a DCB frame from the AP on the 40 MHz channel, a 40 MHz capable HT STA sets its NAV for the 40 MHz channel. It may switch back to 20 MHz mode if it wishes to communicate in the 20 MHz period when receiving the DCB frame.

#### 8.1.3.4.5 Operation at legacy STAs and 20 MHz HT STAs

The NAVs of Legacy STAs and 20 MHz HT STAs are set either by a Beacon or ICB frame in the control channel or by the CTS-to-self or Beacon frame in the extension channel. Their NAVs are reset when they receive a CF-End frame in their operating channel.

### 8.1.4 IBSS Operation

#### 8.1.4.1 Ad-hoc (IBSS) Operation

##### 8.1.4.1.1 Effect of operating mode as an HT IBSS (Informative)

In IBSS operation, an HT IBSS is always discoverable by the legacy IBSS. A legacy device wishing to join the IBSS will discover it and share in the beaconing. This will alert HT devices to its presence based on omission of HT beacon elements.

##### 8.1.4.1.2 Rules of operation of an HT IBSS

Each STA maintains a table for STAs it can see according to the mode of operation of the STA. Stale entries in this table are removed by a timeout process. A STA can be classified as legacy if it is seen to transmit a legacy beacon without the HT elements (note, this also includes legacy APs). Otherwise, its HT IBSS operating parameters are discovered from the HT element in the beacon. This element includes the field: IBSS mode.

The mode of operation of an individual STA is defined in the following table, along with the rules for operation.

**Table 10 – IBSS Mode Definitions**

| HT IBSS Mode      | Description                  | Condition                                            | Beacon Tx     |
|-------------------|------------------------------|------------------------------------------------------|---------------|
| Discoverable IBSS | Only HT IBSS on this channel | No legacy devices in STA table                       | Legacy format |
| Mixed IBSS        | Mixture of HT IBSS and       | One or more legacy devices are present in STA table. | Legacy format |



### 8.1.4.1.3 Rules for IBSS Use of Protection Mechanism

When operating in Mixed IBSS mode, an HT IBSS STA acting as the initiator of a frame exchange sequence shall use a legacy protection mechanism.

Otherwise, the STA should use HT frame formats.

## 8.2 Channel management

### 8.2.1 Channel Management at the AP

The AP transmits a beacon containing the following elements:

**Table 11 – Beacon Elements for HT Channel Management**

| Element                  | Description                                                                      | Values                                                           |
|--------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------------|
| Permitted Width Set      | This is the set of channel widths that may be used within the BSS.               | {20} or {20, 40}                                                 |
| Control Channel Number   | Channel number for the control channel                                           |                                                                  |
| Extension Channel Offset | Describes the location of the extension channel relative to the control channel. | 1 = 1 channel above,<br>-1 = 1 channel below,<br>0 = not present |

An HT AP shall receive the beacons of other HT BSSs on its channel. If one of these indicates a subset of its current permitted width set, the AP shall reduce its permitted width set so that it matches or shall select a new operating channel.

HT BSSs shall only overlap HT BSSs with the same control channel and extension channel location.<sup>6</sup>

### 8.2.2 Channel Management at the STA

All transmissions must use a width in the permitted width set.

In unmanaged mixed mode, all transmissions of unaggregated control and broadcast frames must be receivable by legacy devices operating on the control channel.

A STA shall only transmit an HT PPDU to a peer STA using a width that it knows the peer to support and that is within the permitted width set.

<sup>6</sup> This, together with the requirement for the same basic width set ensures that any pure-mode control frames sent in one BSS can be received in any overlapping HT BSS.

## 8.2.3 Channel Selection Methods

### 8.2.3.1 Introduction (Informative)

The best coexistence is achieved when all BSSs occupy separate channels and when legacy and HT devices do not overlap.

The HT AP should prefer to operate a pure mode BSS (i.e. no overlapping legacy BSS) because overlapping BSS requires a mixed mode operation that may entail higher overhead.

The mixed-capable AP can detect co-channel legacy BSSs arriving on its control channel without the need for scanning. This may cause it to enter a mixed mode of operation.

The AP may also detect co-channel legacy BSS arriving on a non-control channel. It may do this by scanning during an 802.11h "quiet" period, or by getting one of its STAs to scan for it, again using 802.11h signaling<sup>7</sup>. Alternatively, the AP may be able to receive legacy MPDUs on either overlapped channel.

On detecting the arrival of a co-channel legacy BSS on the non-control channel, the AP has to either adjust its permitted channel widths to avoid the legacy BSS, select a new set of channel parameters or switch to 20 MHz Base Managed Mixed Mode.

The AP may also scan periodically all channels, and evaluate whether there is a better channel (as defined in 8.2.3.3) to operate on. If it discovers a better channel, it may instruct its STAs to change channel parameters using signaling in its beacon.

Note: If 802.11h-like DFS becomes mandatory in all geographies, this behavior should be consistent with those requirements. If DFS is not mandatory, operation of this automatic channel selection may be disabled to permit fully manually administered installations.

### 8.2.3.2 Rules

The HT AP shall either be configured manually or configure itself automatically as described in this section.

The HT AP shall scan its environment before selecting channel parameters. If the AP is capable of mixed mode operation, it shall use mixed mode to scan.

If the selected channel parameters overlap an existing HT BSS, then they must use the same control channel and extension channel offset and permitted width set.

The AP shall reselect new channel parameters if an HT BSS that does not have the same control channel, extension channel offset and permitted width set starts operating on an overlapped channel.

Given a choice of 40MHz channel selections permitted by the previous rules, the AP should prefer a channel selection that aligns its 40MHz channel with the starting (i.e. lowest frequency) pair of adjacent 20MHz channels within any band or sub-band plus zero or more times 40MHz.

The purpose of this recommendation is to avoid introducing 20MHz "holes" between adjacent operating 40MHz BSS, thus making them unavailable for 40MHz operation.

---

<sup>7</sup> Note, the assumption that 802.11h will be used (perhaps in modified form) by TGn.

### 8.2.3.3 Method to determine Best channel and channel width (Informative)

The method described here selects the channel parameters that maximize aggregate throughput. It also has the side effect of generally avoiding operation with co-channel legacy devices.

The HT AP keeps a database BSS and load information per 20 MHz channel. In each such channel it records its observations of load <sup>8</sup>, and the number of legacy and HT BSSs. Alternatively it can record load for legacy and HT traffic separately if it is capable of making that measurement.

Each HT BSS that permits 40MHz operation will have an entry in each 20-MHz channel it overlaps. The HT BSS load measurement is applied to each such overlapped channel.

The device monitors or estimates its own load. If its load is not known, the device assumes a load of 100% for itself.

From any configuration of channel parameters, BSSs and loads, the device can calculate the following performance metric. It sums the product of load and rate over all channels to determine an aggregate throughput. For channels with only legacy BSSs, it uses the highest legacy rate. For channels with only new devices, it uses the highest HT rate. For channels with a mixture, it first de-rates the HT highest rate to allow for use of a protection mechanism and then averages this with the legacy rate weighting the average according to the number of BSSs of each type. Alternatively, if it is collecting the load per BSS type, it sums the product of the appropriate rate (legacy or "mixed mode" HT rate) and load.

In considering a channel parameter configuration to evaluate the performance metric, the device shall not allow a configuration if it:

- Has an HT BSS with a different value of control channel or extension channel offset
- Has an HT BSS with a different permitted width set

#### 8.2.3.3.1 First time Channel Selection

When starting operation, the device performs the following steps:

- It scans all channels to build the database.
- It considers adding its load into each channel in turn to find the position and width and evaluates the performance metric. As it adds its own load into a channel, it caps the load at 100%.
- It selects the combination of position and width that results in the highest value of the performance metric.

#### 8.2.3.3.2 Subsequent Channel Selection

In order to update its channel parameters, the device first removes its estimated current load from its current channel(s) and then performs the same algorithm as described in the previous section.

---

<sup>8</sup> Load is defined as the percentage of time the channel is busy (averaged over some observation interval).

### 8.3 TRMS Power-Saving Management

MIMO systems can reduce power consumption by only enabling a single receive chain during periods of inactivity. The STA may be raised to full receive capability following the reception of a unicast MPDU contained in a PPDU that can be received on a single receive chain.

This section defines the TRMS protocol. The mechanism is referred to as Timed Receive Mode Switching (TRMS) since it relies on a timer in the STA to trigger the transition to reduced receive mode and corresponding timers in the AP and STA peers to track the state change. The timers are reset when an MPDU is transmitted by the TRMS STA.

As a special case, an operating mode is supported where the STA reduces receive capability after each sequence. This mode could take advantage of any protection mode where a SISO frame exchange already prefixes each sequence by providing power savings at no protocol overhead.

A STA shall support TRMS operation in other STAs with a zero hold-on time. It is an option of a STA to support TRMS operation in other STAs with a non-zero hold-on time.

When a STA that does not support TRMS operation in other STAs with a non-zero hold-on time transmits to a STA that is in TRMS enabled mode, it will assume that the STA uses a zero hold-on time. This will cause it to prefix any exchange to that STA with a SISO packet. This may or may not (depending on the exchange sequence used and the type of protection used) create a performance reduction compared to support of a non-zero hold-on timer.

#### 8.3.1 BSS Association, DLP Setup and Mode Changes

##### 8.3.1.1 Association

When associating, a STA that wishes to operate using TRMS includes the TRMS IE in its association or reassociation request.

If the STA wishes to update the TRMS parameters under which it is operating after association, then it sends a directed TRMS Update frame to the AP with the new parameters.

##### 8.3.1.2 DLP Setup

A STA that supports TRMS operation in its DLP peers includes a HT capability element with an asserted TRMS Support bit in the DLP request or response frame. A STA initiating a DLP session that wishes to operate using TRMS includes the TRMS IE in the DLP request frame.

A STA that receives a DLP request with the TRMS Support bit set and that wishes to operate using TRMS includes a TRMS IE in the DLP response.

If a new DLP session results in the STA changing TRMS operating parameters it should send a TRMS Update to the AP and its other DLP peers.

##### 8.3.1.3 Mode Changes

A STA may change its TRMS operating parameters. When doing this it sends a directed TRMS Update to the AP and each of its DLP peers. The STA should send the updates before the new parameters take effect if the parameters decrease the stay-awake time or enable TRMS.

A STA may activate or deactivate TRMS operation at any time.

### 8.3.1.4 IBSS Operation

A STA that wishes to operate using TRMS broadcasts a TRMS Update frame and then enables TRMS operation. Once enabled, the STA should include the TRMS IE in future beacons.

Like IBSS power-saving, a STA only has potentially stale information about a peer's TRMS mode. A STA can refresh this information by performing a capability exchange using directed Probe MPDUs. It may infer that its knowledge is stale if it fails to transmit to a STA on the assumption that it is TRMS-disabled, but successfully transmits when it assumes it to be TRMS-enabled.

### 8.3.2 TRMS Operation

A STA using TRMS maintains a running timer that is reset each time a frame is transmitted. If the timer reaches the stay-awake time then the STA switches to reduced receive operation unless a frame is being received, in which case the switch will be delayed until immediately after the frame has been received. The STA returns to full receive operation after transmitting any frame.

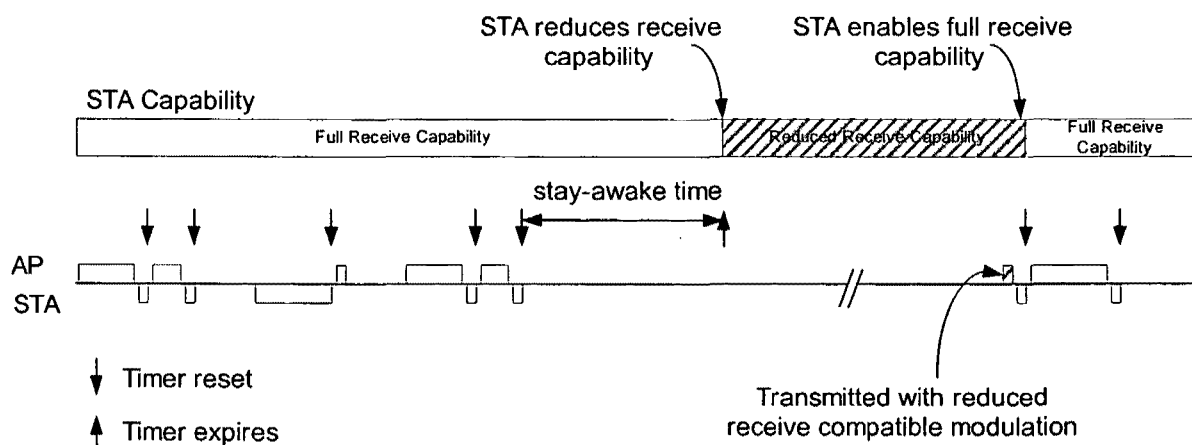


**Figure 27 – Data transfer example with timed receive mode switching**

An AP maintains a running timer for each associated STA that is operating using TRMS. The AP resets the timer for a particular TRMS using STA each time it receives a frame from that STA (whether or not the frame is addressed to the AP). If the timer reaches the stay-awake time then the TRMS STA is assumed to have switched to reduced receive operation.

A STA that is a DLP or IBSS peer to other STAs using TRMS maintains a running timer for each such peer. Each time this STA receives a frame that is addressed to it and that was transmitted by such a peer, it resets the corresponding timer. It may also reset the timer if it receives a frame from such a peer that is not addressed to it. If the timer reaches the stay-awake time then the peer TRMS STA is assumed to have switched to reduced receive mode.

Frames sent to a TRMS STA that is assumed to be operating with reduced receive capability shall be transmitted using a modulation compatible with the TRMS STA's reduced receive capability.

### 1 8.3.3 Performance Impact of using TRMS mode (Informative)

2 In TRMS mode with a non-zero timer value, this value can adjust the compromise between  
3 staying MIMO-enabled longer than necessary and the overhead of switching into a MIMO-  
4 enabled state. This is only relevant for bursty traffic. For periodic traffic where there is a single  
5 exchange sequence per period, there is no benefit in using a non-zero value of the timer.

6 The overhead of entering a MIMO\_enabled state depends on the details of the frame exchange  
7 sequence and protection used.

8

| Sequence Type                                             | Overhead                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| LongNAV<br>IAC+RAC+Data/Data/BA+RAC/BA                    | In the case of a basic sequence, this overhead is zero because the initial packet is already a SISO packet.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| LongNAV ABF (forward)                                     | The overhead is still zero                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| LongNAV with legacy devices                               | The overhead is zero because the legacy initial MPDUs are suitable SISO packets                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| LongNAV ABF (both directions)                             | <p>The ABF sounding for the reverse-link cannot occur in the first packet, so ABF trained reverse-link data can first be sent in the 4<sup>th</sup> PPDU.</p> <p>However this creates no additional overhead, because the operation of the RDL/RDR/RDG protocol does not permit reverse-direction data until the 4<sup>th</sup> PPDU, except in the case of periodic RDR.</p> <p>Periodic RDR is there to support applications like VoIP, and I don't expect to see VoIP handsets doing ABF transmissions.</p>                                                                                                                                                                                                                                                                                                                              |
| Pairwise Spoofing<br>Untrained<br>IAC/Data/Data/BA+RAC/BA | <p>This sequence will not work with a MIMO MCS for the first MPDU.</p> <p>It makes little sense to transmit a SISO MCS for the first packet. Also there are practical difficulties knowing what MCS to use because any training established when the receiver is MIMO-enabled will not apply when it is MIMO-disabled.</p> <p>The alternative is to add an initial IAC/RAC exchange. This brings the following advantages:</p> <ul style="list-style-type: none"> <li>• Collisions are detected cheaply</li> <li>• Data is protected from hidden nodes</li> <li>• Data can be trained (fresh MCS and/or ABF)</li> </ul> <p>These benefits are not useful if there are small numbers of contending stations, there are no hidden nodes, and training information is still fresh. In that case the additional IAC/RAC is a real overhead.</p> |
| Pairwise Spoofing<br>Trained forward-direction data       | <p>No overhead as the sequence has to be:</p> <p>IAC(TRQ)+RAC(HT-LTFs)+IAC/Data/...</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

|                                                      |                                                                     |
|------------------------------------------------------|---------------------------------------------------------------------|
|                                                      | The initial IAC can be SISO.                                        |
| Pairwise Spoofing reversed<br>direction trained data | Same analysis as the LongNAV case. There is no additional overhead. |

1

2

## 9. Background to Protection Mechanisms (Informative)

### 9.1 Introduction to Protection Mechanisms

Protection of HT exchanges from legacy devices (if present) and other HT devices is necessary for two reasons:

- Legacy devices do not understand HT PPDU formats
- On a link between two HT STAs that is adapted to the channel between those STAs, the probability that a 3<sup>rd</sup> party STA will be able to reliably receive the MPDUs is small. This is particularly true when closed-loop adaptation is used.

There are two broad classes of protection defined in this document.

The first is called "Spoofing". It uses the legacy PLCP rate and length fields to indicate a duration that may or may not correspond to the duration implied by the HT signal field.

Spoofing is effective because legacy devices respect the duration contained in the legacy signal field, even if they cannot correctly decode the data. The signal field is transmitted using a robust modulation and omnidirectional antenna pattern.

The second class of protection relies on mechanisms to set the NAV using MAC layer signaling. In the presence of legacy devices, this requires that this signaling is carried in legacy receivable MPDUs.

### 9.2 Effect of Spoofing

The Spoofing Mechanism is an effective way to protect media from nodes that can not decode the "Duration" field in the MAC Header, which could be the majority of third party nodes in an 802.11n environment, particularly if Closed-Loop MIMO is being used.

The "Duration" field is purposed to set the NAV for third party nodes that the packet is not intended to, in order to prevent these nodes from interrupting the response from the recipient of that packet. However, when certain PHY features are used in 802.11n, the MAC Header which contains the "Duration" Field will not be decodable to all legacy nodes and most of the third party nodes. This is because the MAC Header will be coded with the optimized rate and mode for the recipient of the packet, which makes it difficult for third party nodes to correctly decode the MAC Header.

The spoofing mechanism solves this problem by virtually setting the NAV Duration in the PHY header where the information is coded at the lowest rate that every recipient can decode. By utilizing this Spoofed NAV, the system can assure higher protection of the media from legacy and third party nodes, without adding unwanted overhead of sending legacy packets for media protection.

An HT STA interprets a spoofed PLCP duration as one source of NAV setting, in addition to any MPDUs that it correctly receives in the PPDU. It can receive after the current PPDU regardless of the spoofed duration.



A legacy STA interprets a spoofed PLCP duration as a PPDU of that duration, and remains in the receiving state for the whole duration. It is therefore not capable of acquiring new PPDU's until this period has finished.

### 9.3 Pairwise spoofing

The Pairwise Spoofing mechanism is a way to maintain protection from hidden nodes, by disallowing third party nodes to initiate transmission during the duration of the intended response of a packet.

The mechanism takes after the "Virtual Carrier Sense" with the "Network Allocation Vector (NAV)" specified in the 802.11 standard. Each packet will contain a duration field (or a Spoofed NAV field: See section 7.1.7.1 for details), and nodes that receive packets destined to another node will assume channel occupancy for the time specified in that duration field.

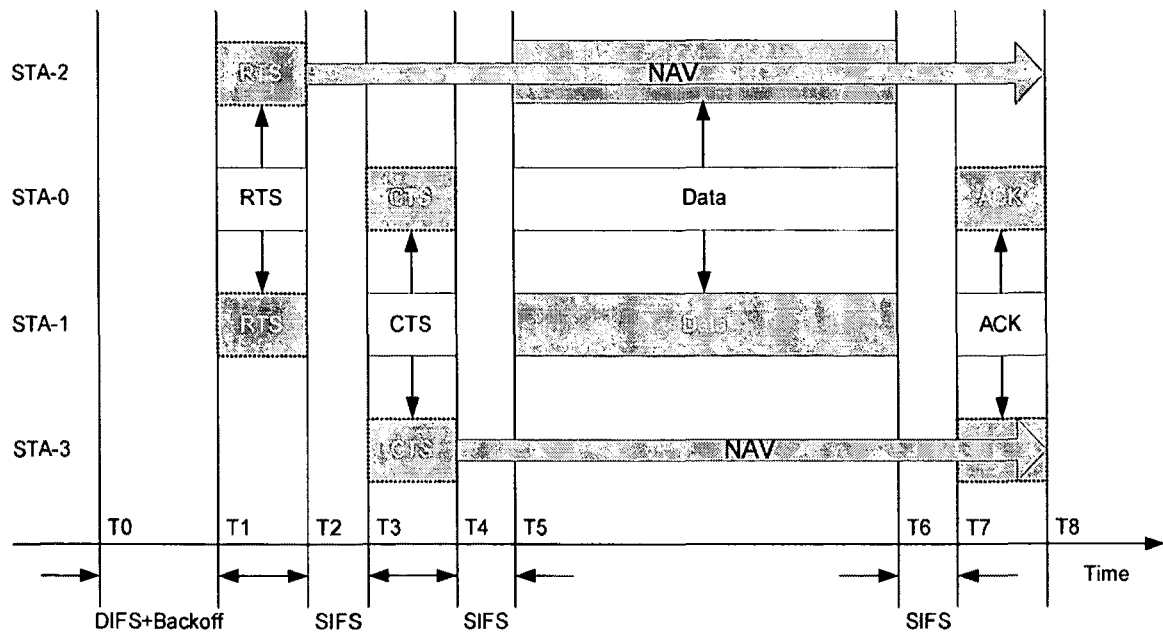


Figure 28 – Standard Virtual Carrier Sense

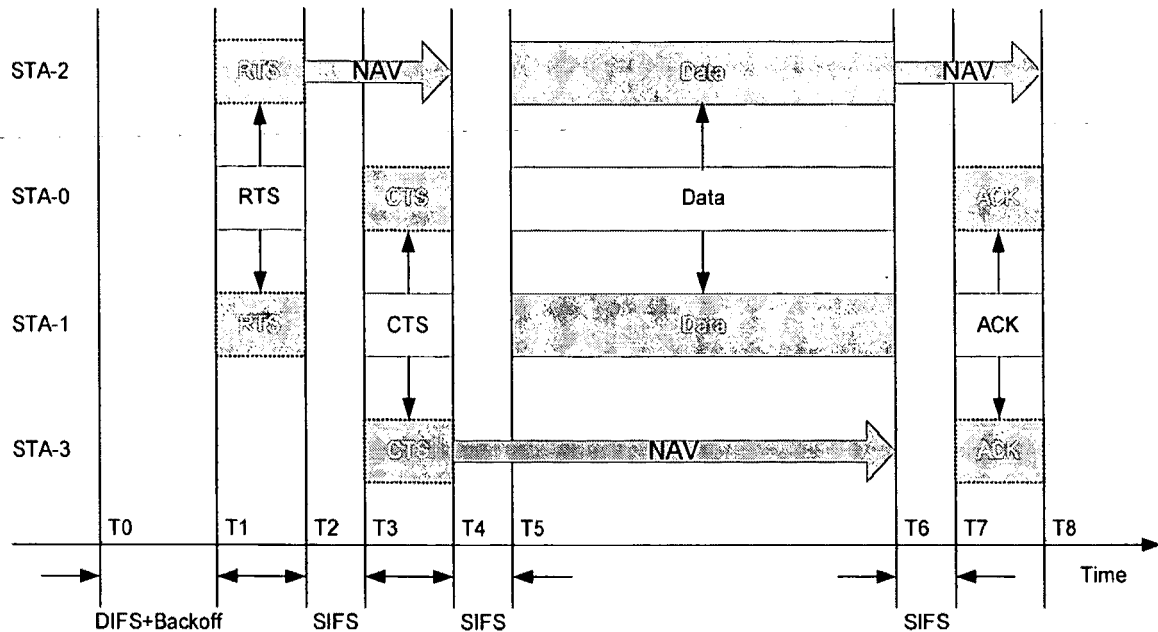


**Figure 29 – Pairwise Spoofing Mechanism**

With the Pairwise Spoofing method, the duration will be set to protect the intended response packet. In the standard 802.11 MAC, when using RTS / CTS, the duration fields in the RTS / CTS / DATA packets point at the end of the ACK. By using this original method, because the Duration must be fixed when sending RTS, the mode and rate in which the data packet would be sent at must be fixed before sending RTS. However, in realistic environments where advanced techniques like MIMO are used, channel conditions vary rapidly and optimization of MIMO modes by the RTS / CTS transaction will become essential. By shortening the NAV duration so that it protects only the following packet, the rate and mode that the DATA packet is sent at can be selected by the recipient of the packet, allowing more flexible adaptation, without sacrificing the needed protection from hidden nodes. Furthermore, the shortening of the NAV can contribute to less waste of medium time when the RTS / CTS packets fail to be received by their counterparts.

#### 9.4 Selecting between Pairwise Spoofing and LongNAV

The selection of protection mechanism is made by the initiator.

Use of Pairwise Spoofing is indicated by the FPD element in an IAC. This causes the RAC to generate a PPDU with a spoofed duration.

The initiator should operate under LongNAV rules if the NAV has already been set (e.g. by a QoS CF-poll sent by the HC).

In unmanaged mixed mode, protection from co-channel 802.11b devices shall be provided using LongNAV.

Otherwise the choice between Pairwise Spoofing and LongNAV can be made on the basis of trading flexibility of scheduling with performance.

## 9.5 HT PPDU Format with Legacy Protection

An HT PPDU Format looks like the following (See section 11.1.1.3 for a detailed description of the HT PPDU Format.)

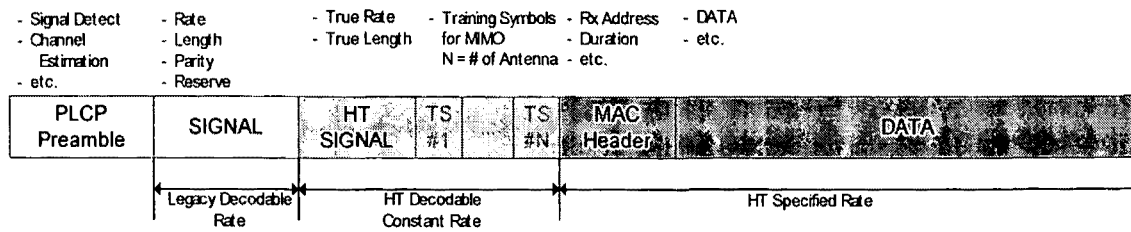


**Figure 30 – PPDU Format with Legacy Protection**

The PLCP Preamble is followed by a legacy SIGNAL Field. This SIGNAL Field is coded at a constant legacy rate that all nodes can decode at (for 802.11a nodes, 6[Mbps]). The legacy SIGNAL Field contains Rate and Length Fields used for spoofing the legacy nodes.

The legacy SIGNAL Field is followed by an HT SIGNAL Field which contains the True Rate and True Length. This field is coded at a rate and mode that all HT nodes can decode.

The HT SIGNAL Field is followed by the MAC Header. In the MAC Header, the Duration Field is set for setting the NAV for third party nodes that receive this packet. However, from the MAC Header on, the mode and rate is optimized for the intend recipient of the packet, so third party nodes will very unlikely be able to decode the MAC Header properly which will destroy protection by the NAV mechanism.

### 9.5.1 Interpretation by a Legacy Node

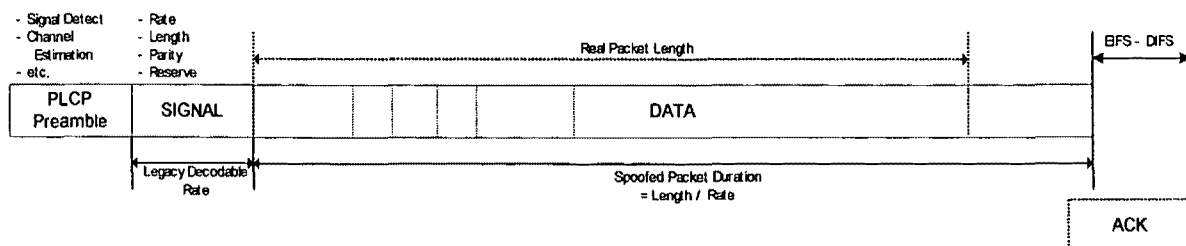


**Figure 31 – When Received by a Legacy Node**

When this HT PPDU is received by a legacy node, it decodes the legacy SIGNAL Field and tries to receive the packet for Length / Rate. When it finishes its reception, it finds that the CRC has failed for the data frame and defers for the EIFS period (instead of DIFS). After the media has been idle for that EIFS period, it restarts its contending mechanism. Therefore, an HT node who requires protection from legacy nodes, will set its Length and Rate Field so that the;

$\text{Length} / \text{Rate} = \text{NAV Duration} - (\text{EIFS} - \text{DIFS})$

There could be a number of combinations of Lengths and Rates to achieve the same “Length / Rate”, so the initiator will have the liberty to choose among the combinations. The maximum duration that an initiator can set by spoofing is determined by the maximum length of the packet and the minimum rate that the original protocol can withstand.

The signal energy level will go down during the reception of the packet, because the actual packet length is less than the spoofed length. But, according to the IEEE 802.11a MAC

Specification (See IEEE Std 802.11a – 1999, page 37, Figure 125), legacy nodes are required to honour the Length and Rate field, and must keep quiet for the Length / Rate. This requirement is also a part of the compliant test plan specified by the WiFi Alliance.

#### 9.5.2 Interpretation by an HT Node

As seen in Figure 30, in an HT PPDU, a legacy SIGNAL Field is followed by an HT SIGNAL Field coded at unified rate. This HT SIGNAL Field will contain the True Rate and the True Length that HT nodes will use. However, after decoding the legacy SIGNAL Field, an HT node will not know whether the SIGNAL Field is spoofed and is followed by an HT SIGNAL Field (sent at unified rate), or the packet is a legacy “un-spoofed” packet and is followed by a MAC Header coded at a rate specified in the SIGNAL Field.

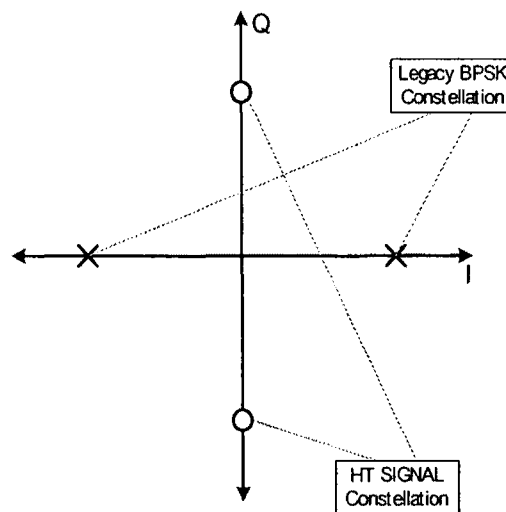


**Figure 32 – HT Signal Field BPSK Constellation**

Therefore, an HT SIGNAL Field will be transmitted with a 90[degrees] rotation, for BPSK mapping, from the I-Q plane indicated in the legacy PLCP Preamble. An HT device will decode the BPSK constellation specified in the PLCP Preamble at the rate indicated in the SIGNAL Field, and at the same time will decode, at the unified rate for HT SIGNAL Field, the BPSK constellation 90[degrees] from its original.

After decoding the two constellations in parallel for a given length of the HT SIGNAL Field, an HT node will check its CRC for the HT SIGNAL Field. If the CRC passes, it will recognize that this is an HT PPDU and continue to decode the MAC Header using the True Rate and True Length specified in the HT SIGNAL Field. If the CRC fails, it will recognize that it is a legacy PPDU and interpret the legacy MAC Header that it has been receiving.

### 9.5.2.1 MPDU Not Decodable

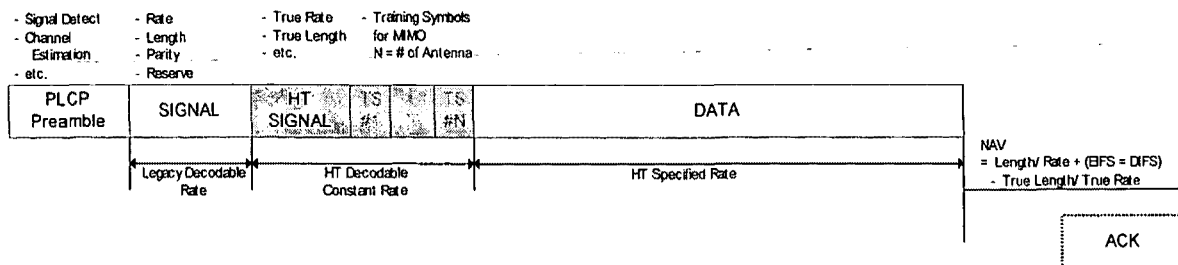


**Figure 33 – When Received by an HT Node but MPDU is not Decodable**

After decoding the HT SIGNAL Field, an HT node will attempt to decode the following MPDU with the specified rate. When the MPDU's FCS is not correct, it will discard the MPDU and will calculate the NAV duration that it should defer. Because the spoofed NAV Duration is (EIFS – DIFS) less than the intended Duration, to prevent unfairness to legacy nodes, the NAV will be set according to the rules defined in section 7.1.7.2.2.

### 9.5.2.2 MPDU Decodable

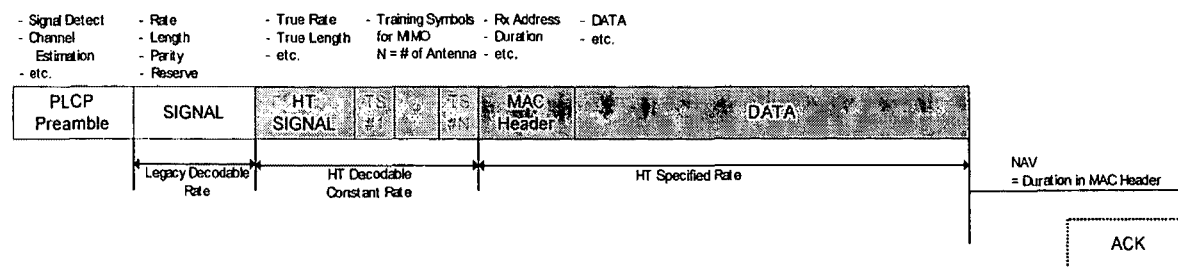


**Figure 34 – When Received by an HT Node and the MPDU is Decodable**

When the MPDU is decodable, an HT node will continue on with its MAC operation. If the Receive Address in the MAC Header does not match itself, it will set its NAV to the Duration indicated following existing 802.11 rules.

## 9.6 Protection mechanisms for MRA

### 9.6.1 How to choose between LongNAV and spoofing in MRA

The choice of protection mechanism is the choice of the initiator. If using a polled TXOP, or during the CFP, NAV protection has already been provided, and spoofing is not necessary.

However if the NAV has not been set, it is more effective to use spoofing protection.

There is only one possible performance advantage for LongNAV, if the final (or only) response PPDU is shorter than the grant, the initiator does not need to wait until the end of the scheduled response period, but can initiate additional transmissions a SIFS after the end of the actual response.

The recommended choice of protection mechanism is listed below:

Use LongNAV:

- During Polled TXOPs (zero overhead)
- For long aggregates
- Where maximum flexibility in scheduling decisions must be kept
- For .11b coexistence

Use spoofing:

- For short aggregates
- In IBSS or ad-hoc mesh networks

### 9.6.2 Protection from Third Party HT Nodes

The protection of multi-responses from third party HT nodes is achieved using either single-ended spoofing or LongNAV.

In both cases, all STAs that can hear the initiator will have a non-zero NAV during the response periods, preventing them from transmission.

A response period for a receiver might not be used up, for some reason. This leaves the WM idle, possibly for more than a SIFS time. Although this unused TXOP is wasted, it does not create any problem, since all nodes that can hear the initiator will have their NAV set during the responses.

### 9.6.3 Protection from Hidden Nodes

In the case of MRA transmission from an HT AP, all nodes within the BSS should be able to hear and honor the spoofed NAV in the aggregate header, which is always transmitted at the most robust rate, there are no nodes hidden to the AP.

### 9.6.4 Protection from Legacy Nodes

Protection of the MRA from legacy nodes may be achieved via the spoofed NAV in the PLCP header of a MRA aggregate. Although not recognizing an HT MPDU, a legacy client should still be able to recognize such a spoofed NAV from the legacy PLCP header of the MRA aggregate and therefore enters a receiving state for the indicated duration, thereby stopping it from initiating transmissions during the indicated duration.

Alternatively the initiator transmits a legacy compatible PPDU that sets the NAV.

In both cases, the level of protection afforded by this method is the same as CTS-to-self.

Equation Chapter 1 Section 1

1

2

3

## 10. PHY-SAP service specification

The PHY service is provided to the MAC entry at an STA through the PHY service access point (PHY-SAP), as shown in Figure 11 of [1] and described in Clause 12 of that reference.

The amendments to the PHY-SAP parameters TXVECTOR and RXVECTOR are described in Sections 10.1.1 and 10.1.2 respectively.

### 10.1 PHY Specific Service Parameter List

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require PHY-dependent MAC state machines running in the MAC sublayer in order to meet certain PMD requirements. The PHY-dependent MAC state machine resides in a sublayer defined as the MAC sublayer management entity (MLME). In certain PMD implementations, the MLME may need to interact with the PLME as part of the normal PHY SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PMD. This subclause addresses the TXVECTOR and RXVECTOR for the MIMO-OFDM High Throughput PHY. The service parameters for TXVECTOR and RXVECTOR shall follow subclause 10.1.1 and 10.1.2.

#### 10.1.1 TXVECTOR

The TXVECTOR is an array of fields sent from the MAC to the PHY instructing the PHY how to transmit the PPDU.

| Parameter   | Associated Primitive           | Value                                                                                                                                     |
|-------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| PPDU FORMAT | PHY-TXSTART.request (TXVECTOR) | Legacy 20 in 20<br>HT 20 in 20<br>Legacy upper 20 in 40<br>Legacy lower 20 in 40<br>HT upper 20 in 40<br>HT lower 20 in 40<br>HT 40 in 40 |
| L-LENGTH    | PHY-TXSTART.request (TXVECTOR) | 1 – 4095                                                                                                                                  |
| L-DATARATE  | PHY-TXSTART.request (TXVECTOR) | 6, 9, 12, 18, 24, 36, 48,<br>and 54 (Support of 6, 12, and<br>24 data rates are mandatory.)                                               |
| L-SERVICE   | PHY-TXSTART.request (TXVECTOR) | Scrambler initialization;                                                                                                                 |



|                 |                                   |                                                          |
|-----------------|-----------------------------------|----------------------------------------------------------|
|                 |                                   | 7 null bits + 9<br>reserved null bits                    |
| TX_PWR_LEVEL    | PHY-TXSTART.request<br>(TXVECTOR) | 1 – 8                                                    |
| HT-LENGTH       | PHY-TXSTART.request<br>(TXVECTOR) | 1 – 264143                                               |
| MCS             | PHY-TXSTART.request<br>(TXVECTOR) | 0 – 63                                                   |
| ADV CODING      | PHY-TXSTART.request<br>(TXVECTOR) | 0, 1, 2                                                  |
| SOUNDING        | PHY-TXSTART.request<br>(TXVECTOR) | 0, 1                                                     |
| NLTF            | PHY-TXSTART.request<br>(TXVECTOR) | 2 – 4                                                    |
| AGGREGATE       | PHY-TXSTART.request<br>(TXVECTOR) | 0, 1                                                     |
| SCRAMBLER-INIT  | PHY-TXSTART.request<br>(TXVECTOR) | 0, 1, 2, 3                                               |
| SHORT-GI        | PHY-TXSTART.request<br>(TXVECTOR) | 0, 1                                                     |
| BEAMFORMED      | PHY-TXSTART.request<br>(TXVECTOR) | 0, 1                                                     |
| BEAMFORM MATRIX | PHY-TXSTART.request<br>(TXVECTOR) | $N_{TX} \times N_{SS} \times N_{SD}$ complex<br>matrices |

1 **Table 12: Table of parameters for the TX Vector**

2 **10.1.1.1 TXVECTOR PPDU FORMAT**

3 The PPDU FORMAT field specifies whether the PPDU is to be sent using a legacy PPDU  
4 format or using a high-throughput format. Legacy is interpreted to be 802.11g if operating in the  
5 2.4 GHz band and 802.11a if operating in the 5 GHz band. Furthermore, it specifies the channel  
6 (i.e, the full 20MHz channel, the upper 20MHz sub-channel in the 40MHz channel, the lower  
7 20MHz sub-channel in the 40MHz channel, or the full 40MHz channel) at which the PPDU is to  
8 be sent.

9

10 The value of this field effects the interpretation of many of the other TXVECTOR fields.

11

12 **10.1.1.2 TXVECTOR L-LENGTH**

13 The allowed values for the L-LENGTH parameter are in the range of 1–4095.

In legacy format this parameter is used to indicate the number of octets in the MPDU which the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start the transmission. In high-throughput format this parameter (along with L-DATARATE) is used to spoof the length of the current PPDU and possibly additional PDUs.

#### 10.1.1.3 TXVECTOR L-DATARATE

In Legacy Format the L-DATARATE parameter describes the bit rate at which the PLCP shall transmit the PSDU. Its value can be any of the rates: 6, 9, 12, 18, 24, 36, 48, and 54. Data rates of 6, 12, and 24 shall be supported; other rates may also be supported. In high-throughput format this parameter (along with L-LENGTH) is used to spoof the length of the current PPDU and possibly additional PDUs. For spoofing purposes, L-DATARATE in the L-SIG is set to 6Mbps.

#### 10.1.1.4 TXVECTOR L-SERVICE

In legacy format the L-SERVICE parameter consists of 7 null bits used for the scrambler initialization and 9 null bits reserved for future use. In HT format this parameter is Null.

#### 10.1.1.5 TXVECTOR TXPWR\_LEVEL

The allowed values for the TXPWR\_LEVEL parameter are in the range from 1–8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission. In high-throughput format the transmit power is the aggregate of the power from all transmit antennas.

#### 10.1.1.6 TXVECTOR HT-LENGTH

The allowed values for this parameter are 1 – 264143. In HT format this parameter indicates the number of octets in the PSDU to be sent in the PPDU. In legacy format this parameter is Null.

#### 10.1.1.7 TXVECTOR MCS

The allowed values for this parameter are 0 – 63. In HT format this parameter indicates the modulation and coding scheme. The number is an index into the MCS table given in Table 7 of current PHY draft. In legacy format this parameter is Null.

#### 10.1.1.8 TXVECTOR ADV CODING

In HT format this parameter indicates whether advanced coding is used. A value of 0 indicates that advanced coding is not used. In legacy format this parameter is Null. A value of 1 indicates LDPC coding, whereas a value of 2 indicates RS coding option.

**10.1.1.9 TXVECTOR SOUNDING**

In HT format this parameter indicates whether this PPDU is a sounding PPDU. A value of 0 indicates that it is not a sounding PPDU. A value of 1 indicates that it is a sounding PPDU. In legacy format this parameter is Null.

**10.1.1.10 TXVECTOR NLTF**

In high-throughout format this parameter specifies the number of long training fields. In legacy format this parameter is Null.

**10.1.1.11 TXVECTOR AGGREGATE**

In high-throughout format this parameter indicates whether the PPDU contains an aggregate PSDU. A value of 0 indicates that the PSDU is not an aggregate and a value of 1 indicates that the PSDU is an aggregate. In legacy format this parameter is Null.

**10.1.1.12 TXVECTOR SCRAMBLER-INIT**

In high-throughout format this is the scrambler initialization field. It is a two bit field. In legacy format this parameter is Null.

**10.1.1.13 TXVECTOR SHORT-GI**

In high-throughout format this parameter indicates whether the data is sent with a short guard interval (0.4 us). A value of zero indicates a standard GI and a value of 1 indicates a short GI. In legacy format this parameter is Null.

**10.1.1.14 TXVECTOR BEAMFORMED**

In high-throughout format this parameter indicates whether a beamforming matrix is applied to the data. A value of zero indicates that no beamforming is applied and a value of 1 indicates that beamforming is applied. In legacy format this parameter is Null.

**10.1.1.15 TXVECTOR BEAMFORM MATRIX**

In high-throughout format this field gives the  $N_{TX} \times N_{SS} \times N_{SD}$  complex matrices which is used to beamform the PPDU. This field is only valid when the BEAMFORMING parameter is one. In legacy format this parameter is Null.

## 10.1.2 RXVECTOR

The RXVECTOR is an array of fields sent from the PHY to the MAC giving information regarding the received PPDU.

| Parameter   | Associated Primitive               | Value                                                                                                                                     |
|-------------|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| PPDU FORMAT | PHY-RXSTART.indicate<br>(RXVECTOR) | Legacy 20 in 20<br>HT 20 in 20<br>Legacy upper 20 in 40<br>Legacy lower 20 in 40<br>HT upper 20 in 40<br>HT lower 20 in 40<br>HT 40 in 40 |
| L-LENGTH    | PHY-RXSTART.indicate<br>(RXVECTOR) | 1 – 4095                                                                                                                                  |
| RSSI        | PHY-RXSTART.indicate<br>(RXVECTOR) | 0 – RSSI maximum                                                                                                                          |
| L-DATARATE  | PHY-RXSTART.indicate<br>(RXVECTOR) | 6, 9, 12, 18, 24, 36, 48,<br>and 54                                                                                                       |
|             |                                    |                                                                                                                                           |
| BW          | PHY-RXSTART.indicate<br>(RXVECTOR) | 20, 40                                                                                                                                    |
| HT-LENGTH   | PHY-RXSTART.indicate<br>(RXVECTOR) | 1 – 264143                                                                                                                                |
| MCS         | PHY-RXSTART.indicate<br>(RXVECTOR) | 0 – 63                                                                                                                                    |
| ADV CODING  | PHY-RXSTART.indicate<br>(RXVECTOR) | 0, 1, 2                                                                                                                                   |
| SOUNDING    | PHY-RXSTART.indicate<br>(RXVECTOR) | 0, 1                                                                                                                                      |
| NLTF        | PHY-RXSTART.indicate<br>(RXVECTOR) | 1 – 4                                                                                                                                     |
| AGGREGATE   | PHY-RXSTART.indicate<br>(RXVECTOR) | 0, 1                                                                                                                                      |
| SHORT-GI    | PHY-RXSTART.indicate<br>(RXVECTOR) | 0, 1                                                                                                                                      |

**Table 13: Table of parameters for the RX Vector**

**10.1.2.1 RXVECTOR PPDU FORMAT**

The PPDU FORMAT field specifies whether the received PPDU has a legacy PPDU format or a high-throughput format. Legacy is interpreted to be 802.11g if operating in the 2.4 GHz band and 802.11a if operating in the 5 GHz band. Furthermore, it specifies the channel (i.e, the full 20MHz channel, the upper 20MHz sub-channel in the 40MHz channel, the lower 20MHz sub-channel in the 40MHz channel, or the full 40MHz channel) at which the received PPDU was sent.

**10.1.2.2 RXVECTOR L-LENGTH**

The allowed values for the L-LENGTH parameter are in the range of 1–4095. This parameter is used to indicate the value of the L-LENGTH field in received PPDU. If this was a legacy PPDU then this parameter is the actual length of the PPDU. If this is a HT PPDU then this parameter, along with the L-DATARATE parameter, is used to calculate the spoofed duration.

**10.1.2.3 RXVECTOR RSSI**

The allowed values for the receive signal strength indicator (RSSI) parameter are in the range from 0 through RSSI maximum. This parameter is a measure by the PHY sub-layer of the energy observed at the antenna used to receive the current PPDU. RSSI shall be measured during the reception of the PLCP preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. The value of RSSI is the maximum of the RSSI values from each receive antenna.

**10.1.2.4 RXVECTOR L-DATARATE**

The allowed values for L-DATARATE are: 6, 9, 12, 18, 24, 36, 48, and 54. This parameter is used to indicate the value of the L-DATARATE field in the received PPDU. If this is a legacy PPDU this is the data rate at which the data was transmitted. If this is an HT PPDU then this parameter, along with L-LENGTH, is used to calculate the spoof duration.

**10.1.2.5 RXVECTOR BW**

In high-throughput format this parameter specifies whether the received PPDU was a 20 MHz bandwidth or 40 MHz bandwidth HT PPDU. In legacy format this parameter is Null.

**10.1.2.6 RXVECTOR HT-LENGTH**

The allowed values for this parameter are 1 – 264143. In HT format this parameter indicates the value contained in the HT-LENGTH field. This parameter specifies the number of octets to be transferred from the PHY to the MAC sub-layer. In legacy format this parameter is Null.

**10.1.2.7 RXVECTOR MCS**

The allowed values for this parameter are 0 – 63. The number is an index into the MCS table given in Table 7 of current PHY draft. In HT format this parameter indicates the value of the MCS field in the PPDU HT-SIGNAL field. In legacy format this parameter is Null.

**10.1.2.8 RXVECTOR ADV CODING**

In HT format this parameter indicates whether advanced coding was used in the PPDU. A value of 0 indicates that advanced coding is not used. In legacy format this parameter is Null. A value of 1 indicates LDPC coding, whereas a value of 2 indicates RS coding option.

**10.1.2.9 RXVECTOR SOUNDING**

In HT format this parameter indicates whether this PPDU is a sounding PPDU. A value of 0 indicates that it is not a sounding PPDU. A value of 1 indicates that it is a sounding PPDU. In legacy format this parameter is Null.

**10.1.2.10 RXVECTOR NLTF**

In high-throughout format this parameter specifies the number of long training fields. In legacy format this parameter is Null.

**10.1.2.11 RXVECTOR REUSE L-PREABLE**

In high-throughout format this parameter indicates whether the legacy preamble can be reused to estimate the channel of one of the spatial streams. A value of 0 indicates no reuse and a value of 1 indicates reuse. In legacy format this parameter is Null. (Comment: This comes from PHY draft 3.0. Is this still included?)

**10.1.2.12 RXVECTOR AGGREGATE**

In high-throughout format this parameter indicates whether the PPDU contains an aggregate PSDU. A value of 0 indicates that the PSDU is not an aggregate and a value of 1 indicates that the PSDU is an aggregate. This value is used by the MAC sub-layer to indicate whether de-aggregation is required. In legacy format this parameter is Null.

### 10.1.2.13 RXVECTOR SHORT-GI

In high-throughout format this parameter indicates whether the data was sent with a short guard interval (0.4 us). A value of zero indicates a standard GI and a value of 1 indicates a short GI. In legacy format this parameter is ignored.

## 11. MIMO-OFDM HT PHY specification

### 11.1 Overview

#### 11.1.1 Introduction (Informative)

With the aim to increase the maximum PHY layer data rate, our proposal introduces two primary techniques:

- Transmission of Multiple Spatial Streams via Multiple Transmit Antennas. Our recommendation is to make 2 antennas mandatory, with the option to scale to 4 antennas.
- Extended Bandwidth signaling. 20MHz channelization shall be mandatory worldwide. Our recommendation is to support 40MHz channelization in regulatory domains that will permit wider bandwidth operation

We have also introduced several secondary techniques for increasing throughput. These include:

- A reduced guard interval of 400ns, channel dispersion permitting (e.g. TGn channel model B)
- Higher channel coding rate of 7/8
- 256-QAM in certain advanced transmission modes

Due to the susceptibility of a wireless channel to multipath fading, especially with multiple antennas, our proposal has also introduced several techniques for improving the robustness of the link between the transmitter and the receiver, with the aim to keep the client (station) configuration low-cost and low-power:

- Transmitter beamforming (with the understanding that Access Points will be able to support more than 2 antennas, while the client stations would be restricted to 2 antennas).
- Advanced channel coding (such as LDPC). Such codes have a larger minimum free distance compared to the existing 802.11a convolutional code, and hence, are able to better exploit the frequency and spatial diversity in the channel.
- Advanced Transmitter beamforming techniques. These include water-filling concepts in the spatial domain, such as unequal power ratios and different choice of modulation-coding schemes on the various spatial streams.

### 11.1.1.1 Frequency Bands of Operation

Our proposal supports operation of devices in 2.4GHz, 5GHz, and 4.9GHz. Operation in 4.9GHz shall conform to 802.11j rules.

### 11.1.1.2 Options for throughput enhancement

The throughput calculation for 802.11a, at its highest data rate, can be factorized as:

$$\text{Data Rate} = \frac{20M \text{ time samples}}{1 \text{ second}} \cdot \frac{48 \text{ freq tones}}{64 \text{ freq tones}} \cdot \frac{6 \text{ coded bits}}{1 \text{ freq tone}} \cdot \frac{3 \text{ info bits}}{4 \text{ coded bits}} \cdot \frac{64 \text{ freq tones}}{80 \text{ times samples}}$$

channel spacing      guard band overhead      constellation size      coding rate      guard interval overhead

$$= 54M \text{ info bits/second}$$

Besides spatial multiplexing, there are 4 other options for increasing data rate: (a) increasing the channel bandwidth, (b) increasing the constellation size, (c) increasing the coding rate, and (d) reducing the guard interval (GI) overhead. These options are summarized in Table 14.

| 802.11a/g                                                 | Our Proposal                                           | Requirement                        | Throughput Scaling Factor          |
|-----------------------------------------------------------|--------------------------------------------------------|------------------------------------|------------------------------------|
| Channel BW = 20MHz<br><br>Number of data subcarriers = 48 | Channel BW = 20MHz<br>Number of data subcarriers = 48  | Mandatory in device                | 1x                                 |
|                                                           | Channel BW = 40MHz<br>Number of data subcarriers = 108 | Mandatory in device                | 2.25x                              |
|                                                           | Channel BW larger than 40MHz                           | Not supported in device            |                                    |
| Number of Transmit Antennas = 1                           | Number of Transmit Antennas = 2                        | Mandatory in device                | 2x                                 |
|                                                           | Number of Transmit Antennas > 2                        | Optional in device (e.g. 3 and 4)  | 3x or 4x                           |
| Maximum Constellation Size = 64QAM                        | 64-QAM                                                 | Mandatory in device                | 1x                                 |
|                                                           | greater than 64QAM (i.e. 128 or 256 QAM)               | 256-QAM supported in ABF-MIMO mode | 1.16x (128-QAM)<br>1.33x (256-QAM) |
| GI = 800ns<br><br>Tsymbol = 3200ns                        | GI / Tsymbol = 800ns/3200ns                            | Mandatory in device                | 1x                                 |
|                                                           | GI / Tsymbol = 400ns/3200ns                            | Optional in device                 | 1.11x                              |
|                                                           | GI / Tsymbol = 800ns / 6400ns                          | Not supported in device            | 1.11x                              |
|                                                           | GI / Tsymbol = 400ns / 6400ns                          | Not supported in device            | 1.176x                             |
| Coding Rate                                               | ½, 2/3, ¾                                              | Mandatory in device                | 1x                                 |
|                                                           | 7/8 (advanced coding option)                           | Optional in device                 | 1.167x                             |

**Table 14: Options for Throughput Enhancement**

Of the options presented in Table 14 for throughput enhancement, our proposal focuses upon using spatial multiplexing (via multiple transmit antennas) and bandwidth expansion (from 20Mhz to 40Mhz) as means for increasing the physical layer data rates. This is because both



spatial multiplexing and channel bandwidth increase data rate by integer increments, whereas the rest of the techniques increase the data rate by fractional increments.

The use of a shorter Guard Interval (GI=400ns) and 7/8-th rate coding is optional for the data portion of the PPDU. Using 4 spatial streams in 40MHz, this leads to a maximum PHY data rate of 630Mbps, which is more than 10x the current data rate of 54Mbps. Note that the High Throughput (HT) preamble shall always use the full GI, i.e. 800us.

The basic mandatory configuration in our PHY proposal for throughput enhancement is 2 transmit antennas across a 20MHz channel bandwidth. The transmitter datapath is shown in Figure 35.

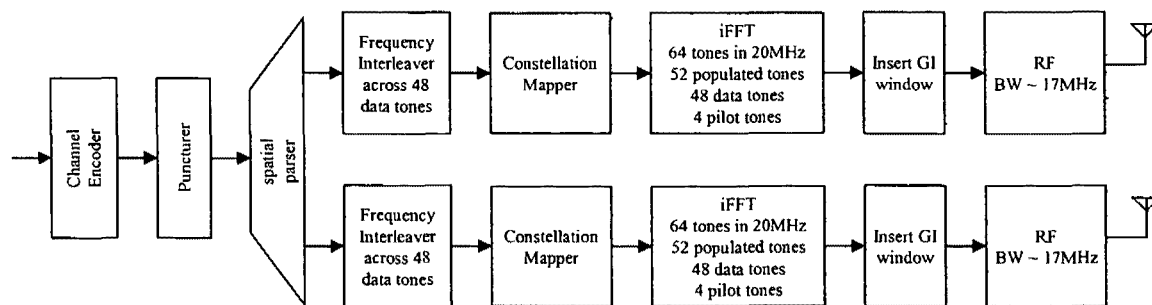


**Figure 35: Transmitter Datapath for 2-antenna MIMO in 20MHz**

Our proposal also includes provisions for 40MHz signaling in regulatory domains that permit it. The transmitter datapath for such a configuration is shown in Figure 36:

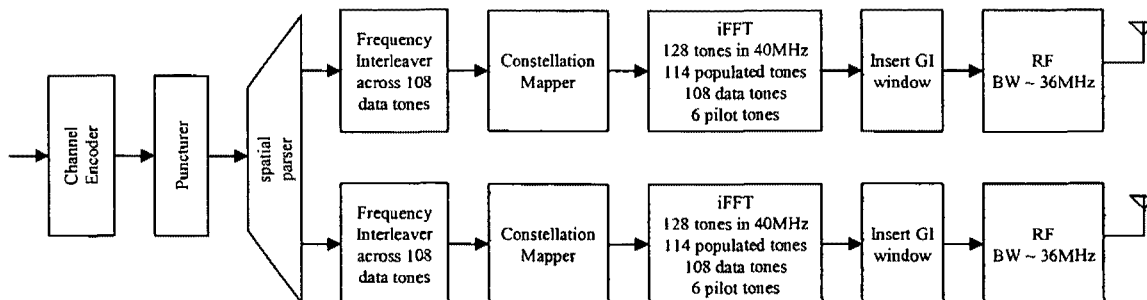
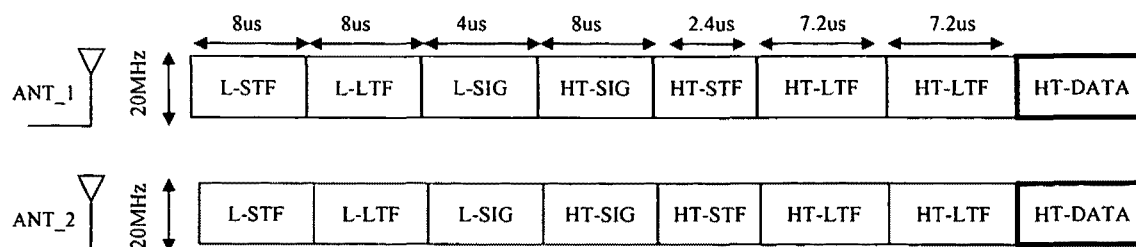


**Figure 36: Transmitter datapath for 2-antenna MIMO in 40MHz<sup>9</sup>**

### 11.1.1.3 PPDU Format for the Basic (Mandatory) MIMO Transmission

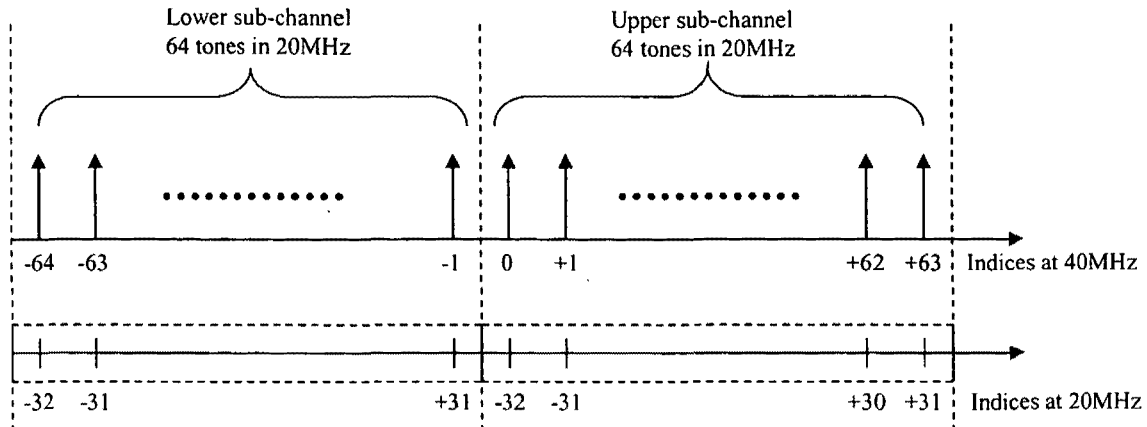
The PPDU format for transmission using 2 antennas in a 20MHz channelization is shown in Figure 37:



<sup>9</sup> 40MHz operation by an HT device shall only be permitted in those regulatory domain that allow it.

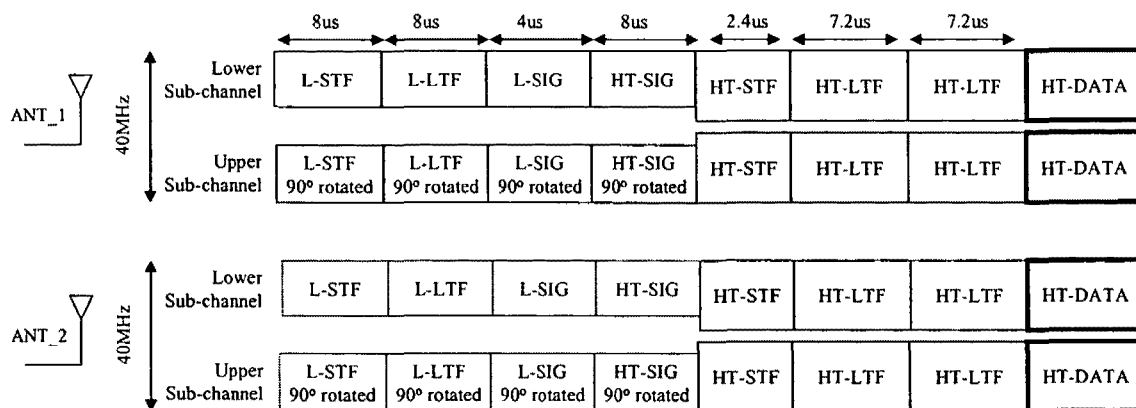
# Figure 37: PPDU Format for 2x20 Mandatory Basic MIMO Transmission

In the 40MHz bandwidth, there are two 20MHz wide sub-channels. The upper sub-channel spans from 0 to +63, and the lower sub-channel spans from -64 to -1, as shown in Figure 38. A 40MHz-capable HT device receiving a 20MHz-only transmission shall indicate to the MAC which sub-channel is currently active.



## Figure 38: Upper and Lower sub-channel specification in 40MHz

The PPDU format from two transmit antennas, each 40MHz wide, is shown in Figure 39.



## Figure 39: PPDU Format for 2x40 Mandatory Basic MIMO Transmission<sup>10</sup>

The legacy part of the HT preamble (i.e. L-STF to L-SIG) and HT-SIG may either be transmitted from one antenna or both antennas. If transmitted from both antennas, the mapping of this single spatial stream to two antennas has to be such that beamforming in the far-field is mitigated. One method for achieving this is to use a cyclical delay diversity (CDD) mapping. The optional part of the PPDU, corresponding to the CDD format, is shown in red color in Figure 37 and Figure 39.

### 11.1.1.4 HT PCLP Preamble for Synchronization purposes and Legacy Interoperability

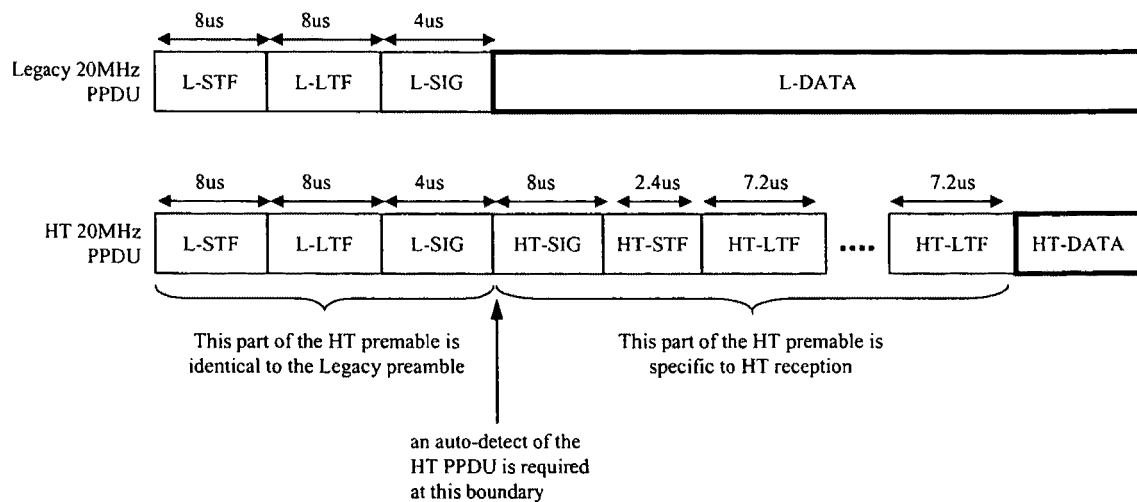
The functions performed by the preamble include:

1. Start-of-Packet (SoP) detection

<sup>10</sup> 40MHz operation by an HT device shall only be permitted in those regulatory domain that allow it.

- 1      2. AGC
- 2      3. Coarse Frequency Offset Estimation
- 3      4. Coarse Timing Offset Estimation
- 4      5. Fine Timing Offset Estimation
- 5      6. Fine Frequency Offset Estimation
- 6      7. Channel Estimation

7 The High Throughput (HT) preamble in our proposal is a concatenation of the legacy preamble  
 8 (identical to 802.11a/g) and a HT-specific preamble, as shown in Figure 40:



9

10 **Figure 40: HT Preamble format**

11 Concatenation of the legacy preamble allows PHY layer interoperability with 802.11a and ERP-  
 12 802.11g modems.

13 A HT receiver does not know apriori whether it is receiving a legacy PPDU or a HT PPDU.  
 14 Hence, a HT receiver has to perform an auto-detect after the legacy signal field (L-SIG) as to  
 15 whether a HT-SIG is being received or legacy data (L-DATA). Our preamble format includes  
 16 two provisions for auto-detecting the HT-SIG: (a) transmitting the HT-SIG as a BPSK signal on  
 17 the quadrature axis instead of the in-phase axis, and (b) inverting the pilot polarity in going from  
 18 the L-SIG to the HT-SIG.

19 The legacy part of the HT preamble allows a legacy receiver to properly decode the L-SIG. A  
 20 HT receiver shall also perform functions 1 through 7 (SoP to Channel Estimation) to successfully  
 21 decode the HT-SIG. It is anticipated that functions 1 through 4 (and perhaps function 5) are  
 22 performed by the legacy short training field (L-STF), and functions 5 through 7 are performed by  
 23 the legacy long training field (L-LTF).

24 Since a HT device (in our proposal) shall support multiple transmit antennas, the legacy part of  
 25 the preamble can either be transmitted from one antenna or from multiple antennas. If more than  
 26 one antenna is used for transmission, it is recommended that the signal be shifted in a cyclical  
 27 fashion across the transmit antenna array. This technique introduces cyclical delay diversity  
 28 (CDD), and it tends to reduce the "effective" length of the guard interval, as seen by a legacy  
 29 device. Hence, the total shift across the transmit antenna array should be limited to 50ns.

1 In the 40MHz mode, the L-STF in the lower sub-channel is identical to legacy, whereas the L-  
2 STF in the upper sub-channel is a 90 degree phase rotation of the legacy STF. This rotation is  
3 performed to keep the PAPR of the STF low (see Figure 38 and Figure 39)

4 Since a legacy OFDM RX is not expected to “understand” any transmission after the L-SIG, the  
5 RATE and LENGTH fields in the L-SIG are “spoofed” such that a legacy OFDM RX can defer  
6 for the correct period of time.

7 The HT-SIG contains information needed to correctly de-map and decode the HT data field (i.e.  
8 the MIMO-OFDM symbols). It also contains fields for supporting advanced techniques that are  
9 described next.

10 Since the L-STF does not provide a sufficiently accurate power measurement for MIMO AGC  
11 purposes, a HT-STF has been introduced after the HT-SIG. The HT-STF is tone-interleaved  
12 symbol across the transmit antenna array. The HT short training symbol uses 24 tones (L-STF  
13 uses 12 tones in a 20 MHz channel). The choice of 24 tones permits accurate AGC  
14 measurements across 4 transmit antennas. In the 40 MHz channel, 48 tones are used in the HT-  
15 STF. The 24 (48) tones are interleaved across the antennas, i.e., 6 (12) tones are used per antenna  
16 if there are 4 transmitter antennas, and likewise 12 (24) are used per antenna if there are 2  
17 transmitter antennas. The length of the HT-STF is 1.6 $\mu$ s. Since, the purpose of HT-STF is purely  
18 for AGC purposes, only one STS is needed. Together with the 0.8 $\mu$ s guard interval, the total  
19 length of the HT-STF is 2.4 $\mu$ s. The GI of the HT-STF, i.e. the first 0.8 $\mu$ s, would contain echoes  
20 from the previous symbol. Hence, a clean measurement of power is made in the 1.6 $\mu$ s portion of  
21 the HT-STF. It is anticipated that the RF transient settling after the AGC switch would occur in  
22 the GI of the HT-LTF that follows the HT-STF.

23 After the AGC has been “fine-tuned” for HT reception, channel estimation and fine frequency  
24 offset estimation are performed using the HT Long Training Symbols. The number of HT-LTFs  
25 is equal to the number of antennas in the basic MIMO mode. For example, with two transmit  
26 antennas, two HT-LTFs are sent. The HT-LTF is also tone interleaved to minimize the power  
27 fluctuation with respect to the AGC setting (obtained via the HT-STF). Therefore, one HT-LTF  
28 would cover half of the tones in the two antenna case. Remaining tones are covered in the second  
29 HT-LTF. The HT-LTF consists of two Long Training Symbols (LTS) as in 802.11a/g and a  
30 regular guard interval of 0.8  $\mu$ s. The total length of one HT-LTF is 7.2 $\mu$ s.

#### 31 11.1.1.5 Duplicate 6Mbps mode

32 The lowest data rate in the 40MHz mode would be 13.5Mbps (= 6Mbps x 2.25), if independent  
33 information bits are mapped to the upper and lower sub-channels. A 6Mbps mode in 40MHz is  
34 obtained by duplicating the data from the lower sub-channel to the upper sub-channel. For the  
35 6Mbps mode in 40MHz, the MPDU is encoded, punctured, interleaved, and constellation-  
36 mapped as a 6Mbps transmission in 20MHz. The duplication is performed just prior to the iFFT  
37 sub-carrier mapping, as shown in Figure 41.

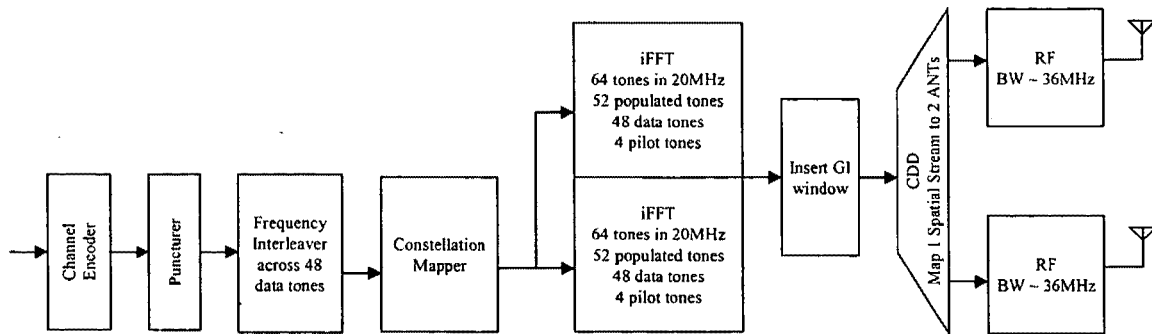


**Figure 41: Transmitter configuration for 6Mbps in 40MHz<sup>11</sup>**

Since the 6Mbps duplicate mode comprises of 1 spatial stream, only 1 HT-LTF is needed. Also note that there is no tone-fill past the HT-SIG, unlike the regular 40MHz PPDU format shown in Figure 39. The PPDU format for the 6Mbps duplicate mode is shown in Figure 42:

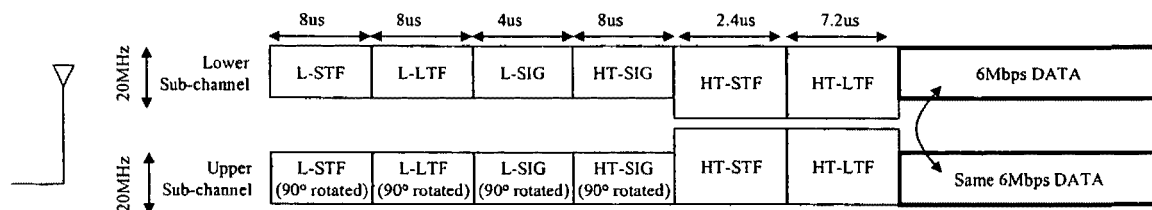


**Figure 42: PPDU format for 6Mbps duplicate mode**

Pilot locations in the duplicate mode follow the pilot locations in the 20MHz mode. The duplicate 6Mbps mode (in 40MHz) is signaled as mode 32 in the MCS set (see Table 20).

#### 11.1.1.6 Support for Advanced Techniques

All advanced techniques are optional in our proposal.

In our basic mandatory 40MHz MIMO mode, the number of data streams created by the spatial parser in Figure 35 is the same as the number of transmit antennas. And, in this basic configuration, each data stream (henceforth called spatial stream) is mapped to exactly one transmit antenna.

If Channel State Information (CSI) is available at the transmitter, we can perform spatial “shaping” using a steering matrix for each sub-carrier, as shown in Figure 43. In SVD style MIMO, the steering matrix is obtained via singular value decomposition (SVD) of the physical channel transfer function matrix,  $H$ . In SVD-MIMO, each spatial stream is “transmitted” on a “singular vector” obtained from the SVD of  $H$ . We can further perform spatial water-filling by selecting an optimum power level, modulation level, and coding rate for each spatial stream.

Our proposal introduces two classes of transmit beamforming: basic beamforming with MIMO (BF-MIMO), and advanced beamforming with MIMO (ABF-MIMO). In basic transmit

<sup>11</sup> 40MHz operation by an HT device shall only be permitted in those regulatory domain that allow it.

beamforming, only spatial steering is performed. In advanced beamforming, each spatial stream has a unique MCS set and a unique power level. We also support bi-directional beamforming in the ABF-MIMO mode.

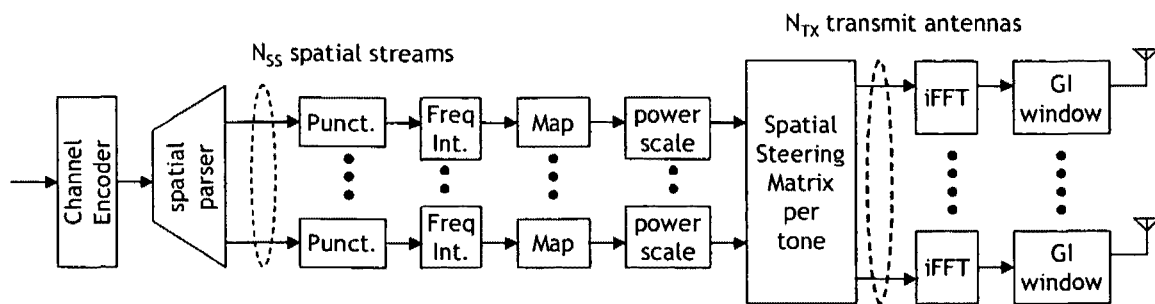


**Figure 43: Transmitter Datapath with option to perform spatial shaping**

If there is only one spatial stream at the transmitter, we can perform transmit beamforming using CSIT. If SVD of  $H$  is used to perform beamforming, that is termed as eigenbeamforming.

We also have the option of introducing advanced coding schemes in our proposal, such as LDPC or concatenated Reed-Solomon/Convolutional encoding. The use of advanced coding is signaled in the HT-SIG.

#### 11.1.1.7 Feedback Mechanisms

Our proposal consists of several feedback mechanisms, supported at the MAC layer, as shown in Table 15.

| Nature of Feedback | Device Requirement  | Type of Feedback                                 | Description                                                                                                                                                                                                                                                                                                                   |
|--------------------|---------------------|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Implicit Feedback  | Mandatory in device | Binary Response packet                           | <ul style="list-style-type: none"> <li>This only provides information to the TX whether its choice of the modulation-coding mode was supported by the channel.</li> <li>Does not provide any information to help perform spatial shaping</li> <li>Used when transmitting to legacy devices</li> </ul>                         |
| Implicit Feedback  | Optional            | Binary Response packet sent as a sounding packet | <ul style="list-style-type: none"> <li>Allows the Initiator to estimate the physical channel in the reverse link. If reciprocity can be assumed, and if the number of TX and RX antennas are identical at the recipient, the TX can use the derived CSI to perform spatial shaping (e.g. in the style of ABF-MIMO)</li> </ul> |
| Explicit Feedback  | Mandatory           | RR (Rate Recommendation) Response packet         | <ul style="list-style-type: none"> <li>The response packet contains a rate recommendation to the TX</li> <li>Since spatial shaping at the initiator is not desired, HT-LTFs are not appended</li> </ul>                                                                                                                       |

|                   |           |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------------|-----------|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Explicit Feedback | Mandatory | RR Response packet sent as a sounding packet | <ul style="list-style-type: none"> <li>The response packet contains a rate recommendation to the TX</li> <li>Response packet does not contain forward link Channel State Information (CSIT)</li> <li>However, the sounding packet allows reverse link channel estimation. And, assuming reciprocity and equal number of TX RX antennas at the recipient, the initiator can perform spatial shaping.</li> </ul> |
|-------------------|-----------|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## 1 Table 15: Feedback Mechanisms

### 2 11.1.1.8 Comparison among MIMO transmission modes

3 Our proposal supports three classes of MIMO Transmissions Modes, as outlined in Table 16:

4

| MIMO Modes                                   | Characteristic                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Extent of TX adaptation                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Basic-MIMO (Mandatory)                       | <ul style="list-style-type: none"> <li>Typically, <math>N_{SS} = N_{TX}</math></li> <li>Each spatial stream is mapped to one antenna</li> </ul>                                                                                                                                                                                                                                                                                                                                    | <ul style="list-style-type: none"> <li>No adaptation is performed in the spatial domain</li> <li>MCS selection (adaptation) is based upon either: (1) binary feedback (i.e. ACK/noACK), or (2) recommendation from the RX, or (3) availability of CSI at the TX</li> <li>All spatial streams shall use the same MCS and transmit at same power</li> </ul> |
| Basic-MIMO with TX Beamforming (Optional)    | <ul style="list-style-type: none"> <li>Typically, <math>N_{SS} \leq N_{TX}</math></li> <li>All spatial streams are spatially shaped via a steering matrix</li> <li>The steering matrix is defined for each tone in the OFDM modulation</li> <li>All spatial streams have identical MCS and power levels</li> </ul>                                                                                                                                                                 | <ul style="list-style-type: none"> <li>CSI is required at the TX</li> <li>Sounding packet from the recipient to the initiator is required to estimate the CSI at the transmitter</li> <li>RF calibration is required since reciprocity is used to perform TX beamforming</li> </ul>                                                                       |
| Advanced MIMO with TX Beamforming (Optional) | <ul style="list-style-type: none"> <li>Typically, <math>N_{SS} \leq N_{TX}</math></li> <li>All spatial streams are spatially shaped via a steering matrix</li> <li>The steering matrix is defined for each tone in the OFDM modulation</li> <li>Power levels for each spatial stream do not have to be identical</li> <li>MCS for each spatial stream does not have to be identical</li> <li>Bi-Directional Advanced Beamforming MIMO is supported via UD decomposition</li> </ul> | <ul style="list-style-type: none"> <li>CSI is required at the TX</li> <li>Sounding packet from the recipient to the initiator is required to estimate the CSI at the transmitter</li> <li>RF calibration is required since reciprocity is used to perform TX beamforming</li> </ul>                                                                       |

## 5 Table 16: MIMO Transmission options

### 11.1.1.9 “Modulation-Coding Scheme” (MCS) set for basic MIMO mode

Our proposal augments the 802.11a MCS set through the use of multiple spatial streams and bandwidth extension. The complete set is shown in Table 20. Our proposal recommends a mandatory data of 243Mbps using two spatial streams in regulatory domains that permit 40MHz operation. And, with an eye towards the future, our proposal supports scalability to 4 spatial streams, offering data rates in excess of 600Mbps.

### 11.1.2 Timing related parameters

| Parameter                                          | Value for 20 MHz Channel      | Value for 40 MHz Channel       |
|----------------------------------------------------|-------------------------------|--------------------------------|
| $N_{SD}$ : Number of data subcarriers              | 48                            | 108                            |
| $N_{SP}$ : Number of pilot subcarriers             | 4                             | 6                              |
| $N_{SN}$ : Number of center null subcarriers       | 1 (tone = 0)                  | 3 (tones = -1,0,+1)            |
| $N_{SR}$ : Subcarrier range<br>(index range)       | 26<br>(-26 ... +26)           | 58<br>(-58 ... +58)            |
| $\Delta_F$ : Subcarrier frequency spacing          | 0.3125 MHz<br>(= 20 MHz / 64) | 0.3125 MHz<br>(= 40 MHz / 128) |
| $T_{FFT}$ : IFFT/FFT period                        | 3.2 $\mu$ sec                 | 3.2 $\mu$ sec                  |
| $T_{GI}$ : GI duration                             | 0.8 $\mu$ sec                 | 0.8 $\mu$ sec                  |
| $T_{ShortGI}$ : Short GI duration                  | 0.4 $\mu$ sec                 | 0.4 $\mu$ sec                  |
| $T_{GI2}$ : Legacy LongTraining symbol GI duration | 1.6 $\mu$ sec                 | 1.6 $\mu$ sec                  |
| $T_{SYM}$ : Symbol interval                        | 4 $\mu$ sec                   | 4 $\mu$ sec                    |
| $T_{LONG}$ : Long training field duration          | 8 $\mu$ sec                   | 8 $\mu$ sec                    |
| $T_{HT-LONG}$ : HT Long training field duration    | 7.2 $\mu$ sec                 | 7.2 $\mu$ sec                  |
| $T_{SHORT}$ : Short training field duration        | 8 $\mu$ sec                   | 8 $\mu$ sec                    |
| $T_{HT-SHORT}$ : HT Short training field duration  | 2.4 $\mu$ sec                 | 2.4 $\mu$ sec                  |
| $T_S$ : Nyquist sampling interval                  | 50nsec                        | 25nsec                         |

**Table 17: Timing Related Parameters**

### 11.1.3 Mathematical conventions in signal descriptions

The transmitted signals will be described using the complex baseband signal notation. The transmitted signal at RF,  $r_{RF}(t)$ , is related to the complex baseband signal by the following relationship:

$$r_{RF}(t) = \text{Re}\{r(t)\exp(j2\pi f_c t)\} \quad (1)$$



where

$\text{Re}\{\cdot\}$  represents the real part of a complex variable;

$f_c$  denotes the center frequency of the carrier.

The transmitted baseband signal consists of several subframes. The timing boundaries for the various subframes are shown in Figure 44:

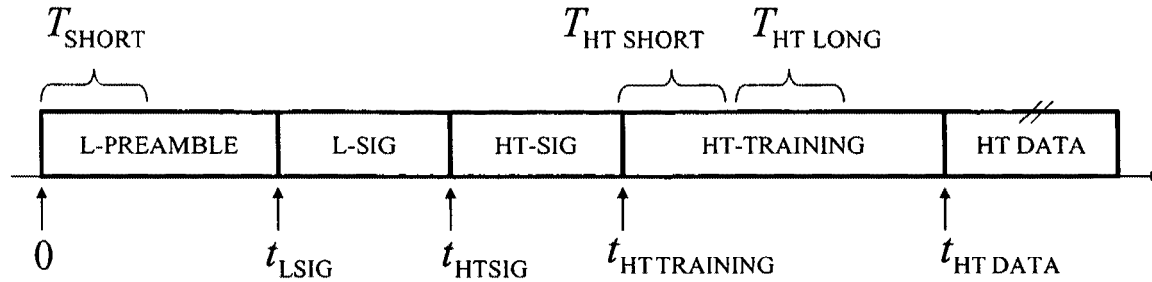


**Figure 44: Timing boundaries for subframes in a HT transmission**

The signal transmitted on antenna  $i_{Tx}$  is given by:

$$\begin{aligned}
 r_{\text{PACKET}}^{(i_{Tx})}(t) = & r_{\text{PREAMBLE}}^{(i_{Tx})}(t) + r_{\text{LSIG}}^{(i_{Tx})}(t - t_{\text{LSIG}}) \\
 & + r_{\text{HTSIG}}^{(i_{Tx})}(t - t_{\text{HTSIG}}) \\
 & + r_{\text{HT TRAINING}}^{(i_{Tx})}(t - t_{\text{HT TRAINING}}) \\
 & + r_{\text{DATA}}^{(i_{Tx})}(t - t_{\text{DATA}})
 \end{aligned} \quad (2)$$

The subframes of (2) are described in 11.2.1.3.1, 11.2.1.3.2, 11.2.1.4.1, 11.2.1.4.2 and 11.2.1.5. The time offsets  $t_{\text{SUBFRAME}}$  determines the starting time of the corresponding subframe. Per convention, it is assumed that the signal in equation (2) is causal, i.e. signal value is zero when its argument is zero.

All subframes of the signal are constructed using an inverse Fourier transform:

$$r_{\text{SUBFRAME}}^{(i_{Tx})}(t) = w_{\text{SUBFRAME}}(t) \sum_{k=-N_{\text{SR}}}^{N_{\text{SR}}} C_k \exp(j2\pi k \Delta_f t) \quad (3)$$

The PHY related parameters are listed in Table 17.

## 11.2 PLCP sublayer

### 11.2.1 Basic MIMO Mode

As described in Table 16, the basic MIMO mode does not involve any spatial steering. The basic MIMO mode can operate in both 20MHz and 40MHz channel bandwidths.

#### 11.2.1.1 Basic MIMO PPDU format

The HT Physical layer defines a PPDU format that provides interoperability and coexistence with 802.11a stations and with ERP-OFDM stations of 802.11g at the link level without protection mechanisms. Figure 45 shows the PPDU format for the basic MIMO mode:

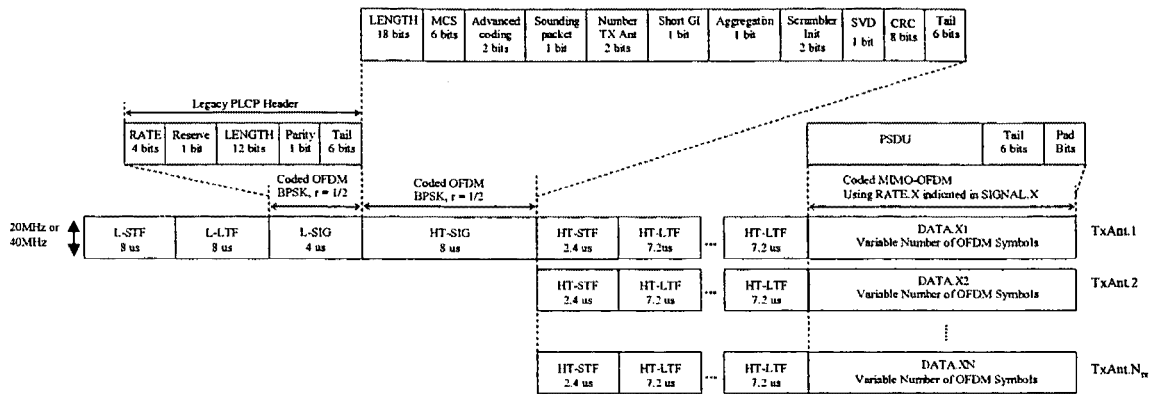


**Figure 45: PPDU Format for  $N_{Tx}$  antennas**

L-STF is the Legacy Short Training Field. Details of the L-STF symbols can be found in clause 11.2.1.3.1. The HT-STF is specific for HT. Details can be found in 11.2.1.3.3

L-LTF stands for Legacy Long Training Field symbol. Details of the L-LTF symbols can be found in clause 11.2.1.3.2. The HT-LTFs are specific for HT and the details can be found in clause 11.2.1.3.4

L-SIG is based on the Legacy SIGNAL field as defined in clause 17.3.4 in ref [2]. The modulation and coding procedure also follows the steps of 17.3.4 in ref [2]. The RATE and LENGTH fields in L-SIG are defined in accordance with “spoofing” procedures described in 11.2.1.4.1.

The HT-SIG field is the signal field dedicated to the HT mode. The structure of this field is the same as the L-SIG. Since our proposal supports interoperability between HT devices and legacy OFDM devices at the PHY layer, a HT receiver will not a-priori know whether a legacy packet is being received or a HT packet. That determination can only be made after the L-SIG. Our proposal supports two mechanisms for signaling a HT transmission: (a) send the HT-SIG as a BPSK signal on the Quadrature axis, instead of on the In-phase axis, and (b) invert the polarity of the pilots in the HT-SIG with respect to the pilots in the L-SIG. These two mechanism allow an auto-detect of a HT transmission. Note that the pilots in the HT-SIG are not transmitted on the Quadrature axis. The definition of the contents of HT-SIG is specified in 11.2.1.4.2.

The L-STF, L-LTF, L-SIG, and HT-SIG should be transmitted from the antenna array such that an omni-directional beam pattern is created in the far field. This reduces the probability of creating hidden nodes in the BSS. One way to create an omni-beam is to transmit these fields from strictly one antenna. However, if the transmitter is power-amplifier limited, array gain can be derived by transmitting on multiple antennas. Since transmitting the same signal from multiple antennas invariably creates beamforming, one way to mitigate beamforming is to phase shift (i.e. time delay) the signal across the transmit antenna array. For an OFDM symbol, the delay can be introduced cyclically. Since delaying the same signal introduces frequency selectivity at the receiver, such a transmission is commonly referred to as “cyclical delay diversity” or CDD. This transmission format is shown in Figure 46:

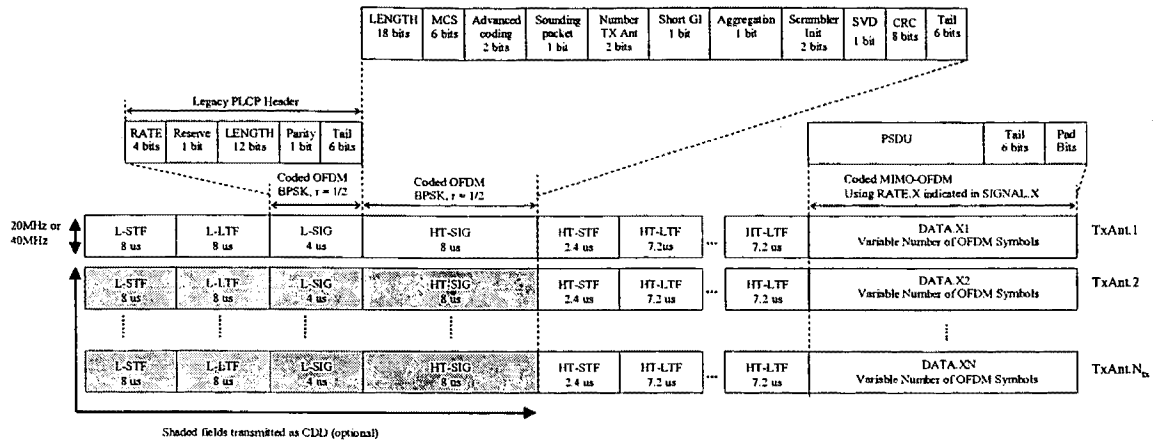


**Figure 46: PPDU format leveraging CDD transmission**

### 11.2.1.2 Legacy Protection

All MIMO transmissions (whether basic or advanced) are protected against legacy OFDM devices at the physical layer, and protected against legacy CCK/DSSS devices at the MAC layer.

The legacy short training field, the legacy long training field and the legacy signal field are transmitted such that a legacy OFDM receiver (802.11g or 802.11a) is able to “understand” these fields. In the basic MIMO mode, the transmitter selects the Modulation Coding Scheme either based on conventional rate selection heuristics or via implicit or explicit feedback. Thus, the RATE and LENGTH fields in the legacy signal field can be “spoofed” to allow the legacy OFDM receivers to correctly set their NAV.

RTS/CTS or CTS-to-self mechanism may be used to protect against legacy CCK/DSSS devices in an 802.11n BSS.

### 11.2.1.3 Training symbols specification

The training fields are used for synchronization purposes. As shown in Figure 45 and Figure 46, at the start of a packet, a legacy short training field is transmitted. The legacy short training field (L-STF) contains ten identical short training symbols. The legacy short training field may be transmitted from a single antenna, or from multiple antennas using CDD (refer to the next section). The legacy long training field follows the legacy short training field. Mapping of the legacy long training field (L-LTF), the L-SIG and the HT-SIG to the antenna array shall be identical to that of the legacy short training field (L-STF). After the HT-SIG, a HT-STF is transmitted across all the antennas to “fine tune” the AGC for MIMO reception. The HT-LTFs subsequently follow the HT-STF. The number of HT LTFs is equal to the number of spatial streams (which equals the number of transmit antennas in the basic MIMO mode). Data transmission follows the HT-LTFs.

#### 11.2.1.3.1 Legacy Short Training Field

The legacy short training symbol in our proposal is identical to the 802.11a short training symbol. The legacy short training OFDM symbol in the 20MHz mode is:

$$S_{-26,26} = \sqrt{13/6} \{0, 0, 1 + j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0, 0, 0, 0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0, 0, 1 + j, 0, 0, 0, 1 + j, 0, 0, 0, 1 + j, 0, 0, 0\} \quad (4)$$

The legacy short training OFDM symbol in 40MHz mode is:

$$S_{-58,58} = \sqrt{13/6} \{0,0,1+j,0,0,0,-1-j,0,0,0,1+j,0,0,0,-1-j,0,0,0,-1-j,0,0,0,1+j,0,0,0, \\ 0,0,0,0,-1-j,0,0,0,-1-j,0,0,0,1+j,0,0,0,1+j,0,0,0,1+j,0,0,0,0,0, \\ 0,0,0,0,0,0,0,0,0,0,j-1,0,0,0,-j+1,0,0,0,j-1,0,0,0,-j+1,0,0,0,-j+1,0,0,0,j-1, \\ 0,0,0,0,0,0,0,-j+1,0,0,0,-j+1,0,0,0,j-1,0,0,0,j-1,0,0,0,j-1,0,0,0,j-1,0,0\} \quad (5)$$

Let  $N_{TX}$  be the total number of transmit antennas. We normalize the transmit power across  $N_{TX}$  transmit antennas to be  $N_{TX}$ .

The short training symbols can be mapped to the transmit antenna array in several ways. L-STF should be transmitted omni-directionally to avoid beamforming, else hidden nodes can be potentially created in the BSS. One simple way is to transmit the L-STF on just one antenna. The L-STF is then described as follows:

$$r_{SHORT}^{(i_{TX})}(t) = \begin{cases} \sqrt{N_{TX}} w_{T.SHORT}(t) \sum_{k=-N_{SR}}^{N_{SR}} S_k \exp\{j2\pi k \Delta_F t\} & i_{TX} = 1 \\ 0 & otherwise \end{cases} \quad (6)$$

Since the legacy short training field (L-STF) constitutes a single spatial stream, it is also possible to map L-STF to multiple transmit antennas. This may be particularly useful if the transmit power is limited by the power amplifier characteristics. However, mapping 1 spatial stream to multiple transmit antennas would invariably result in beamforming, which can be mitigated by introducing a linear phase shift across the transmit antenna array. In the case of OFDM, the delay is introduced cyclically, and is commonly known as Cyclical Delay Diversity (CDD). When the STF is transmitted in a CDD fashion, the short training signal at the  $i_{TX}$ th transmit antenna is generated according to the following rule:

$$r_{SHORT}^{(i_{TX})}(t) = w_{TSHORT}(t) \sum_{k=-N_{CR}}^{N_{SR}} S_k \exp\left\{j2\pi k \Delta_F \left(t - (i_{TX} - 1)T_{shift}\right)\right\} \quad (7)$$

The short training signal is repeated every  $0.8\mu s$ . The entire short training field includes ten such periods, with a total duration of  $8\mu s$ . The short training field at the  $i_{TX}$ th transmit antenna is cyclically shifted by  $(i_{TX} - 1)T_{shift}$ , where  $T_{shift}$  is defined such that  $(N_{TX} - 1) \cdot T_{shift} = 50ns$  for both 20MHz and 40MHz. For example, with 4 transmit antennas,  $T_{shift} = 16.67ns$

#### 11.2.1.3.2 Legacy Long Training Field

The legacy long training OFDM symbol is identical to the 802.11a long training OFDM symbol. In the 20MHz mode, the long training OFDM symbol is given by

$$L_{-26;26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, 1, -1, 1, 1, 1\} \quad (8)$$

Similar to the L-STF, the legacy long training field (L-LTF) can be mapped to either a single antenna, or to multiple antennas via CDD. However, to guarantee AGC accuracy, the antenna mapping for the L-LTF should be identical to that of the L-STF. If only one antenna is used to transmit the legacy long training field, then the long training signal is given by:

$$r_{LONG}^{(i_{TX})}(t) = \begin{cases} \sqrt{N_{TX}} w_{TLONG}(t) \sum_{k=-N_{SR}}^{N_{SR}} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) & i_{TX} = 1 \\ 0 & otherwise \end{cases} \quad (9)$$

where  $T_{G12} = 1.6 \mu s$ .

If the long training signal is generated in a CDD fashion, we get:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{SR}}^{N_{SR}} L_k \exp\{j2\pi k \Delta_F (t - (i_{TX} - 1)T_{Shift} - T_{G12})\} \quad (10)$$

There are two legacy long training symbols in the legacy long training field. This is to ensure channel estimation accuracy, and also to permit fine frequency offset estimation. The total duration of the long training field (L-LTF) is  $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \mu s$ .

The legacy long training OFDM signal in the 40MHz mode is given by:

$$L_{-58;58} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, j, j, -j, -j, j, j, -j, j, -j, j, j, j, j, j, j, -j, -j, j, j, -j, j, -j, j, j, j, 0, j, -j, -j, j, j, -j, j, -j, -j, -j, -j, -j, -j, j, j, -j, -j, j, j, -j, j, -j, j, j, j\} \quad (11)$$

Tones in the upper subchannel (subcarriers +6 to +58) are obtained by phase rotating the 802.11a long OFDM training symbol tones by 90 degrees, whereas the tones within the lower subchannel (subcarriers -58 to -6) are identical to the 802.11a long OFDM training symbol tones.

It should be noted that neither the legacy fields (L-STF, L-LTF, LSIG) nor the HT-SIG undergo any phase rotation in the lower subchannel.

The subcarriers at  $\pm 32$  in 40MHz, which are the DC subcarriers for the legacy 20MHz transmission, are both nulled in the L-LTF. Such an arrangement allows proper synchronization of the 20MHz legacy device.

The legacy long training field together with the short training field constitutes the legacy PLCP preamble. The legacy device can perform the necessary synchronization to decode the legacy signal field. Hence, we can write  $r_{PREAMBLE}(t)$  in (2) as

$$r_{PREAMBLE}^{(i_{TX})}(t) = r_{SHORT}^{(i_{TX})}(t) + r_{LONG}^{(i_{TX})}(t - T_{SHORT}) \quad (12)$$

### 1 11.2.1.3.3 HT-Short Training Field

- 2 The HT-STF follows the HT signal field (see Figure 45), whose only purpose it to “fine tune” the  
 3 AGC for HT MIMO reception. Note that the first AGC operation is performed on the L-STF.  
 4 The HT short training symbol in the 20MHz mode is

$$\begin{aligned}
 & \left\{ \begin{aligned} & \{0, 0, -1-j, 0, 1+j, 0, -1-j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, 1+j, 0, \\ & 0, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, 1+j, 0, -1-j, 0, 0\} \quad N_{TX} = 2 \end{aligned} \right. \quad (13) \\
 & HTS_{-26,26} = \sqrt{13/12} \left\{ \begin{aligned} & \{0, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, -1-j, 0, -1-j, 0, 1+j, 0, -1-j, 0, -1-j, 0, 0, \\ & 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 0\} \quad N_{TX} = 3 \end{aligned} \right. \\
 & \left\{ \begin{aligned} & \{0, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, -1-j, 0, 0, \\ & 0, -1-j, 0, 1+j, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 0\} \quad N_{TX} = 4 \end{aligned} \right.
 \end{aligned}$$

- 6 Unlike the legacy short training symbol which uses 12 tones, the HT-Short training Symbol uses  
 7 24 tones in 20MHz which are tone-interleaved across the transmit antennas. For example, with  
 8  $N_{TX} = 4$ , each antenna would transmit 6 tones, which provide sufficient accuracy for estimating  
 9 the received power from one transmit-antenna to one receive-antenna.  
 10 The HT short training symbol in the 40 MHz mode consists of 48 tones, and is given by:

$$\begin{aligned}
 & \left\{ \begin{aligned} & \{0, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, -1-j, 0, 1+j, 0, -1-j, 0, 1+j, 0, -1-j, 0, 1+j, 0, -1-j, 0, \\ & 0, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, \\ & 0, 0, -1-j, 0, 1+j, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 0\} \quad N_{TX} = 2 \end{aligned} \right. \\
 & HTS_{-58,58} = \sqrt{19/16} \left\{ \begin{aligned} & \{0, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, \\ & 0, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, -1-j, 0, \\ & 0, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 0\} \quad N_{TX} = 3 \end{aligned} \right. \\
 & \left\{ \begin{aligned} & \{0, 0, -1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, 0, \\ & 0, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1-j, 0, -1-j, 0, -1-j, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, -1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, \\ & 0, 0, 1+j, 0, -1-j, 0, -1-j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 1+j, 0, 0\} \quad N_{TX} = 4 \end{aligned} \right. \quad (14)
 \end{aligned}$$

- 12 In the duplicate 6Mbps mode in 40MHz, the HT-STF shown in (14) is used, except for a scaling  
 13 factor change. The scaling factor for the 6Mbps duplicate mode is  $\sqrt{13/12}$ .  
 14 The HT short training signal is then generated by the following rule.

$$r_{MIMOSHORT}^{(i_n)}(t) = w_{MIMOSHORT}(t) \sqrt{N_{TX}} \sum_m \sum_{k=0}^{\left\lfloor \frac{11}{N_{TX}} \right\rfloor} MS_{2N_{TX}k+2(i_n-1)+m} \exp\{j2\pi(2N_{TX}k+2(i_n-1)+m)\Delta_F(t-T_{GI})\} \quad (15)$$

- 16 where  $T_{GI} = 0.8\mu s$ . The elements of  $m$  are  $m \in \{-24, 2\}$  for 20MHz and  $m \in \{-54, -30, 8, 34\}$   
 17 for 40MHz, respectively. The HT short training signal has a period of  $1.6\mu s$  – corresponding to  
 18 24 tones in 20MHz, and 48 tones in 40MHz – which is deemed sufficient for power  
 19 measurement purposes. Since the HT-STF is tone-interleaved at the transmitter, the power  
 20 periodicity of the HT-STF is also  $1.6\mu s$ .

#### 11.2.1.3.4 HT-Long Training Field

The HT long training fields are transmitted after the HT-STF. The number of HT long training fields is equal to the number of spatial streams. In the basic MIMO mode, the number of spatial streams is equal to the number of transmit antennas.

To minimize the power fluctuation between the HT-LTF and the AGC setting (which is derived from the HT-STF), the HT long training symbols are also tone-interleaved across the transmit antenna array. Since each antenna only transmits a sub-set of the tones, the HT long training sequences have been optimized to achieve the lowest peak-to-average power ratio (PAPR). There are a total of 9 sequences:

**Table 18: List of HT Long Training Fields**

| Sequence Number | $N_{TX}$ | BW    | Comment                                            |
|-----------------|----------|-------|----------------------------------------------------|
| 1               | 1        | 20MHz | Same as 802.11a                                    |
| 2               | 2        | 20MHz | 52 tones                                           |
| 3               | 3        | 20MHz | 52 tones                                           |
| 4               | 4        | 20MHz | 52 tones                                           |
| 5               | 1        | 40MHz | Duplicate format,<br>6Mbps in 40MHz<br>(104 Tones) |
| 6               | 1        | 40MHz | 114 tones                                          |
| 7               | 2        | 40MHz | 114 tones                                          |
| 8               | 3        | 40MHz | 114 tones                                          |
| 9               | 4        | 40MHz | 114 tones                                          |

In 20MHz, for  $N_{TX} = 2$ , sequence 1 is identical to the 802.11a LT sequence, as shown in (8).

In 20MHz, for  $N_{TX} = 2$ , sequence 2 is:

$$HTL_{-26,+26} = \{-1, 1, -1, 1, 1, 1, -1, -1, -1, -1, 1, 1, 1, -1, 1, -1, 1, -1, 1, 1, -1, 1, 1, 0, -1, 1, 1, -1, -1, 1, -1, -1, 1, -1, -1, 1, -1, 1, 1, 1, 1, -1, 1, 1, 1, 1, 1, 1\} \quad (16)$$

The tone-interleaving rule across the two antennas in 20MHz is grouped into 2 sets:

$$\begin{aligned} set\_1 &= [-26:2:-2], [+2:2:+26] \\ set\_2 &= [-25:2:-1], [+1:2:+25] \end{aligned} \quad (17)$$

where the notation in the brackets should be read as [starting index : step value : ending index].

$$HTL_{-26,+26} = \{-1 -111111 -1 -1 -11 -1 -1 -1 -1 -111111111 -1 -11 \\ 01 -1 -1 -11 -11 -11 -111 -11 -1 -111 -111 -11 -1 -11\} \quad (18)$$
$$\begin{aligned} set\_1 &= [-26:3:-2], [2:3:26] \\ set\_2 &= [-25:3:-1], [3:3:24] \\ set\_3 &= [-24:3:-3], [1:3:25] \end{aligned} \quad (19)$$
$$HTL_{-26,+26} = \{-111111-1-1-11-1111-111-11-1-1-1111-11-011-11-1-11-1-1-1-11-1-1-11111-111-1111\} \quad (20)$$
$$\begin{aligned} set\_1 &= [-26:4:-2], [3:4:23] \\ set\_2 &= [-25:4:-1], [4:4:24] \\ set\_3 &= [-24:4:-4], [1:4:25] \\ set\_4 &= [-23:4:-3], [2:4:26] \end{aligned} \quad (21)$$
$$HTL_{-58,+58} = \{-1\ 1\ 1\ 1\ 1\ -1\ 1\ 1\ -1\ -1\ -1\ -1\ 1\ 1\ 1\ 1\ 1\ -1\ 1\ 1\ -1\ 1\ -1\ -1\ 1\ 1\ -1\ -1\ 1\ 1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ 1\ 1\ 1\ -1\ -1\ 1\ 1\ -1\ -1\ 1\ 1\ -1\ 1\ 1\ 1\ 000\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ 1\ 1\ 1\ -1\ 1\ -1\ 1\ 1\ -1\ -1\ 1\ -1\ -1\ 1\ -1\ 1\ -1\ -1\ -1\ -1\ 1\ 1\ -1\ -1\ -1\ 1\ 1\ -1\ 1\ 1\ -1\ 1\ -1\ -1\ -1\ -1\ 1\ 1\ 1\}$$
$$HTL_{-58,+58} = \{-1\ 1\ 1\ 1\ 1\ -1\ 1\ 1\ -1\ -1\ -1\ 1\ 1\ -1\ 1\ 1\ -1\ 1\ 1\ -1\ 1\ -1\ 1\ 1\ -1$$
  

$$\begin{aligned} & -1\ 1\ 1\ -1\ -1\ 1\ 1\ -1\ -1\ -1\ 1\ -1\ 1\ 1\ 1\ 1\ -1\ -1\ 1\ -1\ -1\ -1\ -1\ -1\ 1\ -1\ 1\ -1\ 1 \\ & 0\ 0\ 0\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ -1\ 1\ 1\ 1\ -1\ 1\ -1\ 1\ 1\ -1\ -1\ 1\ -1\ 1\ 1\ -1\ 1\ -1 \\ & 1\ -1\ -1\ -1\ -1\ 1\ 1\ -1\ 1\ -1\ -1\ -1\ -1\ 1\ 1\ 1\ 1\ 1\ 1\ -1\ 1\ 1\ -1\ 1\ -1\ 1\ 1\ 1\} \end{aligned} \quad (23)$$

TCL 1002  
p. 832



$$set\_1 = [-58:2:2], [2:2:58]$$

(24)

$$set\_2 = [-57:2:-3], [3:2:57]$$

The tone-interleaving pattern in space and time for the HT long training fields is shown in Figure 47 for 2 antennas (2 spatial streams):

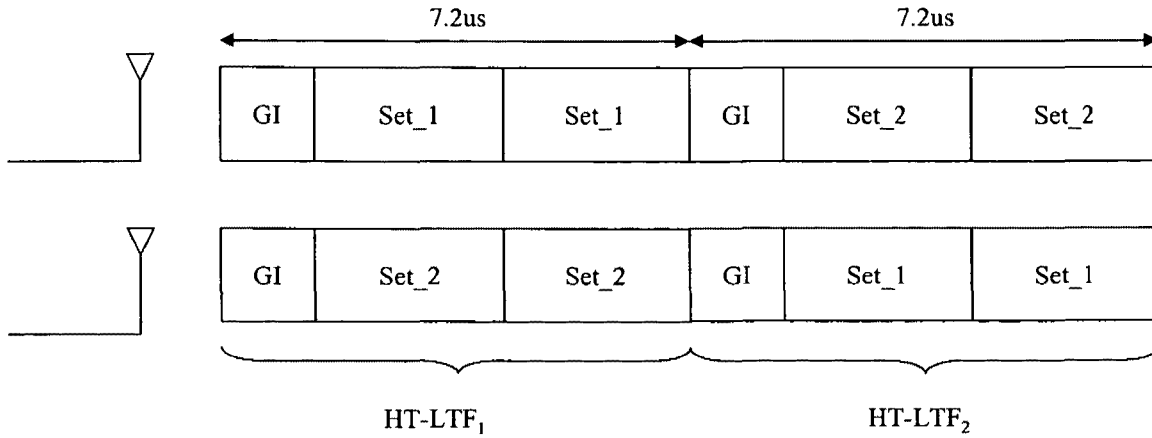


**Figure 47: HT-LTF pattern for 2 antennas (2 spatial streams)**

In 40MHz, for  $N_{TX} = 3$ , sequence 8 is:

$$HTL_{-58,+58} = \{-1 -1 -1 -1 -1 -1 1 1 1 -1 -1 -1 -1 -1 1 1 1 -1 -1 -1 -1 -1 1 1 1 1\}$$

$$1 1 1 1 1 -1 -1 -1 -1 -1 1 1 1 1 1 1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0$$

$$0 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 1 1 1 -1 -1 -1 1 1 1 1 1 1 1 1 -1 -1$$

$$-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 -1 -1 -1 \}$$

(25)

The tone-interleaving rule across 3 antennas in 40MHz is grouped into 3 sets:

$$set\_1 = [-58:3:-4], [2:3:56]$$

$$set\_2 = [-57:3:-3], [3:3:57]$$

(26)

$$set\_3 = [-56:3:-2], [4:3:58]$$

The tone-interleaving pattern in space and time for the HT long training fields is shown in Figure 48 for 3 antennas (3 spatial streams):

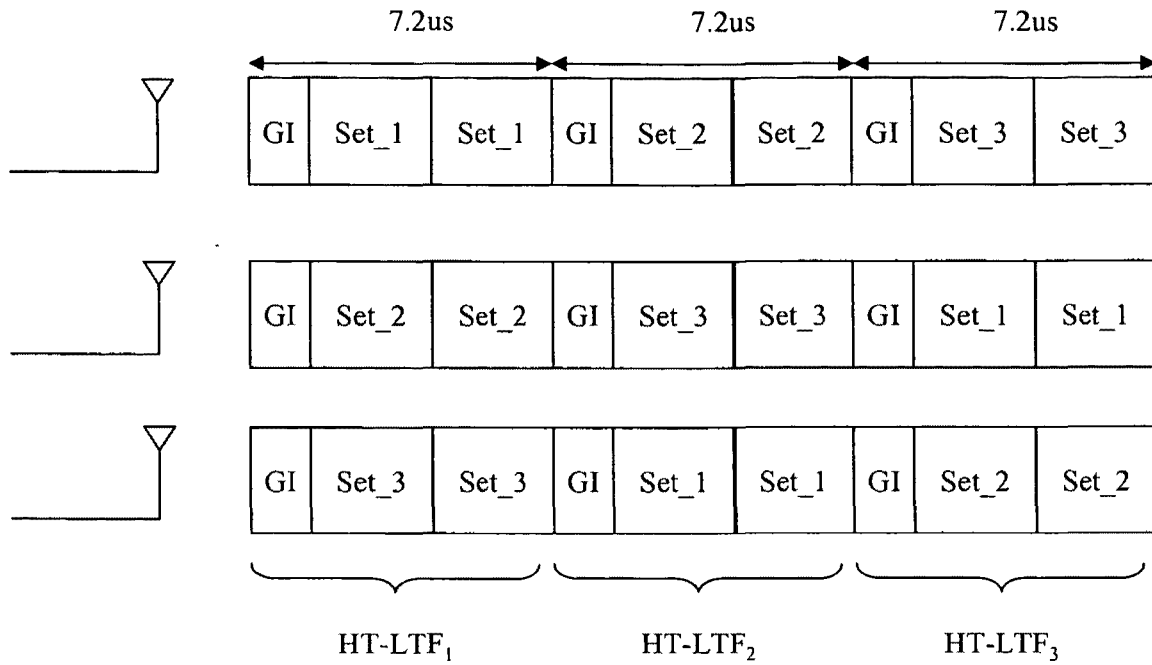


**Figure 48: HT-LTF pattern for 3 antennas (3 spatial streams)**

In 40MHz, for  $N_{TX} = 4$ , sequence 9 is:

$$HTL_{-58,+58} = \{-1 \ 1 \ -1 \ -1 \ -1 \ 1 \ 1 \ -1 \ 1 \ 1 \ 1 \ -1 \ 1 \ 1 \ 1 \ 1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1 \ 1 \ 1 \ 1 \ 1 \ 1 \ -1 \ -1 \ -1 \ 1 \ 0 \\ 0 \ 0 \ -1 \ 1 \ 1 \ -1 \ -1 \ -1 \ -1 \ 1 \ 1 \ 1 \ -1 \ 1 \ 1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1 \ 1 \ 1 \ 1 \ 1 \ 1 \ -1 \ -1 \ -1 \ 1 \ 0 \\ -1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ -1 \ -1 \ -1 \ -1 \ 1 \ 1 \ -1 \ 1 \ 1 \ 1 \ -1 \ 1 \ 1 \ -1 \ -1 \ -1 \ -1 \ -1 \ 1 \ 1 \ 1 \}$$

(27)

The tone-interleaving rule across 4 antennas in 40MHz is grouped into 4 sets:

$$\begin{aligned} set\_1 &= [-58:4:2], [5:4:57] \\ set\_2 &= [-57:4:-5], [2:4:58] \\ set\_3 &= [-56:4:-4], [3:4:55] \\ set\_4 &= [-55:4:-3], [4:4:56] \end{aligned}$$

(28)

The tone-interleaving pattern in space and time for the HT long training fields is shown in Figure 49 for 4 antennas (4 spatial streams):

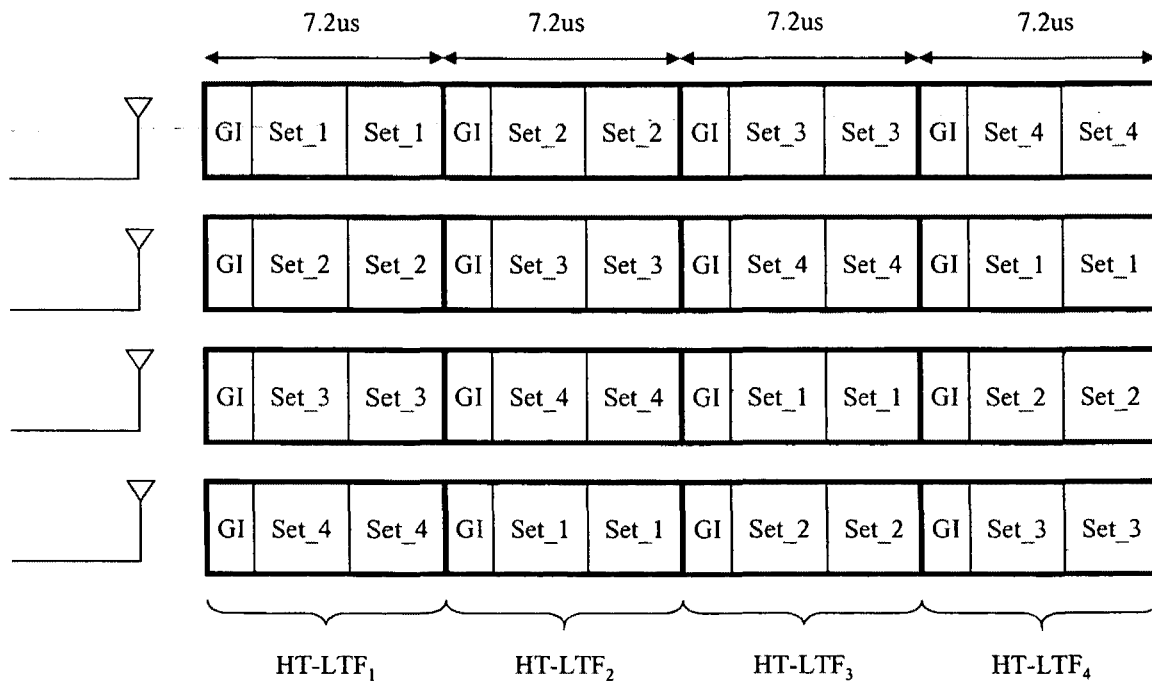


**Figure 49: HT-LTF pattern for 4 antennas (4 spatial streams)**

The HT long training signal is generated similarly to the HT short training signal.

$$r_{HTLONG}^{(i_n)}(t) = w_{HTLONG}(t) \sqrt{N_{TX}} \sum_{k \in \text{set}_{1+((i_n-1)+(n-1)) \bmod N_{TX}}} HTL_k \exp\{j2\pi k \Delta_f (t - T_{GI} - (n-1)T_{HTLONG})\}$$

for  $(n-1)T_{HTLONG} \leq t < nT_{HTLONG}$  and  $n=1, L, N_{TX}$   
for  $i_{TX} \in \{1, K, N_{TX}\}$

One HT long training field consists of two such long training symbol plus a regular 0.8μs guard interval. The total length of one long training field is 7.2μs, i.e.,  $T_{HTLONG} = 7.2\mu s$ . Since only part of tones are transmitted on each antenna at any given long training symbol, it takes  $N_{TX} \cdot T_{HTLONG}$  for all the antennas to cover all the tones. The duration of the HT-LTF is  $N_{TX} \cdot T_{HTLONG}$ .

The HT training fields in (2) for purposes of MIMO training can now be expressed as:

$$r_{HTTRAINING}^{(i_{TX})}(t) = r_{HTSHORT}^{(i_{TX})}(t) + r_{HTLONG}^{(i_{TX})}(t - T_{HTSHORT})$$

If TX beamforming is performed on 1 spatial stream, i.e.  $N_{ss} = 1$ , and  $N_{TX} > 1$ , only one HT-LTF is needed after the HT-STF, and this HT-LTF is identical to the 802.11a sequence, as shown in (8). We should point out that the legacy part of the HT preamble is never beamformed, i.e. L-STF, L-HTF, L-SIG, and HT-SIG. And, the HT-LTF is shaped by the same steering matrix as the HT-DATA, such that channel estimation is independent of the choice of the steering matrix used at the transmitter.

We should point out that the above discussion can be generalized for  $N_{ss} \geq 2$  and  $N_{TX} > N_{ss}$ . This case corresponds to TX beamforming with multiple spatial streams, whereby the number of HT-LTFs is equal to  $N_{ss}$ . And, as mentioned above, in addition to tone-interleaving, the HT-LTF also undergoes the same spatial steering as the HT-DATA fields.

11.2.1.4 Signal fields specification

The legacy long training field L-LTF shall be followed by the signal fields LSIG and HTSIG. The coding and modulation follow the steps of clause 17.3.4 in ref[2]: BPSK modulation is used for the L-SIG and HT-SIG, with code rate 1/2 resulting in 6 Mbit/s. Between the LSIG and the HTSIG symbol, the BPSK modulation shall be rotated counterclockwise by 90 degrees. This phase rotation can be used to “auto-detect” whether the frame being received is legacy or HT. The constellation bit encoding is depicted in Figure 50.

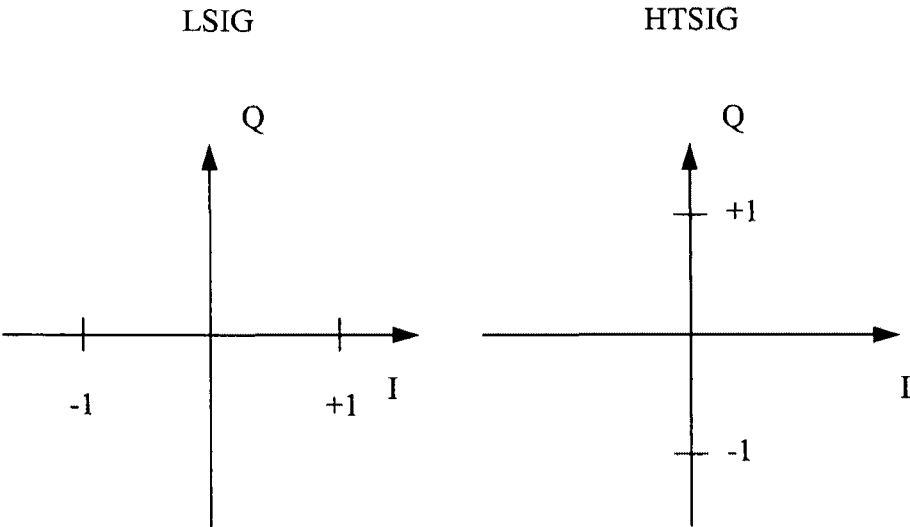


Figure 50: Constellation specification for LSIG and HTSIG

11.2.1.4.1 LSIG

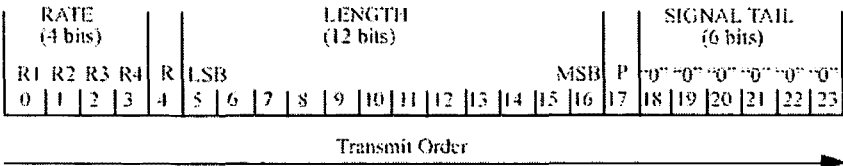


Figure 51: SIGNAL field bit assignment

In the 20MHz mode, the format of the LSIG field shall be the same as the SIGNAL field as defined in figure 111 in 17.3.4 in ref [2]. The combination of RATE and LENGTH is used to signal a station (OFDM mode only) the duration of a HT transmission. This duration does not have to be the actual duration of the HT frame. It can be used to reserve the medium beyond the actual transmission. The reservation of the medium through this kind of signaling is called “spoofing”.

To prevent a legacy station from accessing the medium during a HT frame transmission, the “duration” calculated from the RATE and LENGTH fields shall be at least as large as the actual duration of the HT frame, which is measured from the end of the LSIG field to the end of the DATA field. During an HT transmission, the RATE field is set to 6Mbps, whereas the LENGTH field is set based on the “duration” value.

In the 40MHz mode, the legacy signal field is duplicated such that tones are filled from -58 to -6 (lower-subchannel), and from +6 to +58 (upper-subchannel). The upper subchannel shall be phase rotated by 90 degrees, in the same way as the LTS as described in 11.2.1.3.2

The LSIG shall be transmitted in the same fashion as the legacy short and the legacy long training fields. If L-STF and L-LTF are transmitted from a single antenna, we index that antenna as  $i_{Tx}=1$  to be consistent with 11.2.1.3.2. Denote  $LSIG_{-26,26}$  and  $LSIG_{-58,58}$  as the LSIG OFDM symbol generated for 20MHz and 40Mhz respectively. Then, for transmission over a single antenna, we have,

$$r_{LSIG}^{i_{Tx}}(t) = \begin{cases} \sqrt{N_{Tx}} w_{SYM}(t) \sum_{k=-N_{SR}}^{N_{SR}} LSIG_k \exp\{j2\pi k \Delta_F (t - T_{GI})\} & i_{Tx} = 1 \\ 0 & otherwise \end{cases} \quad (31)$$

Similarly, if the legacy training fields are transmitted across multiple transmit antennas using CDD, we have

$$r_{LSIG}^{(i_{Tx})} = w_{SYM}(t) \sum_{k=-N_{SR}}^{N_{SR}} LSIG_k \exp\{j2\pi k \Delta_F (t - T_{GI} - (i_{Tx} - 1)T_S)\} \quad (32)$$

#### 11.2.1.4.1.1 Data rate (RATE)

For a legacy station (11a or 11g), RATE has the original meaning as is defined in Table 80 of section 17.3.4.1 in ref [2]. For reference the table is repeated here:

| Rate (Mbits/s) | R1-R4 |
|----------------|-------|
| 6              | 1101  |
| 9              | 1111  |
| 12             | 0101  |
| 18             | 0111  |
| 24             | 1001  |
| 36             | 1011  |
| 48             | 0001  |
| 54             | 0011  |

**Table 19: Content of the legacy SIGNAL field**

#### 11.2.1.4.1.2 PLCP length field (LENGTH)

The PLCP length field in HT is used to indicate to both legacy and HT stations a protection duration. It contains a value, which when combined with the rate field defines a duration. The number of bytes in the LENGTH field is calculated based on the perceived RATE of a legacy station defined in R1-R4 and the actual number of bytes that the MAC is currently requesting the

PHY to transmit, taking into account the number of transmit antennas (spatial streams), the bandwidth and the extra fields (symbols) in the preamble.

As indicated in 11.2.1.4.1, the calculated duration is allowed to be longer than the actual duration of the HT transmission. However the LENGTH value should be equal to or smaller than 2346 bytes to avoid mis-interpretation by existing legacy devices.

#### 11.2.1.4.2 HTSIG

The LSIG field shall be followed by the HTSIG, which serves as the signal field for the HT PHY. HTSIG consists of two OFDM symbols: HTSIG1 and HTSIG2. HTSIG1 shall be transmitted first in time.

The encoding of HTSIG1 and HTSIG2 shall be the same as LSIG, with the exception that the BPSK modulation is rotated 90 degrees as described in clause 11.2.1.4.

In the 40MHz mode, the HTSIG1 and HTSIG2 are duplicated. The upper sub-channel shall be phase rotated by 90 degrees in the same way as the L-LTF, as described in 11.2.1.3.2

Figure 52 shows the bit assignment for the two symbols. They will be described in the next clauses.

HTSIG1 and HTSIG2 shall be transmitted in a similar fashion as the LSIG. Denote  $HTSIG_{-26,26}^{1,2}$  and  $HTSIG_{-58,58}^{1,2}$  as the first and second OFDM symbol of the following defined HTSIG as a data field, then,

$$r_{HTSIG}^{(i_{Tx})}(t) = \begin{cases} \sqrt{N_{Tx}} \sum_{n=1}^2 \left[ w_{SYM}(t) \sum_{k=-N_{SR}}^{N_{SR}} HTSIG_k^n \exp\{j2\pi k \Delta_F (t - T_{GI} - (n-1)T_{SYM})\} \right] & i_{Tx} = 1 \\ 0 & otherwise \end{cases} \quad (33)$$

if the legacy training fields are sent only on the first antenna. If CDD is used to transmit the legacy signal fields, then

$$r_{HTSIG}^{(i_{Tx})}(t) = \sum_{n=1}^2 \left[ w_{SYM}(t) \sum_{k=-N_{SR}}^{N_{SR}} HTSIG_k^n \exp\{j2\pi k \Delta_F (t - T_{GI} - (n-1)T_{SYM} - (i_{Tx} - 1)T_S)\} \right] \quad (34)$$

where  $T_{SYM} = 4\mu s$  is the OFDM symbol duration.

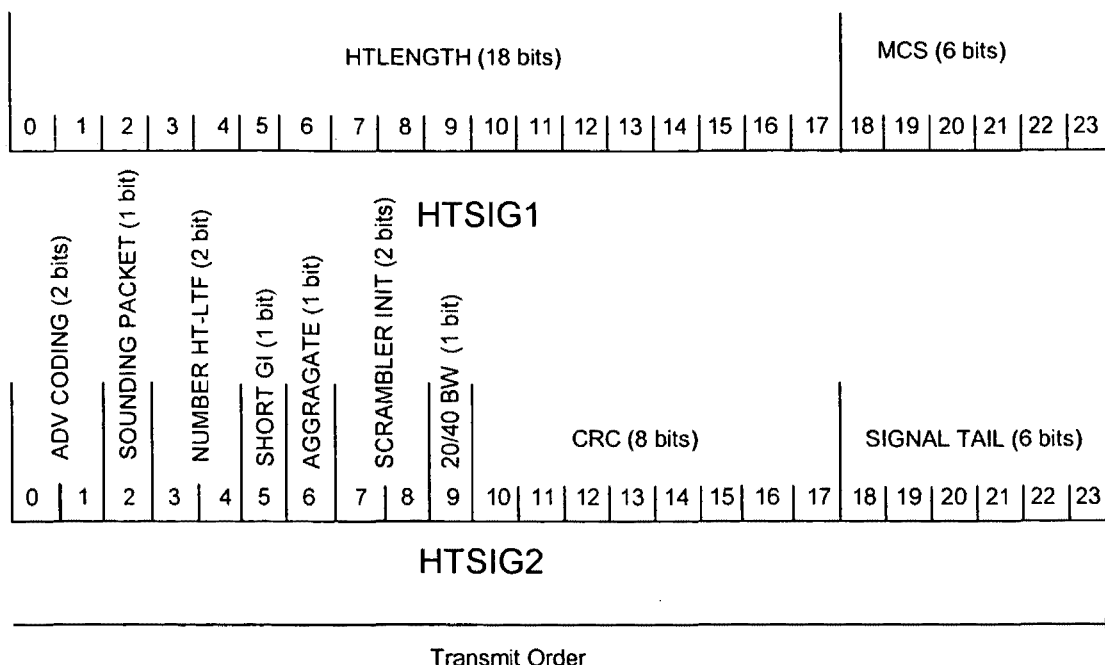


**Figure 52: HT SIGNAL FIELD (HTSIG1 and HTSIG2) bit assignment**

#### 11.2.1.4.2.1 HTLENGTH field

The HTLENGTH field shall be an unsigned 18-bit integer that indicated the number of octets in the PSDU that the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octets that will occur between the MAC and the PHY after receiving a request to start transmission.

Bit 0 is the LSB (least significant bit) and shall be transmitted first in time to the channel encoder.

#### 11.2.1.4.2.2 MCS field

The MCS field is a 6-bit field (bit 18-23 of HTSIG1) and defines the modulation and coding scheme, as indicated in Table 20.

| Bits 18-23 in<br>HT-SIG1<br>(MCS index) | Number of<br>spatial<br>streams | Modulation | Coding rate | GI = 800ns       |                  | GI = 400ns       |                  |
|-----------------------------------------|---------------------------------|------------|-------------|------------------|------------------|------------------|------------------|
|                                         |                                 |            |             | Rate in<br>20MHz | Rate in<br>40MHz | Rate in<br>20MHz | Rate in<br>40MHz |
| 0                                       | 1                               | BPSK       | 1/2         | 6                | 13.5             | 6.67             | 15               |
| 1                                       | 1                               | QPSK       | 1/2         | 12               | 27               | 13.33            | 30               |
| 2                                       | 1                               | QPSK       | 3/4         | 18               | 40.5             | 20               | 45               |
| 3                                       | 1                               | 16-QAM     | 1/2         | 24               | 54               | 26.67            | 60               |
| 4                                       | 1                               | 16-QAM     | 3/4         | 36               | 81               | 40               | 90               |
| 5                                       | 1                               | 64-QAM     | 2/3         | 48               | 108              | 53.33            | 120              |
| 6                                       | 1                               | 64-QAM     | 3/4         | 54               | 121.5            | 60               | 135              |

|    |   |        |     |     |        |        |       |
|----|---|--------|-----|-----|--------|--------|-------|
| 7  | 1 | 64-QAM | 7/8 | 63  | 141.75 | 70     | 157.5 |
| 8  | 2 | BPSK   | 1/2 | 12  | 27     | 13.33  | 30    |
| 9  | 2 | QPSK   | 1/2 | 24  | 54     | 26.67  | 60    |
| 10 | 2 | QPSK   | 3/4 | 36  | 81     | 40     | 90    |
| 11 | 2 | 16-QAM | 1/2 | 48  | 108    | 53.33  | 120   |
| 12 | 2 | 16-QAM | 3/4 | 72  | 162    | 80     | 180   |
| 13 | 2 | 64-QAM | 2/3 | 96  | 216    | 106.67 | 240   |
| 14 | 2 | 64-QAM | 3/4 | 108 | 243    | 120    | 270   |
| 15 | 2 | 64-QAM | 7/8 | 126 | 283.5  | 140    | 315   |
| 16 | 3 | BPSK   | 1/2 | 18  | 40.5   | 20     | 45    |
| 17 | 3 | QPSK   | 1/2 | 36  | 81     | 40     | 90    |
| 18 | 3 | QPSK   | 3/4 | 54  | 121.5  | 60     | 135   |
| 19 | 3 | 16-QAM | 1/2 | 72  | 162    | 80     | 180   |
| 20 | 3 | 16-QAM | 3/4 | 108 | 243    | 120    | 270   |
| 21 | 3 | 64-QAM | 2/3 | 144 | 324    | 160    | 360   |
| 22 | 3 | 64-QAM | 3/4 | 162 | 364.5  | 180    | 405   |
| 23 | 3 | 64-QAM | 7/8 | 189 | 425.25 | 210    | 472.5 |
| 24 | 4 | BPSK   | 1/2 | 24  | 54     | 26.67  | 60    |
| 25 | 4 | QPSK   | 1/2 | 48  | 108    | 53.33  | 120   |
| 26 | 4 | QPSK   | 3/4 | 72  | 162    | 80     | 180   |
| 27 | 4 | 16-QAM | 1/2 | 96  | 216    | 106.67 | 240   |
| 28 | 4 | 16-QAM | 3/4 | 144 | 324    | 160    | 360   |
| 29 | 4 | 64-QAM | 2/3 | 192 | 432    | 213.33 | 480   |
| 30 | 4 | 64-QAM | 3/4 | 216 | 486    | 240    | 540   |
| 31 | 4 | 64-QAM | 7/8 | 252 | 567    | 280    | 630   |
| 32 | 1 | BPSK   | 1/2 |     | 6      |        | 6.67  |

1

2

**Table 20: MCS field content for the basic mode**

3

MCS indices from 33 to 63 (31 in number) are reserved for the Advanced MIMO Mode.



**11.2.1.4.2.3 ADVCODING**

ADVCODING is a 2-bit field signaling that advanced coding is used.

| Bit 0,1 HTSIG2 | Action       |
|----------------|--------------|
| 0              | No ADVCODING |
| 1              | LDPC         |
| 2              | RS           |
| 3              | NOT USED     |

**Table 21: ADVCODING Field Content**

**11.2.1.4.2.4 SOUNDING PACKET**

This bit indicates that MIMO training is per antenna and ALL antennas are excited. If set, the packet can be used for antenna-to-antenna channel estimation necessary for closed loop beam forming. If NOT set, the packet cannot be used as a sounding packet either because the MIMO training excites fewer spatial streams than antennas, or because beam forming has been applied.

**11.2.1.4.2.5 NUMBER (of) HT-LTF**

These bits indicate the number of HT-LTFs in the current PPDU. This enumeration relates to the sounding packet, which is used to train the full spatial channel between the transmit and the receive antenna array. Note that the number of HT-LTFs is less than or equal to the number of transmit antennas.

**11.2.1.4.2.6 SHORT GI**

SHORT GI is a 1-bit field. If SHORT GI is 1, the Short Guard Interval is used in the data portion of the frame.

**11.2.1.4.2.7 AGGREGATE**

AGGREGATE is a 1-bit field. If AGGREGATE is 1, aggregation in the PPDU is used.

This field robustly transports the AGGREGATE parameter of the PHY DATA service, which is present in both TXVECTOR and RXVECTOR. The MAC uses this transported parameter to interpret the PSDU as either unaggregated or aggregated.

**11.2.1.4.2.8 SCRAMBLERINIT**

SCRAMBLERINIT is a 2-bit field that contains the initialization value of the scrambler. This value is used to initialize the scrambler at the receiver.

**11.2.1.4.2.9 20/40 BW**

This bit indicates whether the current PPDU is signaled in 20MHz or 40MHz. A value of 0 indicates 20MHz, whereas a value of 1 indicates 40MHz.

#### 11.2.1.4.2.10 CRC

CRC is an 8-bit CRC value. The CRC is taken over LSIG, HTSIG1 and bit0-bit9 of HTSIG2.

The CRC field shall be the one's complement of the remainder generated by the modulo 2 division of the protected bits by the polynomial

$$x^8 + x^2 + x^1 + x^0 \quad (35)$$

where the shift-register state shall be preset to all-ones. The protected bits shall be bit0-bit16 of LSIG, bit0-bit23 of HTSIG1, and bit0-bit9 of HTSIG2. The protected bits shall be processed by the CRC encoder in transmit order. A schematic of the processing is shown in Figure 53.

As an example, consider the following values for the LSIG, HTSIG1 and HTSIG2 fields:

1101 0001 1101 1101 0000 0000 [LSIG]

0111 1011 0100 1011 1010 0000 [HTSIG1]

0010 1101 10CC CCCC CC00 0000 [HTSIG2]

where  $b_0 \dots b_{23}$  [leftmost bit ( $b_0$ ) is transmitted first in time]

Then, the protected bits that are input to the CRC encoder are

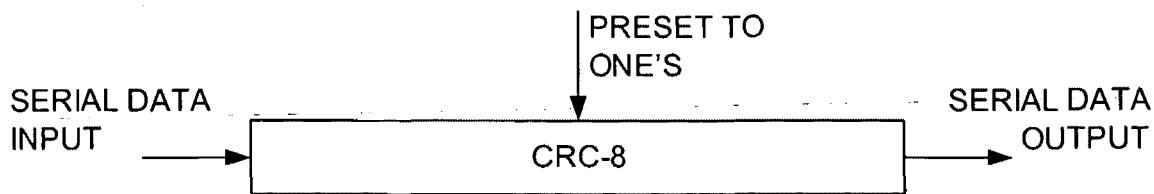
1101 0001 1101 1101 0, 0111 1011 0100 1011 1010 0000, 0010 1101 10

and the calculated CRC8 equals

00001101

so that HTSIG2 equals

0010 1101 1000 0011 0100 0000



1. Present shift register to all one's
2. Shift bit0-bit16 of LSIG, HTSIG1, and bit0-bit9 of HTSIG2 through the shift register
3. Take one's complement of the remainder
4. Transmit out serial  $x^7$  first

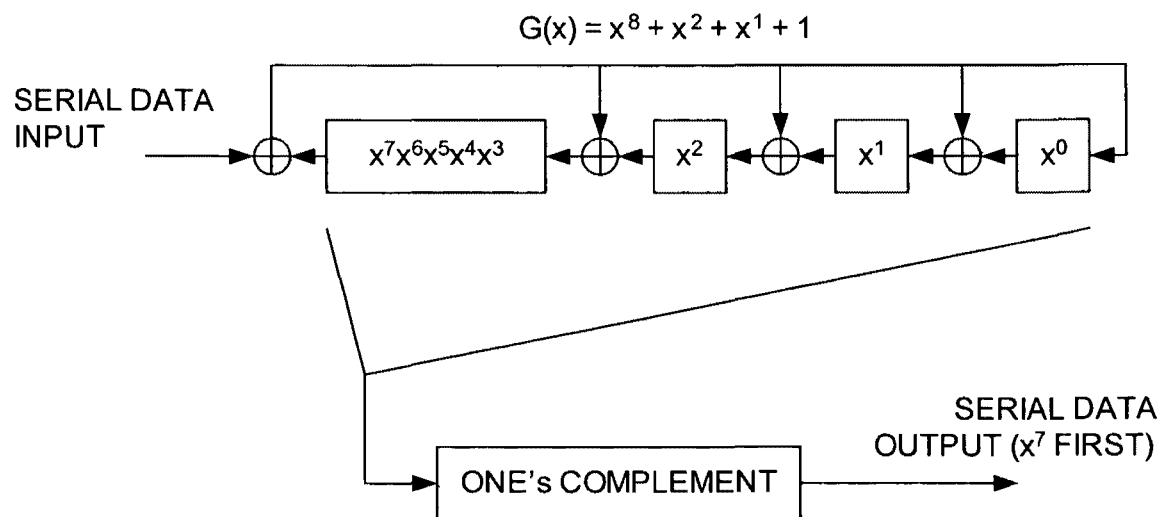


**Figure 53: Generation of CRC bits**

#### 11.2.1.4.2.11 SIGNALTAIL

The bits 18-23 constitute the SIGNALTAIL field, and all 6 bits shall be set to zero.

#### 11.2.1.5 Datafield

Contrary to 801.11a the data field contains no SERVICE field.

The data field contains the PSDU, the Tail bits and the PAD bits. All bits in the DATA field are scrambled, as described in 11.2.1.5.31.2. The PPDU is de-multiplexed across several spatial streams, which are created after the parser. Figure 35. shows the de-multiplexing across 2 spatial streams. Our proposal supports up to 4 spatial streams.

#### 11.2.1.5.1 PSDU tail bit field (TAIL)

The PSDU tail bit field shall be six bits of "0," which are required to return the convolutional encoder to the "zero state." This procedure improves the error probability of the convolutional decoder, which relies on future bits when decoding and which may be not be available past the

end of the message. The PLCP tail bit field shall be produced by replacing six scrambled “zero” bits following the message end with six nonscrambled “zero” bits.

#### **11.2.1.5.2 Pad bits (PAD)**

The length of the message is extended so that it becomes a multiple of the number of data bits per OFDM symbol for each data (spatial) stream. The number of Pad bits is dependent how the bits are divided over the spatial streams.

#### **11.2.1.5.3 PLCP Data Scrambler and Descrambler**

The 11a Scrambler and Descrambler will be used as described in 17.3.5.4 in ref [2].

The DATA field, composed of PSDU, tail, and pad parts, shall be scrambled with the length-127 frame-synchronous scrambler.

The scrambler shall be initialized according to the INITSCRAMBLER fields in HTSIG2.

As described in 11.2.1.5.1 the PLCP tail bit field shall be produced by replacing six scrambled “zero” bits following the message end with six nonscrambled “zero” bits.

#### **11.2.1.5.4 Antenna streams / Transmitter architecture**

The transmitter architecture with 2 spatial streams in the basic MIMO mode is shown in Figure 35. In the basic MIMO mode, the number of spatial streams equals the number of active transmit antennas. By active, we imply those antennas that transmit datafields.

The information bits first go through a convolutional encoder. The convolutional encoder is of rate  $\frac{1}{2}$ , from which other rates are derived by puncturing (see 11.2.1.5.6). The output of the puncturer feeds into the spatial parser, which creates several spatial streams, using round robin cycling. The frequency interleaver places the bits in the frequency domain and the constellation position according to the rules of the 802.11a interleaver. The interleaved bits are then mapped to constellation points. The resulting QAM symbols are fed as a block of data to the iFFT to create the time-domain signal. The pilot tones are also inserted in the frequency domain. The cyclical prefix is inserted in the time domain, and windowing of the OFDM symbols is also performed in the time domain. The resulting signal is then converted into analog format via a Digital-to-Analog (D/A) converter.

#### **11.2.1.5.5 Encoder**

The DATA field shall be coded with the convolutional encoder of coding rate  $R=1/2$ . The encoder is defined in clause 17.3.5.5 in ref [2]. (The 11a encoder).

#### **11.2.1.5.6 Puncturing of Coded Data**

Coded bits at the output of the convolutional encoder are at rate  $1/2$ . For lower rates, the puncturer can selectively puncture the coded bits to achieve the desired “effective” coding rate of  $2/3$ ,  $3/4$  or  $7/8$ . For code rates of  $2/3$  and  $3/4$  the puncturing patterns are as defined in clause 17.3.5.5 in ref [2]. For a code rate of  $7/8$ , the puncturing pattern is illustrated in Figure 54.

Punctured Coding ( $r = 7/8$ )

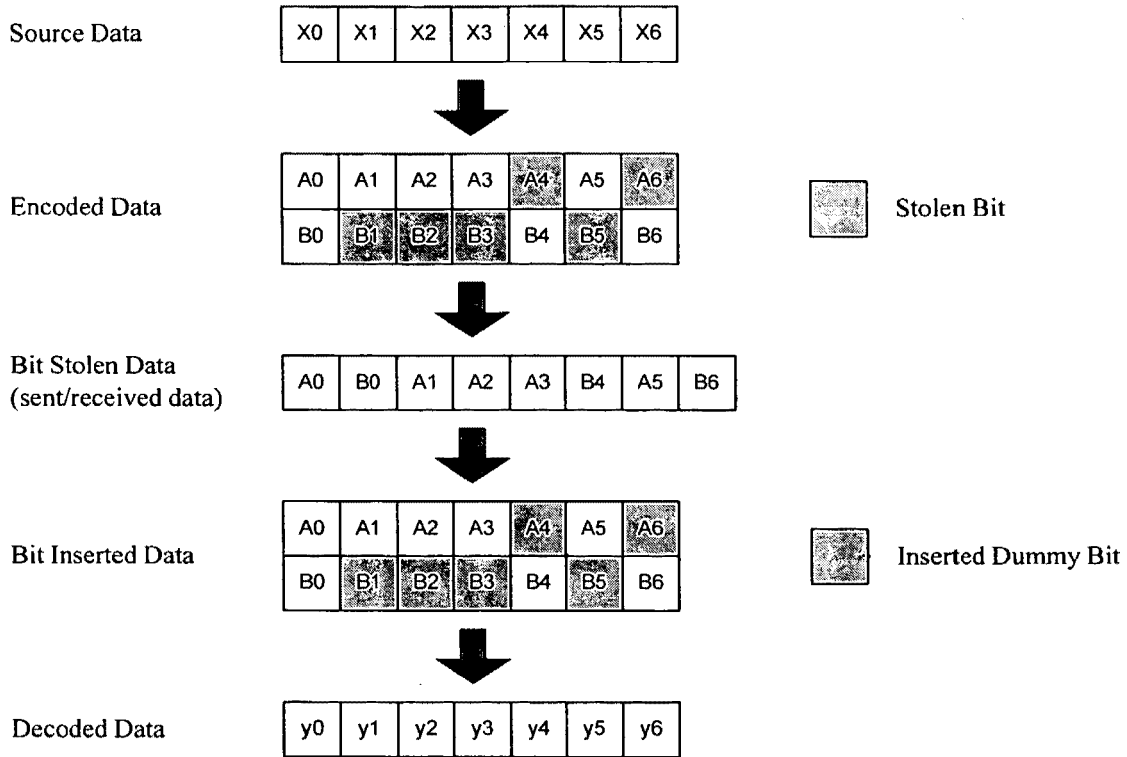


**Figure 54: Puncturing pattern for code rate = 7/8**

In the basic MIMO mode, all spatial streams are identically punctured.

#### 11.2.1.5.7 Data interleaving

Coded and punctured bits are interleaved across spatial streams and frequency tones. There are two steps to the space-frequency interleaving: spatial stream parsing and frequency interleaving.

##### 11.2.1.5.7.1 Spatial Parsing

Encoded and punctured bits are parsed to multiple spatial streams by a round-robin parser. Define:

$$s = \max\{N_{BPSC}/2, 1\} \quad (36)$$

which is the number of QAM bit order values, as in [1] equation (17). Then the parser sends consecutive blocks of  $s$  bits to different spatial streams in a round-robin fashion starting with the first spatial stream. The reason for parsing in blocks of  $s$  bits is to prevent clustering of QAM orders.

### 11.2.1.5.7.2 Frequency interleaver

All encoded bits shall be interleaved by a separate block interleaver for each spatial stream, with a block size corresponding to the number of bits in a single OFDM symbol,  $N_{CBPS}$ . The block interleavers are based on the 802.11a interleaver, with certain modifications to allow for multiple spatial streams and 40MHz transmissions.

The basic interleaver array has  $N_{row}$  rows and  $N_{column}$  columns. These parameters are specified in

Table 22 where  $N_{BPSC}$  is the number of coded bits per subcarrier (e.g.  $N_{BPSC} = 1$  for BPSK, 2 for QPSK, 4 for 16 QAM, etc).

**Table 22: Interleaver Parameters**

|                 | $N_{column}$ | $N_{row}$    |
|-----------------|--------------|--------------|
| 20 MHz channels | 16           | $3 N_{BPSC}$ |
| 40 MHz channels | 18           | $6 N_{BPSC}$ |

The interleaver is defined by a two-step permutation. The first permutation ensures that adjacent coded bits are mapped onto nonadjacent subcarriers. The first permutation is modified from the 802.11a interleaver such that the column indexes in the array are rotated for each spatial stream. The second permutation ensures that coded bits are mapped alternately onto less and more significant bits of the constellation and thereby long runs of low reliability (LSB) bits are avoided.

The index of the coded bit before the first permutation shall be denoted by  $k$ ;  $i$  shall be the index after the first and before the second permutation; and  $j$  shall be the index after the second permutation, just prior to modulation mapping.

The first permutation is defined by the rule

$$i = N_{row} \times (((k \bmod N_{column}) + i_{SS}) \bmod N_{column}) + \text{floor}(k / N_{column}) \quad k = 0, 1, K, N_{CBPS} - 1 \quad (37)$$

where  $i_{SS} = 0, 1, K, N_{SS} - 1$  is the index of the spatial stream on which this interleaver is operating. The insertion of  $i_{SS}$  is a modification of the 802.11a interleaver. This results in a "column offset" in the de-interleaving process. That is, bits are read in by rows and out by columns, but starting with column  $i_{SS}$  in a column-cyclic fashion.

The second permutation is defined by the rule

$$j = s \times \text{floor}(i / s) + (i + N_{CBPS} - \text{floor}(N_{column} \times i / N_{CBPS})) \bmod s \quad i = 0, 1, K, N_{CBPS} - 1 \quad (38)$$

where  $s$  is determined according to

$$s = \max(N_{BPSC} / 2, 1) \quad (39)$$

The deinterleaver, which performs the inverse relation, is also defined by two permutations.

Here the index of the original received bit before the first permutation shall be denoted by  $j$ ;  $i$  shall be the index after the first and before the second permutation; and  $k$  shall be the index after the second permutation.

The first permutation is defined by the rule

$$i = s \times \text{floor}(j / s) + (j + \text{floor}(N_{column} \times j / N_{CBPS})) \bmod s \quad j = 0, 1, K, N_{CBPS} - 1 \quad (40)$$

where  $s$  is as defined in Equation (39)

This permutation is the inverse of the permutation described in Equation (38)

The second permutation is defined by the rule

$$k = N_{column} (i \bmod N_{row}) + (\text{floor}(i / N_{row}) - i_{ss} + N_{column}) \bmod N_{column} \quad i = 0, 1, K, N_{CBPS} - 1 \quad (41)$$

This permutation is the inverse of the permutation described in Equation (37).

#### 11.2.1.5.8 Subcarrier Modulation Mapping

The subcarrier modulation mapping will be identical to clause 17.3.5.7 in ref [2].

There is one exception as described in clause 11.2.1.4. The mapping of the HTSIG field shall be 90 degrees rotated.

#### 11.2.1.5.9 MIMO-OFDM symbol iFFT mapping

For the MIMO-OFDM operation in 20 MHz bandwidth, the modulation coding scheme (MCS) for each spatial stream will be identical to that in IEEE 802.11a (clause 17.3.5.9 in ref [2]).

Construction of the OFDM data symbol in 40MHz begins with bonding two adjacent 20MHz OFDM symbols, as shown in Figure 55. There are a total of 11 guard tones between the two 20MHz channels, ranging from -5 to +5. Note that the legacy channels occupy tones from -58 to -6 in the lower sub-channel, and from +6 to +58 in the upper sub-channel. Of the 11 guard tones, 3 are nulled out: -1, 0, +1. This provides 8 additional data tones. Two DC tones are also inherited from the legacy sub-channels. These occur at -32 and +32 in the lower and upper sub-channels respectively. There are 4 pilot tones in each legacy sub-channel, and when mapped to the 40MHz iFFT indices, they occur at  $\pm 53, \pm 39, \pm 25, \pm 11$ . Of these 8 tones, the two tones at -39 and +39 are swapped with data, leading to a total of 6 pilot tones in the 40MHz channel. Tone assigned during 40MHz for DATA symbols can be summarized as:

$$\text{Nulled Tones} = \{-64K - 59, -1, 0, +1, +59K + 63\}$$

$$\text{Populated Tones} = \{-58K - 2, +2K + 58\}$$

$$\text{Pilot Tones} = \{-53, -25, -11, +11, +25, +53\}$$

$$\text{Data Tones} = \{\text{Populated Tones}\} - \{\text{Pilot Tones}\}$$

(42)

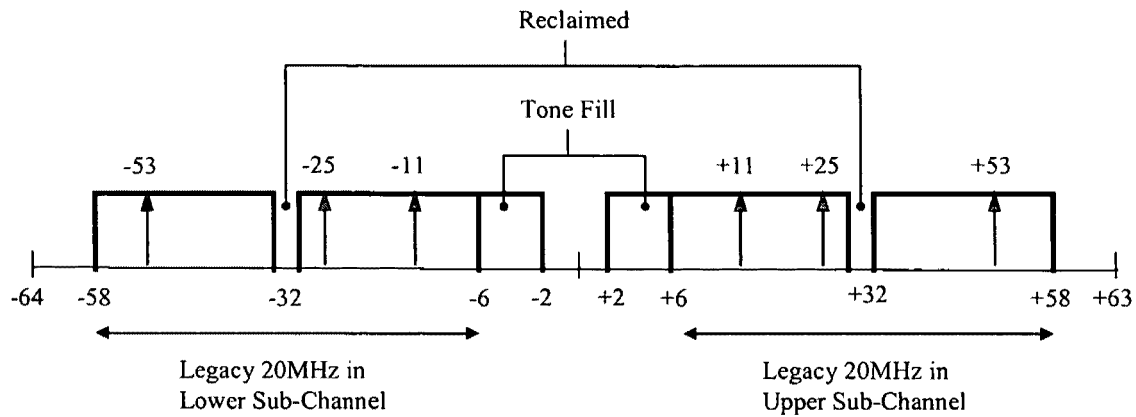
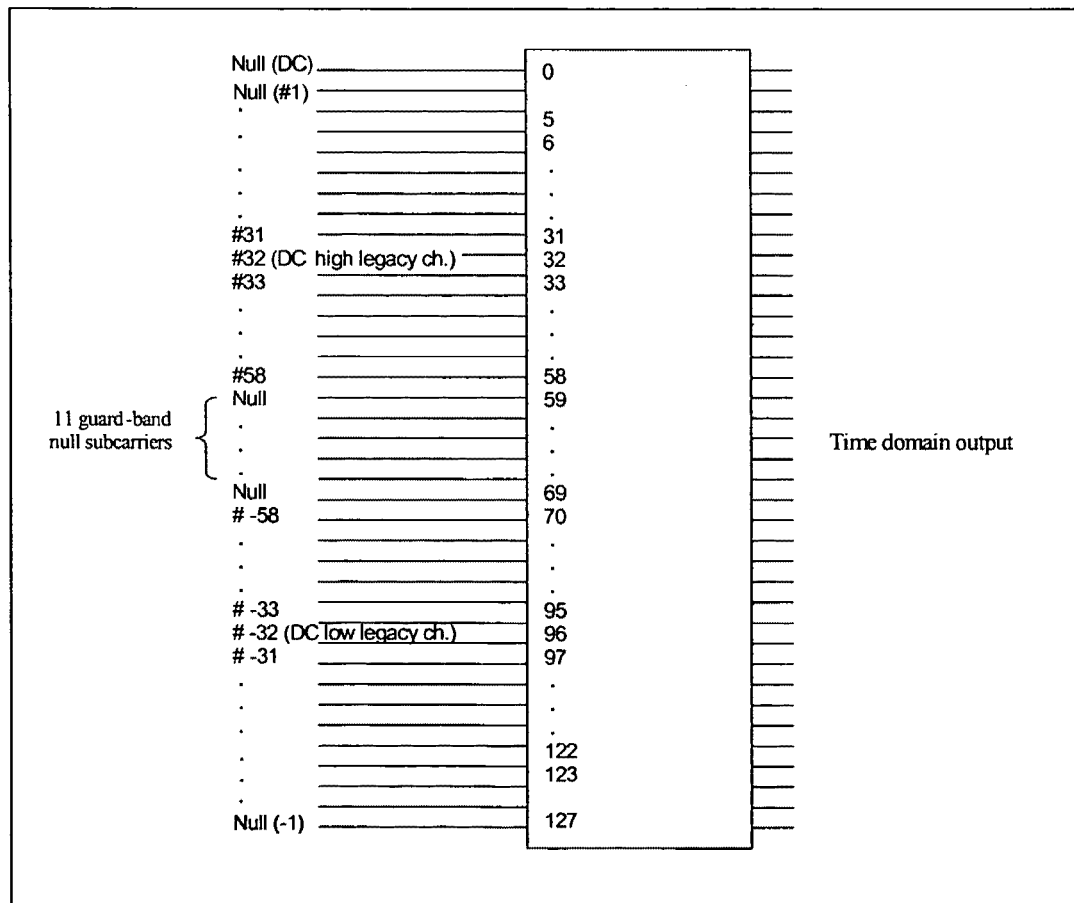


**Figure 55: Tone Format for Fat Channel at 40MHz**

The mapping of the input of the 40MHz channel to a 128-point IFFT is illustrated in Figure 56.





# Figure 56 Inputs and Outputs of IFFT for a 40 MHz channel

The complex numbers after the mapping are divided into groups of  $N_{SD}$ , where  $N_{SD} = 48$  in the 20MHz mode and  $N_{SD} = 108$  in the 40MHz mode. Following the convention in clause 17.3.5.9 in ref [2], the complex number is denoted as  $d_{k,n}^{(i_{TX})}$ , which corresponds to the  $k$  th subcarrier in the  $n$  th OFDM symbol that is transmitted from the  $i_{TX}$  th antenna.

An OFDM data symbol,  $r_{DATA,n}^{(i_{TX})}(t)$ , is defined as

$$r_{DATA,n}^{(i_{TX})}(t) = w_{SYM}(t) \left( \sum_{k=0}^{N_{SD}-1} d_{k,n}^{(i_{TX})} \exp(j2\pi M(k)\Delta_F(t-T_{GI})) \right. \\ \left. + p_{n+3} \sum_{k=-N_{SR}}^{N_{SR}} P_k^{(i_{TX})} \exp(j2\pi k\Delta_F(t-T_{GI})) \right) \quad (43)$$

where function  $M(k)$ , defines the mapping from the logical subcarrier number  $k$  to a value between  $-N_{SR}$  and  $+N_{SR}$ , while skipping the pilot subcarriers and DC and its adjacent subcarriers.  $M(k)$  in the 20MHz mode is same as the one defined in clause 17.3.5.9 in ref [2].

$M(k)$  in the 40MHz mode is defined as

$$M(k) = \begin{cases} k-58 & 0 \leq k \leq 4 \\ k-57 & 5 \leq k \leq 31 \\ k-56 & 32 \leq k \leq 44 \\ k-55 & 45 \leq k \leq 53 \\ k-52 & 54 \leq k \leq 62 \\ k-51 & 63 \leq k \leq 75 \\ k-50 & 76 \leq k \leq 102 \\ k-49 & 103 \leq k \leq 107 \end{cases} \quad (44)$$

The contribution of pilot subcarriers in the 20MHz mode is given by (24) in clause 17.3.5.9 in ref [2]. The subcarrier frequency locations in the 20MHz mode is shown in Figure 117 in clause 17.3.5.9 in ref [2]. The subcarrier frequency locations in the 40MHz mode is shown in Figure 55.

The iFFT mapping for the 6Mbps duplicate mode in 40MHz differs slightly from the mapping shown in (43):

$$r_{DATA,n}^{(i)}(t) = w_{SYM}(t) \left( \sum_{k=0}^{N_{SD}-1} d_{k,n} \exp(j2\pi (M(k)-32)\Delta_F(t-T_{GI})) + j \sum_{k=0}^{N_{SD}-1} d_{k,n} \exp(j2\pi (M(k)+32)\Delta_F(t-T_{GI})) \right. \\ \left. + p_{n+1} \sum_{k=-N_{SR}}^{N_{SR}} P_k \exp(j2\pi (k-32)\Delta_F(t-T_{GI})) + jp_{n+1} \sum_{k=-N_{SR}}^{N_{SR}} P_k \exp(j2\pi (k+32)\Delta_F(t-T_{GI})) \right) \quad (45)$$

where,  $N_{SD} = 48$  and  $N_{SR} = 26$  are values that correspond to a 20MHz transmission.  $M(k)$ ,  $P_k$  and  $p_n$  follow the definitions in (23) to (25) in clause 17.3.5.9 in [ref 2].  $P_k$  for the HT 40MHz mode is defined in 11.2.1.5.10.2.

1 The concatenation of  $N_{SYM}$  OFDM symbols can now be written as

$$2 \quad r_{DATA}^{(i_{Tx})}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}^{(i_{Tx})}(t - nT_{SYM}) \quad (46)$$

#### 3 4 **11.2.1.5.10 Pilot subcarrier**

5 In each OFDM symbol, four of the subcarriers in 20 MHz mode and six of the subcarriers in 40  
6 MHz mode are dedicated to pilot signals in order to make the coherent detection robust against  
7 frequency offsets and phase noise. These pilot signals shall be allocated to subcarriers -21, -7,  
8 +7, and +21 in the 20MHz mode, and to subcarriers -53, -25, -11, +11, +25 and +53 in the  
9 40MHz mode.

10

#### 11 **11.2.1.5.10.1 Legacy pilot subcarriers**

12 Legacy pilots are defined as 802.11a. Refer to clause 17.3.5.8 in ref [2].

13

#### 14 **11.2.1.5.10.2 Pilot subcarriers in HT mode**

15 The contribution of pilot subcarriers at the  $i_{Tx}$ th transmission stream in 20MHz mode is  
16 produced by the inverse Fourier transform of the sequence  $P_k^{(i_{Tx})}$ , which is defined as:

$$17 \quad P_{-26,26}^{(i_{Tx})} = \{0,0,0,0,0,P_{-21}^{(i_{Tx})},0,0,0,0,0,0,0,0,0,0,P_{-7}^{(i_{Tx})},0,0,0,0,0,0,0, \\ 18 \quad 0,0,0,0,0,0,P_7^{(i_{Tx})},0,0,0,0,0,0,0,0,0,0,-P_{21}^{(i_{Tx})},0,0,0,0,0\} \quad (47)$$

18 where the non-zero elements of  $P_k^{(i_{Tx})}$  are generated by the following rule:

$$19 \quad P_k^{(i_{Tx})} = \exp\left\{\frac{j\pi}{2}(i_{Tx}-1)m\right\}, \quad m = \frac{1}{2}\left(\frac{k}{7}+3\right) \quad (48)$$

20 In the 40MHz mode,  $P_k^{(i_{Tx})}$  is given by

$$21 \quad P_{-58,58}^{(i_{Tx})} = \{0,0,0,0,0,P_{-53}^{(i_{Tx})},0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,P_{-25}^{(i_{Tx})},0,0, \\ 22 \quad 0,0,0,0,0,0,0,0,0,-P_{-11}^{(i_{Tx})},0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,P_{11}^{(i_{Tx})},0,0,0,0, \\ 23 \quad 0,0,0,0,0,0,0,0,-P_{25}^{(i_{Tx})},0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0, \\ 24 \quad 0,0,P_{53}^{(i_{Tx})},0,0,0,0,0\} \quad (49)$$

22 where the non-zero element of  $P_k^{(i_{Tx})}$  are generated by the following rule:

$$23 \quad P_k^{(i_{Tx})} = \exp\left\{\frac{j\pi}{2}(i_{Tx}-1)m\right\}, \quad m = \begin{cases} \frac{(k+11)}{14} + 3, & k = -53, -25, -11 \\ \frac{(k+3)}{14} + 3, & k = 11, 25, 53 \end{cases} \quad (50)$$

The polarity of the pilot subcarriers is controlled by sequence  $p_n$ , which is a cyclic extension of the 127 elements sequence as defined in clause 17.3.5.9 in ref[2].

#### 11.2.1.5.11 GI / windowing

The windowing function in both 20MHz and 40MHz modes is the same as the one described in clause 17.3.2.4 and 17.3.2.5 in ref [2]. The example in clause 17.3.2.5 in ref [2] still holds for the 20MHz modes. In the 40MHz modes, the changes in this example is the sampling rate becomes 40MHz and  $T_{TR} = 50ns$ , then the discrete implementation of the windowing function is

$$w_T[n] = w_T(nT_s) = \begin{cases} 1 & 1 \leq n \leq 159 \\ 0.5 & 0,160 \\ 0 & otherwise \end{cases} \quad (51)$$

#### 11.2.1.6 Clear channel assessment

When operating in the 5 GHz band the HT PHY shall follow the CCA requirements of 11a, clause 17.3.10.5 in ref [2]. When operating in the 2.4 GHz band the HT PHY shall follow the 11g spec according to 19.3.5 and 19.4.6 in ref [3].

#### 11.2.1.7 PMD operating spec

In the 20 MHz bandwidth mode the HT PHY shall follow the 11a spec (clause 17.3.8 in ref [2]) and subsequent specifications when operating in the 5 GHz band.

In the 20 MHz bandwidth mode the HT PHY shall follow the 11g spec (clause 19.4) when operating in the 2.4 MHz band.

#### 11.2.1.7.1 Transmit spectral mask

##### 11.2.1.7.1.1 20MHz channel spacing

In the 20 MHz bandwidth mode the HT PHY shall follow 17.3.9.2 in ref [2]. The transmitted spectrum shall have a 0dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18MHz, -20dBr at 11 MHz frequency offset, -28dBr at 20MHz frequency offset and -45dBr at 30MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 1. The measurements shall be made using a 100kHz resolution bandwidth and a 30kHz video bandwidth.

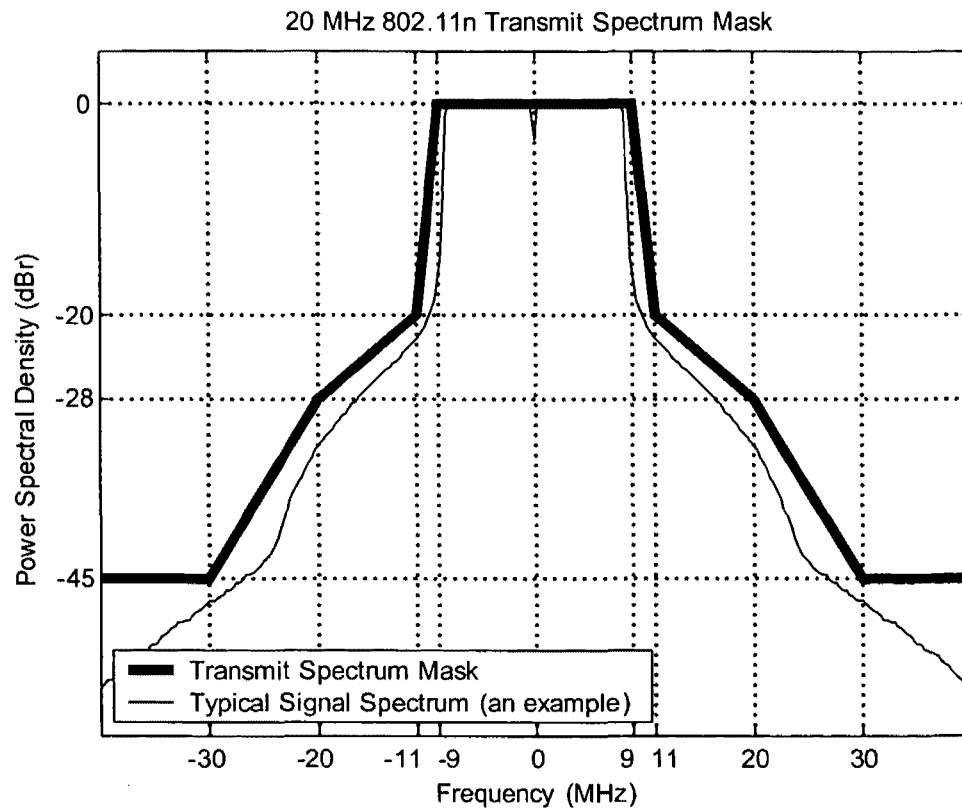


**Figure 57: Transmit Spectrum Mask for 20MHz channelization**

#### 11.2.1.7.1.2 40MHz channel spacing

The transmitted spectrum shall have a 0dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 38MHz, -20dBr at 21 MHz frequency offset, and -45dBr at 60MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 2. The measurements shall be made using a 100kHz resolution bandwidth and a 30kHz video bandwidth.

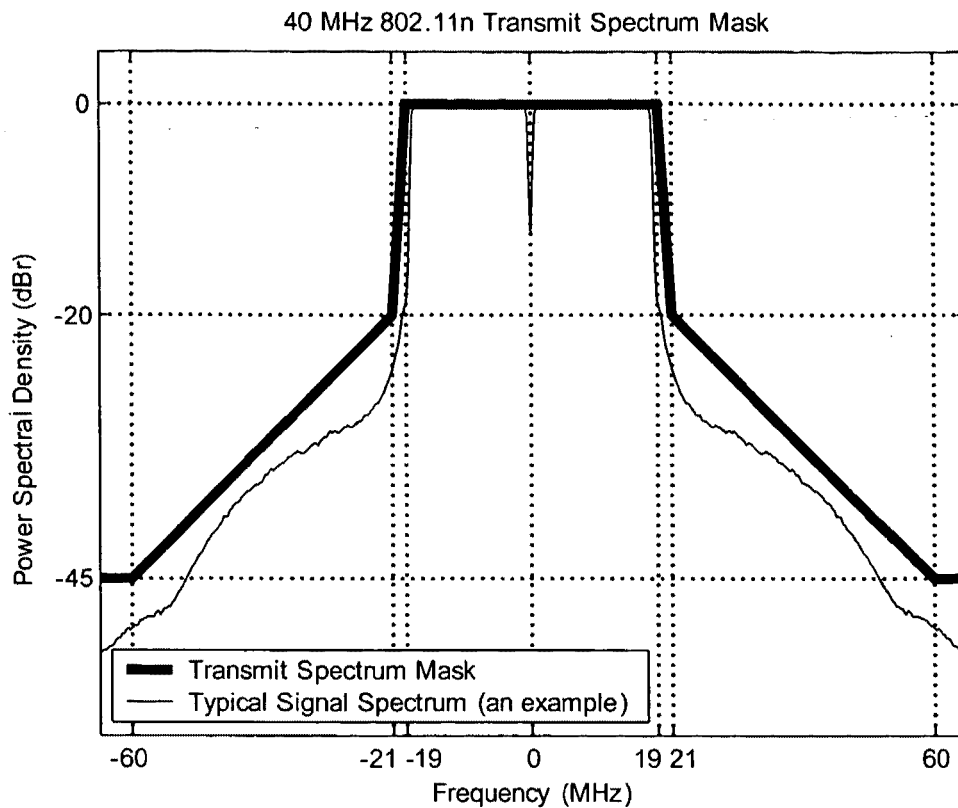


**Figure 58: Transmit spectrum mask for 40MHz channelization**

A HT device transmitting a 20MHz signal in a 40MHz BSS shall conform to the spectral mask shown in Figure 58.

## 11.2.2 Basic Transmit Beamforming (Optional Mode)

### 11.2.2.1 Introduction

One method of improving the SNR at the receiver, for a given distance between stations, is to apply transmit beamforming. A basic requirement for transmit beamforming is the availability of channel state information (CSI). In our proposal, CSI is obtained by assuming channel reciprocity. The initiator sends a request for a sounding packet to the intended recipient, which in turn sends a sounding packet back to the initiator. The initiator extracts the CSI from this packet, and assumes that the forward channel is identical to the reverse channel. Assumption of channel reciprocity also requires radio calibration, since the TX-RX radio pair on the reverse link is different from the TX-RX pair on the forward link. Our proposal also includes a packet exchange sequence to help perform radio calibration.

### 11.2.2.2 Motivation of MIMO-Beamforming (Informative)

Beamforming-MIMO can achieve higher throughput than basic MIMO at same SNR, or conversely, higher range at the same data rate. The benefit of TX beamforming is most

pronounced when the number of TX antennas is larger than the RX antennas, when multiple spatial streams are being transmitted. For e.g., a typical configuration involving TX beamforming could be either 3 or 4 antennas at the AP, and 2 antennas at the client. Hence, the client is kept low-cost, while the AP shoulders a higher cost burden.

### 11.2.2.3 Description of BF-MIMO

#### 11.2.2.3.1 Beamformed PPDU

The transmitter may choose to use antenna beamforming in order to increase the antenna gain in the direction of an intended receiver. The beamforming process is represented mathematically as a linear transformation, mapping the streams of data to the transmit antennas.

Let  $x$  be the  $N_{SS}$  dimensional vector of data, where each element of  $x$  is from one of the spatial streams of data. The beamforming transformation is represented by a  $N_{TX} \times N_{SS}$  matrix,  $V$ . The beamforming operation, on a per subcarrier basis, is represented by,

$$y_{N_{TX} \times 1} = V_{N_{TX} \times N_{SS}} \cdot x_{N_{SS} \times 1} \quad (52)$$

The  $y$  vector is an  $N_{TX}$  dimensional vector whose elements get mapped to the  $N_{TX}$  antennas. The beamforming matrix  $V$  is applied to the HT-STF and HT-LTF training fields as well as the data. There are several methods for calculating  $V$ . One of them involves singular value decomposition (SVD) of the channel transfer matrix  $H$ .

It is optional for a device to be able to perform TX beamforming. However, it is mandatory that a device to receive a beamformed packet, which implies that the device should be able to send a sounding packet to the initiator.

### 11.2.2.3.2 Channel sounding

#### 11.2.2.3.2.1 Channel sounding principle

In order for a STA to send a beamformed PPDU (BF-PPDU) to another STA it is necessary for the STA to have channel state information from the transmitter to the receiver. To simplify the explanation we will introduce several new terms. The STA that is to send a BF-PPDU is referred to as the beamforming STA and the STA that is to receive the BF-PPDU is referred to as the non-beamforming STA.

Using implicit feedback, the non-beamforming STA sends a sounding PPDU to the beamforming STA, which enables the beamforming STA to estimate the channel from the non-beamforming STA to the beamforming STA. This channel estimate is used to calculate the required beamforming matrix for the beamforming-STA to non-beamforming STA transmission.

#### 11.2.2.3.2.2 Sounding PPDU format

In a non-sounding PPDU the number of HT-LTFs is equal to the number of spatial streams, which may be less than the number of transmit antennas. However, in order to calculate the

beamforming matrix from one STA to another STA it is necessary to estimate the full channel matrix, which requires that the PPDU include a full set of  $N_{TX}$  LTFs. In order to facilitate estimation of the complete channel matrix, a sounding PPDU is introduced. A sounding PPDU fully excites the channel, enabling estimation of the full channel matrix. No beamforming shall be applied to either the LTFs or the data in a sounding-PPDU. In other words the beamforming matrix,  $V$ , is the identity matrix. Thus techniques such as Walsh + CDD should not be applied to sounding PPDU.

In the sounding PPDU, the “sounding bit” in the HT-SIG is set to “one”. The number of HT-LTFs is equal to the number of transmit antennas, and not necessarily the number of spatial streams. Thus in a sounding PPDU the number of HT-LTFs is set by the NLTF portion of the HT-SIGNAL field, which overrides the setting of the number of HT-LTFs specified by the MCS portion of the HT-SIGNAL field. The NUMBER HT-LTF is identical to the number of TX antennas.

It is mandatory that a STA support the transmission of a sounding PPDU in response to a TRQ message in the IAC MPDU.

### 11.2.2.3.3 Calculation of beamforming matrix using SVD (Informative)

Once a STA has a proper estimate of the channel, then it can use that channel estimate to select a recommended beamforming matrix. There are a variety of techniques that can be used to select the beamforming matrix. One method of selecting the beamforming matrix is by calculating the singular value decomposition of the channel from this STA to the intended receiving STA. Let  $H$  be the channel matrix from the transmitter to the receiver. The SVD of the channel matrix is given by,

$$H = UDV^H \quad (53)$$

Both  $U$  and  $V$  are unitary matrices and  $D$  is a diagonal matrix of singular values. The transmitter selects the dominant  $N_{SS}$  singular values and then sends only  $N_{SS}$  spatial streams. The first  $N_{SS}$  rows of the  $V$  matrix are used as the beamforming matrix, mapping the spatial streams of data to the TX antennas. This same beamforming matrix is applied to the HT-LTFs, except for one difference. The number of HT-LTFs is equal to  $N_{SS}$ , and each transmission of HT-LTF is shaped by one singular vector.

#### 11.2.2.3.3.1 Channel Reciprocity

To determine the beamforming matrix, the transmitter needs to know the channel from the transmitter to the intended receiver. That channel is estimated using implicit feedback and channel reciprocity. The transmitter uses the previous sounding PPDU sent from the intended receiver to estimate the channel from the intended receiver to the transmitter. In order to estimate the channel from the receiver to the transmitter, it uses the principle of reciprocity. The principle of reciprocity is that the downlink channel (the channel from the AP to the STA) is the transpose of the uplink channel (the channel from the STA to the AP). Letting  $H_D$  be the downlink channel and  $H_U$  be the uplink channel, reciprocity is,

$$H_U = H_D^H \quad (54)$$

#### 11.2.2.3.4 Calibration Calculation (Informative)

Calculation of beamforming matrices using implicit feedback relies on channel reciprocity (the downlink channel is the transpose of the uplink channel, and visa versa). This property is true for the actual wireless channel; however, the composite channel includes not only the actual wireless channel but also the complex gains of the transmitter and receiver amplifiers. The calibration process is used to calibrate for the gains of the transmitter and receiver paths in both STAs

#### 11.2.2.3.5 HT-Short Training Field in BF-MIMO mode

HT-STF is identical to basic MIMO case (refer to section 11.2.1.3.3). The HT-STF undergoes the same spatial steering as the DATA.

#### 11.2.2.3.6 HT-Long Training Field in BF-MIMO mode

HT-LTFs are identical to the basic MIMO case (refer to section 11.2.1.3.4). The HT-LTF undergoes the same spatial steering as the DATA.

#### 11.2.2.3.6.1 MCS field in BF-MIMO mode

MCS set for BF-MIMO is identical to that of basic MIMO, as described in section 11.2.1.4.2.2.

#### 11.2.2.3.7 Antenna streams / Transmitter architecture in BF-MIMO mode

The only difference in the transmitter architecture with respect to the basic MIMO mode is the introduction of the spatial steering matrix, as shown in Figure 59:

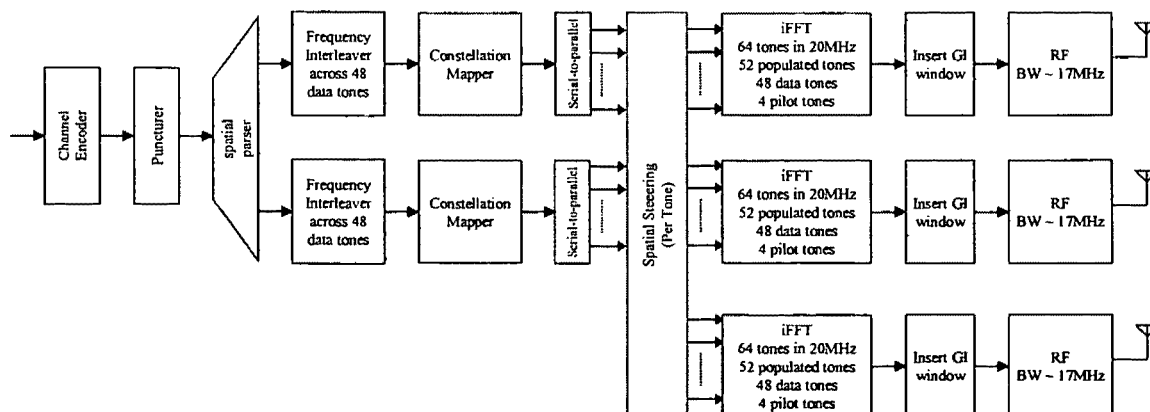


Figure 59: Transmitter architecture for TX Beamforming for  $N_{ss}=2$ , and  $N_{Tx} = 3$



#### 11.2.2.3.8 Puncturing of Coded Data in BF-MIMO mode

TX Beamforming uses the same puncturing pattern as the basic MIMO mode, described in 11.2.1.5.6.

#### 11.2.2.3.9 MCS set in BF-MIMO mode

The MCS is identical for all spatial streams in basic TX beamforming, as is the case in the basic MIMO mode. The MCS set is described in Table 20.

### 11.2.3 Advanced Transmit Beamforming (Optional Mode)

In our proposal, there are two class of BF-MIMO. The first one is basic BF-MIMO (as described in section 11.2.2). When AP uses this mode, STA would receive a beamformed frame as a basic MIMO frame. No additional functionality is required at the STA, except for the ability of the STA to send a sounding-PPDU and support feedback calibration. An extension to the basic BF-MIMO mode is the advanced BF-MIMO mode, which includes the following highlights:

- Unequal power among the spatial streams
- Independent MCS for each spatial stream
- Support for bi-directional beamforming

#### 11.2.3.1 Required Capability for supporting of ABF-MIMO mode

In this mode, STA should support additional functionality to achieve better performance. These include:

- The receiving STA has to recognize a TRQ, and should be able to transmit a sounding PPDU as a response to it. (Common to basic BF-MIMO)
- Calibration support using MAC frame. (Common to basic BF-MIMO)
- Power level detection at each spatial stream to support unequal power loading
- Supporting unequal MCS at different spatial stream
- UD decomposition (or an equivalent method) to extract eigenvalues and eigenvectors of the channel matrix. Eigenvalues are used to determine the MCS at the receiver to support pairwise spoofing, and/or link adaptation. Eigenvectors in the U matrix allow bi-directional beamforming to be supported

### 11.2.3.1.1 Power Loading of spatial stream in ABF-MIMO

In ABF-MIMO, additional performance gain is possible if different power levels are applied to different spatial streams. However, to decode the PPDU with different power levels on different spatial streams, the receiver requires knowledge of these power ratios.

In the case of an ABF-PPDU, the values of the power level of each spatial stream can be varied as long as the total output power is maintained constant. Mathematically this can be viewed as multiplying the data vector by an  $N_{SS} \times N_{SS}$  diagonal matrix,  $P$ , where the entries on the diagonal matrix are positive and the sum of the squares of the diagonal entries is  $N_{SS}$ . In other words,

$$p_1^2 + p_2^2 + \dots + p_{N_{SS}}^2 = N_{SS} \quad (55)$$

After the scaling of power ratios, the beamforming matrix,  $V$ , is applied. The operation of power scaling and beamforming is represented as,

$$\hat{y} = V \cdot P \cdot \hat{x} \quad (56)$$

Transmitter should determine the power levels for each spatial stream based on the channel estimates obtained from the sounding packet.

#### 11.2.3.1.1.1 Unequal power loading (Informative)

In order to decode the received ABF-PPDU, the receiver must estimate the power ratios between the spatial streams, which may not be equal to each other.

Once the streams of data have been separated at the receiver, the power ratios of the separated spatial streams can be estimated by estimating the power ratios of the pilot tones. The spatial streams of data can then be scaled using the estimate of the power ratios, derived from the power of the pilot tones.

#### 11.2.3.1.1.2 Extended MCS set for ABF-MIMO mode

ABF-MIMO would use different modulation/coding scheme at each spatial stream. As a result, MCS fields in ABF-MIMO mode have been extended, as shown in Table 23.

**Table 23: Extended MCS set for ABF-MIMO**

| ID# | Stream Count | Stream ID vs Modulation&Coding |           |          |          | Full GI       |               | Half GI       |               |
|-----|--------------|--------------------------------|-----------|----------|----------|---------------|---------------|---------------|---------------|
|     |              | stream 1                       | stream 2  | Stream 3 | stream 4 | Rate in 20MHz | Rate in 40MHz | Rate in 20MHz | Rate in 40MHz |
| 33  | 1            | 256QAM, 3/4                    | N/A       | N/A      | N/A      | 72            | 162           | 80            | 180           |
| 34  | 2            | QPSK, 3/4                      | BPSK, 1/2 | N/A      | N/A      | 24            | 54            | 26.667        | 60            |

|    |          |             |             |            |            |     |       |        |      |
|----|----------|-------------|-------------|------------|------------|-----|-------|--------|------|
| 35 | 2        | QPSK, 3/4   | BPSK, 3/4   | N/A        | N/A        | 27  | 60.75 | 30     | 67.5 |
| 36 | 2        | 16QAM, 1/2  | QPSK, 1/2   | N/A        | N/A        | 36  | 81    | 40     | 90   |
| 37 | 2        | 16QAM, 3/4  | QPSK, 1/2   | N/A        | N/A        | 48  | 108   | 53.333 | 120  |
| 38 | 2        | 16QAM, 3/4  | QPSK, 3/4   | N/A        | N/A        | 54  | 121.5 | 60     | 135  |
| 39 | 2        | 64QAM, 2/3  | BPSK, 1/2   | N/A        | N/A        | 54  | 121.5 | 60     | 135  |
| 40 | 2        | 64QAM, 3/4  | QPSK, 3/4   | N/A        | N/A        | 72  | 162   | 80     | 180  |
| 41 | 2        | 64QAM, 2/3  | 16QAM, 1/2  | N/A        | N/A        | 72  | 162   | 80     | 180  |
| 42 | 2        | 256QAM, 3/4 | 16QAM, 1/2  | N/A        | N/A        | 96  | 216   | 106.67 | 240  |
| 43 | 2        | 256QAM, 3/4 | 16QAM, 3/4  | N/A        | N/A        | 108 | 243   | 120    | 270  |
| 44 | 2        | 256QAM, 3/4 | 256QAM, 3/4 | N/A        | N/A        | 144 | 324   | 160    | 360  |
| 45 | 3        | 16QAM, 3/4  | 16QAM, 1/2  | QPSK, 1/2  | N/A        | 72  | 162   | 80     | 180  |
| 46 | 3        | 64QAM, 2/3  | QPSK, 3/4   | BPSK, 1/2  | N/A        | 72  | 162   | 80     | 180  |
| 47 | 3        | 64QAM, 3/4  | 16QAM, 1/2  | QPSK 3/4   | N/A        | 96  | 216   | 106.67 | 240  |
| 48 | 3        | 64QAM, 3/4  | 16QAM, 3/4  | QPSK, 3/4  | N/A        | 108 | 243   | 120    | 270  |
| 49 | 3        | 64QAM, 3/4  | 64QAM, 2/3  | BPSK, 1/2  | N/A        | 108 | 243   | 120    | 270  |
| 50 | 3        | 64QAM, 3/4  | 64QAM, 3/4  | 16QAM, 3/4 | N/A        | 144 | 324   | 160    | 360  |
| 51 | 3        | 256QAM, 3/4 | 64QAM, 2/3  | 16QAM, 1/2 | N/A        | 144 | 324   | 160    | 360  |
| 52 | 3        | 256QAM, 3/4 | 64QAM, 3/4  | QPSK 3/4   | N/A        | 144 | 324   | 160    | 360  |
| 53 | 3        | 256QAM, 3/4 | 64QAM, 3/4  | 16QAM, 3/4 | N/A        | 162 | 364.5 | 180    | 405  |
| 54 | 3        | 256QAM, 3/4 | 256QAM, 3/4 | QPSK 3/4   | N/A        | 162 | 364.5 | 180    | 405  |
| 55 | 3        | 256QAM, 3/4 | 256QAM, 3/4 | 64QAM, 2/3 | N/A        | 192 | 432   | 213.33 | 480  |
| 56 | 4        | 64QAM, 2/3  | 16QAM, 3/4  | BPSK, 1/2  | BPSK, 1/2  | 96  | 216   | 106.67 | 240  |
| 57 | 4        | 64QAM, 3/4  | 64QAM, 3/4  | 16QAM, 1/2 | QPSK, 1/2  | 144 | 324   | 160    | 360  |
| 58 | 4        | 256QAM, 3/4 | 64QAM, 3/4  | 64QAM, 2/3 | QPSK, 3/4  | 192 | 432   | 213.33 | 480  |
| 59 | 4        | 256QAM, 3/4 | 64QAM, 3/4  | 64QAM, 3/4 | QPSK, 1/2  | 192 | 432   | 213.33 | 480  |
| 60 | 4        | 256QAM, 3/4 | 256QAM, 3/4 | 16QAM, 3/4 | QPSK, 1/2  | 192 | 432   | 213.33 | 480  |
| 61 | 4        | 256QAM, 3/4 | 256QAM, 3/4 | 64QAM, 2/3 | 16QAM, 1/2 | 216 | 486   | 240    | 540  |
| 62 | 4        | 256QAM, 3/4 | 256QAM, 3/4 | 64QAM, 3/4 | QPSK, 3/4  | 216 | 486   | 240    | 540  |
| 63 | reserved | reserved    | reserved    | reserved   | reserved   |     |       |        |      |

1

2 **11.2.3.2 Transmitter Architecture in ABF-MIMO mode**

3 The transmitter architecture for the ABF-MIMO mode includes the provision for independent  
4 MCS for each spatial stream. The Transmit datapath architecture is shown in Figure 60:

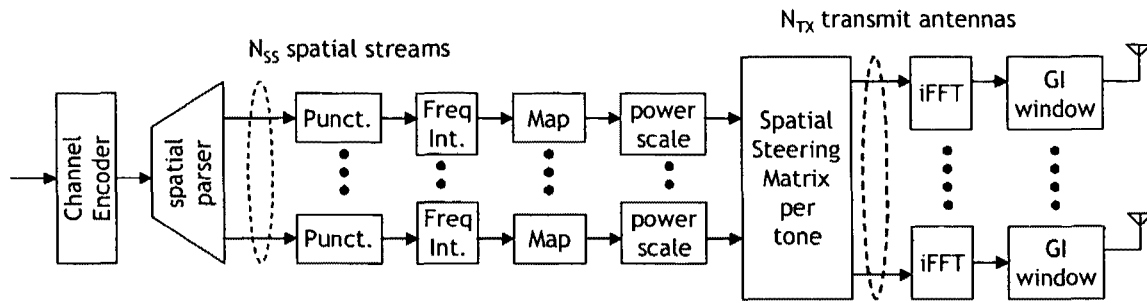


**Figure 60: Transmit Datapath Architecture for ABF-MIMO mode**

#### 11.2.3.2.1 Subcarrier Modulation Mapping in ABF-MIMO mode

256QAM is introduced in the ABF-MIMO mode. The normalization factor  $K_{MOD}$  for 256QAM is  $1/\sqrt{170}$ . For 256-QAM,  $b_0b_1b_2b_3$  determines the I value and  $b_4b_5b_6b_7$  determines the Q value, as illustrated in Table 24. The constellation mapping for 256QAM is as follows.

**Table 24: Constellation Mapping for 256-QAM in ABF-MIMO Mode**

| Input bits $b_0b_1b_2b_3$ | I-out | Input bits $b_4b_5b_6b_7$ | Q-out |
|---------------------------|-------|---------------------------|-------|
| 0000                      | -15   | 0000                      | -15   |
| 0001                      | -13   | 0001                      | -13   |
| 0011                      | -11   | 0011                      | -11   |
| 0010                      | -9    | 0010                      | -9    |
| 0110                      | -7    | 0110                      | -7    |
| 0111                      | -5    | 0111                      | -5    |
| 0101                      | -3    | 0101                      | -3    |
| 0100                      | -1    | 0100                      | -1    |
| 1100                      | 1     | 1100                      | 1     |
| 1101                      | 3     | 1101                      | 3     |
| 1111                      | 5     | 1111                      | 5     |
| 1110                      | 7     | 1110                      | 7     |
| 1010                      | 9     | 1010                      | 9     |
| 1011                      | 11    | 1011                      | 11    |
| 1001                      | 13    | 1001                      | 13    |
| 1000                      | 15    | 1000                      | 15    |

### 11.2.3.2.2 Spatial Parsing with Unequal Puncturing Rates

Puncturing is performed after parsing, as shown in Figure 60 (which is different from basic BF-MIMO, as shown in Figure 59). Parsing is done in cycles. During each cycle, a block of coded bits is parsed to each spatial stream. These blocks are taken to be integer multiples of the puncture cycle of the code; that is, for a rate  $n/(n+1)$  puncturing, the puncture cycle is  $n$  trellis stages, or  $2n$  un-coded bits (the mother code is rate  $1/2$ ). Parameters of the parser are selected to yield the smallest parsing cycle length, hence ensure good mixing of spatial streams within the constraint length of the code.

### 11.2.4 Options for Advanced Coding

Our proposal introduces two flavors of advanced coding: (i) LDPC (low density parity check) coding, and (ii) Concatenated coding using an outer Reed-Solomon (RS) code and the 802.11a convolutional code as the inner code.

#### 11.2.4.1 Low Density Parity Check Codes

There has is great interest in employing a Low Density Parity Check (LDPC) code in the 802.11n standard. It has been shown that LDPC codes, like turbo codes, can provide near Shannon capacity performance. Our proposal has chosen to endorse LDPC due to (a) their ability to provide good performance at high code rates (thus enhancing throughput), and (b) more flexibility in decoder design options.

At the time of submission of this proposal, there are several companies working towards convergence of a precise LDPC code definition within 802.11 task group N. It is expected that this convergence process will continue over the next few months, and the authors of this proposal expect to endorse the outcome of this convergence process. Accordingly, this proposal shall not initially endorse a particular LDPC code. Rather, we shall discuss only overview material on LDPC with indication on how the LDPC can be integrated into the 802.11n standard. Simulation results are presented for a “placeholder” rate  $7/8$  LDPC code.

##### 11.2.4.1.1 LDPC Overview

LDPC codes are block codes that are specified by the parity check matrix of size  $M \times N$  defines an LDPC block code  $(N, K)$ , where  $K$  is the information block size,  $N$  is the length of the codeword, and  $M$  is the number of parity check bits,  $M = N - K$ . The general characteristic of an LDPC parity check matrix is low density of non-zero elements (1's in this case), which allows utilization of efficient decoding algorithms. This particular parity check matrix is designed in a way that enables simple encoding as well. It can be represented in the following form:

$$\mathbf{H} = [\mathbf{H}^d | \mathbf{H}^p] \quad (57)$$

$\mathbf{H}^d$  is an  $M \times K$  matrix and corresponds to the “data” bits of the codeword. The design of this matrix ensures high coding gain.  $\mathbf{H}^p$  is an  $M \times M$  “dual diagonal” matrix and corresponds to the “parity” bits of the codeword. These codes are systematic block codes. Codewords have the structure

$$\mathbf{c} = \begin{bmatrix} \mathbf{d} \\ \mathbf{p} \end{bmatrix} \quad (58)$$

where  $\mathbf{d} = [d_0 \text{L} d_{K-1}]^T$  is the block of (uncoded) data bits and  $\mathbf{p} = [p_0 \text{L} p_{M-1}]^T$  are the parity bits. A codeword is any binary  $N$ -vector  $\mathbf{c}$  that satisfies

$$\mathbf{H}\mathbf{c} = \mathbf{H}^d\mathbf{d} + \mathbf{H}^p\mathbf{p} = \mathbf{0}. \quad (59)$$

Thus, a given the data block  $\mathbf{d}$  is encoded by solving binary equation  $\mathbf{H}^p\mathbf{p} = \mathbf{H}^d\mathbf{d}$  for the parity bits  $\mathbf{p}$ . In principle, this involves inverting the  $M \times M$  matrix  $\mathbf{H}^p$ .

While  $\mathbf{H}^p$  itself may be a “low density” parity matrix (meaning it is mostly of zeros), this property is not generally also true for its inverse. Thus, additional “dual diagonal” structure is imposed in order to in order ensure an efficient encoder. This structure is

$$\mathbf{H}^p = \begin{bmatrix} 1 & 0 & 0 & 0 & \dots & 0 & 0 \\ 1 & 1 & 0 & 0 & \dots & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & \dots & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & \dots & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & \dots & 0 & 1 & 1 \end{bmatrix} \quad (60)$$

It should be clear that  $\mathbf{H}^p\mathbf{p}$  is a differential encoding of the parity bits, and hence, the inverse operation is a very simple differential decoder.

#### 11.2.4.1.2 Recommended Code Parameters

This proposal recommends that the mother LDPC code have rate 7/8. This rate will then match the highest rate available from the convolutional code.

Lower code rates can be obtained by “shortening.” In this method, a data block of  $\mathbf{d}'$  of length  $K' < K$  is encoded by first padding  $K - K'$  zeros to produce a new data vector  $\mathbf{d} = [\mathbf{0}|\mathbf{d}']$ .  $\mathbf{d}$  is then encoded using the rate 7/8 mother code to produce the codeword  $\mathbf{c} = [\mathbf{0}|\mathbf{d}'|\mathbf{p}]$ , however, only  $\mathbf{c}' = [\mathbf{d}'|\mathbf{p}]$  is transmitted. Thus, the shortened code rate is  $K'/(N - K')$ .

This proposal requires that the LDPC design should, by shortening or other methods, provide code rates 1/2, 2/3 and 3/4 in order to match the code rates of provided by punctured convolutional codes.

Selection of the LDPC block size presents trade-off between performance, decoder complexity and decoding time. The last codeword of the PSDU is particularly time critical as it must be decoded within a fraction of a SIFS period. Our studies on decoder complexity have shown that  $N = 2000$  bits is sufficiently long to provide good performance with limited decoder complexity.

Furthermore, the last block decoding problem can be mitigated shortening the last codeword more than the others. This produces a more powerful lower rate code which then requires fewer iterations to decode. Since the vast majority of 802.11n PSDUs should exceed several multiples of 2000 bits, these PSDUs will be encoded using several LDPC codewords. Thus, shorting of the last codeword simultaneously solves the rate matching problem and the SIFS decoding time problem.

#### 11.2.4.1.3 LDPC Implementation in MIMO Architecture

LDPC codes are self interleaved codes, and hence, they do not need a frequency interleaver. Figure 61 shows the MIMO coding architecture to be employed with LDPC. The differences between this architecture and the architecture of Figure 35 are that with LDPC we achieve lower code rates via shortening of the mother rate 7/8 code (rather than puncturing a rate 1/2 convolutional code), and there are no per spatial stream frequency interleavers. The parser is identical to the one described in 11.2.1.5.7.1.

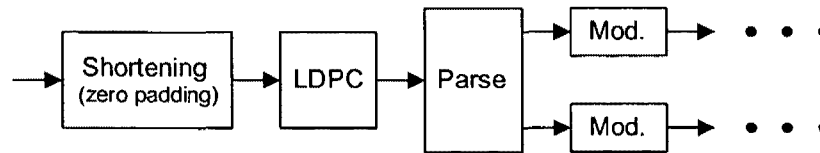


**Figure 61: LDPC inclusion in the transmit datapath architecture**

#### 11.2.4.2 Reed-Solomon Codes

We propose the use of an outer RS encoder in the system as follows:

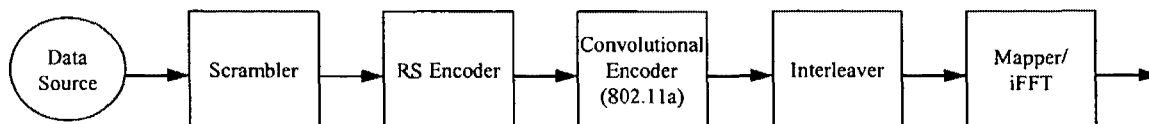


**Figure 62: Concatenated RS and Convolutional encoding**

We propose to use a (220,200) 20 byte-error correcting RS encoding over GF(256) using the following generator polynomial:  $x^8 + x^4 + x^3 + x^2 + 1$ . This is the same generator polynomial used in the ATSC HDTV standard. This code will correct upto 10 byte errors per 220 byte codeword. There is no additional interleaver between the RS encoder and the convolutional encoder. After scrambling, the data bits are grouped into 200 byte groups that are then encoded into 220 bytes in a systematic fashion by the RS encoder.

The proposal does not restrict the packet size to be an integral multiple of 200 bytes. The RS encoder begins encoding data in blocks of 200 bytes and any leftover bytes (< 200) are encoded as a shortened RS codeword with the same number of parity bytes (20). This scheme does not need any other mechanism to inform the receiver as to the number of codewords in a packet. For packet sizes less than 200 bytes, 20 bytes of parity are always appended. In many cases, the

1 number of RS parity bytes is less than the number of pad-bits that are needed to transmit an  
2 integer number of OFDM symbols per antenna, and in those cases the overhead due to the RS  
3 encoding will be zero. For example, in a 2 x 2 rate  $\frac{3}{4}$  64QAM system in 40 MHz, a 100-byte data  
4 packet requires 166-bits as pad-bits. Hence 20 bytes of parity can be accommodated with no  
5 extra overhead.

6

7 (END)



# WWiSE IEEE 802.11n Proposal

September 16, 2004

Airgo Networks, Bermai, Broadcom, Conexant, Realtek,  
STMicroelectronics, Texas Instruments

# Contributors and contact information

- Airgo Networks: VK Jones, [vkjones@airgonetworks.com](mailto:vkjones@airgonetworks.com)
- Bermai: Neil Hamady, [nhamady@bermai.com](mailto:nhamady@bermai.com)
- Broadcom: Jason Trachewsky, [jat@broadcom.com](mailto:jat@broadcom.com)
- Conexant: Michael Seals, [michael.seals@conexant.com](mailto:michael.seals@conexant.com)
- Realtek: Stephan ten Brink, [stenbrink@realtek-us.com](mailto:stenbrink@realtek-us.com)
- STMicroelectronics: George Vlantis, [George.Vlantis@st.com](mailto:George.Vlantis@st.com)
- Texas Instruments: Sean Coffey, [coffey@ti.com](mailto:coffey@ti.com)

# Contents

- **WWiSE approach**
- **Overview of key features**
- **Proposal description**
  - **Physical layer design**
  - **MAC features**
- **Discussion**
- **Summary**

# The WWiSE approach

- WWiSE = World Wide Spectrum Efficiency
- The partnership was formed to develop a specification for next generation WLAN technology suitable for worldwide deployment
- Mandatory modes of the WWiSE proposal comply with current requirements in all major regulatory domains: Europe, Asia, Americas
- Proposal design emphasizes compatibility with existing installed base, building on experience with interoperability in 802.11g and previous 802.11 amendments
- All modes are compatible with QoS and 802.11e
- Maximal spectral efficiency translates to highest performance and throughput in all modes

# The WWiSE approach, contd.

One solution applicable to all markets

*"Synergy and mutual reinforcement is only possible if the following conditions are met:*

- *The same HT technology is able to function in all three markets and environments [home, enterprise, hotspot]– this enhances the utility of HT for the users*
- *... "*
  - Wi-Fi Alliance MRD for High Throughput Technology, Nov. 2003 (doc. 11-03/879r2)

# Overview of key mandatory features

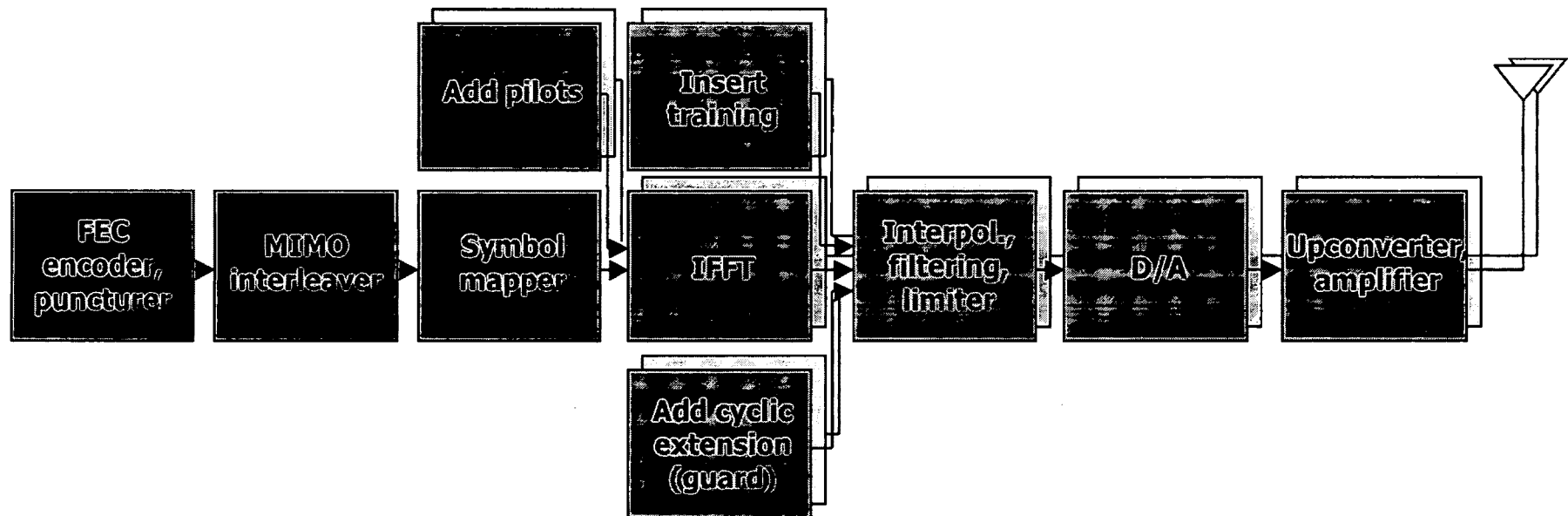
- The WWiSE proposal's mandatory modes are:
  - 2 transmit antennas
  - 20 MHz operation
  - 135 Mbps maximum PHY rate
  - 2x1 transmit diversity modes, 20 MHz
  - Mixed mode preambles enabling on-the-air legacy compatibility
  - Efficient greenfield preambles – no increase in length over legacy
  - Enhanced efficiency MAC mechanisms
  - All components based on enhancement of existing COFDM PHY

2x2 MIMO operation in a 20 MHz channel: Goal is a robust, efficient, small-form-factor, universally compliant 100 Mbps mode that fits naturally with the existing installed base

# Overview of key optional features

- The WWiSE proposal's optional modes are:
  - 3 and 4 transmit antennas
  - 40 MHz operation
  - Up to 540 Mbps PHY rate
  - 2x1, 3x2, 4x2, 4x3 transmit diversity modes
  - Advanced coding: Rate-compatible LDPC code

# Transmitter block diagram





# Unified format

| Code rate | Cyclic prefix, ns | Code      | Constellation |
|-----------|-------------------|-----------|---------------|
| 1/2       | 800               | BCC, LDPC | 16-QAM        |
| 3/4       | 800               | BCC, LDPC | 16-QAM        |
| 2/3       | 800               | BCC, LDPC | 64-QAM        |
| 3/4       | 800               | BCC, LDPC | 64-QAM        |
| 5/6       | 800               | BCC, LDPC | 64-QAM        |

**All combinations of 2, 3, 4 transmit antennas and 20/40 MHz offer exactly these 5 modes**

**All 20 MHz modes have 54 data subcarriers, 2 pilots.**

**All 40 MHz modes have 108 data subcarriers, 4 pilots**

# Advantages of unified format

- Minimization of cost:
  - Development time, testing of modes, and interoperability are significant sources of cost
  - A unified basic plan simplifies these tasks
- Market acceptance and growth
  - Faster time to market
  - The most straightforward scalability
- Rate selection and management:
  - One basic plan across all antenna configurations and bandwidths

## 2 transmitter SDM, 20 MHz (mandatory)

| PHY rate   | Data carriers | Pilots | Code rate | Cyclic prefix, ns | Code | Constellation |
|------------|---------------|--------|-----------|-------------------|------|---------------|
| 54 Mbps    | 54            | 2      | 1/2       | 800               | BCC  | 16-QAM        |
| 81 Mbps    | 54            | 2      | 3/4       | 800               | BCC  | 16-QAM        |
| 108 Mbps   | 54            | 2      | 2/3       | 800               | BCC  | 64-QAM        |
| 121.5 Mbps | 54            | 2      | 3/4       | 800               | BCC  | 64-QAM        |
| 135 Mbps   | 54            | 2      | 5/6       | 800               | BCC  | 64-QAM        |

## 2x1 modes, 20 MHz (mandatory)

| PHY rate    | Data carriers | Pilots | Code rate | Cyclic prefix, ns | Code | Constellation |
|-------------|---------------|--------|-----------|-------------------|------|---------------|
| 6.75 Mbps   | 54            | 2      | 1/2       | 800               | BCC  | BPSK          |
| 10.125 Mbps | 54            | 2      | 3/4       | 800               | BCC  | BPSK          |
| 13.5 Mbps   | 54            | 2      | 1/2       | 800               | BCC  | QPSK          |
| 20.25 Mbps  | 54            | 2      | 3/4       | 800               | BCC  | QPSK          |
| 27 Mbps     | 54            | 2      | 1/2       | 800               | BCC  | 16-QAM        |
| 40.5 Mbps   | 54            | 2      | 3/4       | 800               | BCC  | 16-QAM        |
| 54 Mbps     | 54            | 2      | 2/3       | 800               | BCC  | 64-QAM        |
| 60.75 Mbps  | 54            | 2      | 3/4       | 800               | BCC  | 64-QAM        |

# Optional data modes

- 20 MHz:
  - 3 Tx space-division multiplexing
  - 4 Tx space division multiplexing
  - 3x2, 4x2, 4x3 space-time transmit diversity
- 40 MHz: (all 40 MHz modes optional)
  - 1 Tx antenna
  - 2 Tx space division multiplexing
  - 3 Tx space division multiplexing
  - 4 Tx space division multiplexing
  - 2x1, 3x2, 4x2, 4x3 space-time transmit diversity
- LDPC code option
  - An option in all proposed MIMO configurations and channel bandwidths

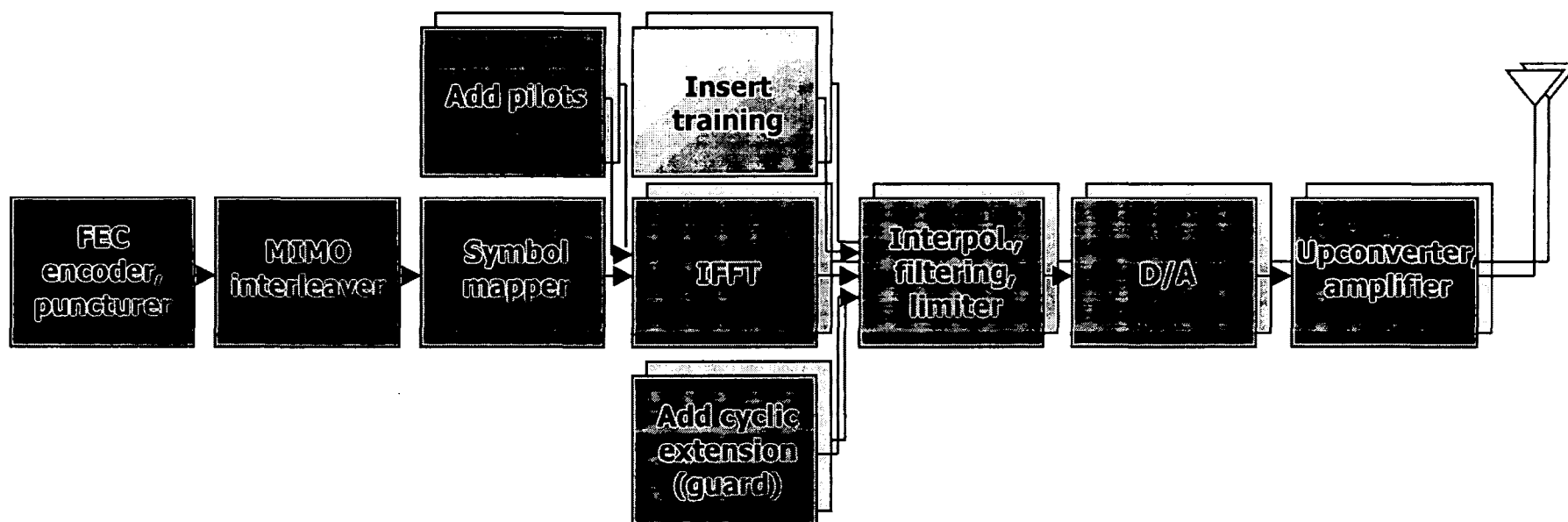
# Optional mode data rates

**20 MHz:**

| Configuration | <i>Rate 1/2,<br/>16-QAM</i> | <i>Rate 3/4,<br/>16-QAM</i> | <i>Rate 2/3,<br/>64-QAM</i> | <i>Rate 3/4,<br/>64-QAM</i> | <i>Rate 5/6,<br/>64-QAM</i> |
|---------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 3 Tx, 20 MHz  | 81                          | 121.5                       | 162                         | 182.25                      | 202.5                       |
| 4 Tx, 20 MHz  | 108                         | 162                         | 216                         | 243                         | 270                         |

**40 MHz:**

| Configuration | <i>Rate 1/2,<br/>16-QAM</i> | <i>Rate 3/4,<br/>16-QAM</i> | <i>Rate 2/3,<br/>64-QAM</i> | <i>Rate 3/4,<br/>64-QAM</i> | <i>Rate 5/6,<br/>64-QAM</i> |
|---------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 1 Tx, 40 MHz  | 54                          | 81                          | 108                         | 121.5                       | 135                         |
| 2 Tx, 40 MHz  | 108                         | 162                         | 216                         | 243                         | 270                         |
| 3 Tx, 40 MHz  | 162                         | 243                         | 324                         | 364.5                       | 405                         |
| 4 Tx, 40 MHz  | 216                         | 364                         | 432                         | 486                         | 540                         |



# Preambles

- Mixed-mode preambles:
  - Capable of operation in presence of legacy 11a/g devices
  - Ensure correct deferral behavior by devices compliant to legacy spec
- Green-field preambles:
  - Operate in time interval or environment with only 11n devices on the air
  - May be used with protection mechanisms, *as in 11g*, or with new burst mode; or in 11n-only BSS
  - Greater efficiency than mixed-mode preambles

Both preamble types are derived from a common basic structure, providing reuse in algorithms



# Short training sequence

2 Transmitters



3 Transmitters



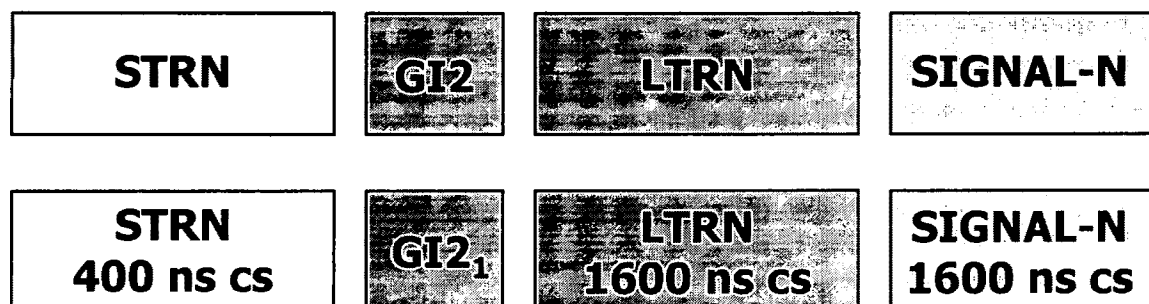
4 Transmitters



20 MHz: STRN = 802.11ag short training sequence  
40 MHz mixed mode: STRN = Pair of 802.11ag short  
sequences separated in frequency by 20 MHz  
40 MHz green field: STRN = Newly defined sequence

cs = Cyclic shift

# Long training sequence and SIGNAL-N, green-field, 2 transmitters



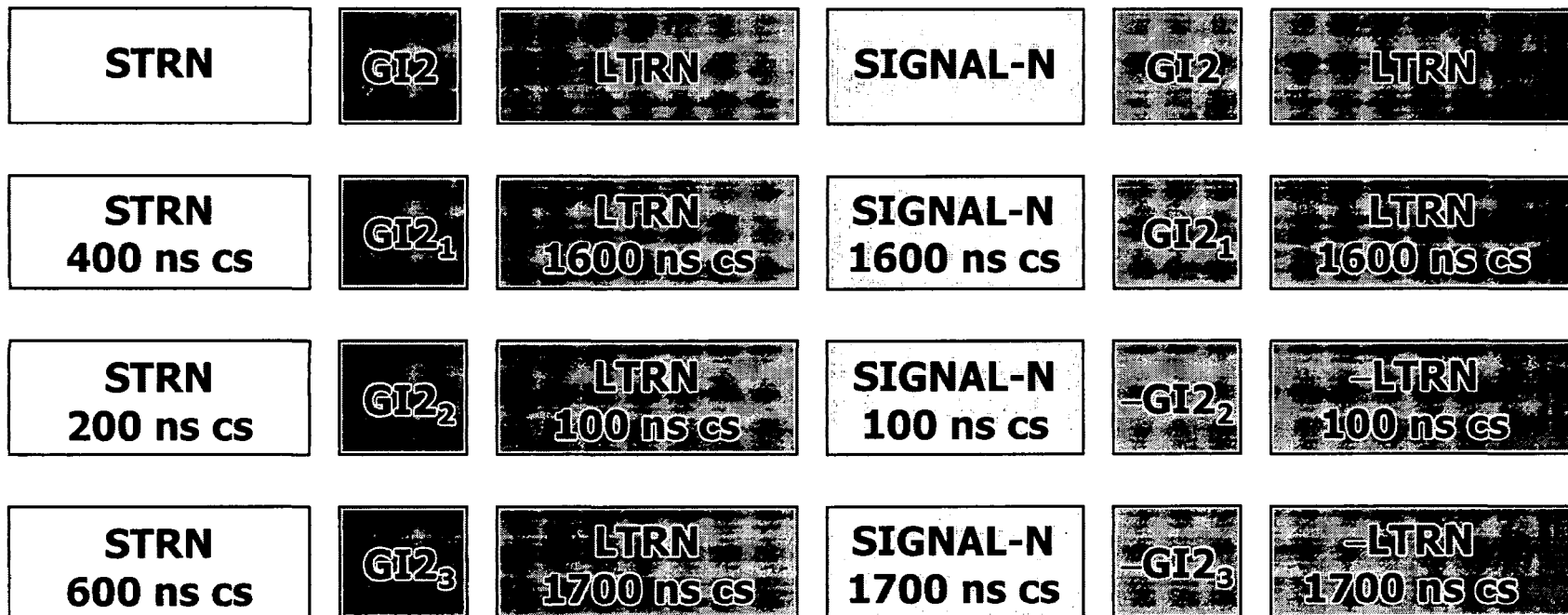
**20 MHz: LTRN = 802.11ag long training sequence with four extra tones, 6.4 usec**

**40 MHz: LTRN = Newly defined sequence, 6.4 usec**

**GI2<sub>1</sub> = GI2 for LTRN with 1600 ns cyclic shift**

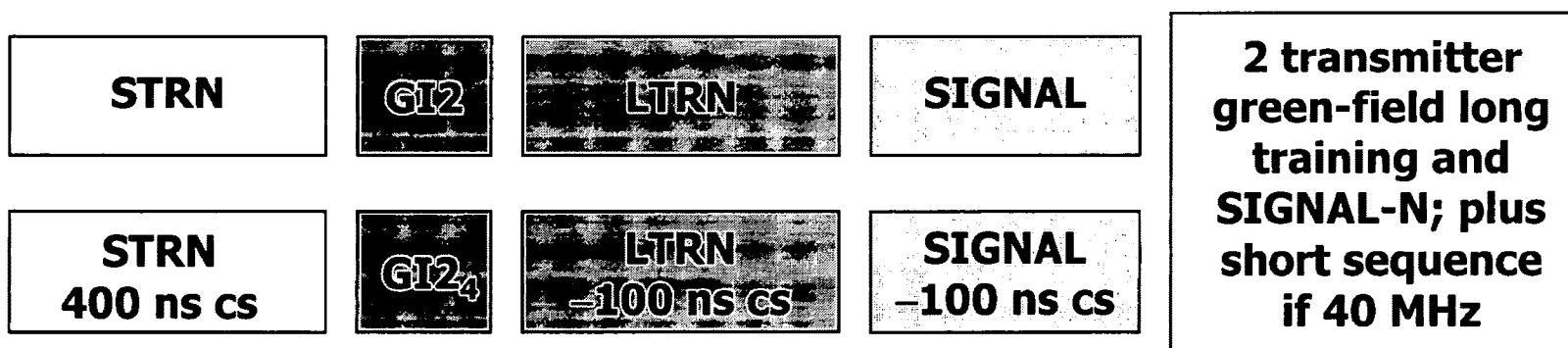
**SIGNAL-N = 54 bits, 4 usec**

# Long training sequence and SIGNAL-N, green-field, 3 and 4 transmitters



**For 3 transmitters, the first three rows are used**

# Long training and SIGNAL fields, mixed mode, 2 transmitters



# Long training and SIGNAL fields, mixed mode, 3 and 4 transmitters

|                           |                        |                            |                              |                                                                                                                         |
|---------------------------|------------------------|----------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>STRN</b>               | <b>GI2</b>             | <b>LTRN</b>                | <b>SIGNAL</b>                | <b>3 or 4<br/>transmitter<br/>green-field long<br/>training and<br/>SIGNAL-N; plus<br/>short training if<br/>40 MHz</b> |
| <b>STRN<br/>400 ns cs</b> | <b>GI2<sub>4</sub></b> | <b>LTRN<br/>-100 ns cs</b> | <b>SIGNAL<br/>-100 ns cs</b> |                                                                                                                         |
| <b>STRN<br/>200 ns cs</b> | <b>GI2<sub>5</sub></b> | <b>LTRN<br/>100 ns cs</b>  | <b>SIGNAL<br/>100 ns cs</b>  |                                                                                                                         |
| <b>STRN<br/>600 ns cs</b> | <b>GI2<sub>6</sub></b> | <b>LTRN<br/>200 ns cs</b>  | <b>SIGNAL<br/>200 ns cs</b>  |                                                                                                                         |

**For 3 transmitters, the first three rows are used**

# Preamble lengths (20 & 40 MHz)

## *Green-field*

| Configuration | Short | First long | SIGNAL | Second long | Total     |
|---------------|-------|------------|--------|-------------|-----------|
| 1x1           | 8     | 8          | 4      | 0           | <b>20</b> |
| 2x2           | 8     | 8          | 4      | 0           | <b>20</b> |
| 3x3           | 8     | 8          | 4      | 8           | <b>28</b> |
| 4x4           | 8     | 8          | 4      | 8           | <b>28</b> |

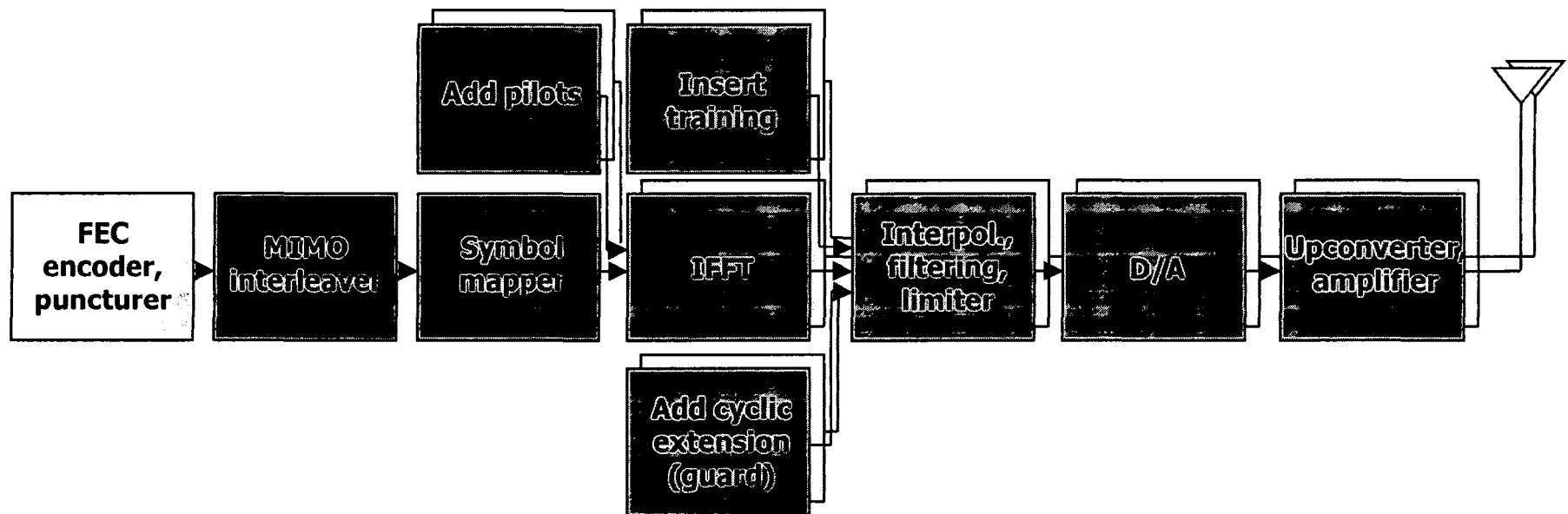
**All space-time block codes follow the pattern with the same number of transmit antennas**

# Preamble lengths (20 & 40 MHz), contd.

## *Mixed mode*

| Configuration | Short | First long | SIGNAL | Second short | Second long | Second SIGNAL | Third long | Total        |
|---------------|-------|------------|--------|--------------|-------------|---------------|------------|--------------|
| 1x1           | 8     | 8          | 4      | –/8          | 8           | 4             | 0          | –/40         |
| 2x2           | 8     | 8          | 4      | 0/8          | 8           | 4             | 0          | <b>32/40</b> |
| 3x3           | 8     | 8          | 4      | 0/8          | 8           | 4             | 8          | <b>40/48</b> |
| 4x4           | 8     | 8          | 4      | 0/8          | 8           | 4             | 8          | <b>40/48</b> |

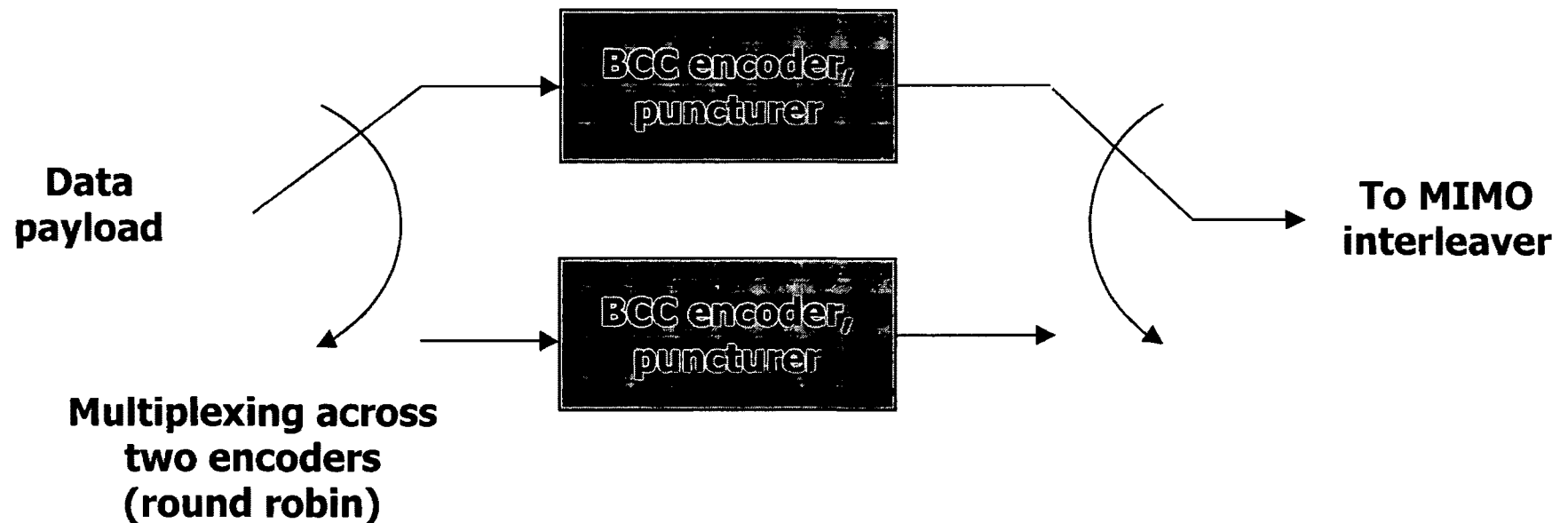
**All space-time block codes follow the pattern with the same number of transmit antennas**





# Parallel encoders

- For 40 MHz modes with more than two spatial streams, two parallel BCC encoders are used:



# Advanced coding option

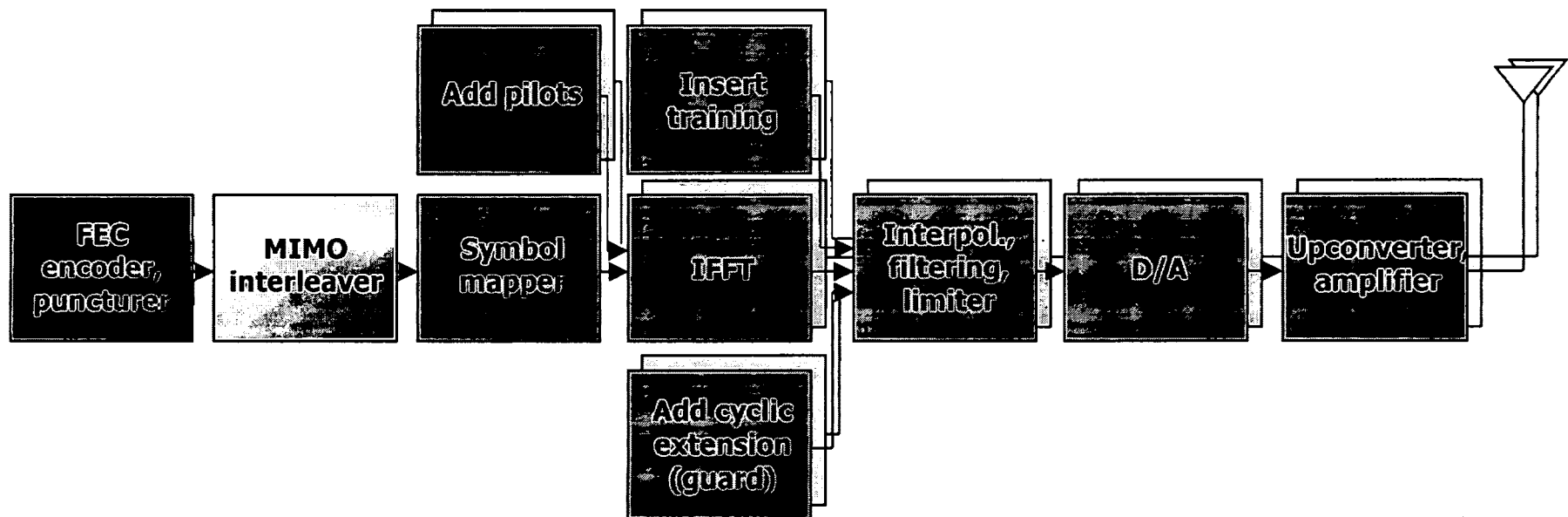
- Rate-compatible LDPC code with the following parameters:

| Rate | Information bits | Block length |
|------|------------------|--------------|
| 1/2  | 972              | 1944         |
| 2/3  | 1296             | 1944         |
| 3/4  | 1458             | 1944         |
| 5/6  | 1620             | 1944         |

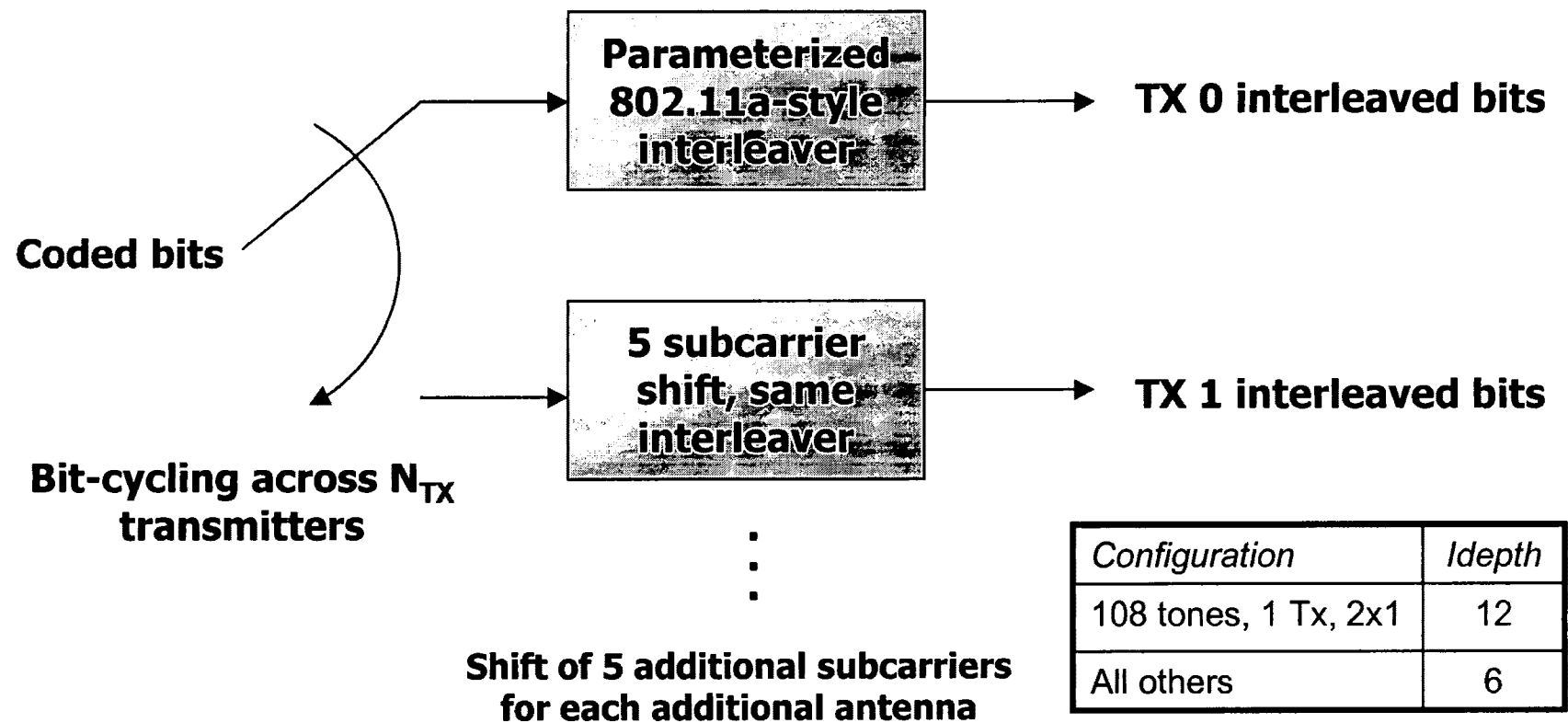
- Transmitter block diagram as for BCC modes, except symbol interleaver, rate-compatible puncturing, and tail bits are not used

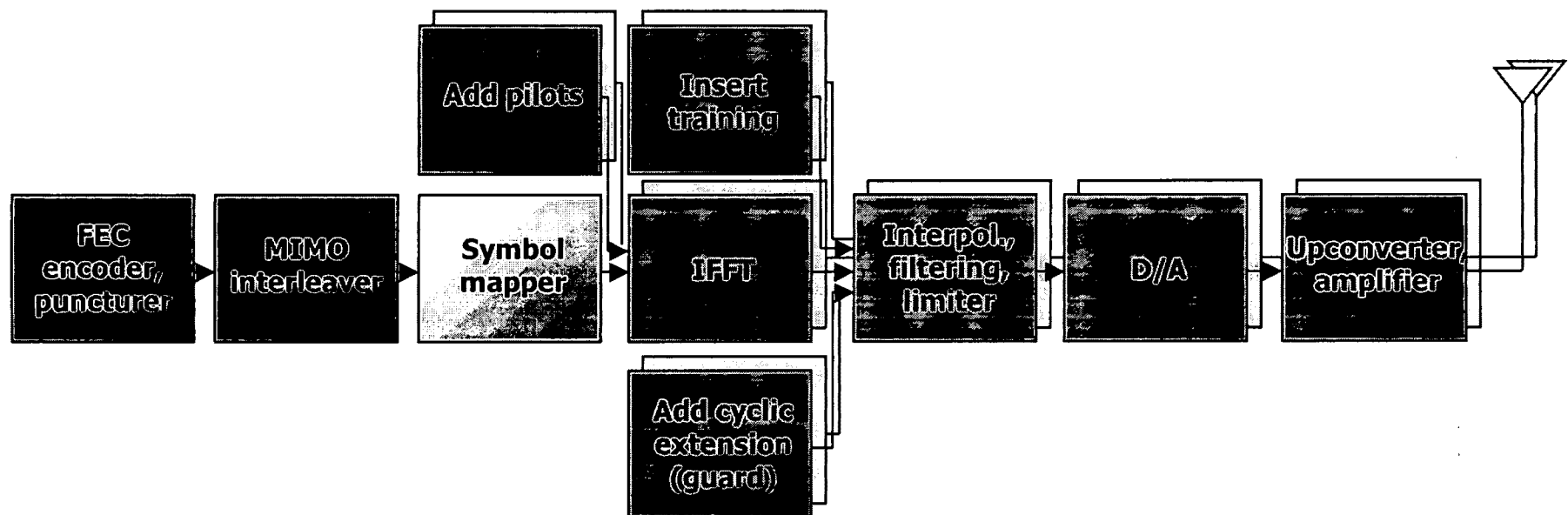
# LDPC code, contd.

- There is no change required to SIFS or to any other system timing parameters when the advanced coding option is used
- The block size of 1944 reduces or eliminates the need for pad bits at the end of a packet
  - Pad bits are eliminated for 2 transmitter operation in 20 MHz channels, and 2x1 and 1x1 in 40 MHz channels
- The four parity check matrices are derived from the rate-1/2 matrix via row combining
- The parity check matrices are structured and based on square-shaped building blocks of size 27x27
- The parity check matrices are structured to enable efficient encoding



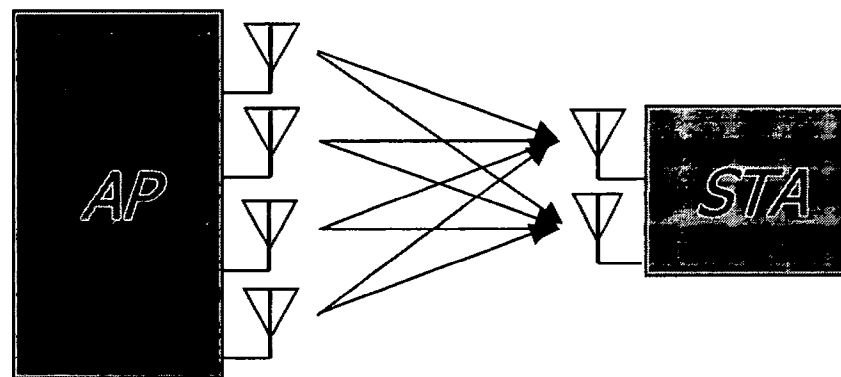
# MIMO interleaving





# Space-time block codes and asymmetry

- Simple space-time block codes (STBCs) are used to handle asymmetric antenna configurations
  - STBC rate always is an integer
    - No new PHY rates result from STBC encoding of streams
  - Block size is always two OFDM symbols
  - STBC encoding follows the stream encoding



# Asymmetric modes, contd.

- These modes are all *open-loop*
  - No channel state information required at transmitter
  - No calibration required
  - No overhead from exchanging channel state information
  - No sensitivity to channel state information errors



# Space-time block codes

- 2x1:

|      | $t_1$    | $t_2$   |
|------|----------|---------|
| Tx 1 | $s_1$    | $s_2$   |
| Tx 2 | $-s_2^*$ | $s_1^*$ |

- 4x2:

|      | $t_1$    | $t_2$   |
|------|----------|---------|
| Tx 1 | $s_1$    | $s_2$   |
| Tx 2 | $-s_2^*$ | $s_1^*$ |
| Tx 3 | $s_3$    | $s_4$   |
| Tx 4 | $-s_4^*$ | $s_3^*$ |

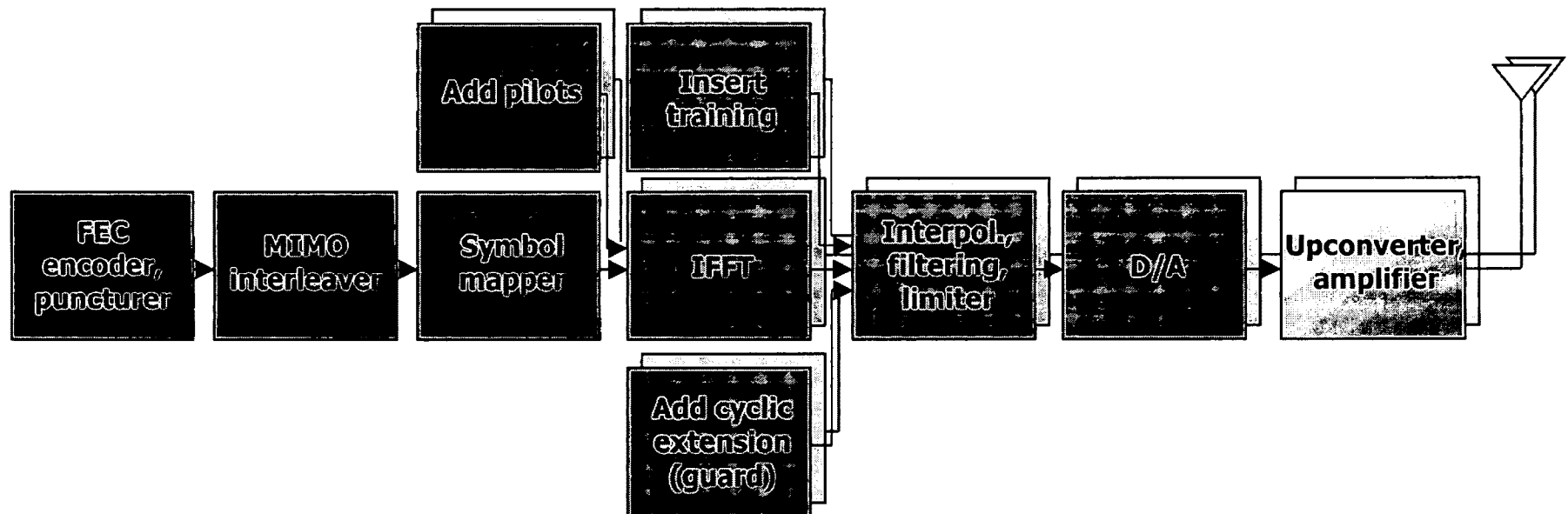
- 3x2:

|      | $t_1$    | $t_2$   |
|------|----------|---------|
| Tx 1 | $s_1$    | $s_2$   |
| Tx 2 | $-s_2^*$ | $s_1^*$ |
| Tx 3 | $s_3$    | $s_4$   |

- 4x3:

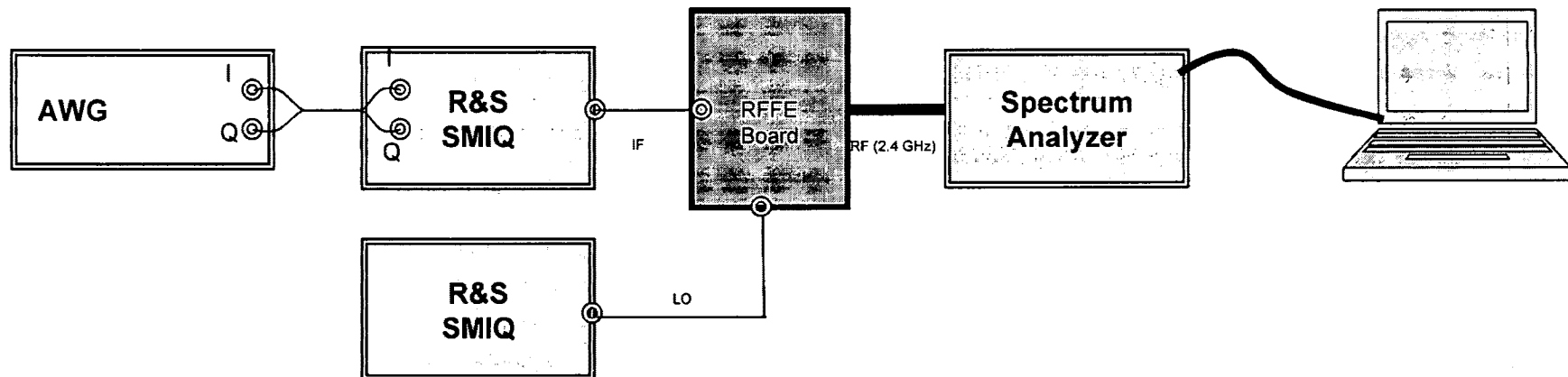
|      | $t_1$    | $t_2$   |
|------|----------|---------|
| Tx 1 | $s_1$    | $s_2$   |
| Tx 2 | $-s_2^*$ | $s_1^*$ |
| Tx 3 | $s_3$    | $s_4$   |
| Tx 4 | $s_5$    | $s_6$   |

**The STBC is applied independently to each OFDM subcarrier**

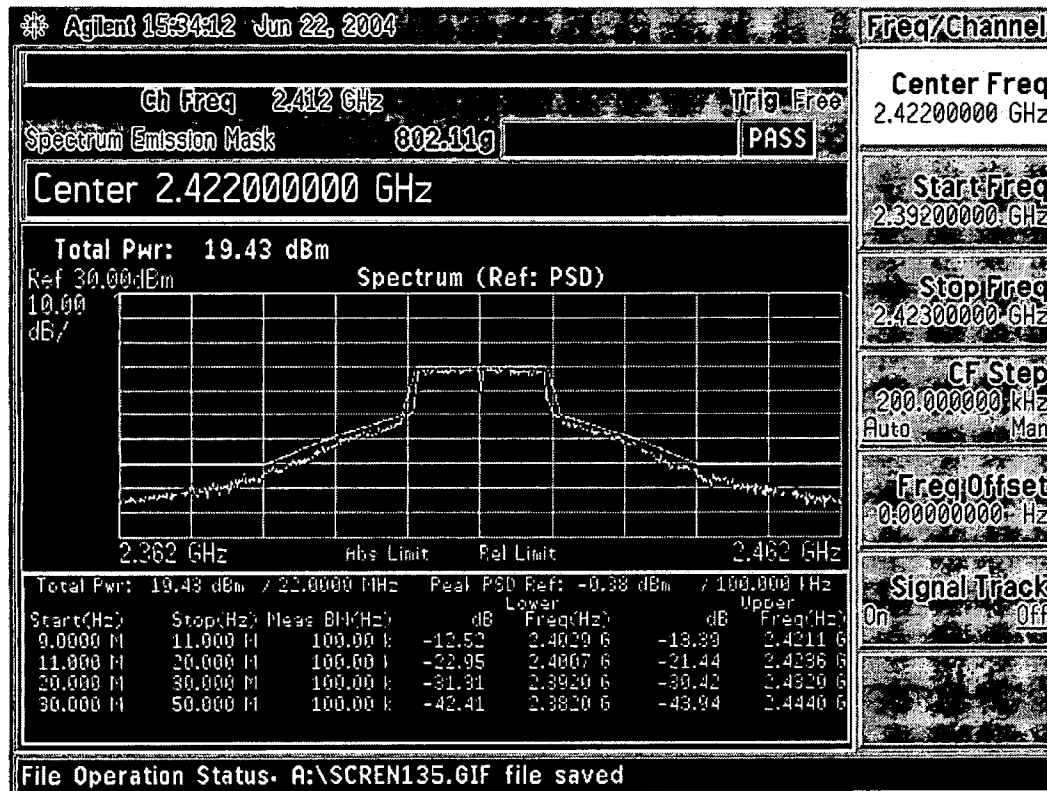


# Power spectral density, 20 MHz

- An AWG is loaded with files representing signal formats of interest.
  - Each file represents about 0.5 msec of randomly modulated OFDM symbols, prepended with short and long training sequences
- Output of AWG is modulated using an R&S SMIQ to IF frequency
- The output of the SMIQ is input to a board with RFFE+PA
  - The PA distorts the input spectrum, producing spectral regrowth.
- The resulting spectrum is recorded on a spectrum analyzer.



# 56-tone OFDM signals



- This is a 56 tone OFDM signal with a short trapezoidal window
- The PA is operated 3.5 dB backed off from PO-1 dB compression point
- The signal meets spectral mask
- The "standard" 52 tone OFDM signal with same window meets mask with a backoff of 3.0 dB

## 2 pilot symbols

- MIMO systems have multiple receive chains, providing receive diversity
- Format uses cyclic modulation of pilot symbols in time and space, for 20 MHz and 40 MHz
  - This provides transmit diversity gain over a static modulation
- Overall the scheme provides robust synchronization with MIMO-OFDM transmission

# MAC features

# MAC features

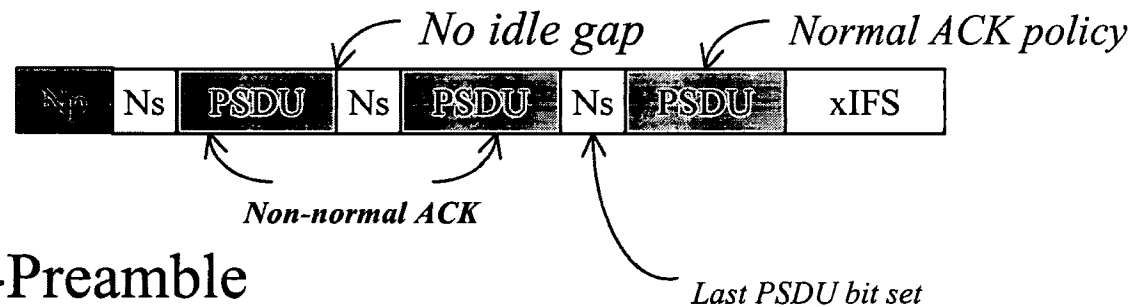
- The WWiSE proposal builds on 802.11e functionality as much as possible, in particular EDCA, HCCA, and Block Ack
  - Block Ack mandatory
- Backward compatibility
- Simplicity
  - Shorter time to standardization
  - Shorter time to productization
- Effectiveness
  - Eliminate the big bottlenecks

# Aggregation

- Bursting and Aggregation:
  - MSDU aggregation
    - Increased maximum PSDU length, to 8191 octets
  - PSDU aggregation = HTP burst:
    - sequence of MPDUs from same transmitter
    - Reduced interframe spacing
      - 0 usec if at same Tx power level and PHY configuration
      - 2 usec otherwise (with preamble)
      - Not dependent on RA



# HTP Burst



= N-Preamble



= N-Signal field @ robust encoding rate

- = PPDU aggregation
- Multiple RA allowed within the burst
- Block Ack Request and Block Ack frames allowed within the burst
- Last PSDU bit indicates to receiver that it should revert to preamble search

# HTP Burst vs. MSDU Aggregation

- HTP burst allows aggregation without incurring latency cost (on-the-fly aggregation)
- HTP allows multiple RA per burst
- HTP allows multiple rates within burst
- HTP allows varying TX power within burst

# Block Ack – Ack Policy

- Block Ack frames now have ACK policy bits
  - Allows:
    - Normal ACK behavior per 802.11e draft
    - No-ACK
    - other settings reserved
  - Reduces Block Ack overhead
    - by eliminating explicit ACKs (as an option)

## Block Ack – Ack Policy, contd.

- Allows multiple RA + Block Ack Frames within a single HTP burst
  - if immediate ACK required:
    - HTP burst broken to allow SIFS + ACK
    - HTP burst single RA, ending with Block Ack Request + SIFS + ACK
    - HTP burst single RA, ending with Block Ack Request + Block Ack + ACK
  - without immediate ACK
    - HTP burst is allowed to continue
    - HTP burst may contain multiple Block Ack Request to multiple RA
- Effectively allows additional, more efficient modes of use for Block Ack mechanism

# Legacy Interaction

- Legacy remediation
  - N-STA detection/advertisement
    - Identification of TGn and non-TGn devices and BSSs
    - Extends ERP information element
    - Uses proven 802.11g signaling
  - Legacy Protection mechanisms
    - Existing protection mechanisms (extended to N/G case)
    - Addition of PLCP length spoofing
  - 40/20 MHz channel switching supported
    - Equitable sharing of resources with legacy

# Simulations

- PHY model in MAC simulations
  - Detailed description in IEEE 802.11-04/877r3
  - TGn MIMO Channel Models
  - Impairments as specified by FRCC
  - Union bound technique to estimate PHY layer frame errors
  - Performance closely matches full simulations for mandatory phy configurations
    - Binary convolutional coding
  - Executes as MATLAB routine called by MAC simulator in NS

# EDCA Simulation Results

- EDCA 2x2 – 20MHz 5GHz (max rate = 135 mbps)
  - **QOS goals met, all flows, all scenarios**
    - S-1: 54 Mbps (52q/1.5nq), latencies *excellent*
    - S-4: 44 Mbps (10q/34nq), latencies *excellent*
    - S-6: 47 Mbps (45q/2nq), latencies *very good*
- EDCA 2x2 – 40MHz 5GHz (max rate = 270 mbps)
  - **Even better, e.g.**
    - S-1: 56 Mbps (52q/3.5nq), latencies *excellent*
    - S-4: 65 Mbps (10q/55nq), latencies *excellent*
    - S-6: 51 Mbps (45q/6nq), latencies *excellent*

\* HTP burst employed in sims, but no aggregation used

# EDCA Simulation Parameters – AP/STA

## e.g., scenario 4

|       | CWMIN | CWMAX   | AIFSN | TXOP LIMIT<br>msec |
|-------|-------|---------|-------|--------------------|
| AC_BK | 31/63 | 511/511 | 4/4   | 2.0/1.0            |
| AC_BE | 31/63 | 127/255 | 4/4   | 3.0/2.5            |
| AC_VI | 15/15 | 31/31   | 3/3   | 2.5/1.1            |
| AC_VO | 7/15  | 31/31   | 2/2   | 1.2/1.0            |



# HCCA Simulation Results

- HCCA 2x2 – 20MHz 5GHz (max rate = 135 mbps)
  - **QOS goals met, all flows, all scenarios**
    - S-1: 80 Mbps (52q/28nq), latencies *excellent*
    - S-4: 86 Mbps (10q/76nq), latencies *very good\**
    - S-6: 63 Mbps (45q/18nq), latencies *excellent*
- HCCA 2x2 – 40MHz 5GHz (max rate = 270 mbps)
  - **Even better, e.g.**
    - S-1: 110 Mbps (52q/58nq), latencies *excellent*
    - S-4: 135 Mbps (10q/125nq), latencies *excellent*
    - S-6: 70 Mbps (46q/24nq), latencies *excellent*

*\* scheduler tuned too much toward BE flows*

# HCCA Simulation Parameters

- HTP burst employed, but no MSDU aggregation used
- Very simple scheduler employed
  - Round robin
    - Same TXOP value granted to all STA, regardless of flow characteristics, number of flows at STA, or priority of flows
    - Each STA polled once per round
    - No real effort put into making an intelligent scheduler
- Results quite good
  - Could be better
    - Better scheduler could be used
    - Could employ MSDU aggregation

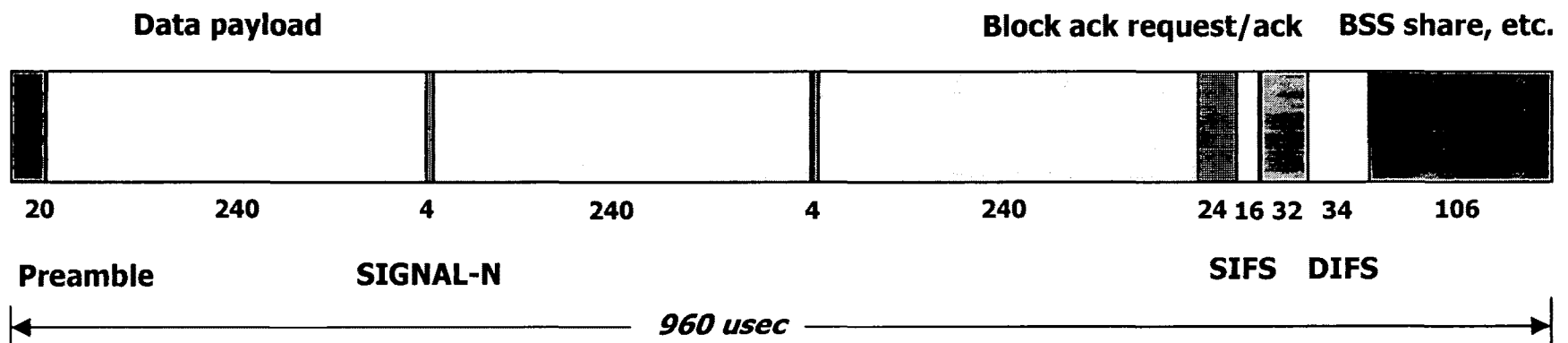
# Discussion

# 100 Mbps throughput

- See response to CC 27 in 11/04-0877-00-000n
- Efficiency upgrades in 802.11e and further enhancements in 11n mean that the 45-50% system efficiencies of old 802.11 systems have evolved to 75-85% in contemporary systems
  - Many such enhancements are commercially available in firmware upgrades from multiple vendors
- 100 Mbps throughput is achieved from 135 Mbps PHY rate in a variety of scenarios
- 100 Mbps throughput may even be achieved from 121.5 Mbps PHY rate

# 100 Mbps throughput, contd.

- Example scenario:
  - 4000 byte packets
  - HTP burst transmission, 3 packets
  - Block ack
  - 10%+ for assorted other users, beacons, etc.



# Modes and robustness

Ways of achieving 100 Mbps throughput robustly:

- *2x2, 20 MHz channel, 121.5 Mbps mode, BCC, MMSE detection.*
  - Requires high MAC efficiency; achievable with both HCCA and EDCA
- *2x2, 20 MHz channel, 135 Mbps mode, LDPC, MMSE detection*
- *2x3, 20 MHz channel, 135 Mbps mode, BCC, MMSE detection.*
  - Requires third radio receive chain; meets feasibility threshold easily
- *2x2, 20 MHz channel, 135 Mbps mode, near-ML detection*
  - Requires reduced-complexity algorithms for detection

# Optionality of 40 MHz

Reasons why 40 MHz channels are not proposed as mandatory:

- Limited worldwide applicability
  - Europe: clause 4.4.2.2 of ETSI EN 301 893 V1.2.3
  - Japan: ARIB STD-T71
- Not necessarily better in performance than two 20 MHz channels
  - Repackaging; System and contention overhead; Dense deployments
- However there are cases where 40 MHz channels make sense
  - We offer full range of 40 MHz modes – all as optional

# Summary

- One unified format for modes

| Code rate | Cyclic prefix, ns | Code      | Constellation |
|-----------|-------------------|-----------|---------------|
| 1/2       | 800               | BCC, LDPC | 16-QAM        |
| 3/4       | 800               | BCC, LDPC | 16-QAM        |
| 2/3       | 800               | BCC, LDPC | 64-QAM        |
| 3/4       | 800               | BCC, LDPC | 64-QAM        |
| 5/6       | 800               | BCC, LDPC | 64-QAM        |

- Used for 2, 3, 4, transmit antennas
- 20 MHz and 40 MHz channels
- Used with open-loop space-time block codes



# WWiSE patent position

# WWiSE Patent Position

- Essential patent claims owned or controlled by WWiSE companies will be available on zero royalty basis
  - Important information on terms & conditions available at
    - <http://www.wwise.org/IPinformation.htm>
    - <http://www.wwise.org/IPstatement.htm>
- IEEE strictly limits discussion of licensing terms & conditions at IEEE meetings
  - WWiSE representatives can answer any questions outside of IEEE meetings
  - Please feel free to contact any of the WWiSE representatives shown on next slide...

# For More Information...

- Visit WWiSE website:
  - [www.wwise.org](http://www.wwise.org)
  
- Or contact:
  - **Rolf DeVegt**                    [rolfdevegt@airgonetworks.com](mailto:rolfdevegt@airgonetworks.com)
  - **Neil Hamady**                [nhamady@bermai.com](mailto:nhamady@bermai.com)
  - **Chris Hansen**              [chansen@broadcom.com](mailto:chansen@broadcom.com)
  - **Jim Zyren**                    [jim.zyren@conexant.com](mailto:jim.zyren@conexant.com)
  - **Thomas Chou**                [thomasc@realtek.com](mailto:thomasc@realtek.com)
  - **George Vlantis**            [george.vlantis@st.com](mailto:george.vlantis@st.com)
  - **Bill Carney**                 [bill.carney@ti.com](mailto:bill.carney@ti.com)

# References and further information

- IEEE 802.11/04-0886-03-000n, "WWiSE group PHY and MAC specification."
- IEEE 802.11/04-0877-04-000n, "WWiSE proposal response to functional requirements and comparison criteria."

See also [www.wwise.org](http://www.wwise.org)

Or send email to [info@wwise.org](mailto:info@wwise.org)

# TGn Sync Proposal

**Date: Aug 13, 2004**

Aon Mujtaba, Agere Systems Inc., ([mujtaba@agere.com](mailto:mujtaba@agere.com))  
Adrian P Stephens, Intel Corporation, ([adrian.p.stephens@intel.com](mailto:adrian.p.stephens@intel.com))  
Alek Purkovic, Nortel Networks ([apurkovi@nortelnetworks.com](mailto:apurkovi@nortelnetworks.com))  
Andrew Myles, Cisco Systems ([amyles@cisco.com](mailto:amyles@cisco.com))  
Brian Johnson, Nortel Networks Corporation, ([brjohnso@nortelnetworks.com](mailto:brjohnso@nortelnetworks.com))  
Daisuke Takeda, Toshiba Corporation, ([daisuke.takeda@toshiba.co.jp](mailto:daisuke.takeda@toshiba.co.jp))  
Darren McNamara, Toshiba Corporation, ([Darren.McNamara@toshiba-trel.com](mailto:Darren.McNamara@toshiba-trel.com))  
Dongjun (DJ) Lee, Samsung Electronics Co. Ltd., ([djthekid.lee@samsung.com](mailto:djthekid.lee@samsung.com))  
David Bagby, Calypso Consulting, ([david.bagby@ieee.org](mailto:david.bagby@ieee.org))  
Eldad Perahia, Cisco Systems, ([eperahia@cisco.com](mailto:eperahia@cisco.com))  
Huanchun Ye, Atheros Communications Inc., ([hcy@atheros.com](mailto:hcy@atheros.com))  
Hui-Ling Lou, Marvell Semiconductor Inc., ([hlou@marvell.com](mailto:hlou@marvell.com))  
James Chen, Marvell Semiconductor Inc., ([jamesc@marvell.com](mailto:jamesc@marvell.com))  
James Mike Wilson, Intel Corporation, ([james.mike.wilson@intel.com](mailto:james.mike.wilson@intel.com))  
Jan Boer, Agere Systems Inc., ([janboer@agere.com](mailto:janboer@agere.com))  
Jari Jokela, Nokia, ([jari.jokela@nokia.com](mailto:jari.jokela@nokia.com))  
Jeff Gilbert, Atheros Communications Inc., ([gilbertj@atheros.com](mailto:gilbertj@atheros.com))  
Joe Pitarresi, Intel Corporation, ([joe.pitarresi@intel.com](mailto:joe.pitarresi@intel.com))  
Jörg Habetha, Royal Philips Electronics, ([joerg.habetha@philips.com](mailto:joerg.habetha@philips.com))  
John Sadowsky, Intel Corporation, ([john.sadowsky@intel.com](mailto:john.sadowsky@intel.com))  
Jon Rosdahl, Samsung Electronics Co. Ltd., ([jon.rosdahl@partner.samsung.com](mailto:jon.rosdahl@partner.samsung.com))  
Luke Qian, Cisco Systems, ([lchia@cisco.com](mailto:lchia@cisco.com))  
Mary Cramer, Agere Systems ([mecramer@agere.com](mailto:mecramer@agere.com))

## Authors (continued)

Masahiro Takagi, Toshiba Corporation, ([masahiro3.takagi@toshiba.co.jp](mailto:masahiro3.takagi@toshiba.co.jp))

Monisha Ghosh, Royal Philips Electronics, ([monisha.ghosh@philips.com](mailto:monisha.ghosh@philips.com))

Nico van Waes, Nokia, ([nico.vanwaes@nokia.com](mailto:nico.vanwaes@nokia.com))

Osama Aboul-Magd, Nortel Networks Corporation, ([osama@nortelnetworks.com](mailto:osama@nortelnetworks.com))

Paul Feinberg, Sony Electronics Inc., ([paul.feinberg@am.sony.com](mailto:paul.feinberg@am.sony.com))

Pen Li, Royal Philips Electronics ([pen.li@philips.com](mailto:pen.li@philips.com))

Peter Loc, Marvell Semiconductor Inc., ([ploc@marvell.com](mailto:ploc@marvell.com))

Pieter-Paul Giesberts, Agere Systems Inc., ([pgiesberts@agere.com](mailto:pgiesberts@agere.com))

Richard van Leeuwen, Agere Systems Inc., ([rleeuwen@agere.com](mailto:rleeuwen@agere.com))

Ronald Rietman, Royal Philips Electronics, ([ronald.rietman@philips.com](mailto:ronald.rietman@philips.com))

Seigo Nakao, SANYO Electric Co. Ltd., ([snakao@gf.hm.rd.sanyo.co.jp](mailto:snakao@gf.hm.rd.sanyo.co.jp))

Sheung Li, Atheros Communications Inc., ([sheung@atheros.com](mailto:sheung@atheros.com))

Stephen Shellhammer, Intel, ([stephen.j.shellhammer@intel.com](mailto:stephen.j.shellhammer@intel.com))

Takushi Kunihiro, Sony Corporation, ([kuni@wcs.sony.co.jp](mailto:kuni@wcs.sony.co.jp))

Teik-Kheong (TK) Tan, Royal Philips Electronics, ([tktan@philips.com](mailto:tktan@philips.com))

Tomoko Adachi, Toshiba Corporation, ([tomo.adachi@toshiba.co.jp](mailto:tomo.adachi@toshiba.co.jp))

Tomoya Yamaura, Sony Corporation, ([yamaura@wcs.sony.co.jp](mailto:yamaura@wcs.sony.co.jp))

Tsuguhide Aoki, Toshiba Corporation, ([tsuguhide.aoki@toshiba.co.jp](mailto:tsuguhide.aoki@toshiba.co.jp))

Won-Joon Choi, Atheros Communications Inc., ([wjchoi@atheros.com](mailto:wjchoi@atheros.com))

Xiaowen Wang, Agere Systems Inc., ([xiaowenw@agere.com](mailto:xiaowenw@agere.com))

Yasuhiko Tanabe, Toshiba Corporation, ([yasuhiko.tanabe@toshiba.co.jp](mailto:yasuhiko.tanabe@toshiba.co.jp))

Yasuhiro Tanaka, SANYO Electric Co. Ltd., ([y\\_tanaka@gf.hm.rd.sanyo.co.jp](mailto:y_tanaka@gf.hm.rd.sanyo.co.jp))

Yoshiharu Doi, SANYO Electric Co. Ltd., ([doi@gf.hm.rd.sanyo.co.jp](mailto:doi@gf.hm.rd.sanyo.co.jp))

Yuichi Morioka, Sony Corporation, ([morioka@wcs.sony.co.jp](mailto:morioka@wcs.sony.co.jp))

Youngsoo Kim, Samsung Electronics Co. Ltd., ([KimYoungsoo@samsung.com](mailto:KimYoungsoo@samsung.com))

# TGn Sync Proposal Team - Background

- Team operated as a technical group to help motivate a *rapid introduction* of the 802.11n standard
- Participating companies from a *broad range of markets*
  - PC
  - Enterprise
  - Consumer Electronics
  - Semiconductor
  - Handset
  - Public Access
- Solution incorporates a *worldwide perspective* of perceived market demand and regulatory concerns
  - Team has representation from the US, Europe and the Pacific Rim

# Proposal Overview

- High throughput and minimal design complexity
  - Superior robustness for a broad range of applications
  - Low cost, low power consumption
- Scalable architecture
- Seamless interoperability with 802.11 legacy devices
- Flexible architecture offering regulatory compliance in all major regulatory domains while preserving interoperability



# PHY Summary of TGn Sync Proposal

- Basic configuration delivers 243 Mbps using only two antennas
  - Follows historical trend of 5x for 802.11 (.11 → .11b → .11a/g)
- Higher optional PHY data rate rates (>600 Mbps) for future generation devices
- MIMO evolution of 802.11 OFDM PHY with spatial division multiplexing of spatial streams
- Multiple antennas (2 mandatory, greater than 2 optional)
- Preamble designed for seamless interoperability with legacy 802.11a/g
- Wider bandwidth options with fully interoperable 20 MHz and 40 MHz\* channel capability
- Support for licensed 10 MHz modes
- Optional enhancements
  - Advanced FEC coding techniques (RS, LDPC)
  - Transmit beamforming with negligible additional cost in receiving client device
  - 1/2 guard interval
  - Rate 7/8 coding

\*Not required in regulatory domains where prohibited.

# MAC Summary of TGn Sync Proposal

- Supports .11e
- Frame aggregation, single and multiple\* destinations
- Bi-directional data flow
- Feedback mechanisms that enhance rate adaptation
- Protection mechanisms for seamless interoperability and coexistence with legacy devices
- Channel management (including receiver assisted channel training protocol)
- Power management

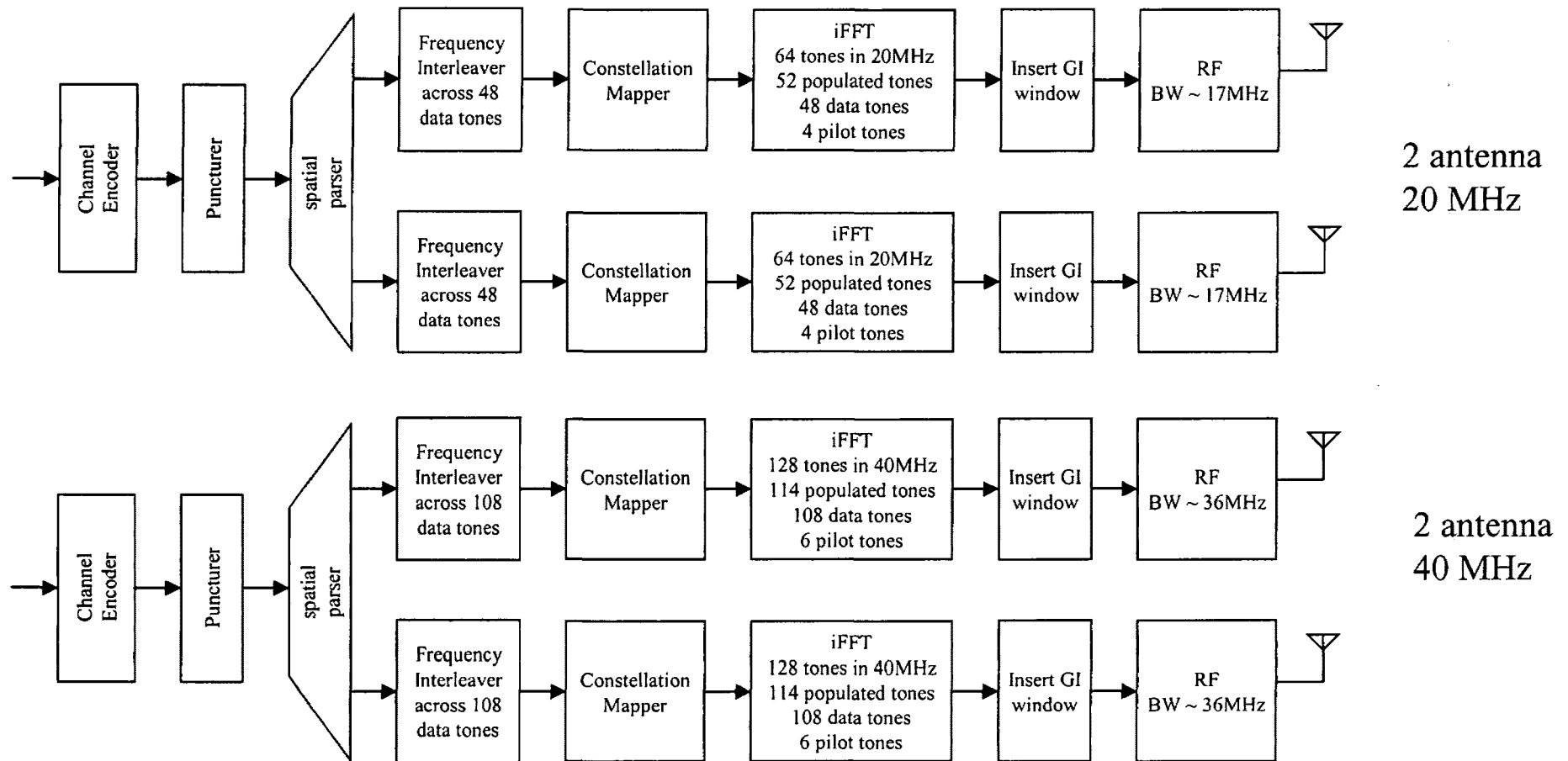
\* Optional

PHY

# Basic Tx Data Path

- FEC coding
  - Conventional  $K = 7$  convolutional code
    - Rates:  $1/2$ ,  $2/3$  and  $3/4$
    - Supports legacy operation
  - Optional LDPC/RS
  - Optional rate  $7/8$  code
- Spatial stream parsing
- Frequency interleaving
  - Block interleaver w/ QAM bit rotation (like 11a)
  - 20 MHz  $\Rightarrow$  16 columns  $\Rightarrow$  freq. sep. = 3 subcarriers
  - 40 MHz  $\Rightarrow$  18 columns  $\Rightarrow$  freq. sep. = 6 subcarriers
- QAM modulation
  - BPSK, QPSK, 16 QAM and 64 QAM
- Optional  $1/2$  guard interval

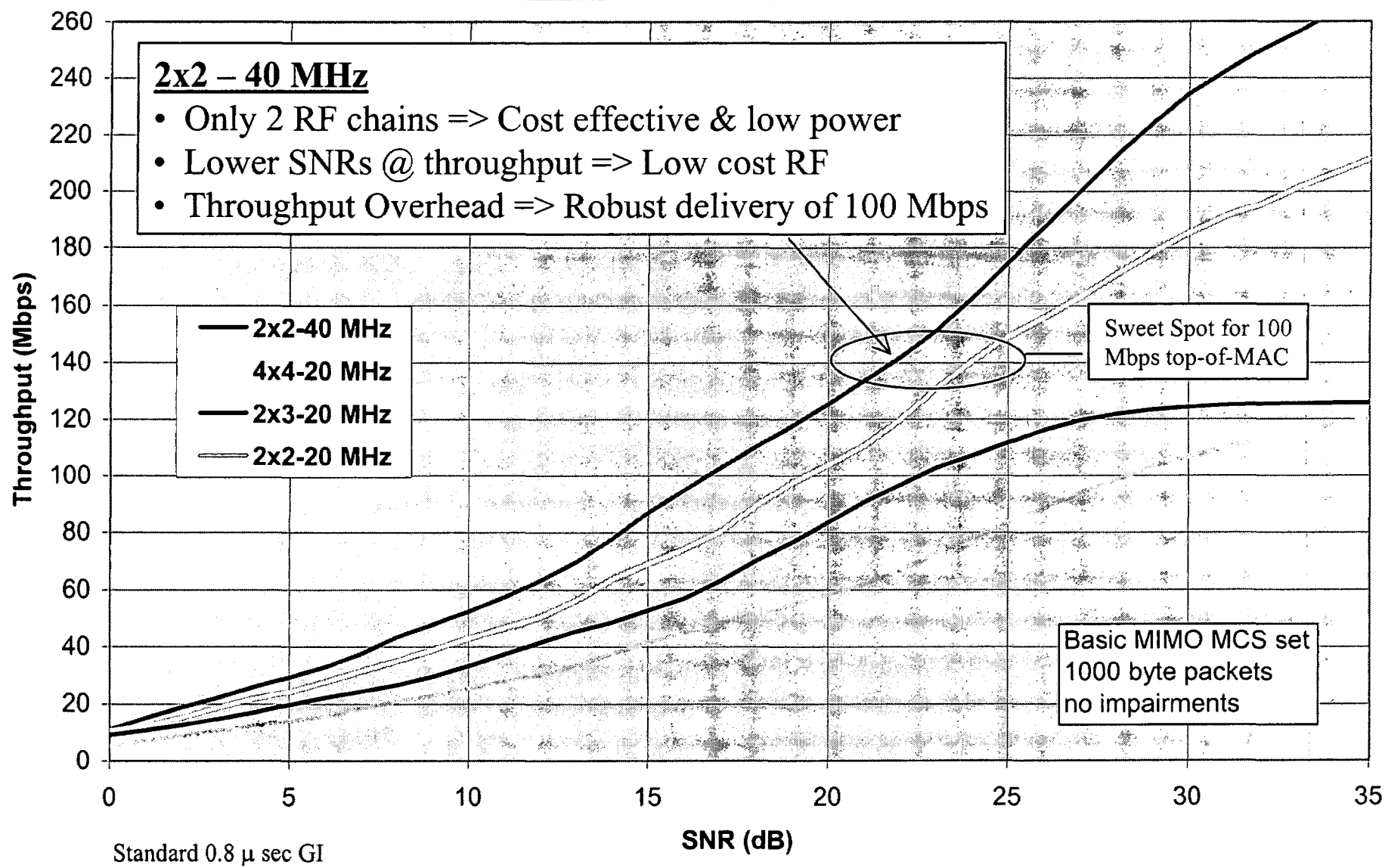
# Basic Tx Data Path



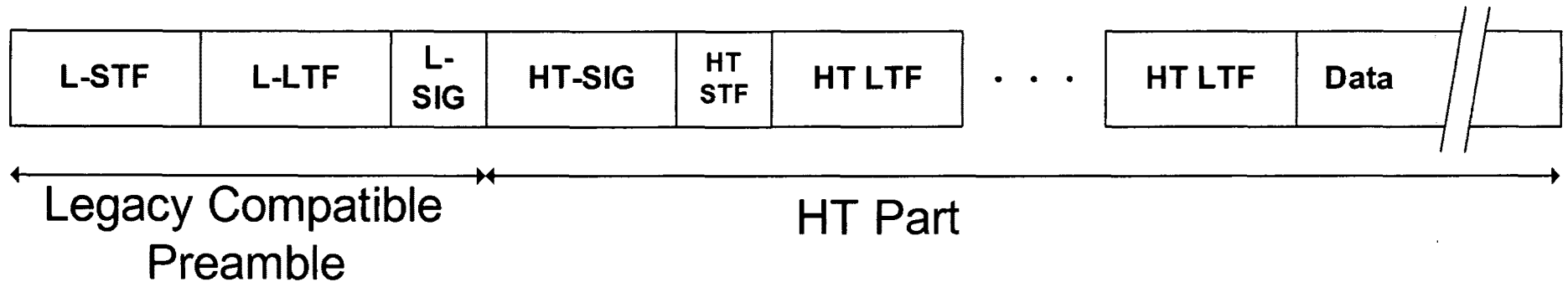
# Basic MCS Set

| Modulation                                                                                       | Code Rate | Data Rates*<br>20 MHz (Mbps)<br>(1,2,3,4 spatial streams) | Data Rates*<br>40 MHz (Mbps)<br>(1,2,3,4 spatial streams) |
|--------------------------------------------------------------------------------------------------|-----------|-----------------------------------------------------------|-----------------------------------------------------------|
| BPSK                                                                                             | 1/2       | 6, 12, 18, 24                                             | 13.5, 27, 45.5, 54                                        |
| QPSK                                                                                             | 1/2       | 12, 24, 36, 48                                            | 27, 54, 81, 108                                           |
| QPSK                                                                                             | 3/4       | 18, 35, 54, 72                                            | 40.5, 81, 121.5, 162                                      |
| 16 QAM                                                                                           | 1/2       | 24, 48, 72, 96                                            | 54, 108, 162, 216                                         |
| 16 QAM                                                                                           | 3/4       | 36, 72, 108, 144                                          | 81, 162, 243, 324                                         |
| 64 QAM                                                                                           | 2/3       | 48, 96, 144, 192                                          | 108, 216, 324, 432                                        |
| 64 QAM                                                                                           | 3/4       | 54, 108, 162, 216                                         | 121.5, 243, 364.5, 486                                    |
| 64 QAM                                                                                           | 7/8       | 63, 126, 189, 252                                         | 141.75, 283.5, 425.25, 567                                |
| <b>+ Duplicate Format, BPSK <math>R = \frac{1}{2}</math> provides 6 Mbps for 40 MHz channels</b> |           |                                                           |                                                           |

**\* Optional short GI (0.4  $\mu$ sec) increases rates by 11.1% for maximum data rate of 640 Mbps**



# PPDU Format



## Legend

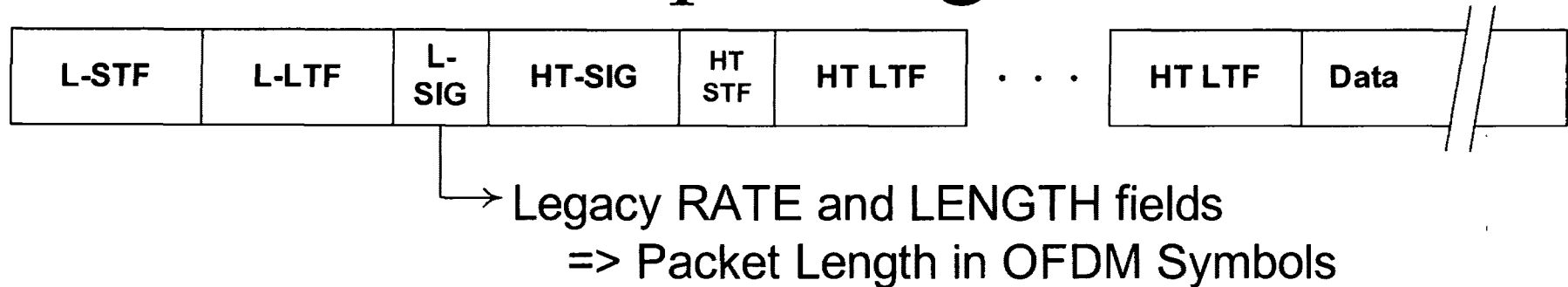
L- Legacy, HT- High Throughput  
STF = Short Training Field  
LTF = Long Training Field  
SIG = Signal Field

## Legacy Compatible

Can be decoded by *any* legacy 802.11a or g compliant device for interoperability



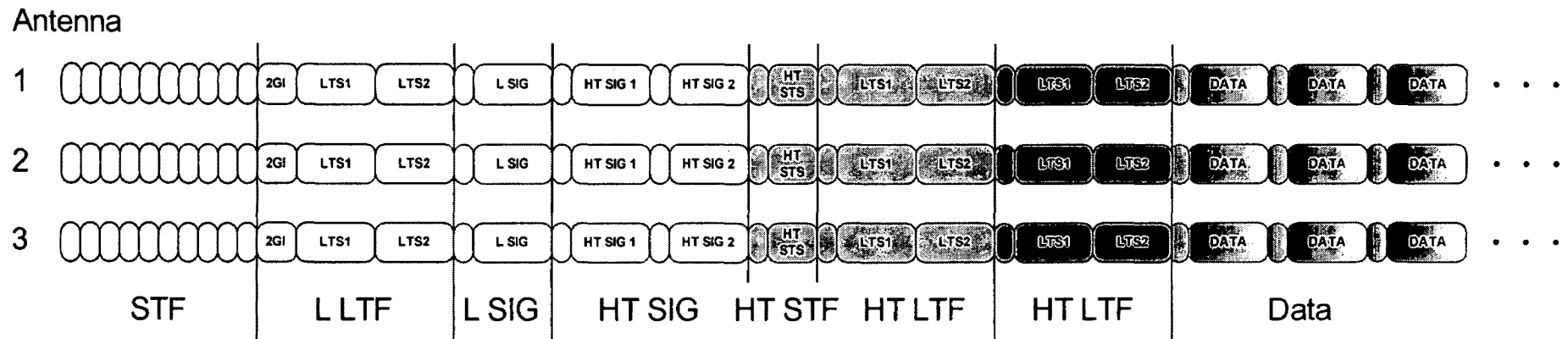
# Spoofing



- RATE and LENGTH  
⇒ PPDU length in OFDM symbols
- Spoofing
  - Spoofing means that the legacy RATE and LENGTH fields are falsely encoded in order to determine a specified length
  - L-SIG RATE = 6 Mbps ⇒ spoofing duration up to ~3 msec

# Training Fields

- Design priorities
  - Backward compatibility with 802.11a/g
  - Robust performance
  - Cost effective implementation
  - Low overhead

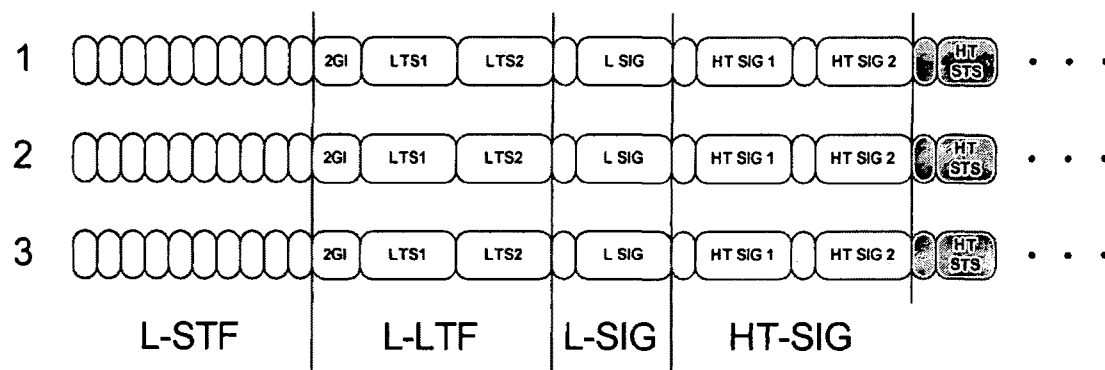


These space-time diagrams apply to both 20 and 40 MHz channels

# Legacy Compatible Preamble

## CDD

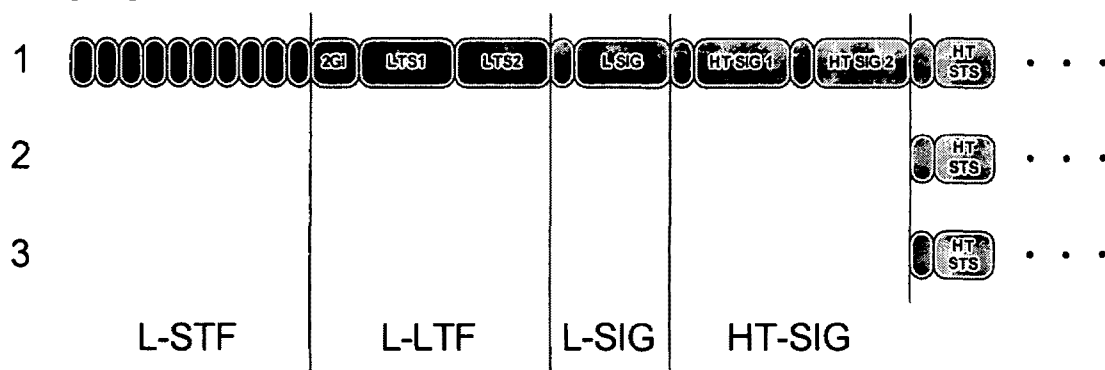
Antenna



The L-STF, L-LTF, L-SIG and HT-SIG are transmitted as a single spatial stream. This may be either transmitted on all Tx antennas via a method such as Cyclic Delay Diversity (CDD), or on a single antenna. These are implementation options.

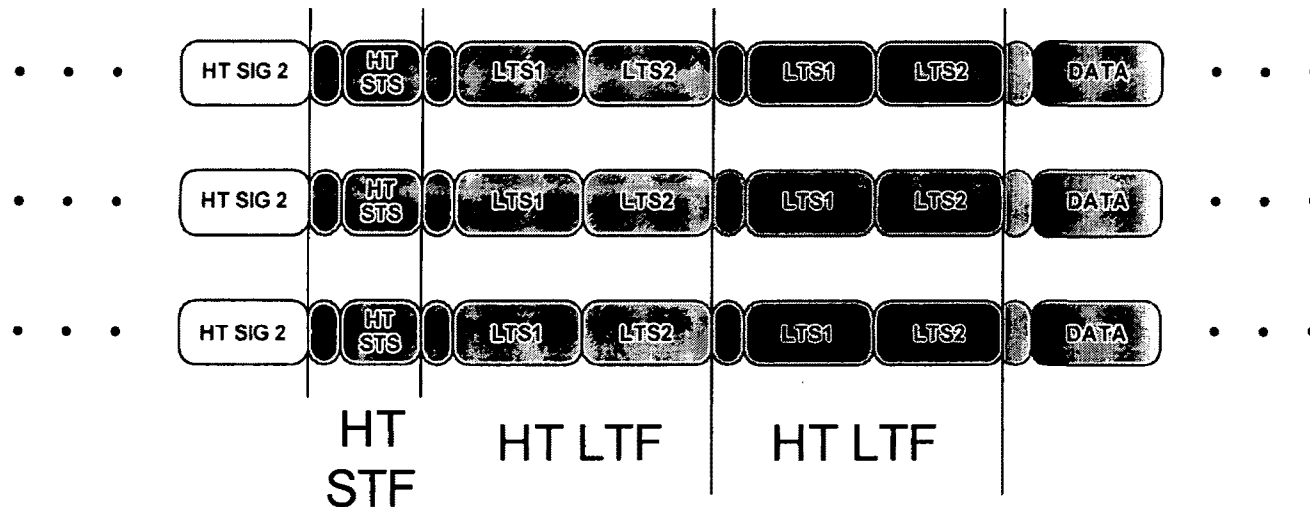
## or single antenna

Antenna



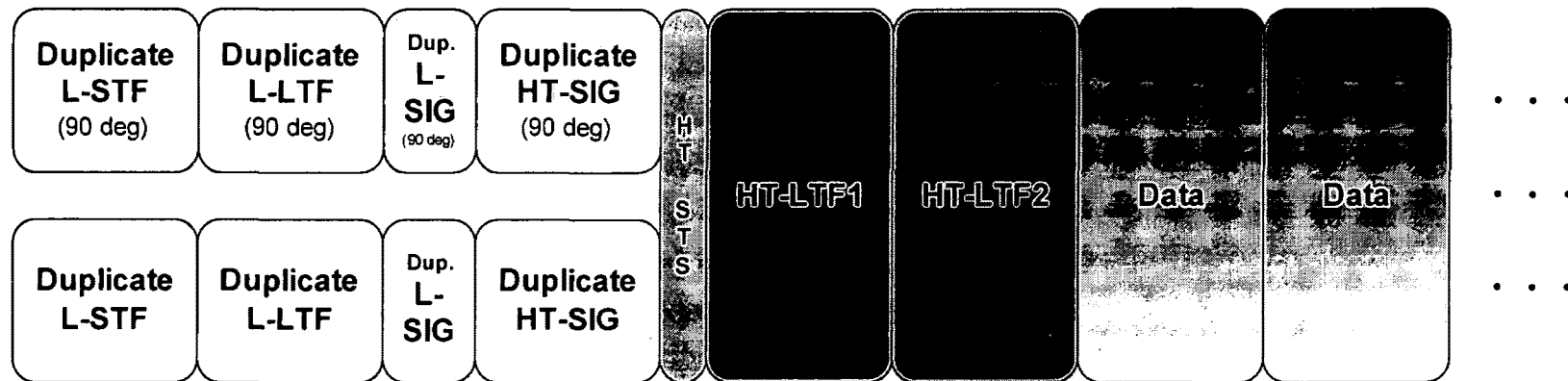
**Requirement:** These fields must be transmitted in an omnidirectional mode that can be demodulated by legacy receivers.

# HT Training Fields



- HT-STF
  - Used for 2<sup>nd</sup> AGC
- HT-LTF
  - Used for MIMO channel estimation
  - Additional frequency or time alignment
- Tone interleaving of spatial streams

# 40 MHz PPDU Format



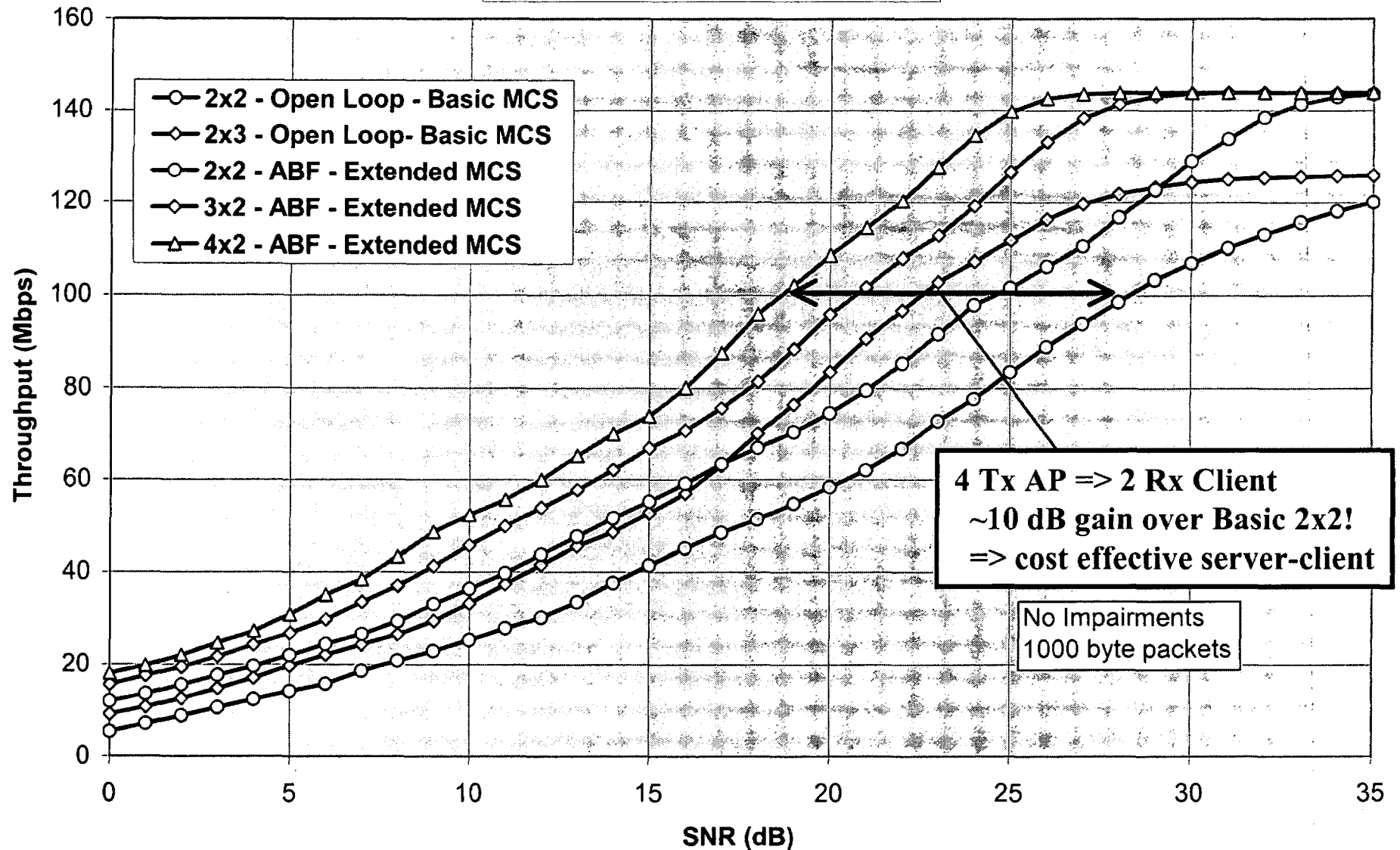
- Duplicate format preamble
  - Provides interoperability with 20 MHz legacy STAs
  - Data, pilot and training tones in each 20 MHz subchannel are identical to corresponding 20 MHz format
  - 90 deg phase shift on upper sub-channel controls PAPR
- HT part
  - 108 data tones + 6 pilots
  - 3 center nulls (not shown)

# 40/20 MHz Interoperability

- **20 MHz PPDU  $\Rightarrow$  40 MHz receiver**
  - Combine modulation symbols from upper & lower sub-channels
  - 20 MHz PPDU in lower sub-channel
    - Zero combining weights in upper subchannel
    - No loss in performance relative to a 20 MHz receiver
  - Use differential sub-channel energy to detect 20 vs. 40 MHz signals
- **40 MHz PPDU  $\Rightarrow$  20 MHz receiver**
  - One sub-channel is sufficient to decode the L-SIG
  - Detects only half of the 40 MHz signal
    - $\Rightarrow$  3 dB performance penalty for 20 MHz clients
- See MAC slides for additional information on 40/20 inter-op

# Transmit Beamforming

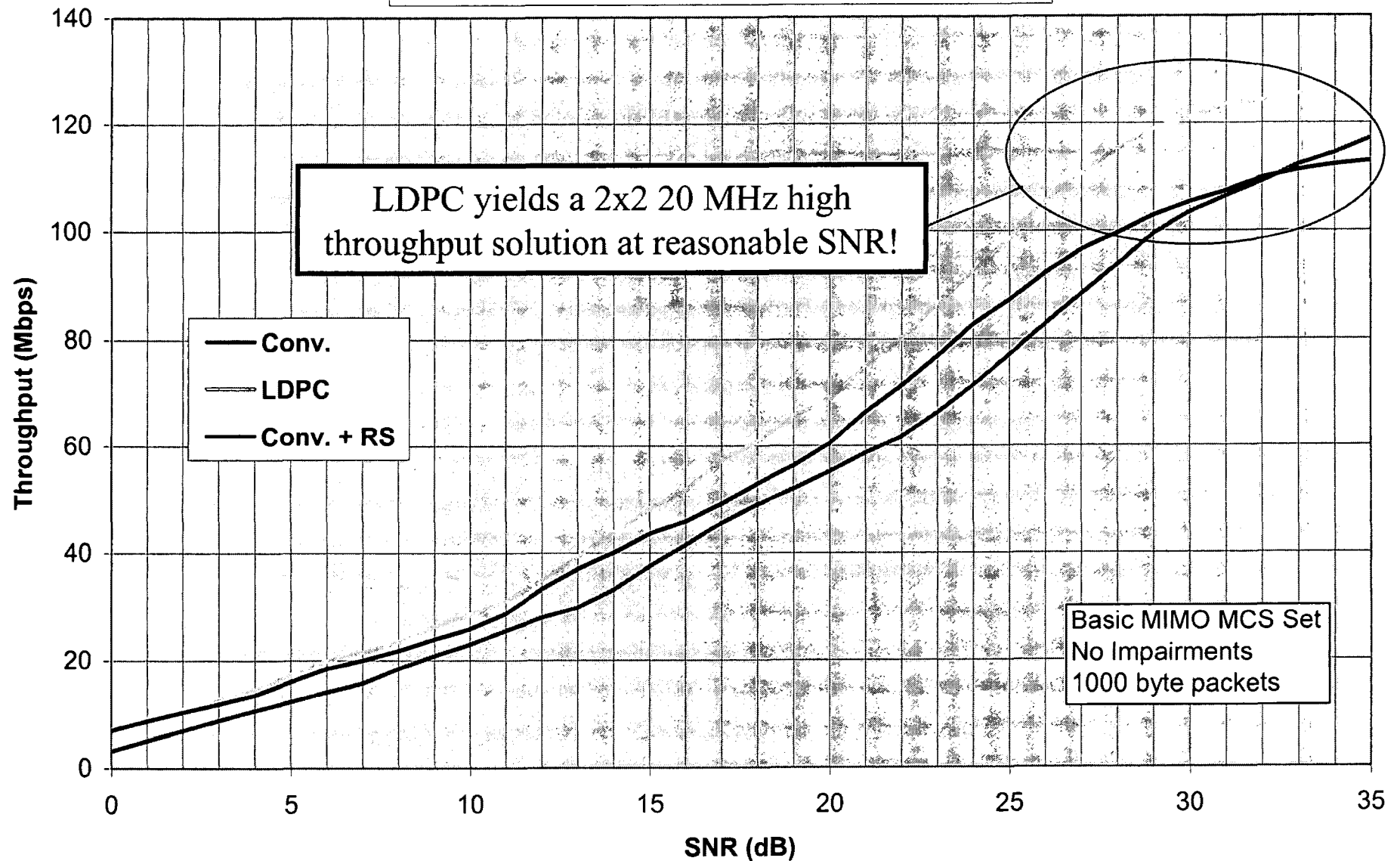
- Basic Beamforming
  - Cost, complexity, and power consumption contained in the AP
    - Enterprise AP, media server AP, set-top box, or desktop PC
  - Very low overhead for BF receive only client
    - Low client cost, essentially zero overhead
    - Low power consumption – battery operated
  - Basic MCS set
  - Channel sounding PPDU provides capability to estimate the channel from all Tx antennas
  - Receiver does not need to know the beamforming specifics at the transmitter
  - Simple packet exchange for calibration
- Optional Advanced Beamforming (ABF)
  - Extended MCS Set
    - Provides independent modulation/coding across spatial streams
  - Support for unequal spatial stream power loading
  - Support for bi-directional beamforming





# Optional Advanced Coding Modes

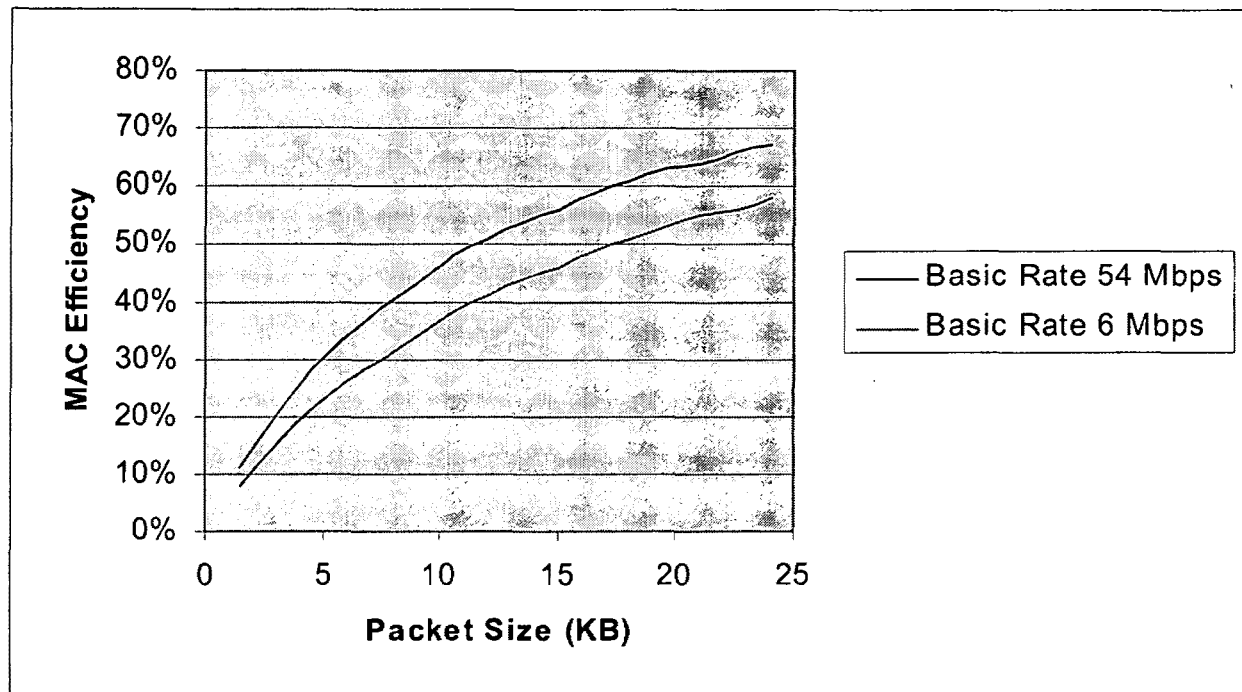
- Low Density Parity Check (LDPC)
  - Superior performance at high code rates (7/8)
- Reed-Solomon (RS)
  - Outer code concatenated with inner convolutional code
  - Very low cost, mature technology



# MAC

# MAC Challenges in HT Environment

- HT requires an improvement in MAC Efficiency
- HT requires effective Rate Adaptation
- HT requires Legacy Protection

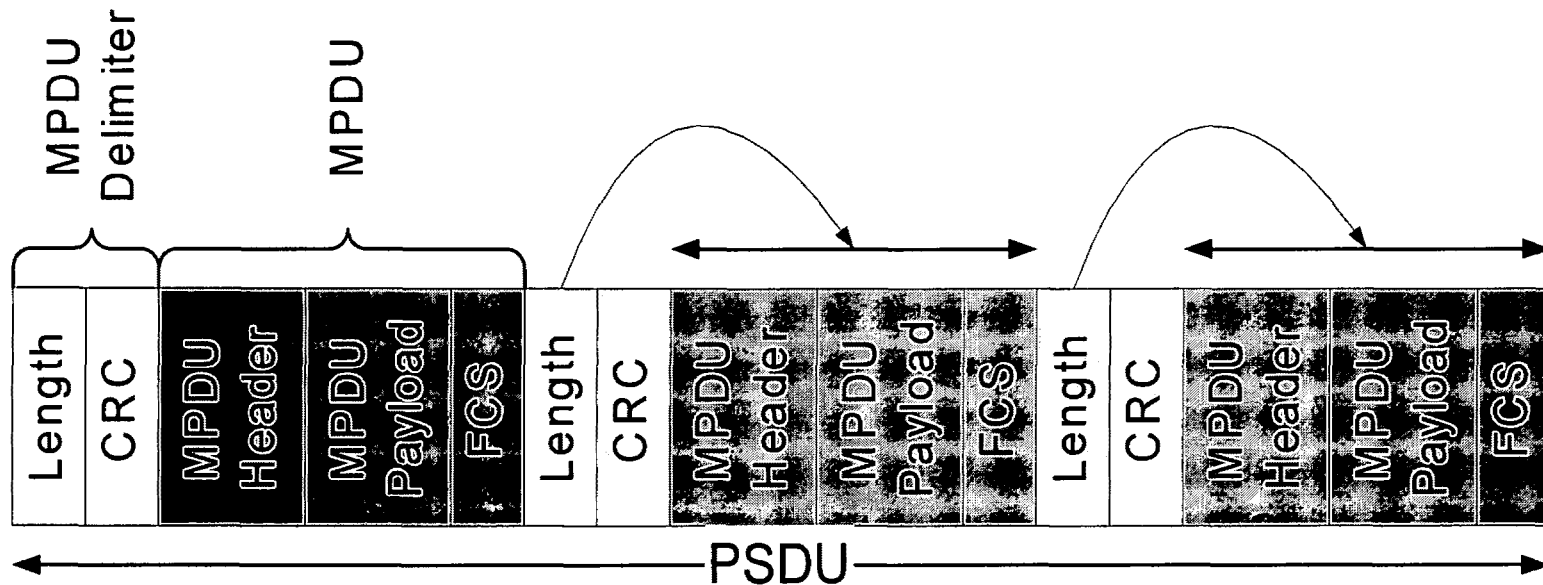


# New MAC Features

- Aggregation Format
- Aggregation Exchanges
  - Protocol for training
  - Protocol for reverse direction data
  - Single and multiple responder
- Header Compression
- Protection Mechanisms
- Coexistence & Channel Management
- MIMO Power Management

# Aggregation Framing

- Robust Structure
- Aggregation Framing is a purely-MAC function (PHY has no knowledge of MPDU boundaries)

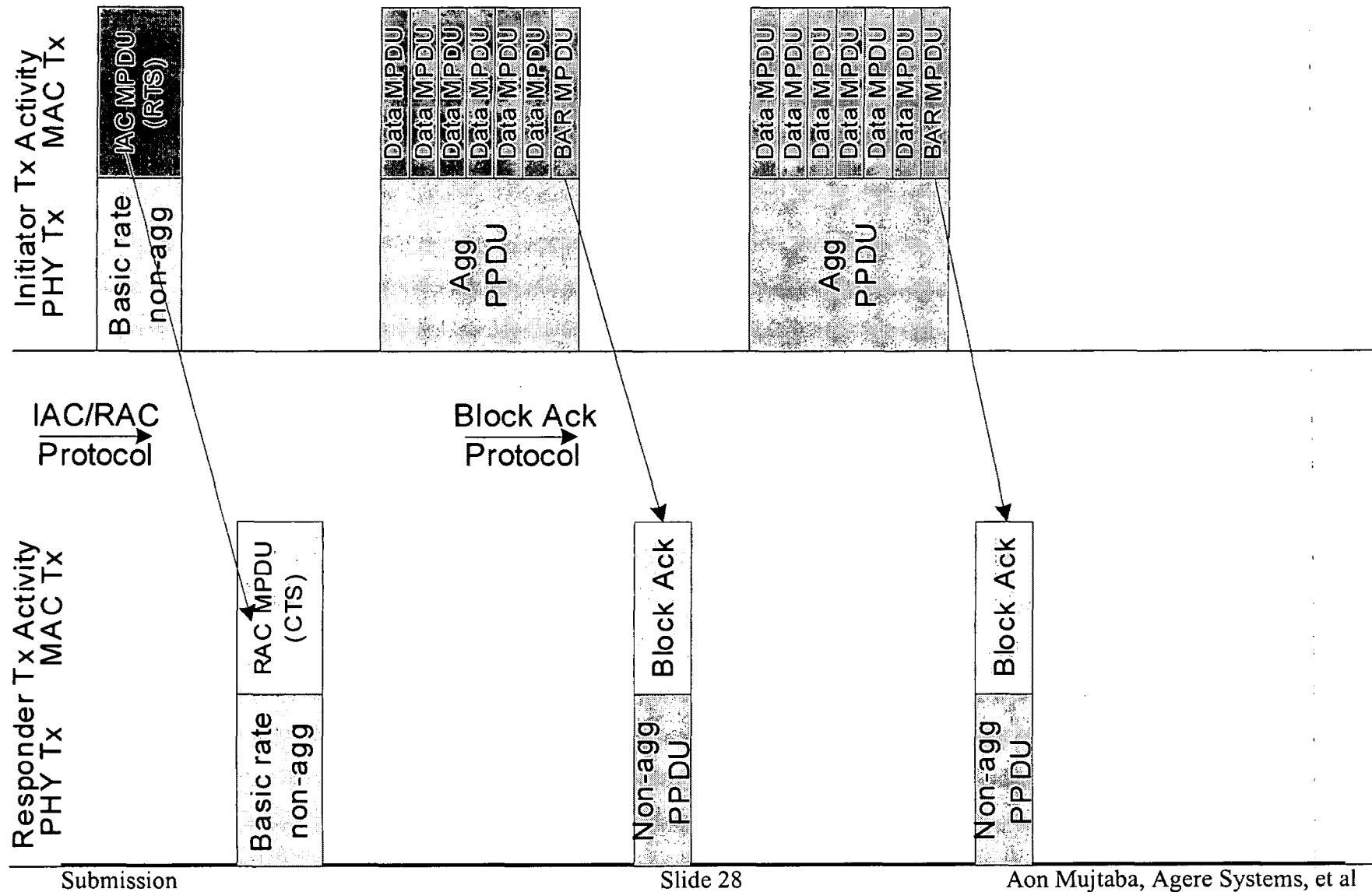


# Aggregate Exchange Sequences

- MPDU or frame exchange sequences now extended to aggregate exchange sequences in which groups of frames are exchanged “at a time”
  - Allows effective use of Aggregate Feature
  - Allows control, data and acknowledgement to be sent in the same PPDU
- An initiator sends a PPDU and a responder may transmit a response PPDU
  - Either PPDU can be an aggregate

(“Initiator” / “responder” are new terms relating to roles in aggregate exchange protocol)

# Basic Aggregate Exchange



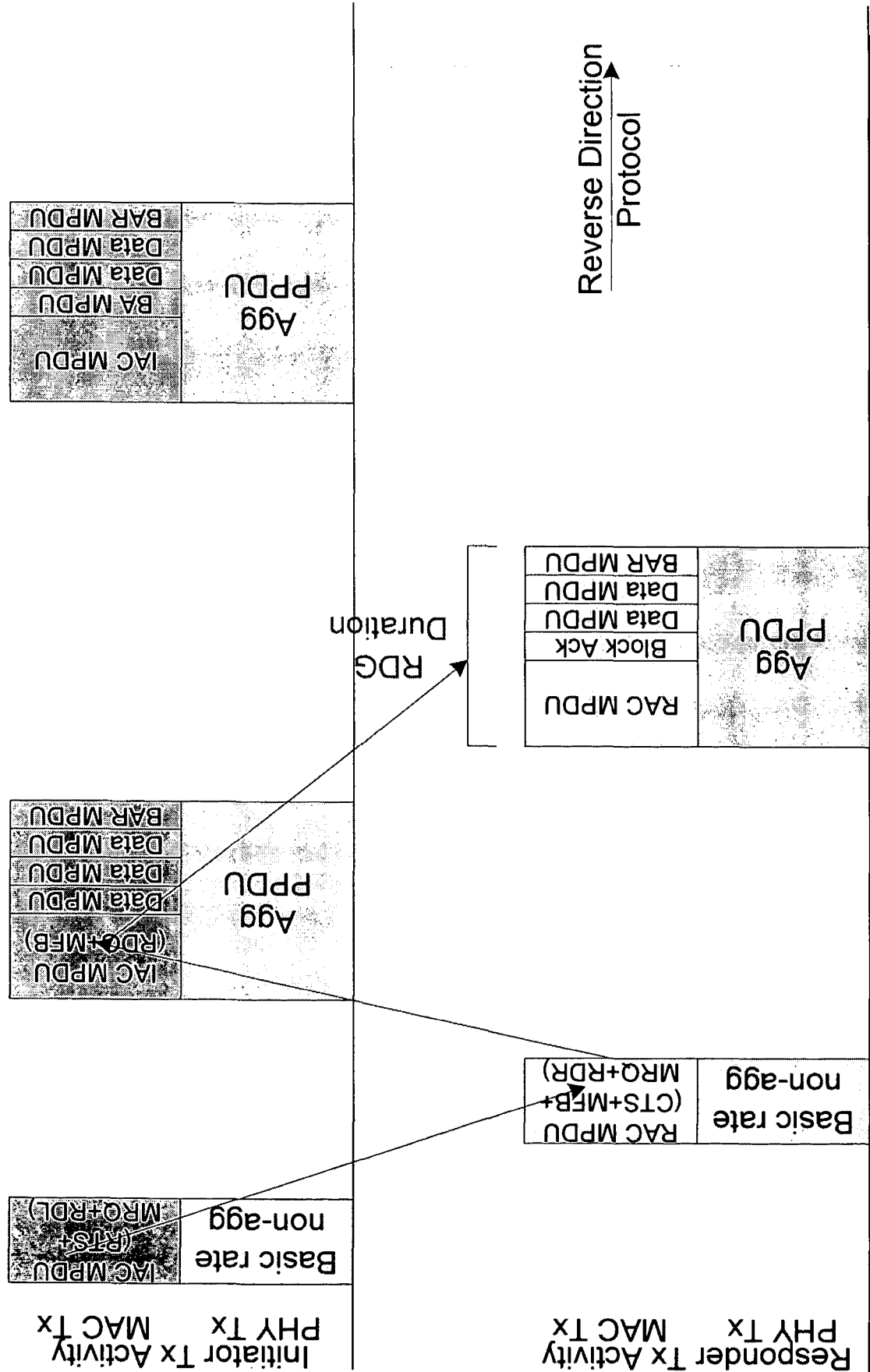
Submission

Slide 28

Aon Mujtaba, Agere Systems, et al



# Reverse Direction Protocol

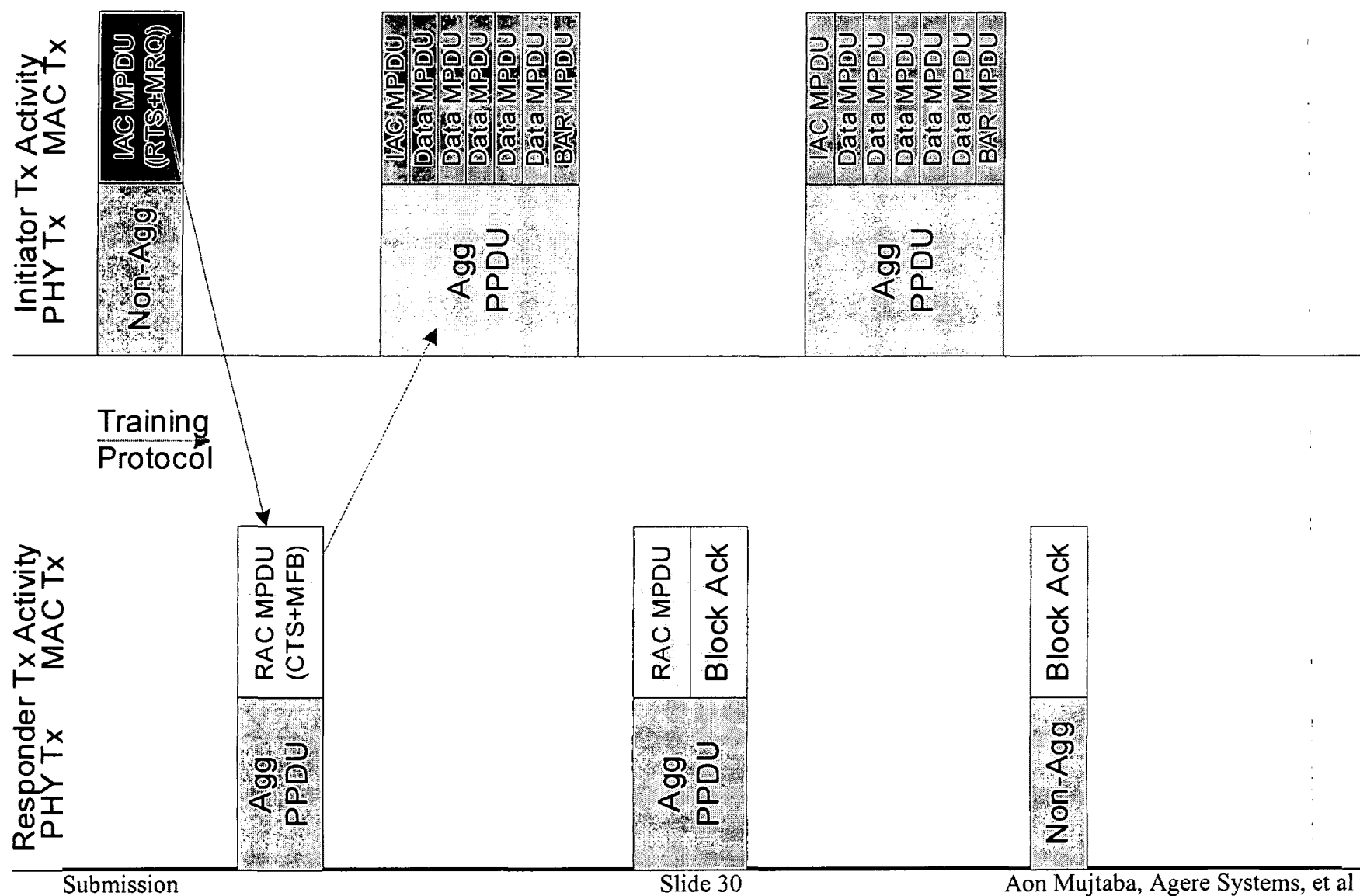


Submission

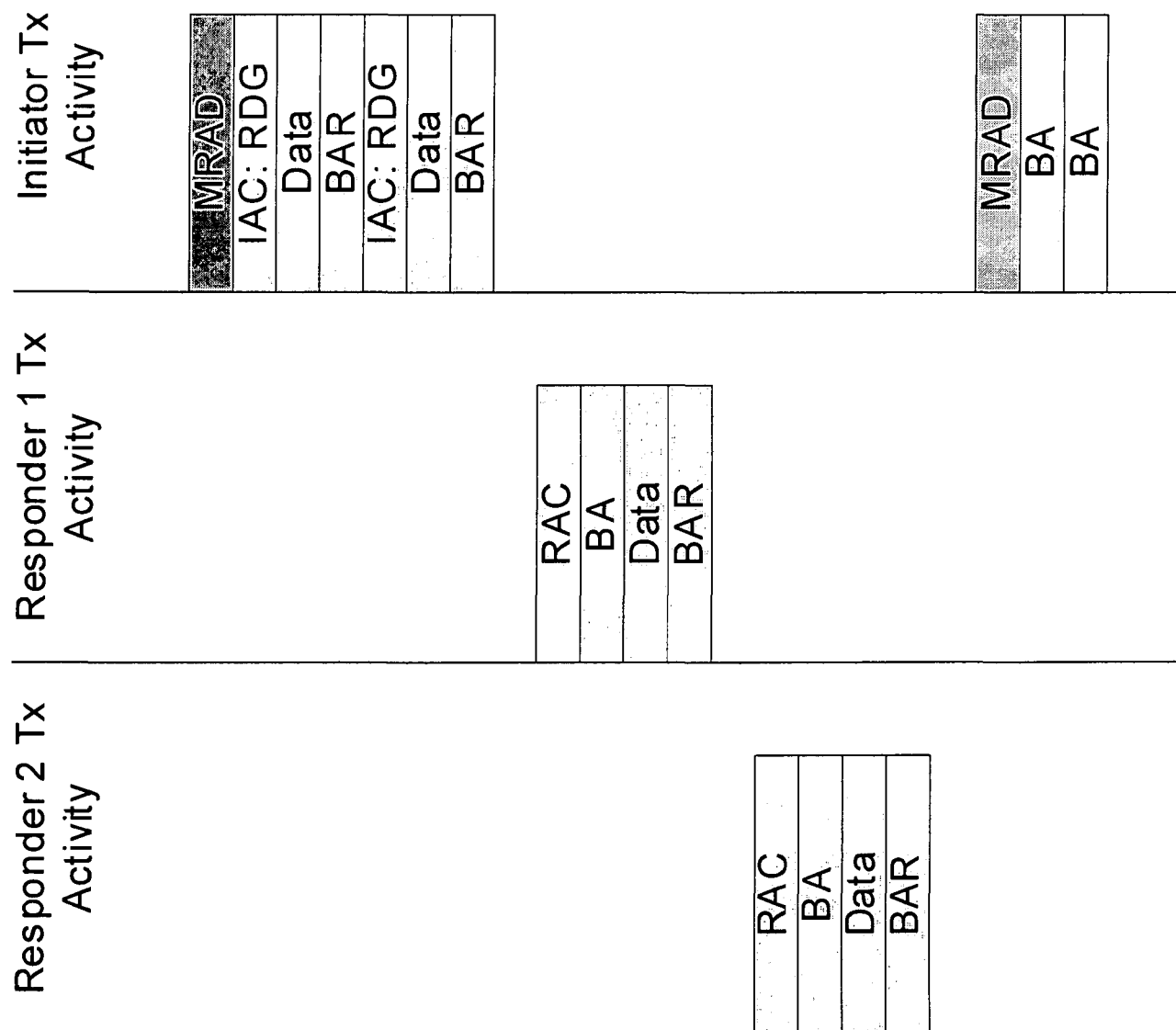
Slide 29

Aon Mujtaba, Agere Systems, et al

# Training Protocol

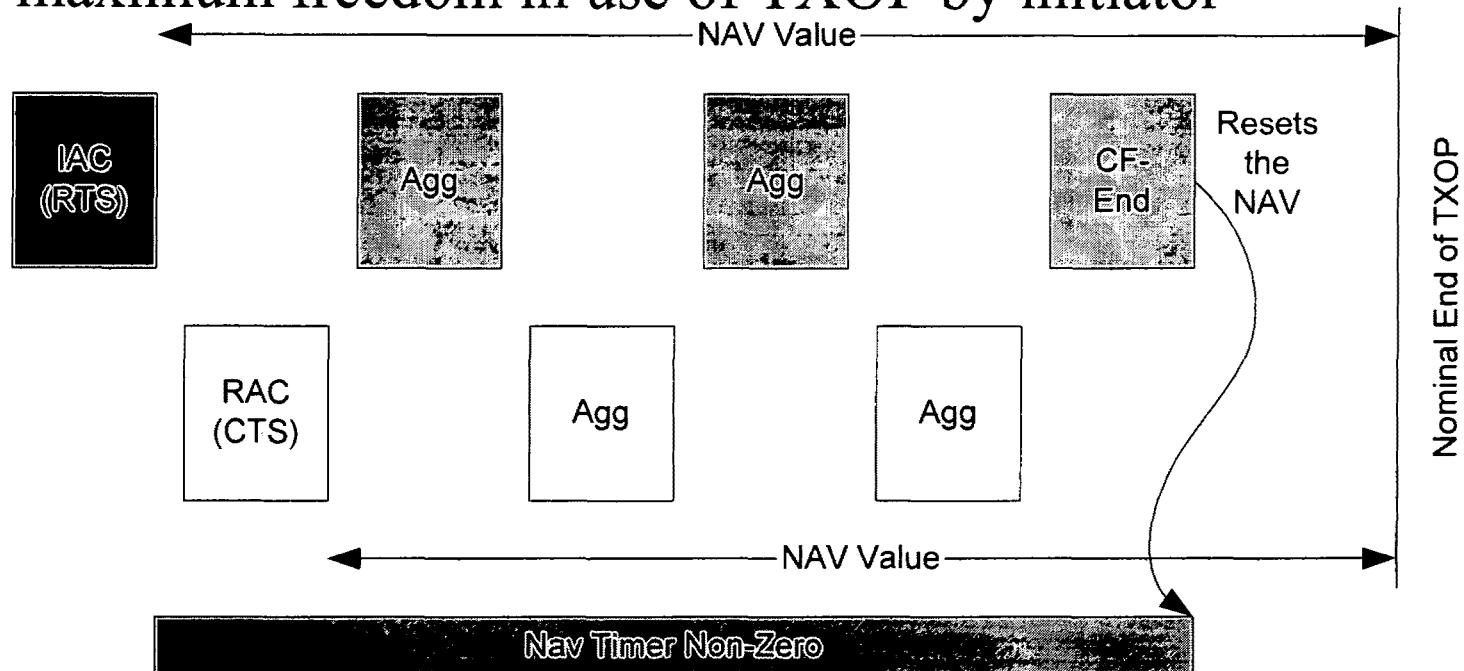


# Periodic Multi-Receiver Aggregation



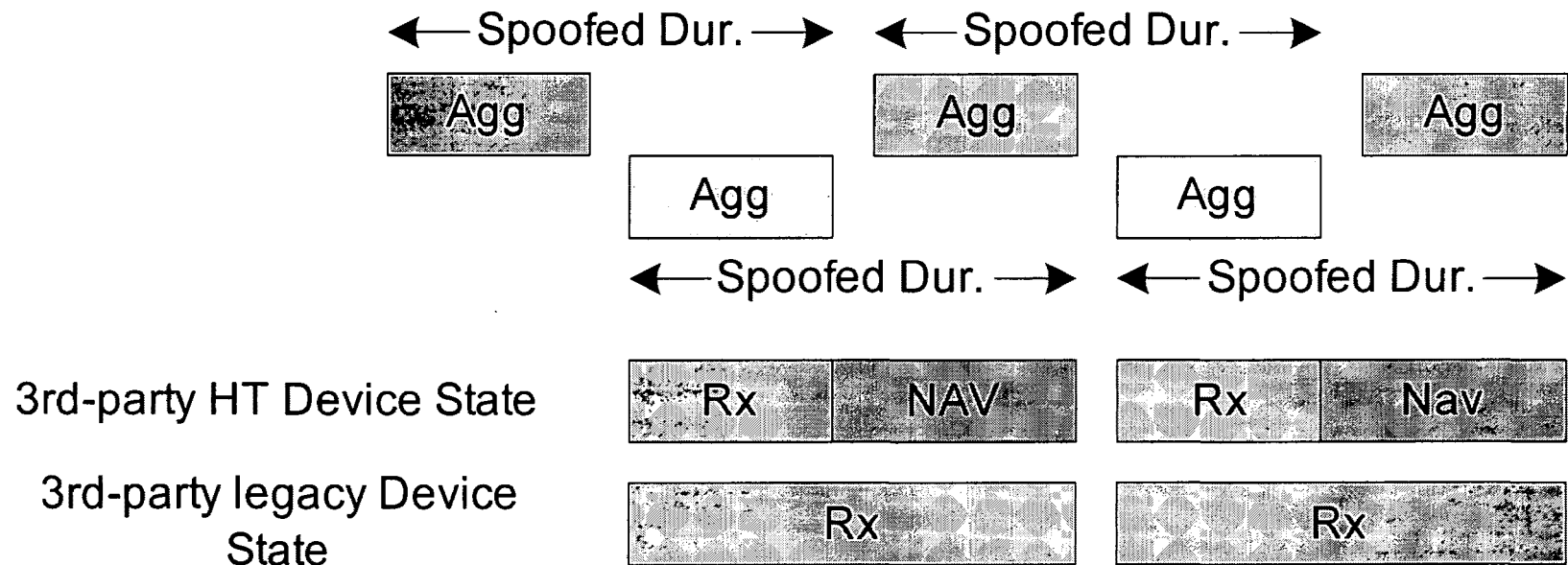
# LongNAV protection

- Provides protection of a sequence of multiple PPDUs
- Provides a solution for .11b
- Comes “for free” with polled TXOP
- Gives maximum freedom in use of TXOP by initiator



# Pairwise Spoofing Protection

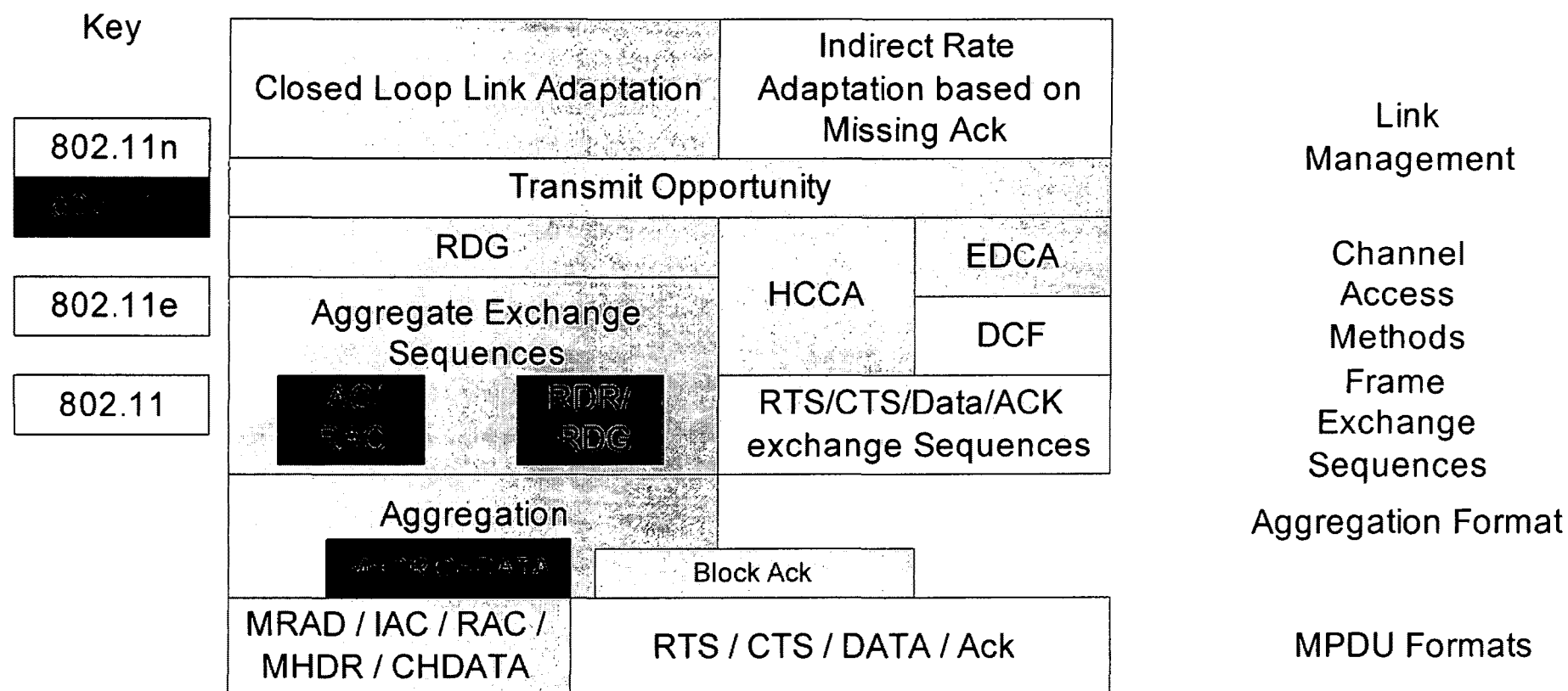
- Protects pairs of PPDU's (current and following)
- Very low overhead, suitable for short exchanges
- Places Legacy devices into receiving mode for spoofed duration
- Spoofing is interpreted by HT devices as a NAV setting



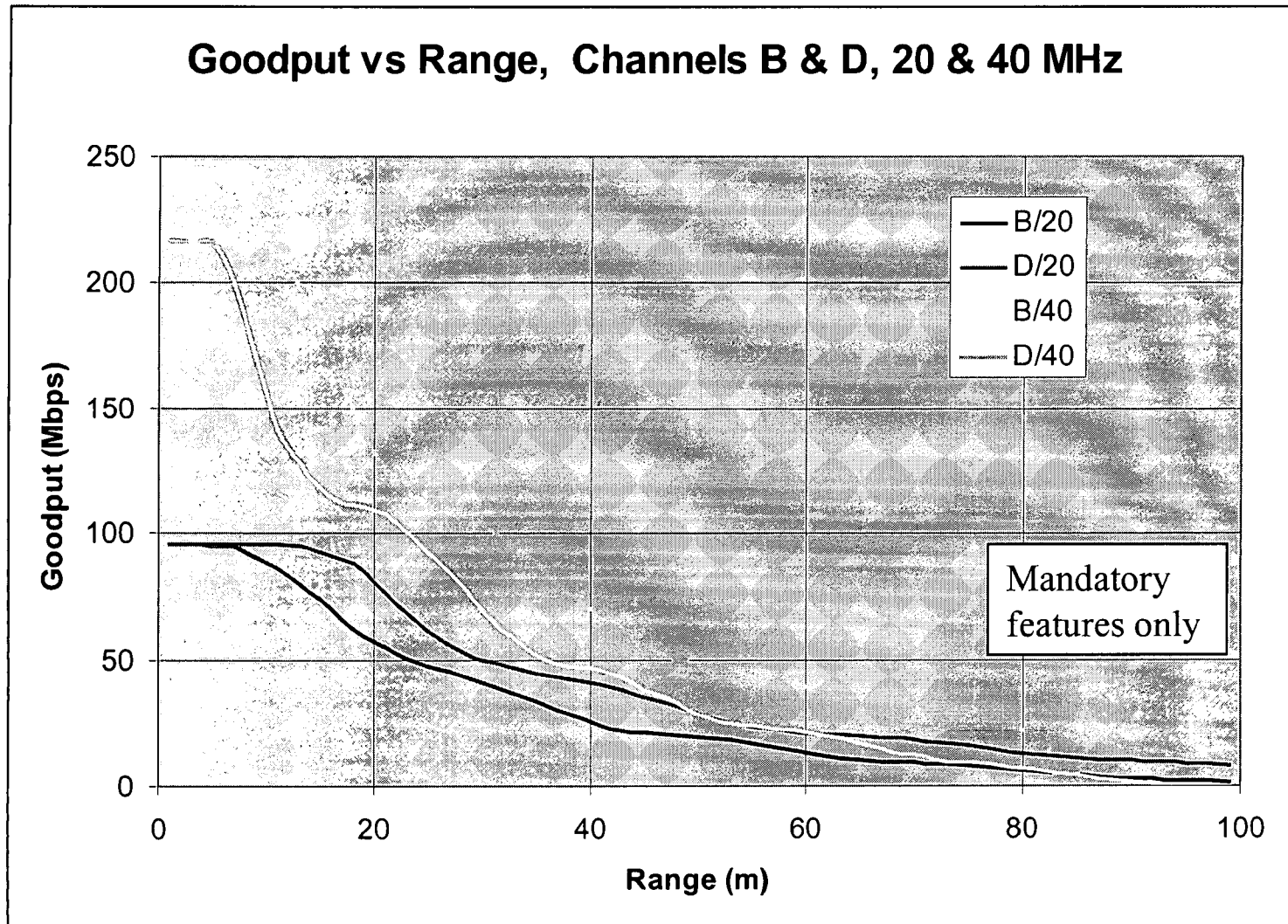
# Operating Mode Selection

- BSS operating mode controls the use of protection mechanisms and 40/20 width switching by HT STA
  - Supports mixed BSS of legacy + HT devices
- HT AP-managed modes
  - If only the control channel is overlapped, managed mixed mode provides a low overhead alternative to mixed mode
  - If both channels are overlapped, 20 MHz base mode allows an HT AP to dynamically switch channel width for 40 MHz-capable HT STA

# MAC Architecture



# CC 28/29 Performance





# MAC Selected CC Performance

| CC#  | Name                                                 | Result           | HCCA      |            |
|------|------------------------------------------------------|------------------|-----------|------------|
|      |                                                      |                  | 2x2x20    | 2x2x40     |
| CC3  | List of goodput results for usage models 1, 4 and 6. | SS1 (Mbps)       | 55.2      | 76.8       |
|      |                                                      | SS4              | 45.1      | 74.1       |
|      |                                                      | SS6              | 44.9      | 62.1       |
| CC18 | HT Usage Models Supported (non QoS)                  | SS1 (Mbps/ratio) | 2.76/0.09 | 24.4/0.8   |
|      |                                                      | SS4              | 36.0/0.07 | 65.0/0.14  |
|      |                                                      | SS6              | 0.1/0.005 | 17.24/0.86 |
| CC19 | HT Usage Models Supported (QoS)                      | SS1              | 17/17     | 17/17      |
|      |                                                      | SS4              | 18/18     | 18/18      |
|      |                                                      | SS6              | 39/39     | 39/39      |
| CC58 | HT Spectral Efficiency                               | bps/Hz           | 5.4       | 6.075      |



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
|-----------------|-------------|----------------------|---------------------|------------------|

11/121,661

05/04/2005

Mark A. Webster

050337-1020

3553

24504

7590

05/20/2008

THOMAS, KAYDEN, HORSTEMEYER & RISLEY, LLP  
600 GALLERIA PARKWAY, S.E.  
STE 1500  
ATLANTA, GA 30339-5994

EXAMINER

LEVITAN, DMITRY

ART UNIT

PAPER NUMBER

2616

MAIL DATE

DELIVERY MODE

05/20/2008

PAPER

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

|                              |                                      |                                       |  |
|------------------------------|--------------------------------------|---------------------------------------|--|
| <b>Office Action Summary</b> | <b>Application No.</b><br>11/121,661 | <b>Applicant(s)</b><br>WEBSTER ET AL. |  |
|                              | <b>Examiner</b><br>Dmitry Levitan    | <b>Art Unit</b><br>2616               |  |

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

### Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

### Status

- 1) ☒ Responsive to communication(s) filed on 04 May 2005.
- 2a) ☐ This action is **FINAL**.                      2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

### Disposition of Claims

- 4) ☒ Claim(s) 1-23 is/are pending in the application.
- 4a) Of the above claim(s) \_\_\_\_\_ is/are withdrawn from consideration.
- 5) ☐ Claim(s) \_\_\_\_\_ is/are allowed.
- 6) ☒ Claim(s) 1-23 is/are rejected.
- 7) ☐ Claim(s) \_\_\_\_\_ is/are objected to.
- 8) ☐ Claim(s) \_\_\_\_\_ are subject to restriction and/or election requirement.

### Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☒ The drawing(s) filed on 04 May 2005 is/are: a) ☒ accepted or b) ☐ objected to by the Examiner.  
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).  
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

### Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All    b) ☐ Some \*    c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
  2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
  3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

\* See the attached detailed Office action for a list of the certified copies not received.

### Attachment(s)

- |                                                                                        |                                                                   |
|----------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| 1) <input checked="" type="checkbox"/> Notice of References Cited (PTO-892)            | 4) <input type="checkbox"/> Interview Summary (PTO-413)           |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)   | Paper No(s)/Mail Date. _____                                      |
| 3) <input checked="" type="checkbox"/> Information Disclosure Statement(s) (PTO/SB/08) | 5) <input type="checkbox"/> Notice of Informal Patent Application |
| Paper No(s)/Mail Date _____                                                            | 6) <input type="checkbox"/> Other: _____                          |

***Claim Rejections - 35 USC § 112***

1. The following is a quotation of the second paragraph of 35 U.S.C. 112:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

2. Claims 1-23 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claims 1, 9 and 21 recite the limitations "the periodic equivalent" in corresponding lines. There is insufficient antecedent basis for this limitation in the claim.

Claims 1, 9 and 21 recite the limitation "the same" in corresponding lines. There is insufficient antecedent basis for this limitation in the claim.

Claims 1, 9 and 21 limitations, directed to "performing the periodic equivalent of the same" is unclear as it is not understood what operations are considered equivalent and what are not.

Claims 1, 9 and 21 recite the limitation "the duration of the cyclic advance" in corresponding lines. There is insufficient antecedent basis for this limitation in the claim.

In addition, it is unclear what is duration of the cyclic advance: is the duration is a number of shifted samples in the cycle, or the time needed to perform one cycle operation.

Claims 5 and 13 limitations, directed to the step of "determining" are unclear, because the claims limitations lack basis/conditions for making a decision/determination.

Claim 22 limitations, directed to "the segment comprising a continuous data stream" are unclear because the limitations are self contradictory, as segment, known as a portion or part, cannot comprise a continuous element, as a continuous element is larger than its portion.

***Claim Rejections - 35 USC § 102***

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent.

The changes made to 35 U.S.C. 102(e) by the American Inventors Protection Act of 1999 (AIPA) and the Intellectual Property and High Technology Technical Amendments Act of 2002 do not apply when the reference is a U.S. patent resulting directly or indirectly from an international application filed before November 29, 2000. Therefore, the prior art date of the reference is determined under 35 U.S.C. 102(e) prior to the amendment by the AIPA (pre-AIPA 35 U.S.C. 102(e)).

4. Claims 1, 3-7, 9-11, 13-16 and 19-23 are rejected (as best understood) under 35 U.S.C. 102(e) as being anticipated by Larsson (US 6,842,487).

5. Regarding claims 1, 9 and 21, Larsson teaches a method and a system, performing a cyclic diversity operation (as shown on Fig. 9 and disclosed on 6:58-7:25) comprising:

providing a OFDM packet corresponding to first transmit antenna (providing one of OFDM symbols:  $n-1$ ,  $n$  or  $n+1$  to first transmit antenna Ant1 TX, as shown on Fig. 9, the antenna that has no cyclic operation, as shown on Fig. 8 and 9 and disclosed on 6:49-57)

performing a periodic cyclic advancing operation on one or more sections of the OFDM packet corresponding to a second transmit antenna (performing cyclic delay operation on the

Art Unit: 2616

same OFDM symbol corresponding to a second transmit antenna Ant 2 TX, as shown on Fig. 8 and 9 by shifting the OFDM samples, as described on 6:40-57), wherein the duration of the periodic cyclic advance operation is less than a guard interval (performing 1 sample cyclic delay operation, which is less than the cyclic prefix, identified as guard interval on 1:30-32, as the length of the cyclic prefix (CP) is three samples, as clearly shown on Fig. 8).

In addition, regarding claims 9 and 21, Larsson teaches logic and means to perform the steps of the method, as disclosed above, in a system, shown on Fig. 9 and disclosed on 6:58-7:26.

6. Regarding claims 3- 6, 10, 11, 13 and 14, Larsson teaches using multiple transmit antennas with cyclic delay operations performed by corresponding Cyclic delay sections on OFDM symbols, as shown on Fig. 9.

7. Regarding claims 7, 15 and 16, Larsson teaches receiving the OFDM packets/symbols from first and second transmit antennas, Ant 1 TX and Ant 2 TX, on receive antenna Ant 1 RX and performing FFT in the windows corresponding to the recovered OFDM symbols/packets, as clearly shown on Fig. 9.

8. Regarding claims 19 and 20, Larsson teaches a system including attenuators, IFFT and cyclic delay blocks, as shown on Fig. 9, which are inherently comprise hardware and digital circuitry, because hardware and digital circuitry are essential for the system operation.

9. Regarding claims 22 and 23, Larsson teaches a stream of OFDM symbols/packets, as shown on Fig. 1, 2 and 9.

***Claim Rejections - 35 USC § 103***

10. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

11. Claims 2 and 12 are rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson. Larsson substantially teaches the limitations of the parent claims (see claims 1 and 9 rejections above).

Larsson does not teach using duration of cyclically advancing step less than 800 nanoseconds.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using duration of cyclically advancing step less than 800 nanoseconds to the system of Larsson as a design choice as the duration of less than 600 or 700 nanoseconds will work in the system as well.

12. Claims 8 and 17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson in view of Admitted Prior Art (Current application, Fig. 1-5 and pages 1-7).

Larsson substantially teaches the limitations of the parent claims (see claims 1, 7, 9, 15 and 16 rejections above), including use of a single input receiver, as shown on Fig. 9 and disclosed on 7:14-25.

Larsson does not teach using single-input, single-output (SISO) receiver.

Admitted Prior Art teaches legacy SISO receivers to be considered/used with multiple antennas systems on Fig. 1 and pages 1 and 2.

Art Unit: 2616

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using single-input, single-output (SISO) receiver of Admitted Prior Art to the system of Larsson to improve the system compatibility with existing SISO receivers.

13. Claim 18 is rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson in view of Admitted Prior Art (Current application, Fig. 1-5 and pages 1-7).

Larsson substantially teaches the limitations of the parent claims (see claim 9 rejections above).

Larsson does not teach using 802.11 compliant device.

Admitted Prior Art teaches using 802.11 receiver device, as shown on Fig. 1 and pages 1 and 2.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using 802.11 compliant, single-input, single-output (SISO) receiver of Admitted Prior Art to the system of Larsson to improve the system compatibility with existing receivers, utilizing 802.11 standard.

### ***Conclusion***

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Dmitry Levitan whose telephone number is (571) 272-3093. The examiner can normally be reached on 8:30 to 4:30.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lynn Feild can be reached on (571) 272-2092. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.



Art Unit: 2616

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Dmitry Levitan  
Primary Examiner  
Art Unit 2616

/Dmitry Levitan/  
Primary Examiner, Art Unit 2616

|                                   |                                       |  |                                                              |             |
|-----------------------------------|---------------------------------------|--|--------------------------------------------------------------|-------------|
| <b>Notice of References Cited</b> | Application/Control No.<br>11/121,661 |  | Applicant(s)/Patent Under<br>Reexamination<br>WEBSTER ET AL. |             |
|                                   | Examiner<br>Dmitry Levitan            |  | Art Unit<br>2616                                             | Page 1 of 1 |

#### U.S. PATENT DOCUMENTS

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Name           | Classification |
|---|---|--------------------------------------------------|-----------------|----------------|----------------|
| * | A | US-6,842,487 B1                                  | 01-2005         | Larsson, Peter | 375/260        |
| * | B | US-2005/0157682 A1                               | 07-2005         | Sandhu, Sumeet | 370/334        |
| * | C | US-2006/0221898 A1                               | 10-2006         | Bossert et al. | 370/330        |
|   | D | US-                                              |                 |                |                |
|   | E | US-                                              |                 |                |                |
|   | F | US-                                              |                 |                |                |
|   | G | US-                                              |                 |                |                |
|   | H | US-                                              |                 |                |                |
|   | I | US-                                              |                 |                |                |
|   | J | US-                                              |                 |                |                |
|   | K | US-                                              |                 |                |                |
|   | L | US-                                              |                 |                |                |
|   | M | US-                                              |                 |                |                |

#### FOREIGN PATENT DOCUMENTS

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Country | Name | Classification |
|---|---|--------------------------------------------------|-----------------|---------|------|----------------|
|   | N |                                                  |                 |         |      |                |
|   | O |                                                  |                 |         |      |                |
|   | P |                                                  |                 |         |      |                |
|   | Q |                                                  |                 |         |      |                |
|   | R |                                                  |                 |         |      |                |
|   | S |                                                  |                 |         |      |                |
|   | T |                                                  |                 |         |      |                |

#### NON-PATENT DOCUMENTS

| * |   | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
|---|---|-------------------------------------------------------------------------------------------|
|   | U |                                                                                           |
|   | V |                                                                                           |
|   | W |                                                                                           |
|   | X |                                                                                           |

\*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)  
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

|                                                                                                                        |                                                |                                                                      |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b><i>Index of Claims</i></b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                                        | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2616                                          |

|   |                 |   |                   |   |                     |   |                 |
|---|-----------------|---|-------------------|---|---------------------|---|-----------------|
| ✓ | <b>Rejected</b> | - | <b>Cancelled</b>  | N | <b>Non-Elected</b>  | A | <b>Appeal</b>   |
| = | <b>Allowed</b>  | ÷ | <b>Restricted</b> | I | <b>Interference</b> | O | <b>Objected</b> |

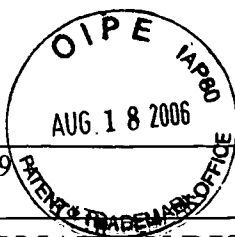
| <input type="checkbox"/> Claims renumbered in the same order as presented by applicant <input type="checkbox"/> CPA <input type="checkbox"/> T.D. <input type="checkbox"/> R.1.47 |          |            |  |  |  |  |  |  |  |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------------|--|--|--|--|--|--|--|--|
| CLAIM                                                                                                                                                                             |          | DATE       |  |  |  |  |  |  |  |  |
| Final                                                                                                                                                                             | Original | 05/16/2008 |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 1        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 2        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 3        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 4        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 5        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 6        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 7        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 8        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 9        | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 10       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 11       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 12       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 13       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 14       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 15       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 16       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 17       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 18       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 19       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 20       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 21       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 22       | ✓          |  |  |  |  |  |  |  |  |
|                                                                                                                                                                                   | 23       | ✓          |  |  |  |  |  |  |  |  |

|                                                                                                              |                                                |                                                                      |
|--------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b>Search Notes</b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                              | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2616                                          |

| SEARCHED |                       |         |          |
|----------|-----------------------|---------|----------|
| Class    | Subclass              | Date    | Examiner |
| 370      | 203-210, 310, 342-345 | 5/16/08 | DL       |
| 455      | 562, 101              | 5/16/08 | DL       |

| SEARCH NOTES |         |          |
|--------------|---------|----------|
| Search Notes | Date    | Examiner |
| IEEE, EAST   | 5/16/08 | DL       |

| INTERFERENCE SEARCH |          |      |          |
|---------------------|----------|------|----------|
| Class               | Subclass | Date | Examiner |
|                     |          |      |          |



| Form PTO-1449                                                                 |      |                                                                                                                                                                                                       |          | Attorney Docket No.<br>50337-1020 |       | Serial No.<br>11/121/661 |                            |
|-------------------------------------------------------------------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------------------------------|-------|--------------------------|----------------------------|
| <b>INFORMATION DISCLOSURE CITATION</b>                                        |      |                                                                                                                                                                                                       |          | Applicant<br>Webster et al.       |       |                          |                            |
| (Use several sheets if necessary)                                             |      |                                                                                                                                                                                                       |          | Filing Date<br>May 4, 2005        |       | Group<br>TBA             |                            |
| <b>U.S. PATENT DOCUMENTS</b>                                                  |      |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
| Examiner Initials                                                             | Item | Document Number                                                                                                                                                                                       | Date     | Name                              | Class | Subclass                 | Filing Date If Appropriate |
|                                                                               | A    | US 2002/0136276 A 1                                                                                                                                                                                   | 09/26/02 | Franceschini, et al.              | 375   | 148                      | 03/08/01                   |
|                                                                               | B    | US 6,754,170 B1                                                                                                                                                                                       | 06/22/04 | Ward                              | 370   | 208                      | 09/29/00                   |
|                                                                               | C    | US 6,574,237 B1                                                                                                                                                                                       | 06/03/03 | Bullman, et al.                   | 370   | 465                      | 06/30/99                   |
|                                                                               | D    | US 2003/0012160 A1                                                                                                                                                                                    | 01/16/03 | Webster, et al.                   | 370   | 335                      | 05/10/02                   |
|                                                                               | E    | US 2003/0016621 A1                                                                                                                                                                                    | 01/23/03 | Li                                | 370   | 203                      | 05/21/01                   |
|                                                                               | F    | US 2003/0072284 A1                                                                                                                                                                                    | 04/17/03 | Webster, et al.                   | 370   | 335                      | 07/09/02                   |
|                                                                               | G    | US 2003/0185241 A1                                                                                                                                                                                    | 10/02/03 | Lu, et al.                        | 370   | 476                      | 08/16/02                   |
|                                                                               | H    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               | I    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               | J    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               | K    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
| <b>FOREIGN PATENT DOCUMENTS</b>                                               |      |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               |      | Document Number                                                                                                                                                                                       | Date     | Country                           | Class | Subclass                 | Translation                |
|                                                                               |      |                                                                                                                                                                                                       |          |                                   |       |                          | Yes No                     |
|                                                                               | L    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               | M    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               | N    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               | O    |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
| <b>OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, etc.)</b> |      |                                                                                                                                                                                                       |          |                                   |       |                          |                            |
|                                                                               | P    | WEBSTER, et al., "LEGACY COMPATIBLE SPATIAL MULTIPLEXING SYSTEMS AND METHODS," having serial number 11/159,812, filed June 22, 2005.                                                                  |          |                                   |       |                          |                            |
|                                                                               | Q    | WEBSTER, et al., "SYSTEMS AND METHODS FOR TRANSMITTER DIVERSITY EXPANSION," having serial number 11/411,619, filed April 26, 2006.                                                                    |          |                                   |       |                          |                            |
| No date.                                                                      | R    | WEBSTER, et al. "PACKET GENERATION SYSTEMS AND METHODS," having serial number 11/106,915, filed April 15, 2005.                                                                                       |          |                                   |       |                          |                            |
|                                                                               | S    | <del>IEEE 802.11 Task Group N Meeting Update, <a href="http://grouper.ieee.org/groups/802/11/Reports/tgn-update.htm">http://grouper.ieee.org/groups/802/11/Reports/tgn-update.htm</a>, pp. 1-7.</del> |          |                                   |       |                          |                            |
|                                                                               | T    | Jon Rosdahl, "Draft PAR for High Throughput Study Group," November 15, 2002, Revision R1: January 16, 2003, IEEE 802.11-02/798r1, pp. 1-9.                                                            |          |                                   |       |                          |                            |
|                                                                               | U    | Jon Rosdahl, "Draft PAR for High Throughput Study Group," November 15, 2002, Revision R6: March 13, 2003, IEEE 802.11-02/798r6, pp. 1-8.                                                              |          |                                   |       |                          |                            |
|                                                                               | V    | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, IEEE 802.11-02/799r0, pp. 1-4.                                                                                  |          |                                   |       |                          |                            |

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.L./

|                                                                                                                                                                                                                                                        |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                        | W  | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 1: January 16, 2003, IEEE 802.11-02/799r1, pp. 1-4.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                                                                                                                                                                                                                                        | X  | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 1: January 16, 2003, IEEE 802.11-02/799r2, pp. 1-5.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                                                                                                                                                                                                                                        | Y  | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 4: March 11, 2003, IEEE 802.11-02/799r3, pp. 1-4.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                                                                                                                                                                                                                                                        | Z  | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 5: March 13, 2003, IEEE 802.11-02/799r5, pp. 1-4.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                                                                                                                                                                                                                                                        | AA | IEEE Std 802 <sup>®</sup> -2001, "802 <sup>®</sup> IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture," IEEE Computer Society, March 8, 2002                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                                                                                                                                                                                                                                                        | BB | Manoneet Singh, et al. and Bruce Edwards, et al., "WwiSE proposal: High throughput extension to the 802.11," IEEE 11-04-0886-00-000n, August 13, 2004.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                                                                                                                                                                                                                                        | CC | Syed Aon Mujtaba, "TGn Sync Proposal Technical Specification," IEEE 802.11-04/889r0, August 13, 2004.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                                                                                                                                                                                                                                        | DD | Aon Mujtaba, Adrian P. Stephens, Alek Purkovic, Andrew Myles, Brian Johnson, Daisuke Takeda, Darren McNamara, Dongjun (DJ) Lee, David Bagby, Eldad Perahia, Huanchun Ye, Hui-Ling Lou, James Chen, James Mike Wilson, Jan Boer, Jari Jokela, Jeff Gilbert, Joe Pitarressi, Jorg Habetha, John Sadowsky, Jon Rosdahl, Luke Qian, Mary Cramer, Masahiro Takagi, Monisha Ghosh, Nico van Waes, Osama Aboul-Magd, Paul Feinberg, Pen Li, Peter Loc, Pieter-Paul Giesberts, Richard van Leeuwen, Ronald Rietman, Seigo Nakao, Sheung Li, Stephen Shellhammer, Takushi Kunihiro, Teik-Kheong, Tomoko Adachi, Tomoya Yamaura, Tsuguhide Aoki, Won-Joon Choi, Xiaowen Wang, Yasuhiko Tanabe, Yasuhiro Tanaka, Yoshiharu Doi, Yichi Morioka, Youngsoo Kim, "TGn Sync Proposal," IEEE 802.11-04/888r0, August 13, 2004. |
|                                                                                                                                                                                                                                                        | EE | VK Jones, Neil Hamady, Jason Trachewsky, Michael Seals, Stephan ten Brink, George Vlantis, Sean Coffey, "WwiSE IEEE 802.11n Proposal," IEEE 802.11-04/0935r3, September 16, 2004.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <p>* EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.</p> |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| EXAMINER'S SIGNATURE:                                                                                                                                                                                                                                  |    | DATE CONSIDERED:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| /Dmitry Levitan/                                                                                                                                                                                                                                       |    | 05/15/2008                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Patent and Trademark Office; U. S. DEPARTMENT OF COMMERCE                                                                                                                                                                                              |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.L./



Form PTO-1449

Attorney Docket No.

50337-1020

Serial No.

11/121,661

**INFORMATION DISCLOSURE CITATION**

Applicant

Webster et al.

*(Use several sheets if necessary)*

Filing Date

05/04/05

Group

To Be Assigned

**U.S. PATENT DOCUMENTS**

| Examiner Initials | Item | Document Number | Date     | Name    | Class | Subclass | Filing Date If Appropriate |
|-------------------|------|-----------------|----------|---------|-------|----------|----------------------------|
|                   | A    | US 2004/0047284 | 03/11/04 | Eidson  | 370   | 203      |                            |
|                   | B    | US 2004/0266339 | 12/30/04 | Larsson | 455   | 7        |                            |
|                   | C    | 6,842,487       | 01/11/05 | Larsson | 375   | 260      |                            |
|                   | D    |                 |          |         |       |          |                            |
|                   | E    |                 |          |         |       |          |                            |
|                   | F    |                 |          |         |       |          |                            |
|                   | G    |                 |          |         |       |          |                            |
|                   | H    |                 |          |         |       |          |                            |
|                   | I    |                 |          |         |       |          |                            |
|                   | J    |                 |          |         |       |          |                            |
|                   | K    |                 |          |         |       |          |                            |

**FOREIGN PATENT DOCUMENTS**

|  | Document Number | Date | Country | Class | Subclass | Translation |    |
|--|-----------------|------|---------|-------|----------|-------------|----|
|  |                 |      |         |       |          | Yes         | No |
|  | L               |      |         |       |          |             |    |
|  | M               |      |         |       |          |             |    |
|  | N               |      |         |       |          |             |    |
|  | O               |      |         |       |          |             |    |

**OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, etc.)**

|  |   |                                                              |
|--|---|--------------------------------------------------------------|
|  | P | Forms PCT/ISA/220, PCT/ISA/210 and PCT/ISA/237               |
|  | Q | ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.L./ |
|  | R |                                                              |

\* EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

EXAMINER'S SIGNATURE:

/Dmitry Levitan/

DATE CONSIDERED:

05/15/2008

Patent and Trademark Office; U. S. DEPARTMENT OF COMMERCE



## UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
 United States Patent and Trademark Office  
 Address: COMMISSIONER FOR PATENTS  
 P.O. Box 1450  
 Alexandria, Virginia 22313-1450  
 www.uspto.gov

## BIB DATA SHEET

CONFIRMATION NO. 3553

|                                                                                                                                                                                                                                                                                                               |                                                                                                                   |                                                          |                                                                                                                                                                                                                                                                           |                                           |                           |                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|---------------------------|--------------------------------|
| <b>SERIAL NUMBER</b><br>11/121,661                                                                                                                                                                                                                                                                            | <b>FILING or 371(c) DATE</b><br>05/04/2005<br><b>RULE</b>                                                         | <b>CLASS</b><br>370                                      | <b>GROUP ART UNIT</b><br>2616                                                                                                                                                                                                                                             | <b>ATTORNEY DOCKET NO.</b><br>050337-1020 |                           |                                |
| <b>APPLICANTS</b><br>Mark A. Webster, Indian Harbor Beach, FL;<br>Michael J. Seals, Melbourne, FL;<br><b>** CONTINUING DATA *****</b><br>This appln claims benefit of 60/572,481 05/20/2004<br><b>** FOREIGN APPLICATIONS *****</b><br><b>** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **</b><br>05/26/2005 |                                                                                                                   |                                                          |                                                                                                                                                                                                                                                                           |                                           |                           |                                |
| Foreign Priority claimed <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No<br>35 USC 119(a-d) conditions met <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No<br>Verified and Acknowledged <u>/DMITRY LEVITAN/</u><br>Examiner's Signature                               |                                                                                                                   | <input type="checkbox"/> Met after Allowance<br>Initials | <b>STATE OR COUNTRY</b><br>FL                                                                                                                                                                                                                                             | <b>SHEETS DRAWINGS</b><br>11              | <b>TOTAL CLAIMS</b><br>23 | <b>INDEPENDENT CLAIMS</b><br>3 |
| <b>ADDRESS</b><br>THOMAS, KAYDEN, HORSTEMEYER & RISLEY, LLP<br>600 GALLERIA PARKWAY, S.E.<br>STE 1500<br>ATLANTA, GA 30339-5994<br>UNITED STATES                                                                                                                                                              |                                                                                                                   |                                                          |                                                                                                                                                                                                                                                                           |                                           |                           |                                |
| <b>TITLE</b><br>Cyclic diversity systems and methods                                                                                                                                                                                                                                                          |                                                                                                                   |                                                          |                                                                                                                                                                                                                                                                           |                                           |                           |                                |
| <b>FILING FEE RECEIVED</b><br>1150                                                                                                                                                                                                                                                                            | FEES: Authority has been given in Paper<br>No. _____ to charge/credit DEPOSIT ACCOUNT<br>No. _____ for following: |                                                          | <input type="checkbox"/> All Fees<br><input type="checkbox"/> 1.16 Fees (Filing)<br><input type="checkbox"/> 1.17 Fees (Processing Ext. of time)<br><input type="checkbox"/> 1.18 Fees (Issue)<br><input type="checkbox"/> Other _____<br><input type="checkbox"/> Credit |                                           |                           |                                |



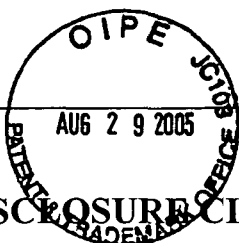
## EAST Search History

| Ref # | Hits | Search Query                                                                                                                                                                       | DBs                    | Default Operator | Plurals | Time Stamp          |
|-------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|------------------|---------|---------------------|
| L4    | 20   | ofdm and<br>(((periodic or cyclic)<br>near2 (advanc\$5<br>or divers\$5 or<br>delay)) and guard<br>\$5 and antenna<br>and @ay< "2005"                                               | US-<br>PGPUB;<br>USPAT | OR               | ON      | 2008/05/16<br>13:20 |
| L8    | 27   | ofdm and<br>((((periodic or<br>cyclic)) near2 (time<br>or timing or<br>duration or interval<br>or period or<br>length)) near3<br>guard) and<br>antenna and mimo<br>and @ay< "2005" | US-<br>PGPUB;<br>USPAT | OR               | ON      | 2008/05/16<br>13:39 |
| S8    | 44   | ofdm and<br>(((periodic or cyclic)<br>near2 (advanc\$5<br>or divers\$5)) and<br>@ay< "2006"                                                                                        | US-<br>PGPUB;<br>USPAT | OR               | ON      | 2008/05/15<br>10:48 |
| S10   | 14   | ofdm and antenna<br>and ((periodic or<br>cyclic) near2<br>(advanc\$5 or divers<br>\$5)) and<br>@ay< "2005"                                                                         | US-<br>PGPUB;<br>USPAT | OR               | ON      | 2008/05/15<br>10:49 |
| S12   | 3    | ofdm and antenna<br>and ((periodic\$4 or<br>cyclic\$4) near2<br>(advanc\$5 or divers<br>\$5)) and guard\$5<br>and @ay< "2005"                                                      | US-<br>PGPUB;<br>USPAT | OR               | ON      | 2008/05/15<br>10:55 |

5/ 16/ 08 1:43:20 PM

C:\Documents and Settings\ DLevitan\ My Documents\ EAST\ Workspaces  
\ 11121661.wsp

Form PTO-1449

**INFORMATION DISCLOSURE CITATION***(Use several sheets if necessary)*Attorney Docket No.  
**50337-1020**Serial No.  
**11/121,661**Applicant  
**Webster, et al.**Filing Date  
**05/04/2005**Group  
**2661****U.S. PATENT DOCUMENTS**

| Examiner Initials | Item | Document Number | Date | Name | Class | Subclass | Filing Date If Appropriate |
|-------------------|------|-----------------|------|------|-------|----------|----------------------------|
|                   |      |                 |      |      |       |          |                            |
|                   |      |                 |      |      |       |          |                            |

**FOREIGN PATENT DOCUMENTS**

|  |  | Document Number | Date | Country | Class | Subclass | Translation |    |
|--|--|-----------------|------|---------|-------|----------|-------------|----|
|  |  |                 |      |         |       |          | Yes         | No |
|  |  |                 |      |         |       |          |             |    |
|  |  |                 |      |         |       |          |             |    |

No date.

**OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, etc.)**

|  |   |                                                                                                                                                                                                       |
|--|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | A | <del>IEEE P802.11 Task Group N Meeting Update <a href="http://grouper.ieee.org/groups/802/11/Reports/tgn_update.htm">http://grouper.ieee.org/groups/802/11/Reports/tgn_update.htm</a>, pp. 1-7.</del> |
|  | B | Jon Rosdahl, "Draft PAR for High Throughput Study Group," November 15, 2002, Revision R1: January 16, 2003, IEEE 802.11-02/798r1, pp. 1-9.                                                            |
|  | C | Jon Rosdahl, "Draft PAR for High Throughput Study Group," November 15, 2002, Revision R6: March 13, 2003, IEEE 802.11-02/798r6, pp. 1-8.                                                              |
|  | D | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, IEEE 802.11-02/799r0, pp. 1-4.                                                                                  |
|  | E | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 1: January 16, 2003, IEEE 802.11-02/799r1, pp. 1-4.                                                    |
|  | F | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 1: January 16, 2003, IEEE 802.11-02/799r2, pp. 1-5.                                                    |
|  | G | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 4: March 11, 2003, IEEE 802.11-02/799r3, pp. 1-4.                                                      |
|  | H | Jon Rosdahl, "Criteria For Standards Development," (FIVE CRITERIA) November 15, 2002, Revision 5: March 13, 2003, IEEE 802.11-02/799r5, pp. 1-4.                                                      |
|  |   | ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.L./                                                                                                                                          |

\* EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.

EXAMINER'S SIGNATURE:

/Dmitry Levitan/

DATE CONSIDERED:

05/15/2008

Patent and Trademark Office; U. S. DEPARTMENT OF COMMERCE

|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------------------------------------------|------------------|--------------------------|-------------------------------|
| Form PTO-1449                                                                                                                                                                                                                                   |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      | Attorney Docket No.<br><b>50337-1020</b> |                  | Serial No.<br><b>TBA</b> |                               |
| <b>INFORMATION DISCLOSURE CITATION</b><br><br><i>(Use several sheets if necessary)</i>                                                                                                                                                          |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      | Applicant<br><b>Webster, et al.</b>      |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      | Filing Date<br><b>May 4, 2005</b>        |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      | Group<br><b>TBA</b>                      |                  |                          |                               |
| <b>U.S. PATENT DOCUMENTS</b>                                                                                                                                                                                                                    |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
| Examiner<br>Initials                                                                                                                                                                                                                            | Item | Document<br>Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Date | Name                                     | Class            | Subclass                 | Filing Date<br>If Appropriate |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
| <b>FOREIGN PATENT DOCUMENTS</b>                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      | Document<br>Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Date | Country                                  | Class            | Subclass                 | Translation                   |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  | Yes    No                |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
| <b>OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, etc.)</b>                                                                                                                                                                   |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 | A    | IEEE Std 802 <sup>®</sup> -2001, "802 <sup>®</sup> IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture," IEEE Computer Society, March 8, 2002                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 | B    | Manoneet Singh, et al. and Bruce Edwards, et al., "WwiSE proposal: High throughput extension to the 802.11," IEEE 11-04-0886-00-000n, August 13, 2004.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 | C    | Syed Aon Mujtaba, "TGn Sync Proposal Technical Specification," IEEE 802.11-04/889r0, August 13, 2004.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 | D    | Aon Mujtaba, Adrian P. Stephens, Alek Purkovic, Andrew Myles, Brian Johnson, Daisuke Takeda, Darren McNamara, Dongjun (DJ) Lee, David Bagby, Eldad Perahia, Huanchun Ye, Hui-Ling Lou, James Chen, James Mike Wilson, Jan Boer, Jari Jokela, Jeff Gilbert, Joe Pitarressi, Jorg Habetha, John Sadowsky, Jon Rosdahl, Luke Qian, Mary Cramer, Masahiro Takagi, Monisha Ghosh, Nico van Waes, Osama Aboul-Magd, Paul Feinberg, Pen Li, Peter Loc, Pieter-Paul Giesberts, Richard van Leeuwen, Ronald Rietman, Seigo Nakao, Sheung Li, Stephen Shellhammer, Takushi Kunihiro, Teik-Kheong, Tomoko Adachi, Tomoya Yamaura, Tsuguhide Aoki, Won-Joon Choi, Xiaowen Wang, Yasuhiko Tanabe, Yasuhiro Tanaka, Yoshiharu Doi, Yichi Morioka, Youngsoo Kim, "TGn Sync Proposal," IEEE 802.11-04/888r0, August 13, 2004. |      |                                          |                  |                          |                               |
|                                                                                                                                                                                                                                                 | E    | VK Jones, Neil Hamady, Jason Trachewsky, Michael Seals, Stephan ten Brink, George Vlantis, Sean Coffey, "WwiSE IEEE 802.11n Proposal," IEEE 802.11-04/0935r3, September 16, 2004.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |      |                                          |                  |                          |                               |
| ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /D.L./                                                                                                                                                                                    |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
| * EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant. |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          |                  |                          |                               |
| EXAMINER'S SIGNATURE:                                                                                                                                                                                                                           |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          | DATE CONSIDERED: |                          |                               |
| /Dmitry Levitan/                                                                                                                                                                                                                                |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |      |                                          | 05/15/2008       |                          |                               |

Patent and Trademark Office; U. S. DEPARTMENT OF COMMERCE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of:

**Webster et al.**

Serial No.: **11/121,661**

Filed: **05/04/2005**

For: **Cyclic Diversity Systems and Methods**

Confirmation No.: **3553**

Group Art Unit: **2616**

Examiner: **Levitan, Dmitry**

Docket No. **050337-1020**

**RESPONSE**  
**TO NON-FINAL OFFICE ACTION**

Mail Stop: Amendment  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, Virginia 22313-1450

Sir:

The outstanding non-final Office Action mailed May 20, 2008 (Paper No. 20080515) has been carefully considered. In response thereto, please enter the following amendments and consider the following remarks. Reconsideration and allowance of the application and presently pending claims, as amended, are respectfully requested.

***AUTHORIZATION TO DEBIT ACCOUNT***

It is believed that no extensions of time or fees for net addition of claims are required, beyond those which may otherwise be provided for in documents accompanying this paper. However, in the event that additional extensions of time are necessary to allow consideration of this paper, such extensions are hereby petitioned under 37 C.F.R. § 1.136(a), and any fees required therefore (including fees for net addition of claims) are hereby authorized to be charged to deposit account no. 50-0835.

## AMENDMENTS TO THE CLAIMS

1. (Currently Amended) A cyclic diversity method, comprising:  
providing an a first orthogonal frequency division multiplexing (OFDM) packet corresponding to a first transmit antenna; and  
cyclically advancing one or more sections of the first OFDM packet, or ~~performing the a~~ periodic equivalent of ~~the same~~, one or more sections of the first OFDM packet, to produce a second OFDM packet, one or more sections of the second OFDM packet corresponding to a second transmit antenna, ~~the a~~ duration of the cyclic advance having a duration less than a guard interval, the duration corresponding to a number of sample shifts in a cycle.
2. (Currently Amended) The method of claim 1, ~~wherein cyclically advancing comprises~~ further comprising cyclically advancing for a duration of less than approximately 800 nanoseconds.
3. (Currently Amended) The method of claim 1, further comprising transmitting the first OFDM packet corresponding to the first transmit antenna from the first transmit antenna and transmitting the second OFDM packet ~~having the one or more cyclically advanced sections~~ from the second transmit antenna.
4. (Currently Amended) The method of claim 1, further comprising transmitting, on additional transmit antennas, the first OFDM packet corresponding to the first transmit antenna with cyclic delay, cyclic advance, or linear time delay ~~for the~~ applied to one or more sections of the first OFDM packet ~~from additional transmit antennas.~~
5. (Currently Amended) The method of claim 1, further comprising determining based on at least one cyclic extension module whether to transmit the first OFDM packet corresponding to the first transmit antenna with a cyclic delay, cyclic advance, or a linear time delay applied to the one or more sections of the first OFDM packet when transmission is to be from additional transmit antennas.

6. (Currently Amended) The method of claim 1, further comprising transmitting the first OFDM packet corresponding to the first transmit antenna and the second OFDM packet having ~~the one or more cyclically advanced sections~~ corresponding to the second transmit antenna from a multiple-antenna transmitter device.

7. (Currently Amended) The method of claim 1, further comprising receiving the first OFDM packet corresponding to the first transmit antenna and the second OFDM packet having ~~the one or more cyclically advanced sections~~ corresponding to the second transmit antenna and placing a fast Fourier Transform (FFT) in an interval corresponding to the duration of a recovered OFDM symbol corresponding to one of the OFDM packets without shifting the FFT into an adjacent OFDM symbol.

8. (Currently Amended) The method of claim 7, ~~wherein receiving and placing further comprising~~ comprises receiving at a single-input, single-output (SISO) receiver device.

9. (Currently Amended) A cyclic diversity system, comprising:  
a logic configured to cyclically advance one or more sections of a first orthogonal frequency division multiplexing (OFDM) packet, or perform the periodic equivalent of the same, ~~one or more sections of an orthogonal frequency division multiplexing (OFDM)~~ the first OFDM packet, to produce a second OFDM packet, the first OFDM packet relative to the OFDM packet to be transmitted on a first transmit antenna, the second OFDM packet having the one or more cyclically advanced sections to be transmitted on a second transmit antenna, ~~the a duration of the cyclic advance having a duration less than a guard interval, the duration corresponding to a number of sample shifts in a cycle.~~

10. (Currently Amended) The system of claim 9, further comprising transmit logic configured to transmit the first OFDM packet and the second OFDM packet ~~having the one or more cyclically advanced sections~~ on the first transmit antenna and the second transmit antenna, respectively.

11. (Currently Amended) The system of claim 10, ~~wherein the further comprising~~ transmit logic ~~is configured to transmit, on additional transmit antennas,~~ the first OFDM packet with a cyclic delay, cyclic advance, or linear time delay ~~for the applied to~~ one or more sections of the first OFDM packet ~~from additional transmit antennas.~~

12. (Currently Amended) The system of claim 9, ~~wherein the logic is further comprising logic~~ configured to cyclically advance the one or more sections of the second OFDM packet to be transmitted from the second transmit antenna for a duration of less than approximately 800 nanoseconds.
13. (Currently Amended) The system of claim 9, ~~wherein the logic is further comprising logic~~ configured to ~~determine whether to~~ transmit the first OFDM packet with at least one of the following: a cyclic delay, cyclic advance, or a linear time delay applied to the one or more sections of the first OFDM packet.
14. (Currently Amended) The system of claim 9, ~~wherein the system is further comprising~~ the system embodied as a multiple-antenna transmitter device.
15. (Currently Amended) The system of claim 9, further comprising receive logic configured to receive the first OFDM packet corresponding to the first transmit antenna and the second OFDM packet ~~having the one or more cyclically advanced sections~~ corresponding to the second transmit antenna.
16. (Original) The system of claim 15, further comprising processing logic configured to place a fast Fourier Transform (FFT) in an interval corresponding to the duration of an OFDM symbol of one of the received OFDM packets without shifting the FFT into an adjacent OFDM symbol.
17. (Currently Amended) The system of claim 16, ~~wherein~~ further comprising the receive logic and the processing logic is located in a single-input, single-output (SISO) receiver device.
18. (Currently Amended) The system of claim 9, ~~wherein the system comprises~~ further comprising an 802.11 compliant device.
19. (Currently Amended) The system of claim 9, ~~wherein the~~ further comprising logic is configured in hardware, software, or a combination of hardware and software.

20. (Currently Amended) The system of claim 9, ~~wherein the~~ further comprising logic is configured in digital circuitry, analog circuitry, or a combination of digital and analog circuitry.

21. (Currently Amended) A cyclic diversity system, comprising:

means for providing an a first orthogonal frequency division multiplexing (OFDM) segment corresponding to a first transmit antenna; and

means for cyclically advancing one or more sections of the first OFDM segment, or ~~performing the a~~ periodic equivalent of ~~the same~~, one or more sections of the first OFDM segment, to produce a second OFDM segment corresponding to a second transmit antenna, the duration of the cyclic advance having a duration less than a guard interval, the duration corresponding to a number of sample shifts in a cycle.

22. (Currently Amended) The system of claim 21, ~~wherein the segment~~ further comprising: ~~comprises~~ a continuous data stream within the segment.

23. (Currently Amended) The system of claim 21, ~~wherein the segment~~ further comprising: ~~comprises~~ a packet.



## **REMARKS**

Upon entry of the foregoing amendments, claims 1-23 remain pending in the present application. Claims 1-15 and 17-23 are amended herein. No new matter is added to the present application by these amendments. Reconsideration and allowance of all claims are respectfully requested.

### **I. Claim Rejections – 35 U.S.C. §112**

Claims 1-23 are rejected under 35 U.S.C. § 112, second paragraph, as allegedly being indefinite. Applicant respectfully traverses this rejection. Claims 1, 5, 9, 13, 21, and 22 are amended to overcome this rejection. Applicant respectfully requests withdrawal of this rejection.

### **II. Claim Rejections – 35 U.S.C. §102(e)**

Claims 1, 3-7, 9-11, 13-16, and 19-23 are rejected under 35 U.S.C. § 102(e) as allegedly being anticipated by Larsson (US 6,842,487). Applicant respectfully traverses this rejection.

#### **A. Independent Claim 1**

Claim 1, as amended, explicitly recites: “***cyclically advancing*** the first OFDM packet”. Conversely, *Larsson* discloses “employing **a cyclic delay**”. (*Larsson*, col. 6, lines 26-29.) As illustrated, based on this passage, *Larsson* fails to teach the claimed feature “***cyclically advancing*** the first OFDM packet”.

For at least the reason that *Larsson* fails to disclose, teach, or suggest the above-mentioned feature, Applicant respectfully submits that claim 1 is allowable in view of the cited art. Therefore, Applicant requests that the rejection of claim 1 be withdrawn.

#### **B. Independent claim 9**

Claim 9, as amended, explicitly recites “a logic configured to ***cyclically advance***”. Referring to column 6, lines 26-29, *Larsson* discloses “employing **a cyclic delay**”. As illustrated, based on this passage, *Larsson* fails to teach the claimed feature “a logic configured to ***cyclically advance***” explicitly recited in claim 9.

For at least the reason that *Larsson* fails to disclose, teach, or suggest the above-mentioned feature, Applicant respectfully submits that claim 9 is allowable in view of the cited art. Therefore, Applicant requests that the rejection of claim 9 be withdrawn.

**C. Independent Claim 21**

Claim 21, as amended, explicitly recites a “means for ***cyclically advancing***”. Referring to column 6, lines 26-29, *Larsson* discloses “employing **a cyclic delay**”. As illustrated, based on this passage, *Larsson* fails to teach the claimed feature a “means for ***cyclically advancing***” as recited in claim 21.

For at least the reason that *Larsson* fails to disclose, teach, or suggest the above-mentioned feature, Applicant respectfully submits that claim 21 is allowable in view of the cited art. Therefore, Applicant requests that the rejection of claim 21 be withdrawn.

**D. Dependent Claims 3-7, 10-11, 13-16, 19-20, 22-23**

Since claim 1 is allowable, Applicant respectfully submits that dependent claims 3-7 are allowable for at least the reason that these claims depend from allowable independent claim 1.

Since claim 9 is allowable, Applicant respectfully submits that dependent claims 10-11, 13-16, and 19-20 are allowable for at least the reason that these claims depend from allowable independent claim 9.

Since claim 21 is allowable, Applicant respectfully submits that dependent claims 22-23 are allowable for at least the reason that these claims depend from allowable independent claim 21. *In re Fine*, 837 F.2d 1071, 5 U.S.P.Q.2d 1596, 1600 (Fed. Cir.1988).

Therefore, Applicant respectfully requests that the rejection of claims 3-7, 10-11, 13-16, 19-20, and 22-23 be withdrawn.

**III. Claim Rejections – 35 U.S.C. §103(a)**

**A. Dependent Claims 2 and 12**

Claims 2 and 12 are rejected under 35 U.S.C. §103(a) as allegedly being unpatentable over *Larsson*. Applicant respectfully traverses this rejection.

Since claim 1 is allowable, Applicant respectfully submits that dependent claim 2 is allowable for at least the reason that this claim depends from allowable independent claim 1.

Since claim 9 is allowable, Applicant respectfully submits that dependent claim 12 is allowable for at least the reason that this claim depends from allowable independent claim 9. *In re Fine*, 837 F.2d 1071, 5 U.S.P.Q.2d 1596, 1600 (Fed. Cir. 1988).

Therefore, Applicant respectfully requests that the rejection of claims 2 and 12 be withdrawn.

**B. Dependent Claims 8, 17 and 18**

Claims 8, 17, and 18 are rejected under 35 U.S.C. §103(a) as allegedly being unpatentable over *Larsson* in view of Admitted Prior Art. Applicant respectfully traverses this rejection.

Applicant respectfully submits that Admitted Prior Art does not overcome the deficiencies of *Larsson* as discussed above in connection with independent claims 1 and 9. For at least this reason, claims 8, 17, and 18 are allowable.

Additionally, since claim 1 is allowable, Applicant respectfully submits that dependent claim 8 is allowable for at least the reason that this claim depends from allowable independent claim 1.

Since claim 9 is allowable, Applicant respectfully submits that dependent claims 17 and 18 are allowable for at least the reason that these claims depend from allowable independent claim 9. *In re Fine*, 837 F.2d 1071, 5 U.S.P.Q.2d 1596, 1600 (Fed. Cir. 1988).

Therefore, Applicant respectfully requests that the rejection of claims 17 and 18 be withdrawn.

### **CONCLUSION**

In light of the foregoing amendments and for at least the reasons set forth above, Applicant respectfully submits that all objections and/or rejections have been traversed, rendered moot, and/or accommodated, and that the now pending claims 1-32 are in condition for allowance. Favorable reconsideration and allowance of the present application and all pending claims are hereby courteously requested. If, in the opinion of the Examiner, a telephonic conference would expedite the examination of this matter, the Examiner is invited to call the undersigned agent at (770) 933-9500.

Respectfully submitted,



Scott A. Horstemeyer, Reg. No. 34,183

**THOMAS, KAYDEN,**  
**HORSTEMEYER & RISLEY, L.L.P.**  
Suite 1500  
600 Galleria Parkway N.W.  
Atlanta, Georgia 30339  
(770) 933-9500

## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 3781988                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | Cyclic diversity systems and methods |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 24504                                |
| <b>Filer:</b>                               | Scott A. Horstemeyer/Julie Campbell  |
| <b>Filer Authorized By:</b>                 | Scott A. Horstemeyer                 |
| <b>Attorney Docket Number:</b>              | 050337-1020                          |
| <b>Receipt Date:</b>                        | 14-AUG-2008                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 15:33:56                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description                  | File Name    | File Size(Bytes) /Message Digest                   | Multi Part /.zip | Pages (if appl.) |
|-----------------|---------------------------------------|--------------|----------------------------------------------------|------------------|------------------|
| 1               | Amendment - After Non-Final Rejection | 00762221.PDF | 324434<br>11462c3c26fa603001d629efafdc3fb0394eb8b7 | no               | 9                |

### Warnings:

### Information:

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

**New Applications Under 35 U.S.C. 111**

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

**National Stage of an International Application under 35 U.S.C. 371**

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

**New International Application Filed with the USPTO as a Receiving Office**

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| <b>PATENT APPLICATION FEE DETERMINATION RECORD</b><br>Substitute for Form PTO-875                                               |                                                                                                                                                                                                                               |                                  |                                    |               | Application or Docket Number<br><b>11/121,661</b> |                                          | Filing Date<br><b>05/04/2005</b> |                         | <input type="checkbox"/> To be Mailed |  |
|---------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|------------------------------------|---------------|---------------------------------------------------|------------------------------------------|----------------------------------|-------------------------|---------------------------------------|--|
| <b>APPLICATION AS FILED – PART I</b>                                                                                            |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| (Column 1)                                                                                                                      |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               |                                                   | SMALL ENTITY <input type="checkbox"/> OR |                                  | OTHER THAN SMALL ENTITY |                                       |  |
| FOR                                                                                                                             | NUMBER FILED                                                                                                                                                                                                                  | NUMBER EXTRA                     | RATE (\$)                          | FEE (\$)      |                                                   | RATE (\$)                                | FEE (\$)                         |                         |                                       |  |
| <input type="checkbox"/> BASIC FEE<br>(37 CFR 1.16(a), (b), or (c))                                                             | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               |                                                   | N/A                                      |                                  |                         |                                       |  |
| <input type="checkbox"/> SEARCH FEE<br>(37 CFR 1.16(k), (l), or (m))                                                            | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               |                                                   | N/A                                      |                                  |                         |                                       |  |
| <input type="checkbox"/> EXAMINATION FEE<br>(37 CFR 1.16(o), (p), or (q))                                                       | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               |                                                   | N/A                                      |                                  |                         |                                       |  |
| TOTAL CLAIMS<br>(37 CFR 1.16(i))                                                                                                | minus 20 =                                                                                                                                                                                                                    | *                                | X \$                               | =             |                                                   | X \$                                     | =                                |                         |                                       |  |
| INDEPENDENT CLAIMS<br>(37 CFR 1.16(h))                                                                                          | minus 3 =                                                                                                                                                                                                                     | *                                | X \$                               | =             |                                                   | X \$                                     | =                                |                         |                                       |  |
| <input type="checkbox"/> APPLICATION SIZE FEE<br>(37 CFR 1.16(s))                                                               | If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| <input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))                                                      |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| * If the difference in column 1 is less than zero, enter "0" in column 2.                                                       |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| <b>APPLICATION AS AMENDED – PART II</b>                                                                                         |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| (Column 1)                                                                                                                      |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               |                                                   | SMALL ENTITY OR                          |                                  | OTHER THAN SMALL ENTITY |                                       |  |
| AMENDMENT                                                                                                                       | 08/14/2008                                                                                                                                                                                                                    | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE (\$)                                         | ADDITIONAL FEE (\$)                      |                                  | RATE (\$)               | ADDITIONAL FEE (\$)                   |  |
|                                                                                                                                 | Total (37 CFR 1.16(i))                                                                                                                                                                                                        | * 23                             | Minus                              | ** 23         | =                                                 | 0                                        |                                  | X \$50=                 | 0                                     |  |
|                                                                                                                                 | Independent (37 CFR 1.16(h))                                                                                                                                                                                                  | * 3                              | Minus                              | *** 3         | =                                                 | 0                                        |                                  | X \$210=                | 0                                     |  |
| <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                                                                  |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                        |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
|                                                                                                                                 |                                                                                                                                                                                                                               |                                  |                                    |               | TOTAL ADD'L FEE                                   |                                          | OR                               | TOTAL ADD'L FEE         | 0                                     |  |
| (Column 1)                                                                                                                      |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               |                                                   | SMALL ENTITY OR                          |                                  | OTHER THAN SMALL ENTITY |                                       |  |
| AMENDMENT                                                                                                                       |                                                                                                                                                                                                                               | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE (\$)                                         | ADDITIONAL FEE (\$)                      |                                  | RATE (\$)               | ADDITIONAL FEE (\$)                   |  |
|                                                                                                                                 | Total (37 CFR 1.16(i))                                                                                                                                                                                                        | *                                | Minus                              | **            | =                                                 |                                          |                                  | X \$                    | =                                     |  |
|                                                                                                                                 | Independent (37 CFR 1.16(h))                                                                                                                                                                                                  | *                                | Minus                              | ***           | =                                                 |                                          |                                  | X \$                    | =                                     |  |
| <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                                                                  |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                        |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
|                                                                                                                                 |                                                                                                                                                                                                                               |                                  |                                    |               | TOTAL ADD'L FEE                                   |                                          | OR                               | TOTAL ADD'L FEE         |                                       |  |
| * If the entry in column 1 is less than the entry in column 2, write "0" in column 3.                                           |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".                                       |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".                                        |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |
| The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1. |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                                          |                                  |                         |                                       |  |

Legal Instrument Examiner:  
/MARQUETTA MCGEE/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
|-----------------|-------------|----------------------|---------------------|------------------|

11/121,661

05/04/2005

Mark A. Webster

050337-1020

3553

24504

7590

10/27/2008

THOMAS, KAYDEN, HORSTEMEYER & RISLEY, LLP  
600 GALLERIA PARKWAY, S.E.  
STE 1500  
ATLANTA, GA 30339-5994

EXAMINER

LEVITAN, DMITRY

ART UNIT

PAPER NUMBER

2416

MAIL DATE

DELIVERY MODE

10/27/2008

PAPER

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.



|                              |                                      |                                       |  |
|------------------------------|--------------------------------------|---------------------------------------|--|
| <b>Office Action Summary</b> | <b>Application No.</b><br>11/121,661 | <b>Applicant(s)</b><br>WEBSTER ET AL. |  |
|                              | <b>Examiner</b><br>Dmitry Levitan    | <b>Art Unit</b><br>2416               |  |

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

### Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

### Status

- 1) ☒ Responsive to communication(s) filed on 27 September 2008.
- 2a) ☒ This action is **FINAL**.                      2b) ☐ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

### Disposition of Claims

- 4) ☒ Claim(s) 1-23 is/are pending in the application.
- 4a) Of the above claim(s) \_\_\_\_\_ is/are withdrawn from consideration.
- 5) ☐ Claim(s) \_\_\_\_\_ is/are allowed.
- 6) ☒ Claim(s) 1-23 is/are rejected.
- 7) ☐ Claim(s) \_\_\_\_\_ is/are objected to.
- 8) ☐ Claim(s) \_\_\_\_\_ are subject to restriction and/or election requirement.

### Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on \_\_\_\_\_ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.  
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).  
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

### Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All    b) ☐ Some \*    c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
  2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
  3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

\* See the attached detailed Office action for a list of the certified copies not received.

### Attachment(s)

- |                                                                                      |                                                                   |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| 1) <input type="checkbox"/> Notice of References Cited (PTO-892)                     | 4) <input type="checkbox"/> Interview Summary (PTO-413)           |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948) | Paper No(s)/Mail Date. _____                                      |
| 3) <input type="checkbox"/> Information Disclosure Statement(s) (PTO/SB/08)          | 5) <input type="checkbox"/> Notice of Informal Patent Application |
| Paper No(s)/Mail Date _____                                                          | 6) <input type="checkbox"/> Other: _____                          |

Art Unit: 2416

Amendment, filed 9/27/08, has been entered. Claims 1-23 remain pending.

***Claim Rejections - 35 USC § 112***

1. Claims 1-23 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claims 1, 9 and 21 recite the limitations "cyclically advancing one or more section of the first OFDM packet, or a periodic equivalent of one or more sections of the first OFDM packet to produce a second OFDM packet" in corresponding lines. These limitations are unclear, because it is not understood what is a periodic equivalent of sections in OFDM packet, and how these limitations are associated with "cyclically advancing" operation.

Claim 1, 9 and 21 limitations, directed to "advancing one or more sections of the first OFDM packet" are unclear, because it is not understood what "advancing" means in the context of the claims.

Examiner believes that advancing a portion of the signal is always relative to the other copy/duplicate of the signal, which is delayed, as advancing signal in time is physically impossible.

Other claims are rejected as the claims depending on the claims rejected above.

***Claim Rejections - 35 USC § 102***

2. Claims 1, 3-7, 9-11, 13-16 and 19-23 are rejected (as best understood) under 35 U.S.C. 102(e) as being anticipated by Larsson (US 6,842,487).

3. Regarding claims 1, 9 and 21, Larsson teaches a method and a system, performing a cyclic diversity operation (as shown on Fig. 9 and disclosed on 6:58-7:25) comprising:

providing a OFDM packet corresponding to first transmit antenna (providing one of OFDM symbols:  $n-1$ ,  $n$  or  $n+1$  to first transmit antenna Ant1 TX, as shown on Fig. 9, and disclosed on 6:49-57)

performing a periodic cyclic advancing operation on one or more sections of the OFDM packet corresponding to a second transmit antenna (performing cyclic delay operation on the same OFDM symbol corresponding to a second transmit antenna Ant 2 TX, as shown on Fig. 8 and 9 by shifting the OFDM samples, as described on 6:40-57, therefore advancing the other portion of the OFDM signal, corresponding to Ant1 TX, as delaying one portion of the signal will advance the other portion of the same signal), wherein the duration of the periodic cyclic advance operation is less than a guard interval (performing 1 sample cyclic delay operation, which is less than the cyclic prefix, identified as guard interval on 1:30-32, as the length of the cyclic prefix (CP) is three samples, as clearly shown on Fig. 8).

In addition, regarding claims 9 and 21, Larsson teaches logic and means to perform the steps of the method, as disclosed above, in a system, shown on Fig. 9 and disclosed on 6:58-7:26.

4. Regarding claims 3- 6, 10, 11, 13 and 14, Larsson teaches using multiple transmit antennas with cyclic delay operations performed by corresponding Cyclic delay sections/modules on OFDM symbols, as shown on Fig. 9.

Art Unit: 2416

5. Regarding claims 7, 15 and 16, Larsson teaches receiving the OFDM packets/symbols from first and second transmit antennas, Ant 1 TX and Ant 2 TX, on receive antenna Ant 1 RX and performing FFT in the windows corresponding to the recovered OFDM symbols/packets, as clearly shown on Fig. 9.

6. Regarding claims 19 and 20, Larsson teaches a system including attenuators, IFFT and cyclic delay blocks, as shown on Fig. 9, which are inherently comprise hardware and digital circuitry, because hardware and digital circuitry are essential for the system operation.

7. Regarding claims 22 and 23, Larsson teaches a stream of OFDM symbols/packets, as shown on Fig. 1, 2 and 9.

### ***Claim Rejections - 35 USC § 103***

8. Claims 2 and 12 are rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson. Larsson substantially teaches the limitations of the parent claims (see claims 1 and 9 rejections above).

Larsson does not teach using duration of cyclically advancing step less than 800 nanoseconds.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using duration of cyclically advancing step less than 800 nanoseconds to the system of Larsson as a design choice as the duration of less than 600 or 700 nanoseconds will work in the system as well.

9. Claims 8 and 17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson in view of Admitted Prior Art (Current application, Fig. 1-5 and pages 1-7).

Art Unit: 2416

Larsson substantially teaches the limitations of the parent claims (see claims 1, 7, 9, 15 and 16 rejections above), including use of a single input receiver, as shown on Fig. 9 and disclosed on 7:14-25.

Larsson does not teach using single-input, single-output (SISO) receiver.

Admitted Prior Art teaches legacy SISO receivers to be considered/used with multiple antennas systems on Fig. 1 and pages 1 and 2.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using single-input, single-output (SISO) receiver of Admitted Prior Art to the system of Larsson to improve the system compatibility with existing SISO receivers.

10. Claim 18 is rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson in view of Admitted Prior Art (Current application, Fig. 1-5 and pages 1-7).

Larsson substantially teaches the limitations of the parent claims (see claim 9 rejections above).

Larsson does not teach using 802.11 compliant device.

Admitted Prior Art teaches using 802.11 receiver device, as shown on Fig. 1 and pages 1 and 2.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using 802.11 compliant, single-input, single-output (SISO) receiver of Admitted Prior Art to the system of Larsson to improve the system compatibility with existing receivers, utilizing 802.11 standard.

***Response to Arguments***

11. Applicant's arguments filed 9/27/08 have been fully considered but they are not persuasive.

On pages 6-8 of the Response, Applicant argues that Larsson does not teach “cyclically advancing” limitations of the independent claims, but teaches only “cyclically delaying”, making the claims patentable over Larsson.

Examiner respectfully disagrees.

Larsson teaching is directed to delaying  $n-1$ ,  $n$ ,  $n+1$  OFDM symbols for antenna ANT 2, inherently advancing  $n-1$ ,  $n$ ,  $n+1$  OFDM symbols for antenna Ant 1, as clearly shown on Fig. 9 and disclosed on 7:27-37.

Signal advancing is understood as a relative operation, where a signal is considered to be advanced in comparison with a delayed copy of itself or with delayed reference signal.

There many devices in electronics to delay a signal, but there are no devices capable to accelerate a signal in time.

Applicant provided no details on implementation of signal “advance”, but the operations of “advancing” of OFDM sections, as shown on Fig. 8 or 9, inherently comprise delaying OFDM sections, similar to method of Larsson, as "advancing" without use of delaying operation is physically impossible.

***Conclusion***

12. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Dmitry Levitan whose telephone number is (571) 272-3093. The examiner can normally be reached on 8:30 to 4:30.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Huy Vu can be reached on (571) 272-3155. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Art Unit: 2416

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Dmitry Levitan  
Primary Examiner  
Art Unit 2416

/Dmitry Levitan/  
Primary Examiner, Art Unit 2416



|                                                                                                                        |                                                |                                                                      |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b><i>Index of Claims</i></b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                                        | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2616                                          |

|   |                 |   |                   |   |                     |   |                 |
|---|-----------------|---|-------------------|---|---------------------|---|-----------------|
| ✓ | <b>Rejected</b> | - | <b>Cancelled</b>  | N | <b>Non-Elected</b>  | A | <b>Appeal</b>   |
| = | <b>Allowed</b>  | ÷ | <b>Restricted</b> | I | <b>Interference</b> | O | <b>Objected</b> |

| <input type="checkbox"/> Claims renumbered in the same order as presented by applicant |          |            |            | <input type="checkbox"/> CPA |  | <input type="checkbox"/> T.D. |  | <input type="checkbox"/> R.1.47 |  |
|----------------------------------------------------------------------------------------|----------|------------|------------|------------------------------|--|-------------------------------|--|---------------------------------|--|
| CLAIM                                                                                  |          | DATE       |            |                              |  |                               |  |                                 |  |
| Final                                                                                  | Original | 05/16/2008 | 10/23/2008 |                              |  |                               |  |                                 |  |
|                                                                                        | 1        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 2        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 3        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 4        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 5        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 6        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 7        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 8        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 9        | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 10       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 11       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 12       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 13       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 14       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 15       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 16       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 17       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 18       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 19       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 20       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 21       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 22       | ✓          | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 23       | ✓          | ✓          |                              |  |                               |  |                                 |  |

|                                                                                                              |                                                |                                                                      |
|--------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b>Search Notes</b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                              | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2616                                          |

| SEARCHED |                       |          |          |
|----------|-----------------------|----------|----------|
| Class    | Subclass              | Date     | Examiner |
| 370      | 203-210, 310, 342-345 | 10/23/08 | DL       |
| 455      | 562, 101              | 10/23/08 | DL       |

| SEARCH NOTES |          |          |
|--------------|----------|----------|
| Search Notes | Date     | Examiner |
| IEEE, EAST   | 10/23/08 | DL       |

| INTERFERENCE SEARCH |          |      |          |
|---------------------|----------|------|----------|
| Class               | Subclass | Date | Examiner |
|                     |          |      |          |

|  |  |
|--|--|
|  |  |
|--|--|

# **REQUEST FOR CONTINUED EXAMINATION(RCE)TRANSMITTAL** **(Submitted Only via EFS-Web)**

|                      |                 |             |            |                               |                 |          |      |
|----------------------|-----------------|-------------|------------|-------------------------------|-----------------|----------|------|
| Application Number   | 11121661        | Filing Date | 2005-05-04 | Docket Number (if applicable) | 08-1424-US      | Art Unit | 2416 |
| First Named Inventor | Mark A. Webster |             |            | Examiner Name                 | Levitan, Dmitry |          |      |

**This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.**

Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. The Instruction Sheet for this form is located at WWW.USPTO.GOV

## **SUBMISSION REQUIRED UNDER 37 CFR 1.114**

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on \_\_\_\_\_

☐ Other \_\_\_\_\_

☒ Enclosed

☒ Amendment/Reply

☐ Information Disclosure Statement (IDS)

☐ Affidavit(s)/ Declaration(s)

☐ Other \_\_\_\_\_

## **MISCELLANEOUS**

☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of months \_\_\_\_\_  
 (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

☐ Other \_\_\_\_\_

## **FEES**

**The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.**

☒ The Director is hereby authorized to charge any underpayment of fees, or credit any overpayments, to  
 Deposit Account No 132490

## **SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED**

☒ Patent Practitioner Signature

☐ Applicant Signature

| Signature of Registered U.S. Patent Practitioner |                        |                     |            |
|--------------------------------------------------|------------------------|---------------------|------------|
| Signature                                        | /Robert J. Irvine III/ | Date (YYYY-MM-DD)   | 2009-01-27 |
| Name                                             | Robert J. Irvine III   | Registration Number | 41865      |

This collection of information is required by 37 CFR 1.114. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450.

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

## Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
(Attorney Docket No. 08-1424-US)**

|                                          |   |                                 |
|------------------------------------------|---|---------------------------------|
| <b>In the Application of:</b>            | ) |                                 |
|                                          | ) |                                 |
| Mark A. Webster et al.                   | ) |                                 |
|                                          | ) | <b>Examiner:</b> Dmitry Levitan |
| <b>Serial No.:</b> 11/121,661            | ) |                                 |
|                                          | ) | <b>Group Art Unit:</b> 2416     |
| <b>Filing Date:</b> May 4, 2005          | ) |                                 |
|                                          | ) | <b>Confirmation No.:</b> 3553   |
| <b>For:</b> Cyclic Diversity Systems And | ) |                                 |
| Methods                                  | ) |                                 |

Mailstop RCE  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

**AMENDMENT AND REQUEST FOR CONTINUED EXAMINATION**

Dear Sir:

In response to the Final Office Action mailed on October 27, 2008, Applicants respectfully submit the following Amendments to Claims with Remarks, in conjunction with a Request for Continued Examination.

**Amendments to Claims** begin on page 2; **Remarks** begin on page 7 of this paper.

## AMENDMENTS TO CLAIMS

1-23. (Canceled)

24. (New) A method for transmitting orthogonal frequency division multiplexing (OFDM) signals to a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals, comprising:

generating an OFDM packet for transmission;

cyclically advancing the OFDM packet to generate one or more shifted versions of the OFDM packet for transmission; and

transmitting the OFDM packet and the one or more shifted versions of the OFDM packet to the legacy OFDM receiver, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.

25. (New) The method of claim 24, further comprising cyclically advancing the OFDM packet for a duration of less than approximately 800 nanoseconds.

26. (New) The method of claim 24, further comprising cyclically advancing the OFDM packet for a duration of less than one half of a guard interval.

27. (New) The method of claim 26, wherein, the duration of the cyclical advancement corresponds to a number of sample shifts in a cycle.

28. (New) The method of claim 24, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause the legacy receiver to produce a plurality of impulsive responses in an acquisition process, and wherein each of the OFDM packet and one

or more shifted version of the OFDM packet corresponds to one of the plurality of impulsive responses.

29. (New) The method of claim 24, further comprising transmitting the OFDM packet and the one or more shifted versions of the OFDM packet from a multiple-antenna transmitter device.

30. (New) The method of claim 29, wherein the impulse responses corresponding to the one or more shifted version of the OFDM packet occur earlier in time than the impulse responses corresponding to the OFDM packet.

31. (New) The method of claim 24, wherein the legacy OFDM receiver is a single-input, single-output (SISO) receiver device.

32. (New) A signal transmitting system for transmitting orthogonal frequency division multiplexing (OFDM) signals to a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals, comprising:

- a first transmit processor for generating a OFDM packet for transmission;

- a plurality of transmit processor for cyclically advancing the OFDM packet to generate one or more shifted versions of the OFDM packet for transmission;

- a plurality of radio transmitters for converting the OFDM packet and the one or more shifted versions of the OFDM packet to corresponding radio signals; and

- a plurality of radio antennas connected to the plurality of radio transmitters for transmitting the radio signals to the legacy OFDM receiver, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.



33. (New) The system of claim 32, wherein each of the plurality of transmit processor includes a cyclic extension module for performing the cyclical advancements.

34. (New) The system of claim 33, wherein each of the cyclic extension modules is configured to cyclically advance the OFDM packet for a duration of less than one half of guard interval.

35. (New) The system of claim 33, wherein each of the cyclic extension modules is configure to cyclically advance the OFDM packet for a duration of less than approximately 800 nanoseconds.

36. (New) The system of claim 32, wherein the first transmit processor is configured to receive incoming data and interleave the received data into a plurality of sub-carrier channels.

37. (New) The system of claim 32, wherein each of the plurality of transmit processors further includes an Inverse Fast Fourier (IFFT) module for generating OFDM symbols from incoming data.

38. (New) The system of claim 9, wherein the plurality of transmit processors perform the cyclical advancements on baseband signals.

39. (New) The system of claim 32, wherein, a duration of the cyclical advancement corresponds to a number of sample shifts in a cycle.

40. (New) The system of claim 32, wherein the first transmit processor and the plurality of transmit processors include application specific integrated circuits (ASICs).

41. (New) The system of claim 32, wherein the transmitter is an 802.11 compliant device.

42. (New) The system of claim 32, wherein the first transmit processor and the plurality of transmit processors include field programmable gate arrays (FPGAs).

43. (New) The system of claim 32, wherein the first transmit processor and the plurality of transmit processor include firmware stored in a memory device and executed by a suitable instruction execution system.

44. (New) A signal transmitting system for transmitting orthogonal frequency division multiplexing (OFDM) signals to a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals, comprising:

means for generating a OFDM packet for transmission;

means for cyclically advancing the OFDM packet to generate one or more shifted versions of the OFDM packet for transmission;

means for converting the OFDM packet and the one or more shifted versions of the OFDM packet to corresponding radio signals; and

means for transmitting the radio signals to the legacy OFDM receiver, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.

45. (New) The system of claim 44, wherein the cyclic advance has a duration less than one of half of a guard interval of the OFDM packet.

46. (New) The system of claim 44, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause the legacy receiver to produce a plurality of impulsive responses in an acquisition process, and wherein each of the OFDM packet and one

or more shifted version of the OFDM packet corresponds to one of the plurality of impulsive responses.

## REMARKS

### 1. Summary of the Office Action

In the Final Office Action mailed on October 27, 2008, the Examiner rejected claims 1, 9, 21 under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter, rejected 1, 3-7, 9-11, 13-16, and 19-23 under 35 U.S.C. 102(e) as being anticipated by Larsson (U.S. Patent No. 6,842,487), rejected claims 2 and 12 under 35 U.S.C. 103(a) as being obvious over Larsson, and rejected claims 8 and 17-18 as being obvious over Larsson in view of Admitted Prior Art.

### 2. Status of Claims

Applicants have canceled claims 1-23 and added new claims 24-46. Currently pending claims are claims 24-46 of which claims 24, 32, and 44 are in independent form and the remaining claims are in dependent form. No new matter is added.

### 3. Response to Rejections under 35 U.S.C. 112, Second Paragraph

As noted above, in the Final Office Action mailed on October 27, 2008, the Examiner rejected independent claims 1, 9, and 21 under U.S.C. 112, second paragraph as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. Applicants submit that the rejection is rendered moot by the present amendments, which have replaced the independent claims that particularly point out and distinctly claim the subject matter.

In rejecting claims 1, 9, and 21, the Examiner asserted that “advancing a portion of the signal is always relative to the other copy/duplicate of the signal, which is delayed, as advancing signal in time is physically impossible.” See the Final Office Action, page 2, lines 14-16. The pending claims recite “cyclically advancing the OFDM packet to generate one or more shifted versions of the OFDM packet...wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.” As further described in specification,

paragraph 0040 and Figure 8, the “cyclical advancement” set forth in the claims is accomplished by shifting the samples of the OFDM symbol in a direction opposite to that described by the prior art. Such “cyclical advancement” is imparted to the “one or more shifted versions of the OFDM packet” relative to the original OFDM packet. As further recited in claim 24, for a legacy receiver that aligns the FFT window based on detecting shifted versions of the OFDM signals, such cyclical advancement cause “an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.” This is clearly described in specification, paragraph 0041 that recites “unlike cyclic delay diversity, cyclic advance diversity does not result in net shifting of the FFT” since the legacy receiver places the FFT after the detection of the last impulse response that is aligned with the symbol boundary of the original OFDM packet. For the reasons set forth above, Applicants respectfully submit that the claims comply with § 112.

#### **4. Response to Rejections under 35 U.S.C. 102(e)**

In the Final Office Action, the Examiner rejected claim 1 under 35 U.S.C. 102(e) as being anticipated by Larsson. Applicants have submitted new claim 24 and respectfully submit that Larsson fails to teach or disclose the subject matter as now set forth in claim 24.

Specifically, claim 24 recites “A method for transmitting orthogonal frequency division multiplexing (OFDM) signals to a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals, comprising...cyclically advancing the OFDM packet...and transmitting the OFDM packet and the one or more shifted versions of the OFDM packet to the legacy OFDM receiver, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.” The Larsson reference, however, fails to suggest or disclose every element. First, Larsson merely describes a receiver having a fast Fourier transform window that is a set period of time. See Larsson, column 3, lines 18-23 and Figure 4. The FFT window as shown in Larsson, Figure 4, is not adjusted as the shifted versions of the OFDM packet are received. Larsson clearly fails to teach or suggest

that the OFDM signals are transmitted to “a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals” as set forth in claim 24. Second, Larsson describes applying a “cyclic delay” to an OFDM symbol by “shifting samples from the end of the OFDM symbol into the beginning of the OFDM symbol and adding a cyclic prefix by copying the last n samples of the OFDM symbol.” See Larsson, column 6, lines 45-49 and Figure 8. Larsson, however, does not appear to suggest the “cyclical advancements” be applied to the OFDM packet as set forth in claim 24. In fact, as described in the specification, the “cyclic delay” described by Larsson would cause the legacy receiver to shift the FFT window into the subsequent symbol and thereby cause intersymbol interference since the intentional cyclic delay is “indistinguishable from the sample shifting that occurs in linear delay diversity” from the receiver standpoint. On the contrary, during the acquisition process, the cyclical advancement as set forth in claim 24 would cause the impulse responses corresponding to the shifted versions of the OFDM packet to occur before the impulse response of the unshifted OFDM packet, thereby preventing the erroneous alignment of the FFT window. For the reasons set forth above, Applicants submit that claim 24 is not anticipated by Larsson.

With respect to claims 32 and 44, Applicants point out that they include similar limitations of claim 24 and therefore are not anticipated by Larsson for at least the same reasons set forth above. Therefore, Applicants respectfully submit that they in condition for allowance.

With respect to the remaining claims, Applicants point out that they depend from independent claims 24, 32, and 44 and therefore are not anticipated by Larsson for at least the same reasons set forth above.

## **5. Response to Rejections under 35 U.S.C. 103 (a)**

With respect to the obviousness rejections, Applicants submit that the deficiencies of Larsson remain even in view of the secondary references, and therefore are patentably distinguished from Larsson for at least the same reasons set forth above.

**6. Conclusion**

In view of the above, Applicant submits that the application is in condition for allowance and respectfully requests the Examiner pass this application to issue. If, in the opinion of the Examiner, a telephone conference would expedite the prosecution of this application, the Examiner is invited to call the undersigned attorney at 312-913-3305.

Respectfully submitted,

McDONNELL BOEHNEN  
HULBERT & BERGHOFF LLP

Date: January 27, 2009

By: /Robert J. Irvine III/  
Robert J. Irvine III  
Registration No.

## Electronic Patent Application Fee Transmittal

|                                                |                                      |                 |               |                             |
|------------------------------------------------|--------------------------------------|-----------------|---------------|-----------------------------|
| <b>Application Number:</b>                     | 11121661                             |                 |               |                             |
| <b>Filing Date:</b>                            | 04-May-2005                          |                 |               |                             |
| <b>Title of Invention:</b>                     | Cyclic diversity systems and methods |                 |               |                             |
| <b>First Named Inventor/Applicant Name:</b>    | Mark A. Webster                      |                 |               |                             |
| <b>Filer:</b>                                  | Robert Johnson Irvine                |                 |               |                             |
| <b>Attorney Docket Number:</b>                 | 050337-1020                          |                 |               |                             |
| Filed as Large Entity                          |                                      |                 |               |                             |
| <b>Utility under 35 USC 111(a) Filing Fees</b> |                                      |                 |               |                             |
| <b>Description</b>                             | <b>Fee Code</b>                      | <b>Quantity</b> | <b>Amount</b> | <b>Sub-Total in USD(\$)</b> |
| <b>Basic Filing:</b>                           |                                      |                 |               |                             |
| <b>Pages:</b>                                  |                                      |                 |               |                             |
| <b>Claims:</b>                                 |                                      |                 |               |                             |
| <b>Miscellaneous-Filing:</b>                   |                                      |                 |               |                             |
| <b>Petition:</b>                               |                                      |                 |               |                             |
| <b>Patent-Appeals-and-Interference:</b>        |                                      |                 |               |                             |
| <b>Post-Allowance-and-Post-Issuance:</b>       |                                      |                 |               |                             |
| <b>Extension-of-Time:</b>                      |                                      |                 |               |                             |



| Description                       | Fee Code | Quantity | Amount | Sub-Total in USD(\$) |
|-----------------------------------|----------|----------|--------|----------------------|
| <b>Miscellaneous:</b>             |          |          |        |                      |
| Request for continued examination | 1801     | 1        | 810    | 810                  |
| <b>Total in USD (\$)</b>          |          |          |        | <b>810</b>           |

## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 4676448                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | Cyclic diversity systems and methods |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 24504                                |
| <b>Filer:</b>                               | Robert Johnson Irvine                |
| <b>Filer Authorized By:</b>                 |                                      |
| <b>Attorney Docket Number:</b>              | 050337-1020                          |
| <b>Receipt Date:</b>                        | 27-JAN-2009                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 18:59:26                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                                          |                 |
|------------------------------------------|-----------------|
| Submitted with Payment                   | yes             |
| Payment Type                             | Deposit Account |
| Payment was successfully received in RAM | \$810           |
| RAM confirmation Number                  | 4280            |
| Deposit Account                          | 132490          |
| Authorized User                          |                 |

### File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/<br>Message Digest | Multi Part /.zip | Pages (if appl.) |
|-----------------|----------------------|-----------|-------------------------------------|------------------|------------------|
|-----------------|----------------------|-----------|-------------------------------------|------------------|------------------|

|                              |                                                     |                          |                                          |     |    |
|------------------------------|-----------------------------------------------------|--------------------------|------------------------------------------|-----|----|
| 1                            | Power of Attorney                                   | POA.pdf                  | 43382                                    | no  | 1  |
|                              |                                                     |                          | 3df8a49bb4ba5c215c99eed21e056b57eedb4020 |     |    |
| Warnings:                    |                                                     |                          |                                          |     |    |
| Information:                 |                                                     |                          |                                          |     |    |
| 2                            | Miscellaneous Incoming Letter                       | Appendix_2.pdf           | 85626                                    | no  | 9  |
|                              |                                                     |                          | fa5eaa27409146615f6a72fac3ff33ea2b2cb77c |     |    |
| Warnings:                    |                                                     |                          |                                          |     |    |
| Information:                 |                                                     |                          |                                          |     |    |
| 3                            | Assignee showing of ownership per 37 CFR 3.73(b).   | 08-1424-US-Statement.pdf | 74520                                    | no  | 1  |
|                              |                                                     |                          | 08898d86246721156d32a49a885af9c89bbf29df |     |    |
| Warnings:                    |                                                     |                          |                                          |     |    |
| Information:                 |                                                     |                          |                                          |     |    |
| 4                            | Request for Continued Examination (RCE)             | 08-1424-US-RCE-REQ.pdf   | 792354                                   | no  | 3  |
|                              |                                                     |                          | f6c18ed2236be746c464e52d89a0f0d20ee7df3c |     |    |
| Warnings:                    |                                                     |                          |                                          |     |    |
| Information:                 |                                                     |                          |                                          |     |    |
| 5                            |                                                     | 08-1424-US-RCE.pdf       | 95855                                    | yes | 10 |
|                              |                                                     |                          | 35397ff3338457b4719c6afea199e8fc6cb24543 |     |    |
|                              | Multipart Description/PDF files in .zip description |                          |                                          |     |    |
|                              | Document Description                                |                          | Start                                    | End |    |
|                              | Amendment Submitted/Entered with Filing of CPA/RCE  |                          | 1                                        | 1   |    |
|                              | Claims                                              |                          | 2                                        | 6   |    |
|                              | Applicant Arguments/Remarks Made in an Amendment    |                          | 7                                        | 10  |    |
| Warnings:                    |                                                     |                          |                                          |     |    |
| Information:                 |                                                     |                          |                                          |     |    |
| 6                            | Fee Worksheet (PTO-06)                              | fee-info.pdf             | 29910                                    | no  | 2  |
|                              |                                                     |                          | 8f3ecd56307ee68ebd81f37695dfb863dd373014 |     |    |
| Warnings:                    |                                                     |                          |                                          |     |    |
| Information:                 |                                                     |                          |                                          |     |    |
| Total Files Size (in bytes): |                                                     |                          | 1121647                                  |     |    |

**This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.**

**New Applications Under 35 U.S.C. 111**

**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**

**National Stage of an International Application under 35 U.S.C. 371**

**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**

**New International Application Filed with the USPTO as a Receiving Office**

**If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.**

**POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO**

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☒ Practitioners associated with the Customer Number:  
OR

20306

☐ Practitioner(s) named below (If more than ten patent practitioners are to be named, then a customer number must be used):

| Name | Registration Number | Name | Registration Number |
|------|---------------------|------|---------------------|
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

☒ The address associated with Customer Number:  
OR

20306

|                                                  |       |     |  |
|--------------------------------------------------|-------|-----|--|
| <input type="checkbox"/> Firm or Individual Name |       |     |  |
| Address                                          |       |     |  |
| City                                             | State | Zip |  |
| Country                                          |       |     |  |
| Telephone                                        | Email |     |  |

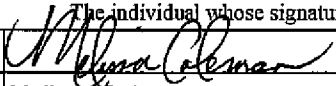
Assignee Name and Address:

Xocyst Transfer AG L.L.C.  
2711 Centerville Road, Suite 400  
Wilmington, DE 19808

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

**SIGNATURE of Assignee of Record**

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

|           |                                                                                     |           |         |
|-----------|-------------------------------------------------------------------------------------|-----------|---------|
| Signature |  | Date      | 12.9.08 |
| Name      | Melissa Coleman                                                                     | Telephone |         |
| Title     | Authorized Person for Xocyst Transfer AG L.L.C.                                     |           |         |

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

American LegalNet, Inc.  
www.USCourtForms.com

**APPENDIX**  
Issued Patents

| Line No. | Patent Number | Title                                                                                                  | Issue Date | Recordation Information                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|---------------|--------------------------------------------------------------------------------------------------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.       | 5,828,692     | BASEBAND DEMODULATOR FOR POLAR OR RECTANGULAR MODULATED SIGNAL IN A CORDLESS SPREAD SPECTRUM TELEPHONE | 10/27/1998 | <p>Reel/Frame: 007898/0071<br/> Assignors: WALLEY, JOHN S.<br/> Assignee: ROCKWELL INTERNATIONAL CORPORATION</p> <p>Reel/Frame: 018847/0871<br/> Assignors: ROCKWELL INTERNATIONAL CORPORATION<br/> Assignee: ROCKWELL SCIENCE CENTER, INC.</p> <p>Reel/Frame: 010415/0761<br/> Assignors: ROCKWELL SCIENCE CENTER, LLC<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p> |
| 2.       | 6,353,413     | MULTI-FUNCTION UNIVERSAL CONTROLLER AND LOCATOR SYSTEMS                                                | 03/05/2002 | <p>Reel/Frame: 020031/0952<br/> Assignors: WHITE, STANLEY A., ET AL.<br/> Assignee: ROCKWELL SCIENCE CENTER, INC.</p> <p>Reel/Frame: 020035/0018<br/> Assignors: ROCKWELL SCIENCE CENTER, LLC<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p>                                                                                                                           |
| 3.       | 7,174,138     | POWER-BASED HARDWARE DIVERSITY                                                                         | 02/06/2007 | <p>Reel/Frame: 016013/0386<br/> Assignors: WEBSTER, MARK A., ET AL.<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p>                                                                                                                                                                                                                                                     |
| 4.       | 7,447,261     | ADAPTIVE FREQUENCY EQUALIZER                                                                           | 11/04/2008 | <p>Reel/Frame: 015990/0117<br/> Assignors: SHEARER, DANIEL D., ET AL.<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p>                                                                                                                                                                                                                                                   |
| 5.       | 7,398,408     | SYSTEMS AND METHODS FOR WAKING UP WIRELESS LAN DEVICES                                                 | 07/08/2008 | <p>Reel/Frame: 016028/0948<br/> Assignors: PALJUG, MICHAEL, ET AL.<br/> Assignee: CONEXANT SYSTEMS, INC.</p>                                                                                                                                                                                                                                                                                                                                                                     |

|    |           |                                  |            |                                                                                                                                                                                                               |
|----|-----------|----------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |           |                                  |            | Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                           |
| 6. | 7,272,109 | MODIFIED OFDM SUBCARRIER PROFILE | 09/18/2007 | Reel/Frame: 016208/0511<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |

**APPENDIX**  
Pending Applications

| Line No. | Application Number | Title                                                                                                                          | Filing Date | Recordation Information                                                                                                                                                                                               |
|----------|--------------------|--------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7.       | 10/977,469         | INDEPENDENT DIRECT LINK PROTOCOL                                                                                               | 11/01/2004  | Reel/Frame: 016329/0091<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 8.       | 10/977,470         | AUTOMATIC PEER DISCOVERY                                                                                                       | 11/01/2004  | Reel/Frame: 016329/0098<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 9.       | 10/977,490         | LOCATION AWARENESS IN WIRELESS NETWORKS                                                                                        | 11/01/2004  | Reel/Frame: 016276/0300<br>Assignors: GODFREY, TIMOTHY<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                 |
| 10.      | 11/035,065         | POWER MANAGEMENT FOR WIRELESS DIRECT LINK                                                                                      | 01/14/2005  | Reel/Frame: 016176/0192<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 11.      | 11/839,152         | METHOD FOR MITIGATING ADVERSE PROCESSOR LOADING IN A PERSONAL COMPUTER IMPLEMENTATION OF A WIRELESS LOCAL AREA NETWORK ADAPTER | 08/15/2007  | Reel/Frame: 021340/0829<br>Assignors: SCHULTZ, RICHARD DOUGLAS, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 12.      | 10/830,570         | SIGNALING EXTENDED FUNCTIONALITY AND MANAGEMENT INFORMATION IN A NETWORK                                                       | 04/23/2004  | Reel/Frame: 014759/0610<br>Assignors: FISCHER, MICHAEL ANDREW, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.  |
| 13.      | 10/830,575         | MANAGING COEXISTENCE OF SEPARATE PROTOCOLS SHARING THE SAME COMMUNICATIONS CHANNEL                                             | 04/23/2004  | Reel/Frame: 014874/0546<br>Assignors: FISCHER, MICHAEL ANDREW, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.                                                                                                             |



|     |            |                                                                                                           |            |                                                                                                                                                                                                                      |
|-----|------------|-----------------------------------------------------------------------------------------------------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                                                                           |            | Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                                  |
| 14. | 10/861,064 | MANAGING AN ACCESS POINT IN THE PRESENCE OF SEPARATE PROTOCOLS THAT SHARE THE SAME COMMUNICATIONS CHANNEL | 06/04/2004 | Reel/Frame: 014874/0569<br>Assignors: GODFREY, TIMOTHY GORDON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 15. | 10/861,065 | INTELLIGENT DOWNSTREAM TRAFFIC DELIVERY TO MULTI-PROTOCOL STATIONS                                        | 06/04/2004 | Reel/Frame: 014874/0569<br>Assignors: GODFREY, TIMOTHY GORDON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 16. | 10/861,066 | METHOD AND APPARATUS FOR VEHICLE TRACKING AND CONTROL                                                     | 06/04/2004 | Reel/Frame: 015434/0482<br>Assignors: GODFREY, TIMOTHY GORDON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 17. | 12/168,706 | SYSTEMS AND METHODS FOR WAKE-ON-LAN FOR WIRELESS LAN DEVICES                                              | 07/07/2008 | Reel/Frame: 021443/0717<br>Assignors: PALJUG, MICHAEL<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                 |
| 18. | 11/033,524 | METHOD AND SYSTEM FOR HIGH DATA RATE MULTI-CHANNEL WLAN ARCHITECTURE                                      | 01/12/2005 | Reel/Frame: 016506/0056<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 19. | 11/083,080 | MULTICHANNEL MAC DATA STREAM FOR WIRELESS COMMUNICATION                                                   | 03/18/2005 | Reel/Frame: 018862/0395<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                  |
| 20. | 11/105,909 | DUAL MODE COMMUNICATION SYSTEMS AND METHODS                                                               | 04/13/2005 | Reel/Frame: 016654/0241<br>Assignors: SEALS, MICHAEL J., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607                                                                                   |

|     |            |                                                                             |            |                                                                                                                                                                                                               |
|-----|------------|-----------------------------------------------------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                                             |            | Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                                                      |
| 21. | 11/106,915 | PACKET GENERATION SYSTEMS AND METHODS                                       | 04/15/2005 | Reel/Frame: 016200/0420<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 22. | 11/121,661 | CYCLIC DIVERSITY SYSTEMS AND METHODS                                        | 05/04/2005 | Reel/Frame: 016541/0490<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 23. | 11/159,812 | LEGACY COMPATIBLE SPATIAL MULTIPLEXING SYSTEMS AND METHODS                  | 06/22/2005 | Reel/Frame: 016639/0012<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 24. | 11/186,260 | PACKET PROCESSING SYSTEMS AND METHODS                                       | 07/21/2005 | Reel/Frame: 016678/0134<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 25. | 11/185,665 | PACKET GENERATION SYSTEMS AND METHODS                                       | 07/20/2005 | Reel/Frame: 016643/0802<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 26. | 11/203,617 | SYSTEMS AND METHODS FOR DECREASING LATENCY IN A DIGITAL TRANSMISSION SYSTEM | 08/12/2005 | Reel/Frame: 018804/0373<br>Assignors: HEDBERG, DAVID, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.   |
| 27. | 11/433,599 | CODING SYSTEMS AND METHODS                                                  | 05/12/2006 | Reel/Frame: 017865/0305<br>Assignors: HEDBERG, DAVID<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 28. | 11/314,143 | SYSTEMS AND METHODS FOR THE CONNECTION AND REMOTE CONFIGURATION             | 12/21/2005 | Reel/Frame: 017404/0053<br>Assignors: WENTINK, MENZO, ET AL.                                                                                                                                                  |

|     |            |                                                                                                    |            |                                                                                                                                                                                                                     |
|-----|------------|----------------------------------------------------------------------------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            | OF WIRELESS CLIENTS                                                                                |            | Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                         |
| 29. | 11/314,149 | SYSTEMS AND METHODS FOR DEVICE DISCOVERY                                                           | 12/21/2005 | Reel/Frame: 017416/0241<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.       |
| 30. | 11/410,707 | BEAMFORMING SYSTEMS AND METHODS                                                                    | 04/25/2006 | Reel/Frame: 018043/0355<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.       |
| 31. | 11/411,619 | SYSTEMS AND METHODS FOR TRANSMITTER DIVERSITY EXPANSION                                            | 04/26/2006 | Reel/Frame: 018043/0463<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.       |
| 32. | 11/448,603 | METHOD OF CODING DATA                                                                              | 06/06/2006 | Reel/Frame: 018176/0506<br>Assignors: MITTELSTEADT, CIMARRON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 33. | 11/549,438 | MAC PROTECTION                                                                                     | 10/13/2006 | Reel/Frame: 018389/0627<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.         |
| 34. | 11/555,916 | HIGH-POTENCY SWEETENER COMPOSITION WITH PROBIOTICS/PREBIOTICS AND COMPOSITIONS SWEETENED THEREWITH | 11/02/2006 | Reel/Frame: 018521/0176<br>Assignors: PRAKASH, INDRA, ET AL.<br>Assignee: THE COCA-COLA COMPANY<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.          |
| 35. | 11/557,516 | COLLISION AVOIDANCE SYSTEMS AND METHODS                                                            | 11/08/2006 | Reel/Frame: 018493/0986<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607                                                                                             |

|     |            |                                                  |            |                                                                                                                                                                                                            |
|-----|------------|--------------------------------------------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                  |            | Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                                                   |
| 36. | 11/651,879 | SYMMETRIC TRANSMIT OPPORTUNITY (TXOP) TRUNCATION | 01/10/2007 | Reel/Frame: 018782/0584<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 37. | 11/613,020 | MORE POWER SAVE MULTI-POLL INDICATION            | 12/19/2006 | Reel/Frame: 018995/0126<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 38. | 11/627,181 | TRANSMIT ANNOUNCEMENT INDICATION                 | 01/25/2007 | Reel/Frame: 020630/0654<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 39. | 11/638,157 | DUAL CTS PROTECTION SYSTEMS AND METHODS          | 12/13/2006 | Reel/Frame: 018680/0742<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 40. | 11/680,612 | METHODS AND SYSTEMS FOR LDPC CODING              | 02/28/2007 | Reel/Frame: 019555/0669<br>Assignors: KOSE, CENK<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.            |
| 41. | 11/683,526 | TRANSMISSION USING A PLURALITY OF PROTOCOLS      | 03/08/2007 | Reel/Frame: 018980/0592<br>Assignors: CARTER, TRENT, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 42. | 11/686,147 | POWER SAVE IMPROVEMENT                           | 03/14/2007 | Reel/Frame: 019011/0698<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 43. | 11/688,274 | SLEEP MODE SYSTEMS AND METHODS                   | 03/20/2007 | Reel/Frame: 019033/0419<br>Assignors: CARTER, TRENT R.                                                                                                                                                     |

|     |            |                                                                                                                                      |            |                                                                                                                                                                                                                        |
|-----|------------|--------------------------------------------------------------------------------------------------------------------------------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                                                                                                      |            | Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                            |
| 44. | 11/750,684 | ACCESS POINT POLLING SYSTEMS AND METHODS                                                                                             | 05/18/2007 | Reel/Frame: 019374/0776<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                    |
| 45. | 11/750,693 | COMMUNICATION ROAMING SYSTEMS AND METHODS                                                                                            | 05/18/2007 | Reel/Frame: 019315/0231<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                    |
| 46. | 10/460,684 | METHOD FOR MINIMIZING RECEIVE PACKAGE PROCESSING FOR A PERSONAL COMPUTER IMPLEMENTATION OF A WIRELESS LOCAL AREA NETWORK ADAPTER     | 06/12/2003 | REEL/FRAAME: 018000/0476<br>ASSIGNORS: SCHULTZ, RICHARD DOUGLAS ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C. |
| 47. | 10/625,799 | METHOD FOR MITIGATING ADVERSE PROCESSOR LOADING IN A PERSONAL COMPUTER IMPLEMENTATION OF A WIRELESS LOCAL AREA NETWORK ADAPTER       | 07/23/2003 | REEL/FRAAME: 018000/ 0130<br>ASSIGNORS: SCHULTZ, RICHARD, ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C.       |
| 48. | 12/246,219 | ADAPTIVE FREQUENCY EQUALIZER                                                                                                         | 10/06/2008 | REEL/FRAAME: 015990/0117<br>ASSIGNORS: SHEARER, DANIEL D., ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C.      |
| 49. | 11/239,657 | SYSTEM AND METHOD FOR NON-INTERFERING SIGNALING AND RECEPTION OF OVERLAPPING SINGLE CARRIER TRANSMISSIONS OVER DELAY SPREAD CHANNELS | 09/28/2005 | REEL/FRAAME: 018307/0337<br>ASSIGNORS: EIDSON, DONALD BRIAN<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C.            |
| 50. | 11/556,916 | SYSTEMS AND METHODS FOR FACILITATING COMMUNICATION BETWEEN COMMUNICATION DEVICES                                                     | 11/06/2006 | REEL/FRAAME: 018789/0982<br>ASSIGNORS: WENTINK, MENZO, ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022134/0518                                                                                      |

|  |  |  |  |                                                                          |
|--|--|--|--|--------------------------------------------------------------------------|
|  |  |  |  | ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C. |
|--|--|--|--|--------------------------------------------------------------------------|

**STATEMENT UNDER 37 CFR 3.73(b)**Applicant/Patent Owner: XOCYST TRANSFER AG L.L.C.Application No./Patent No.: 11/121,661 Filed/Issue Date: 05/04/2005Entitled: CYCLIC DIVERSITY SYSTEMS AND METHODSXOCYST TRANSFER AG L.L.C., a corporation

(Name of Assignee)

(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest; or
2. ☐ an assignee of less than the entire right, title and interest  
(The extent (by percentage) of its ownership interest is \_\_\_\_\_%)

in the patent application/patent identified above by virtue of either:

- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

**OR**

- B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: See attached Appendix, line 22 To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.
2. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.
3. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

☒ Additional documents in the chain of title are listed on a supplemental sheet.☒ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Robert J. Irvine III/

Signature

Robert J. Irvine III

Printed or Typed Name

Attorney of Record

Title

January 23, 2009

Date

312-913-0001

Telephone Number

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| <b>PATENT APPLICATION FEE DETERMINATION RECORD</b><br>Substitute for Form PTO-875                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                               |                                  |                                    |               | Application or Docket Number<br><b>11/121,661</b> |                     | Filing Date<br><b>05/04/2005</b> |                     | <input type="checkbox"/> To be Mailed |          |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|------------------------------------|---------------|---------------------------------------------------|---------------------|----------------------------------|---------------------|---------------------------------------|----------|---|
| <b>APPLICATION AS FILED – PART I</b>                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               | SMALL ENTITY <input type="checkbox"/>             |                     | OR                               |                     | OTHER THAN SMALL ENTITY               |          |   |
| FOR                                                                                                                                                                                                                                                                                                                                                                                                                                  | NUMBER FILED                                                                                                                                                                                                                  | NUMBER EXTRA                     | RATE (\$)                          | FEE (\$)      | RATE (\$)                                         | FEE (\$)            |                                  |                     |                                       |          |   |
| <input type="checkbox"/> BASIC FEE<br>(37 CFR 1.16(a), (b), or (c))                                                                                                                                                                                                                                                                                                                                                                  | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               | N/A                                               |                     |                                  |                     |                                       |          |   |
| <input type="checkbox"/> SEARCH FEE<br>(37 CFR 1.16(k), (l), or (m))                                                                                                                                                                                                                                                                                                                                                                 | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               | N/A                                               |                     |                                  |                     |                                       |          |   |
| <input type="checkbox"/> EXAMINATION FEE<br>(37 CFR 1.16(o), (p), or (q))                                                                                                                                                                                                                                                                                                                                                            | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               | N/A                                               |                     |                                  |                     |                                       |          |   |
| TOTAL CLAIMS<br>(37 CFR 1.16(i))                                                                                                                                                                                                                                                                                                                                                                                                     | minus 20 =                                                                                                                                                                                                                    | *                                | X \$                               | =             | OR                                                | X \$                | =                                |                     |                                       |          |   |
| INDEPENDENT CLAIMS<br>(37 CFR 1.16(h))                                                                                                                                                                                                                                                                                                                                                                                               | minus 3 =                                                                                                                                                                                                                     | *                                | X \$                               | =             | OR                                                | X \$                | =                                |                     |                                       |          |   |
| <input type="checkbox"/> APPLICATION SIZE FEE<br>(37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                    | If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| <input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| * If the difference in column 1 is less than zero, enter "0" in column 2.                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                               |                                  | TOTAL                              |               | TOTAL                                             |                     |                                  |                     |                                       |          |   |
| <b>APPLICATION AS AMENDED – PART II</b>                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               | (Column 3)                                        |                     | SMALL ENTITY                     |                     | OR OTHER THAN SMALL ENTITY            |          |   |
| AMENDMENT                                                                                                                                                                                                                                                                                                                                                                                                                            | 01/27/2009                                                                                                                                                                                                                    | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE (\$)                                         | ADDITIONAL FEE (\$) | RATE (\$)                        | ADDITIONAL FEE (\$) |                                       |          |   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Total (37 CFR 1.16(i))                                                                                                                                                                                                        | * 23                             | Minus                              | ** 23         | =                                                 | 0                   | X \$                             | =                   | OR                                    | X \$52=  | 0 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Independent (37 CFR 1.16(h))                                                                                                                                                                                                  | * 3                              | Minus                              | *** 3         | =                                                 | 0                   | X \$                             | =                   | OR                                    | X \$220= | 0 |
| <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| TOTAL ADD'L FEE                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     | OR                               | TOTAL ADD'L FEE     | 0                                     |          |   |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               | (Column 3)                                        |                     | SMALL ENTITY                     |                     | OR OTHER THAN SMALL ENTITY            |          |   |
| AMENDMENT                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                               | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE (\$)                                         | ADDITIONAL FEE (\$) | RATE (\$)                        | ADDITIONAL FEE (\$) |                                       |          |   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Total (37 CFR 1.16(i))                                                                                                                                                                                                        | *                                | Minus                              | **            | =                                                 |                     | X \$                             | =                   | OR                                    | X \$     | = |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Independent (37 CFR 1.16(h))                                                                                                                                                                                                  | *                                | Minus                              | ***           | =                                                 |                     | X \$                             | =                   | OR                                    | X \$     | = |
| <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |
| TOTAL ADD'L FEE                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     | OR                               | TOTAL ADD'L FEE     |                                       |          |   |
| <p>* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.</p> <p>** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".</p> <p>*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".</p> <p>The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.</p> |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |          |   |

Legal Instrument Examiner:  
/DEBORAH NASH/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



**POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO**

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☒ Practitioners associated with the Customer Number:  
OR

20306

☐ Practitioner(s) named below (If more than ten patent practitioners are to be named, then a customer number must be used):

| Name | Registration Number | Name | Registration Number |
|------|---------------------|------|---------------------|
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

☒ The address associated with Customer Number:  
OR

20306

|                                                  |       |     |  |
|--------------------------------------------------|-------|-----|--|
| <input type="checkbox"/> Firm or Individual Name |       |     |  |
| Address                                          |       |     |  |
| City                                             | State | Zip |  |
| Country                                          |       |     |  |
| Telephone                                        | Email |     |  |

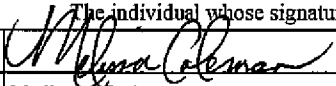
Assignee Name and Address:

Xocyst Transfer AG L.L.C.  
2711 Centerville Road, Suite 400  
Wilmington, DE 19808

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

**SIGNATURE of Assignee of Record**

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

|           |                                                                                     |           |         |
|-----------|-------------------------------------------------------------------------------------|-----------|---------|
| Signature |  | Date      | 12.9.08 |
| Name      | Melissa Coleman                                                                     | Telephone |         |
| Title     | Authorized Person for Xocyst Transfer AG L.L.C.                                     |           |         |

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

American LegalNet, Inc.  
www.USCourtForms.com

**APPENDIX**  
Issued Patents

| Line No. | Patent Number | Title                                                                                                  | Issue Date | Recordation Information                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|---------------|--------------------------------------------------------------------------------------------------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.       | 5,828,692     | BASEBAND DEMODULATOR FOR POLAR OR RECTANGULAR MODULATED SIGNAL IN A CORDLESS SPREAD SPECTRUM TELEPHONE | 10/27/1998 | <p>Reel/Frame: 007898/0071<br/> Assignors: WALLEY, JOHN S.<br/> Assignee: ROCKWELL INTERNATIONAL CORPORATION</p> <p>Reel/Frame: 018847/0871<br/> Assignors: ROCKWELL INTERNATIONAL CORPORATION<br/> Assignee: ROCKWELL SCIENCE CENTER, INC.</p> <p>Reel/Frame: 010415/0761<br/> Assignors: ROCKWELL SCIENCE CENTER, LLC<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p> |
| 2.       | 6,353,413     | MULTI-FUNCTION UNIVERSAL CONTROLLER AND LOCATOR SYSTEMS                                                | 03/05/2002 | <p>Reel/Frame: 020031/0952<br/> Assignors: WHITE, STANLEY A., ET AL.<br/> Assignee: ROCKWELL SCIENCE CENTER, INC.</p> <p>Reel/Frame: 020035/0018<br/> Assignors: ROCKWELL SCIENCE CENTER, LLC<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p>                                                                                                                           |
| 3.       | 7,174,138     | POWER-BASED HARDWARE DIVERSITY                                                                         | 02/06/2007 | <p>Reel/Frame: 016013/0386<br/> Assignors: WEBSTER, MARK A., ET AL.<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p>                                                                                                                                                                                                                                                     |
| 4.       | 7,447,261     | ADAPTIVE FREQUENCY EQUALIZER                                                                           | 11/04/2008 | <p>Reel/Frame: 015990/0117<br/> Assignors: SHEARER, DANIEL D., ET AL.<br/> Assignee: CONEXANT SYSTEMS, INC.</p> <p>Reel/Frame: 022043/0607<br/> Assignors: CONEXANT SYSTEMS, INC.<br/> Assignee: XOCYST TRANSFER AG L.L.C.</p>                                                                                                                                                                                                                                                   |
| 5.       | 7,398,408     | SYSTEMS AND METHODS FOR WAKING UP WIRELESS LAN DEVICES                                                 | 07/08/2008 | <p>Reel/Frame: 016028/0948<br/> Assignors: PALJUG, MICHAEL, ET AL.<br/> Assignee: CONEXANT SYSTEMS, INC.</p>                                                                                                                                                                                                                                                                                                                                                                     |

|    |           |                                  |            |                                                                                                                                                                                                               |
|----|-----------|----------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |           |                                  |            | Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                           |
| 6. | 7,272,109 | MODIFIED OFDM SUBCARRIER PROFILE | 09/18/2007 | Reel/Frame: 016208/0511<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |

**APPENDIX**  
Pending Applications

| Line No. | Application Number | Title                                                                                                                          | Filing Date | Recordation Information                                                                                                                                                                                               |
|----------|--------------------|--------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7.       | 10/977,469         | INDEPENDENT DIRECT LINK PROTOCOL                                                                                               | 11/01/2004  | Reel/Frame: 016329/0091<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 8.       | 10/977,470         | AUTOMATIC PEER DISCOVERY                                                                                                       | 11/01/2004  | Reel/Frame: 016329/0098<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 9.       | 10/977,490         | LOCATION AWARENESS IN WIRELESS NETWORKS                                                                                        | 11/01/2004  | Reel/Frame: 016276/0300<br>Assignors: GODFREY, TIMOTHY<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                 |
| 10.      | 11/035,065         | POWER MANAGEMENT FOR WIRELESS DIRECT LINK                                                                                      | 01/14/2005  | Reel/Frame: 016176/0192<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 11.      | 11/839,152         | METHOD FOR MITIGATING ADVERSE PROCESSOR LOADING IN A PERSONAL COMPUTER IMPLEMENTATION OF A WIRELESS LOCAL AREA NETWORK ADAPTER | 08/15/2007  | Reel/Frame: 021340/0829<br>Assignors: SCHULTZ, RICHARD DOUGLAS, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 12.      | 10/830,570         | SIGNALING EXTENDED FUNCTIONALITY AND MANAGEMENT INFORMATION IN A NETWORK                                                       | 04/23/2004  | Reel/Frame: 014759/0610<br>Assignors: FISCHER, MICHAEL ANDREW, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.  |
| 13.      | 10/830,575         | MANAGING COEXISTENCE OF SEPARATE PROTOCOLS SHARING THE SAME COMMUNICATIONS CHANNEL                                             | 04/23/2004  | Reel/Frame: 014874/0546<br>Assignors: FISCHER, MICHAEL ANDREW, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.                                                                                                             |

|     |            |                                                                                                           |            |                                                                                                                                                                                                                      |
|-----|------------|-----------------------------------------------------------------------------------------------------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                                                                           |            | Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                                  |
| 14. | 10/861,064 | MANAGING AN ACCESS POINT IN THE PRESENCE OF SEPARATE PROTOCOLS THAT SHARE THE SAME COMMUNICATIONS CHANNEL | 06/04/2004 | Reel/Frame: 014874/0569<br>Assignors: GODFREY, TIMOTHY GORDON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 15. | 10/861,065 | INTELLIGENT DOWNSTREAM TRAFFIC DELIVERY TO MULTI-PROTOCOL STATIONS                                        | 06/04/2004 | Reel/Frame: 014874/0569<br>Assignors: GODFREY, TIMOTHY GORDON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 16. | 10/861,066 | METHOD AND APPARATUS FOR VEHICLE TRACKING AND CONTROL                                                     | 06/04/2004 | Reel/Frame: 015434/0482<br>Assignors: GODFREY, TIMOTHY GORDON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 17. | 12/168,706 | SYSTEMS AND METHODS FOR WAKE-ON-LAN FOR WIRELESS LAN DEVICES                                              | 07/07/2008 | Reel/Frame: 021443/0717<br>Assignors: PALJUG, MICHAEL<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                 |
| 18. | 11/033,524 | METHOD AND SYSTEM FOR HIGH DATA RATE MULTI-CHANNEL WLAN ARCHITECTURE                                      | 01/12/2005 | Reel/Frame: 016506/0056<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 19. | 11/083,080 | MULTICHANNEL MAC DATA STREAM FOR WIRELESS COMMUNICATION                                                   | 03/18/2005 | Reel/Frame: 018862/0395<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                  |
| 20. | 11/105,909 | DUAL MODE COMMUNICATION SYSTEMS AND METHODS                                                               | 04/13/2005 | Reel/Frame: 016654/0241<br>Assignors: SEALS, MICHAEL J., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607                                                                                   |

|     |            |                                                                             |            |                                                                                                                                                                                                               |
|-----|------------|-----------------------------------------------------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                                             |            | Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                                                      |
| 21. | 11/106,915 | PACKET GENERATION SYSTEMS AND METHODS                                       | 04/15/2005 | Reel/Frame: 016200/0420<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 22. | 11/121,661 | CYCLIC DIVERSITY SYSTEMS AND METHODS                                        | 05/04/2005 | Reel/Frame: 016541/0490<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 23. | 11/159,812 | LEGACY COMPATIBLE SPATIAL MULTIPLEXING SYSTEMS AND METHODS                  | 06/22/2005 | Reel/Frame: 016639/0012<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 24. | 11/186,260 | PACKET PROCESSING SYSTEMS AND METHODS                                       | 07/21/2005 | Reel/Frame: 016678/0134<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 25. | 11/185,665 | PACKET GENERATION SYSTEMS AND METHODS                                       | 07/20/2005 | Reel/Frame: 016643/0802<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 26. | 11/203,617 | SYSTEMS AND METHODS FOR DECREASING LATENCY IN A DIGITAL TRANSMISSION SYSTEM | 08/12/2005 | Reel/Frame: 018804/0373<br>Assignors: HEDBERG, DAVID, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.   |
| 27. | 11/433,599 | CODING SYSTEMS AND METHODS                                                  | 05/12/2006 | Reel/Frame: 017865/0305<br>Assignors: HEDBERG, DAVID<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.           |
| 28. | 11/314,143 | SYSTEMS AND METHODS FOR THE CONNECTION AND REMOTE CONFIGURATION             | 12/21/2005 | Reel/Frame: 017404/0053<br>Assignors: WENTINK, MENZO, ET AL.                                                                                                                                                  |

|     |            |                                                                                  |            |                                                                                                                                                                                                                     |
|-----|------------|----------------------------------------------------------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            | OF WIRELESS CLIENTS                                                              |            | Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                         |
| 29. | 11/314,149 | SYSTEMS AND METHODS FOR DEVICE DISCOVERY                                         | 12/21/2005 | Reel/Frame: 017416/0241<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.       |
| 30. | 11/410,707 | BEAMFORMING SYSTEMS AND METHODS                                                  | 04/25/2006 | Reel/Frame: 018043/0355<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.       |
| 31. | 11/411,619 | SYSTEMS AND METHODS FOR TRANSMITTER DIVERSITY EXPANSION                          | 04/26/2006 | Reel/Frame: 018043/0463<br>Assignors: WEBSTER, MARK A., ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.       |
| 32. | 11/448,603 | METHOD OF CODING DATA                                                            | 06/06/2006 | Reel/Frame: 018176/0506<br>Assignors: MITTELSTEADT, CIMARRON, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 33. | 11/549,438 | MAC PROTECTION                                                                   | 10/13/2006 | Reel/Frame: 018389/0627<br>Assignors: WENTINK, MENZO, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.         |
| 34. | 11/556,916 | SYSTEMS AND METHODS FOR FACILITATING COMMUNICATION BETWEEN COMMUNICATION DEVICES | 11/06/2006 | REEL/FRAME: 018789/0982<br>ASSIGNORS: WENTINK, MENZO, ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAME: 022134/0518<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C.         |
| 35. | 11/557,516 | COLLISION AVOIDANCE SYSTEMS AND METHODS                                          | 11/08/2006 | Reel/Frame: 018493/0986<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607                                                                                             |

|     |            |                                                  |            |                                                                                                                                                                                                            |
|-----|------------|--------------------------------------------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                  |            | Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                                                                                   |
| 36. | 11/651,879 | SYMMETRIC TRANSMIT OPPORTUNITY (TXOP) TRUNCATION | 01/10/2007 | Reel/Frame: 018782/0584<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 37. | 11/613,020 | MORE POWER SAVE MULTI-POLL INDICATION            | 12/19/2006 | Reel/Frame: 018995/0126<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 38. | 11/627,181 | TRANSMIT ANNOUNCEMENT INDICATION                 | 01/25/2007 | Reel/Frame: 020630/0654<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 39. | 11/638,157 | DUAL CTS PROTECTION SYSTEMS AND METHODS          | 12/13/2006 | Reel/Frame: 018680/0742<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 40. | 11/680,612 | METHODS AND SYSTEMS FOR LDPC CODING              | 02/28/2007 | Reel/Frame: 019555/0669<br>Assignors: KOSE, CENK<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.            |
| 41. | 11/683,526 | TRANSMISSION USING A PLURALITY OF PROTOCOLS      | 03/08/2007 | Reel/Frame: 018980/0592<br>Assignors: CARTER, TRENT, ET AL.<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C. |
| 42. | 11/686,147 | POWER SAVE IMPROVEMENT                           | 03/14/2007 | Reel/Frame: 019011/0698<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.        |
| 43. | 11/688,274 | SLEEP MODE SYSTEMS AND METHODS                   | 03/20/2007 | Reel/Frame: 019033/0419<br>Assignors: CARTER, TRENT R.                                                                                                                                                     |



|     |            |                                                                                                                                      |            |                                                                                                                                                                                                                        |
|-----|------------|--------------------------------------------------------------------------------------------------------------------------------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |            |                                                                                                                                      |            | Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                                                                            |
| 44. | 11/750,684 | ACCESS POINT POLLING SYSTEMS AND METHODS                                                                                             | 05/18/2007 | Reel/Frame: 019374/0776<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                    |
| 45. | 11/750,693 | COMMUNICATION ROAMING SYSTEMS AND METHODS                                                                                            | 05/18/2007 | Reel/Frame: 019315/0231<br>Assignors: WENTINK, MENZO<br>Assignee: CONEXANT SYSTEMS, INC.<br><br>Reel/Frame: 022043/0607<br>Assignors: CONEXANT SYSTEMS, INC.<br>Assignee: XOCYST TRANSFER AG L.L.C.                    |
| 46. | 10/460,684 | METHOD FOR MINIMIZING RECEIVE PACKAGE PROCESSING FOR A PERSONAL COMPUTER IMPLEMENTATION OF A WIRELESS LOCAL AREA NETWORK ADAPTER     | 06/12/2003 | REEL/FRAAME: 018000/0476<br>ASSIGNORS: SCHULTZ, RICHARD DOUGLAS ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C. |
| 47. | 10/625,799 | METHOD FOR MITIGATING ADVERSE PROCESSOR LOADING IN A PERSONAL COMPUTER IMPLEMENTATION OF A WIRELESS LOCAL AREA NETWORK ADAPTER       | 07/23/2003 | REEL/FRAAME: 018000/ 0130<br>ASSIGNORS: SCHULTZ, RICHARD, ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C.       |
| 48. | 12/246,219 | ADAPTIVE FREQUENCY EQUALIZER                                                                                                         | 10/06/2008 | REEL/FRAAME: 015990/0117<br>ASSIGNORS: SHEARER, DANIEL D., ET AL.<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C.      |
| 49. | 11/239,657 | SYSTEM AND METHOD FOR NON-INTERFERING SIGNALING AND RECEPTION OF OVERLAPPING SINGLE CARRIER TRANSMISSIONS OVER DELAY SPREAD CHANNELS | 09/28/2005 | REEL/FRAAME: 018307/0337<br>ASSIGNORS: EIDSON, DONALD BRIAN<br>ASSIGNEE: CONEXANT SYSTEMS, INC.<br><br>REEL/FRAAME: 022043/0607<br>ASSIGNORS: CONEXANT SYSTEMS, INC.<br>ASSIGNEE: XOCYST TRANSFER AG L.L.C.            |

**STATEMENT UNDER 37 CFR 3.73(b)**Applicant/Patent Owner: XOCYST TRANSFER AG L.L.C.Application No./Patent No.: 11/121,661 Filed/Issue Date: 05/04/2005Entitled: CYCLIC DIVERSITY SYSTEMS AND METHODSXOCYST TRANSFER AG L.L.C., a corporation

(Name of Assignee)

(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest; or
2. ☐ an assignee of less than the entire right, title and interest  
(The extent (by percentage) of its ownership interest is \_\_\_\_\_%)

in the patent application/patent identified above by virtue of either:

- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

**OR**

- B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: See attached Appendix, line 22 To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.
2. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.
3. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark Office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

☒ Additional documents in the chain of title are listed on a supplemental sheet.☒ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Robert J. Irvine III/

Signature

Robert J. Irvine III

Printed or Typed Name

Attorney of Record

Title

February 26, 2009

Date

312-913-0001

Telephone Number

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 4867951                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | Cyclic diversity systems and methods |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 20306                                |
| <b>Filer:</b>                               | Robert Johnson Irvine                |
| <b>Filer Authorized By:</b>                 |                                      |
| <b>Attorney Docket Number:</b>              | 050337-1020                          |
| <b>Receipt Date:</b>                        | 03-MAR-2009                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 19:39:46                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/<br>Message Digest               | Multi Part /.zip | Pages (if appl.) |
|-----------------|----------------------|-----------|---------------------------------------------------|------------------|------------------|
| 1               | Power of Attorney    | POA.pdf   | 43382<br>3df8a49bb4ba5c215c99eed21e056b57eedb4020 | no               | 1                |

### Warnings:

### Information:

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                   |                          |                                                   |    |   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|--------------------------|---------------------------------------------------|----|---|
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Miscellaneous Incoming Letter                     | Appendix_2.pdf           | 84656<br>66c9c76f39b0ee727bfff7744f7497fd8b682c22 | no | 8 |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                   |                          |                                                   |    |   |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                   |                          |                                                   |    |   |
| 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Assignee showing of ownership per 37 CFR 3.73(b). | 08-1424-US-Statement.pdf | 74524<br>de8cf398f7f4b19cca8bfb720157754cdd3137c6 | no | 1 |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                   |                          |                                                   |    |   |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                   |                          |                                                   |    |   |
| <b>Total Files Size (in bytes):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                   |                          | 202562                                            |    |   |
| <p><b>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</b></p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/> <b>If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</b></p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/> <b>If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</b></p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/> <b>If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</b></p> |                                                   |                          |                                                   |    |   |



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
|-----------------|-------------|----------------------|---------------------|------------------|

11/121,661

05/04/2005

Mark A. Webster

050337-1020

3553

20306

7590

03/09/2009

MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606

EXAMINER

LEVITAN, DMITRY

ART UNIT

PAPER NUMBER

2416

MAIL DATE

DELIVERY MODE

03/09/2009

PAPER

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

|                              |                                      |                                       |  |
|------------------------------|--------------------------------------|---------------------------------------|--|
| <b>Office Action Summary</b> | <b>Application No.</b><br>11/121,661 | <b>Applicant(s)</b><br>WEBSTER ET AL. |  |
|                              | <b>Examiner</b><br>Dmitry Levitan    | <b>Art Unit</b><br>2416               |  |

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

### Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

### Status

- 1) ☒ Responsive to communication(s) filed on 27 January 2009.
- 2a) ☐ This action is **FINAL**.                      2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

### Disposition of Claims

- 4) ☒ Claim(s) 24-46 is/are pending in the application.
- 4a) Of the above claim(s) \_\_\_\_\_ is/are withdrawn from consideration.
- 5) ☐ Claim(s) \_\_\_\_\_ is/are allowed.
- 6) ☒ Claim(s) 24-46 is/are rejected.
- 7) ☐ Claim(s) \_\_\_\_\_ is/are objected to.
- 8) ☐ Claim(s) \_\_\_\_\_ are subject to restriction and/or election requirement.

### Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on \_\_\_\_\_ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.  
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).  
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

### Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All    b) ☐ Some \*    c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
  2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
  3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

\* See the attached detailed Office action for a list of the certified copies not received.

### Attachment(s)

- |                                                                                      |                                                                   |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| 1) <input type="checkbox"/> Notice of References Cited (PTO-892)                     | 4) <input type="checkbox"/> Interview Summary (PTO-413)           |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948) | Paper No(s)/Mail Date. _____                                      |
| 3) <input type="checkbox"/> Information Disclosure Statement(s) (PTO/SB/08)          | 5) <input type="checkbox"/> Notice of Informal Patent Application |
| Paper No(s)/Mail Date _____                                                          | 6) <input type="checkbox"/> Other: _____                          |

Art Unit: 2416

Amendment, filed 1/27/09, has been entered. Claims 24-46 remain pending.

***Claim Rejections - 35 USC § 112***

1. Claims 24-46 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention.

Claims 24, 32 and 44 limitations, directed to “cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet” are not supported by the original disclosure.

Cited portion of the specification, [0041], contains no disclosure of FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.

Claims 26, 34 and 45 limitations, directed to advancing the OFDM packet for a duration of less than one half of a guard interval" are not supported by the disclosure, as filed.

Other claims are rejected as the claims depending on the claims rejected above.

2. In light of Applicant’s amendment, the rejection of claims 1-23 under 35 U.S.C. 112, second paragraph, set in the previous Office action, has been withdrawn.

Claims limitations, directed to “cyclical advancing of OFDM packet” are understood as shifting a portion of the OFDM packet from it’s end to the packet’s beginning.

3. Claims 30 and 38 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claim 30 recites the limitation "the impulse responses" in line 1. There is insufficient antecedent basis for this limitation in the claim.

Claim 38 is incomplete, because it depends on claim 9, which has been cancelled.

***Claim Rejections - 35 USC § 103***

4. Claims 24, 26-34, 36-39, 41 and 44-46 are rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson (US 6,842,487) in view of Admitted Prior Art (Current application, Fig. 1-5 and pages 1-7).

5. Regarding claims 24, 31, 32 and 44, Larsson substantially teaches the limitations of claims:

A method and a system for transmitting orthogonal frequency division multiplexing (OFDM) signals to an OFDM receiver (OFDM transmit and receive system, as shown on Fig. 9 and disclosed on 6:58-7:37), comprising:

generating an OFDM packet for transmission (generating OFDM symbol for transmission, as disclosed on 6:58-64);

cyclically advancing the OFDM packet to generate one or more shifted versions of the OFDM packet for transmission (shifting a portion of OFDM symbol from the end of the symbol to the



symbol beginning, as shown on Fig. 8 and disclosed on 6:39-57); and transmitting the OFDM packet and the one or more shifted versions of the OFDM packet to the OFDM receiver (transmitting 1-M shifted versions of the OFDM symbol as shown on Fig. 9 and disclosed on 7:6-13), wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet (aligning OFDM n-1, n and n+1 symbols with corresponding FFT windows, as shown on Fig. 9).

Larsson does not teach using legacy SISO receiver.

Admitted Prior Art teaches using a SISO receiver, as shown on Fig. 1 and disclosed on pages 2, 5 and 6.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using legacy SISO receiver of Admitted Prior Art to the system of Larsson to improve the system compatibility with existing SISO receivers.

In addition, regarding claims 32 and 44, Larsson teaches:  
a first transmit processor/means for generating a OFDM packet for transmission (IFFT block, as shown on Fig. 9 and disclosed on 6:58-63, wherein IFFT block inherently comprises a processor, because a processor is essential for performing IFFT operation);  
transmit processor/means for cyclically advancing the OFDM packet to generate one or more shifted versions of the OFDM packet for transmission ( blocks of Fig. 9 to perform square root and cyclic delay operation in corresponding paths 1-M, inherently done by a processor, because a processor is essential for these operations);  
radio transmitter/means for converting the OFDM packet and the one or more shifted versions of

Art Unit: 2416

the OFDM packet to corresponding radio signals (radio transmitter is inherent in the transmission system of Fig. 9, because it is essential for conversion of OFDM symbols into radio signals); and

a plurality of radio antennas/means connected to the radio transmitter for transmitting the radio signals to the OFDM receiver (multiple antennas Ant1 – AntM, shown on Fig. 9 and inherently connected with a transmitter).

Larsson in view of Admitted Prior Art does not teach using separate transmit and radio processors for each path of Larsson system.

Official notice is taken that using separate processors for separate operations is well known and expected in the art.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using separate processors for separate operations to the system of Larsson in view of Admitted Prior Art to improve the system speed of processing OFDM symbols for transmission.

6. Regarding claims 26, 27, 39 and 45, Larsson teaches performing cyclical shift, as shown on Fig. 8 and disclosed on 6:39-58, wherein the duration of cyclic shift operation is equal to one sample, what is smaller than guard interval/cyclic prefix CP, which comprises three samples, as shown on Fig. 8.

7. Regarding claims 28 and 46, Admitted Prior Art teaches legacy receiver to produce a plurality of impulse responses corresponding to OFDM symbols, as shown on Fig. 4B and disclosed on pages 5 and 6.

Art Unit: 2416

8. Regarding claim 29, Larsson teaches transmitting one or more shifted versions of the OFDM packet/symbol from multiple-antenna transmitter device, as shown on Fig. 9.

9. Regarding claim 30 (as best understood), Admitted Prior Art teaches delaying OFDM symbols as a result of multi-path effect and producing corresponding plurality of impulse responses corresponding to OFDM symbols, wherein shifted and non shifted symbols can arrive in any sequence, as shown on Fig. 4B and disclosed on pages 5 and 6.

10. Regarding claim 33, Larsson teaches transmitting one or more shifted versions of the OFDM packet/symbol from multiple-antenna transmitter device, as shown on Fig. 9, wherein the shift operation is performed on all, except first, paths.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to use shifting of OFDM symbols on all paths of the system of Larsson in view of Admitted Prior Art as a design choice, the system will work without use of un shifted OFDM symbol and with any number of paths in the system.

11. Regarding claim 34, Larsson teaches performing cyclical shift, as shown on Fig. 8 and disclosed on 6:39-58, wherein the cyclic shift operation is equal to one sample, what is smaller than guard interval/cyclic prefix CP, comprising three samples on Fig. 8.

12. Regarding claim 36, Larsson teaches performing interleaving the data received for transmission on a plurality of sub-carriers, as disclosed on 8:10-16.

13. Regarding claim 37, Larsson teaches performing IFFT for generating OFDM symbols, as shown on Fig. 9 and disclosed on 6:58-64.

Larsson in view of Admitted Prior Art does not teach each transmit processor/operation path to include IFFT blocks.

Official notice is taken that performing operations in parallel to increase the system speed is well known and expected in the art.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using separate IFFT blocks for each path of the system of Larsson in view of Admitted Prior Art to improve the system speed of processing OFDM symbols for transmission.

14. Regarding claim 38 (as best understood), Admitted Prior Art teaches transmit processor 102 comprising baseband processing, as shown on Fig. 1 and disclosed on page 2.

15. Regarding claim 41, Admitted Prior Art teaches transmitter 102 on Fig. 1 as 802.11 compliant device on page 2.

16. Claims 25 and 35 are rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson in view of Admitted Prior Art.

Larsson in view of Admitted Prior Art substantially teaches the limitations of the parent claims (see claims 24, 32 and 33 rejections above).

Larsson in view of Admitted Prior Art does not teach using duration of cyclically advancing step less than 800 nanoseconds.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using duration of cyclically advancing step less than 800 nanoseconds to the system of Larsson in view of Admitted Prior Art as a design choice as the duration of less than 600 or 700 nanoseconds will work in the system as well.

17. Claims 40, 42 and 43 are rejected under 35 U.S.C. 103(a) as being unpatentable over Larsson in view of Admitted Prior Art.

Larsson in view of Admitted Prior Art substantially teaches the limitations of the parent claims (see claims 32 rejections above).

Larsson in view of Admitted Prior Art does not teach using ASIC, FPGA or firmware stored in a memory to implement the disclosed method.

Official notice is taken that using ASIC, FPGA or firmware stored in a memory for a method or system implementation are well known and expected in the art.

It would have been obvious to one of ordinary skill in the art at the time the invention was made to add using ASIC, FPGA or firmware stored in a memory to the system of Larsson in view of Admitted Prior Art to implement the described method and system using well known approaches.

### ***Response to Arguments***

18. Applicant's arguments filed 1/27/09 have been fully considered but they are not persuasive.

On page 8 and 9 of the Response, Applicant argues that claims 24, 32 and 44 are allowable because Larsson does not teach FFT window alignment to be substantially coincident with the symbol boundary of OFDM packet.

Examiner respectfully disagrees.

Larson clearly teaches OFDM symbols  $n-1$ ,  $n$  and  $n+1$  substantially aligned with FFT window symbols  $n-1$ ,  $n$  and  $n+1$  boundaries, as shown on Fig. 9.

Art Unit: 2416

In addition, claims 24, 32 and 44 limitations “cause an FFT window alignment to be substantially coincident with the symbol boundary of OFDM packet” are not given patentable value, because they are not positive limitations, as they are directed to a desired result/goal without any positive steps/ blocks on how to achieve the result.

Also, the cited limitations of claims 24, 32 and 46 were identified above as new matter.

On pages 8 and 9 of the Response, Applicant argues that Larsson does not teach “cyclically advancing” limitations of the independent claims, but teaches only “cyclically delaying”, making the claims patentable over Larsson.

Examiner respectfully disagrees.

Larsson teaches cyclical operation of shifting of a portion of the OFDM signal from the symbol end to the symbol beginning, which results in advancement of the shifted portion and in delay of the other portion of the symbol, pushed back by the advanced portion, as disclosed on 5:20-40. Therefore, Applicant’s emphasis on the advancing data in the cyclical shift is not a patentable feature over similar cyclical shift operation of Larsson, wherein some portion of the symbol is advanced and other portion of the symbol is delayed.

Appendix to the Specification has been considered.

***Conclusion***

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Dmitry Levitan whose telephone number is (571) 272-3093. The examiner can normally be reached on 8:30 to 4:30.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Huy Vu can be reached on (571) 272-3155. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Dmitry Levitan/  
Primary Examiner, Art Unit 2416

|                                                                                                                        |                                                |                                                                      |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b><i>Index of Claims</i></b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                                        | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2416                                          |

|   |                 |   |                   |   |                     |   |                 |
|---|-----------------|---|-------------------|---|---------------------|---|-----------------|
| ✓ | <b>Rejected</b> | - | <b>Cancelled</b>  | N | <b>Non-Elected</b>  | A | <b>Appeal</b>   |
| = | <b>Allowed</b>  | ÷ | <b>Restricted</b> | I | <b>Interference</b> | O | <b>Objected</b> |

| <input type="checkbox"/> Claims renumbered in the same order as presented by applicant |          | <input type="checkbox"/> CPA |            | <input type="checkbox"/> T.D. |  | <input type="checkbox"/> R.1.47 |  |  |  |
|----------------------------------------------------------------------------------------|----------|------------------------------|------------|-------------------------------|--|---------------------------------|--|--|--|
| CLAIM                                                                                  |          | DATE                         |            |                               |  |                                 |  |  |  |
| Final                                                                                  | Original | 05/16/2008                   | 10/23/2008 | 02/27/2009                    |  |                                 |  |  |  |
|                                                                                        | 1        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 2        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 3        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 4        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 5        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 6        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 7        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 8        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 9        | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 10       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 11       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 12       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 13       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 14       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 15       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 16       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 17       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 18       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 19       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 20       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 21       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 22       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 23       | ✓                            | ✓          | -                             |  |                                 |  |  |  |
|                                                                                        | 24       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 25       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 26       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 27       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 28       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 29       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 30       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 31       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 32       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 33       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 34       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 35       |                              |            | ✓                             |  |                                 |  |  |  |
|                                                                                        | 36       |                              |            | ✓                             |  |                                 |  |  |  |



|                                                                                                                        |                                                |                                                                      |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b><i>Index of Claims</i></b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                                        | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2416                                          |

|   |                 |   |                   |   |                     |   |                 |
|---|-----------------|---|-------------------|---|---------------------|---|-----------------|
| ✓ | <b>Rejected</b> | - | <b>Cancelled</b>  | N | <b>Non-Elected</b>  | A | <b>Appeal</b>   |
| = | <b>Allowed</b>  | ÷ | <b>Restricted</b> | I | <b>Interference</b> | O | <b>Objected</b> |

| <input type="checkbox"/> Claims renumbered in the same order as presented by applicant |          |            |            |            | <input type="checkbox"/> CPA |  | <input type="checkbox"/> T.D. |  | <input type="checkbox"/> R.1.47 |  |
|----------------------------------------------------------------------------------------|----------|------------|------------|------------|------------------------------|--|-------------------------------|--|---------------------------------|--|
| CLAIM                                                                                  |          | DATE       |            |            |                              |  |                               |  |                                 |  |
| Final                                                                                  | Original | 05/16/2008 | 10/23/2008 | 02/27/2009 |                              |  |                               |  |                                 |  |
|                                                                                        | 37       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 38       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 39       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 40       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 41       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 42       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 43       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 44       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 45       |            |            | ✓          |                              |  |                               |  |                                 |  |
|                                                                                        | 46       |            |            | ✓          |                              |  |                               |  |                                 |  |

|                                                                                                              |                                                |                                                                      |
|--------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b>Search Notes</b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                              | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2416                                          |

| SEARCHED |                       |         |          |
|----------|-----------------------|---------|----------|
| Class    | Subclass              | Date    | Examiner |
| 370      | 203-210, 310, 342-345 | 1/27/09 | DL       |
| 455      | 562, 101              | 1/27/09 | DL       |

| SEARCH NOTES |         |          |
|--------------|---------|----------|
| Search Notes | Date    | Examiner |
| IEEE, EAST   | 1/27/09 | DL       |

| INTERFERENCE SEARCH |          |      |          |
|---------------------|----------|------|----------|
| Class               | Subclass | Date | Examiner |
|                     |          |      |          |

|  |  |
|--|--|
|  |  |
|--|--|



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 11/121,661         | 05/04/2005            | Mark A. Webster       | 050337-1020            |

**CONFIRMATION NO. 3553**

**POA ACCEPTANCE LETTER**

20306  
MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606



Date Mailed: 03/11/2009

## NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/27/2009.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/dpnash/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 11/121,661         | 05/04/2005            | Mark A. Webster       | 050337-1020            |

**CONFIRMATION NO. 3553**

## POWER OF ATTORNEY NOTICE

20306  
MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606



Date Mailed: 03/11/2009

## NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/27/2009.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/dpnash/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION<br>NUMBER | FILING or<br>371(c) DATE | GRP ART<br>UNIT | FIL FEE REC'D | ATTY. DOCKET NO | TOT CLAIMS | IND CLAIMS |
|-----------------------|--------------------------|-----------------|---------------|-----------------|------------|------------|
| 11/121,661            | 05/04/2005               | 2416            | 1150          | 050337-1020     | 23         | 3          |

**CONFIRMATION NO. 3553**

**CORRECTED FILING RECEIPT**

20306  
MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606



Date Mailed: 03/13/2009

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

**Applicant(s)**

Mark A. Webster, Indian Harbor Beach, FL;  
Michael J. Seals, Melbourne, FL;

**Assignment For Published Patent Application**

Conexant Systems, Inc., Newport Beach, CA

**Power of Attorney:** The patent practitioners associated with Customer Number 20306

**Domestic Priority data as claimed by applicant**

This appln claims benefit of 60/572,481 05/20/2004

**Foreign Applications**

**If Required, Foreign Filing License Granted:** 05/26/2005

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 11/121,661**

**Projected Publication Date:** Not Applicable

**Non-Publication Request:** No

**Early Publication Request:** No

**Title**

Cyclic diversity systems and methods

**Preliminary Class**

370

**PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

**LICENSE FOR FOREIGN FILING UNDER****Title 35, United States Code, Section 184****Title 37, Code of Federal Regulations, 5.11 & 5.15****GRANTED**

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as

set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

#### **NOT GRANTED**

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**  
**(Attorney Docket No. 08-1424-US)**

|                                          |   |                                 |
|------------------------------------------|---|---------------------------------|
| <b>In the Application of:</b>            | ) |                                 |
|                                          | ) |                                 |
| Mark A. Webster et al.                   | ) |                                 |
|                                          | ) | <b>Examiner:</b> Dmitry Levitan |
| <b>Serial No.:</b> 11/121,661            | ) |                                 |
|                                          | ) | <b>Group Art Unit:</b> 2416     |
| <b>Filing Date:</b> May 4, 2005          | ) |                                 |
|                                          | ) | <b>Confirmation No.:</b> 3553   |
| <b>For:</b> Cyclic Diversity Systems And | ) |                                 |
| Methods                                  | ) |                                 |

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

**AMENDMENT**

Dear Sir:

In response to the Office Action mailed on March 9, 2009, Applicants respectfully submit the following Amendments to Claims with Remarks.

**Amendments to Claims** begin on page 2;

**Remarks** begin on page 8 of this paper.



## AMENDMENTS TO CLAIMS

1-23. (Canceled)

24. (Currently Amended) A method for transmitting orthogonal frequency division multiplexing (OFDM) signals ~~to a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals,~~ comprising:

generating ~~an~~ a first OFDM packet for transmission including a guard interval portion and a symbol data portion each comprised of a plurality of samples;

cyclically advancing the first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate ~~one or more a~~ shifted version ~~versions~~ of the first OFDM packet for transmission; and

substantially simultaneously transmitting the first OFDM packet and the ~~one or more~~ shifted version ~~versions~~ of the OFDM packet ~~to the legacy OFDM receiver,~~ wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first 'n' samples of the symbol data portion of the first OFDM packet, where 'n' is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet ~~wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet.~~

25. (Previously Presented) The method of claim 24, further comprising cyclically advancing the OFDM packet for a duration of less than approximately 800 nanoseconds.

26. (Currently Amended) The method of claim 24, further comprising cyclically advancing the OFDM packet for a duration of less than one half of ~~[[a]]~~ the sample duration of the guard interval portion.

27. (Canceled)

28. (Currently Amended) The method of claim 24, further comprising a legacy receiver, and wherein the cyclical advancements of the ~~one or more~~ shifted ~~versions~~ version of the OFDM packet cause the legacy receiver to produce a plurality of ~~impulsive~~ impulse responses in an acquisition process, and wherein each of the first OFDM packet and ~~one or more~~ the shifted version of the OFDM packet corresponds to one of the plurality of ~~impulsive~~ impulse responses.

29. (Currently Amended) The method of claim 24, further comprising transmitting the first OFDM packet and the ~~one or more~~ shifted ~~versions~~ version of the OFDM packet from a multiple-antenna transmitter device.

30. (Currently Amended) The method of claim ~~[[29]]~~ 28, wherein ~~the an~~ an impulse ~~responses~~ response corresponding to the ~~one or more~~ shifted version of the OFDM packet ~~occur~~ occurs earlier in time than ~~the an~~ an impulse ~~responses~~ response corresponding to the first OFDM packet.

31. (Currently Amended) The method of claim ~~[[24]]~~ 28, wherein the legacy OFDM receiver is a single-input, single-output (SISO) receiver device.

32. (Currently Amended) A signal transmitting system for transmitting orthogonal frequency division multiplexing (OFDM) signals ~~to a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals,~~ comprising:

a first transmit processor for generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each compromised of a plurality of samples;

~~a plurality of~~ second transmit processor for cyclically advancing the first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate ~~one or more~~ a shifted versions version of the first OFDM packet for transmission;

a plurality of radio transmitters for converting the OFDM packet and the ~~one or more~~ shifted ~~versions~~ version of the OFDM packet to corresponding radio signals; and

a plurality of radio antennas ~~connected~~ correspondingly coupled to the plurality of radio transmitters for transmitting the radio signals ~~to the legacy OFDM receiver, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet~~

wherein the first transmit processor and the second transmit processor are configured to substantially simultaneously cause the transmission of the first OFDM packet and the shifted version of the OFDM packet via corresponding transmitters and antennas, wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first 'n' samples of the symbol data portion of the first OFDM packet, where 'n' is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet.

33. (Currently Amended) The system of claim 32, wherein each of the ~~plurality of~~ first and second transmit ~~processor~~ processors includes a cyclic extension module for performing the cyclical advancements.

34. (Currently Amended) The system of claim 33, wherein each of the cyclic extension modules is configured to cyclically advance the OFDM packet for a duration of less than one half of sample duration of the guard interval.

35. (Previously Presented) The system of claim 33, wherein each of the cyclic extension modules is configure to cyclically advance the OFDM packet for a duration of less than approximately 800 nanoseconds.

36. (Previously Presented) The system of claim 32, wherein the first transmit processor is configured to receive incoming data and interleave the received data into a plurality of sub-carrier channels.

37. (Previously Presented) The system of claim 32, wherein each of the plurality of transmit processors further includes an Inverse Fast Fourier (IFFT) module for generating OFDM symbols from incoming data.

38. (Currently Amended) The system of claim ~~[[9]]~~ 32, wherein the ~~plurality of~~ first and second transmit processors perform the cyclical advancements on baseband signals.

39. (Canceled)

40. (Currently Amended) The system of claim 32, wherein the first and second transmit ~~processor and the plurality of transmit~~ processors include application specific integrated circuits (ASICs).

41. (Previously Presented) The system of claim 32, wherein the transmitter is an 802.11 compliant device.

42. (Currently Amended) The system of claim 32, wherein the first and second transmit ~~processor and the plurality of transmit~~ processors include field programmable gate arrays (FPGAs).

43. (Currently Amended) The system of claim 32, wherein the first and second transmit ~~processor and the plurality of transmit processor~~ processors include firmware stored in a memory device and executed by a suitable instruction execution system.

44. (Currently Amended) A signal transmitting system for transmitting orthogonal frequency division multiplexing (OFDM) signals ~~to a legacy OFDM receiver that aligns a Fast Fourier Transform (FFT) window based on detecting shifted versions of the OFDM signals,~~ comprising:

means for generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each compromised of a plurality of samples;

means for cyclically advancing the first OFDM packet including a guard interval portion and a symbol data portion each compromised of a plurality of samples by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate ~~one or more~~ a shifted ~~versions~~ version of the first OFDM packet for transmission;

means for converting the first OFDM packet and the ~~one or more~~ shifted ~~versions~~ version of the OFDM packet to corresponding radio signals; and

means for ~~transmitting the radio signals to the legacy OFDM receiver, wherein the cyclical advancements of the one or more shifted versions of the OFDM packet cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet~~ substantially simultaneously causing the transmission of the first OFDM packet and the shifted version of the OFDM packet, wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first 'n' samples of the symbol data portion of the first OFDM packet, where 'n' is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet.

45. (Currently Amended) The system of claim 44, wherein the cyclic advance has a duration less than one of half of sample duration of the ~~[[a]]~~ guard interval of the OFDM packet.

46. (Currently Amended) The system of claim 44, further comprising a legacy receiver, and wherein the cyclical advancements of the ~~one or more~~ shifted ~~versions~~ version of the OFDM packet cause the legacy receiver to produce a plurality of ~~impulsive~~ impulse responses in an acquisition process, and wherein each of the first OFDM packet and ~~one or more~~ the shifted version of the OFDM packet corresponds to one of the plurality of ~~impulsive~~ impulse responses.

## **REMARKS**

### **1. Summary of the Office Action**

In the Office Action mailed on March 9, 2009, the Examiner rejected claims 24-46 under 35 U.S.C. 112, first paragraph, rejected claims 30 and 38 under 35 U.S.C. § 112, second paragraph, rejected claims 24, 26-34, 36-39, 41, and 44-46 under 35 U.S.C. 103(a) as being unpatentable over Larsson (U.S. Patent No. 6,842,487), in view of Admitted Prior Art.

### **2. Status of Claims**

Applicants have amended independent claims 24, 32, and 44, and dependent claims 26, 28-31, 33-34, 38, 40, 42, 43, 45, and 46. Claims 27 and 39 have been canceled. Currently pending claims are claims 24-26, 28-38, and 40-46, of which claims 24, 32, and 44 are in independent form and the remaining claims are in dependent form. No new matter is added.

### **3. Response to Rejections under 35 U.S.C. 112, First Paragraph**

As noted above, in the Office Action mailed on March 9, 2009, the Examiner rejected independent claims 24-46 under U.S.C. 112, first paragraph as failing to comply with the written description requirement.

Specifically regarding claims 24, 32, and 44, Applicants submit that the cited claim element “cause an FFT window alignment to be substantially coincident with the symbol boundary of the OFDM packet” has been removed in light of the current amendments to the claims. In light of the forgoing, Applicants submit that the Examiner rejection under 35 U.S.C. § 112, first paragraph, is moot and should be withdrawn.

Specifically regarding claims 26, 34, and 45, Applicants submit that the specification enables the entire range of duration less than a guard interval, and are entitled to claim any portion of such range. See, for example, the Abstract of the specification, paragraph [0015], and

paragraph [0040], all of which describe and enable a cyclic advance of less than the guard interval, which necessarily includes the range of “less than one half of a guard interval.”

#### **4. Response to Rejections under 35 U.S.C. 112, Second Paragraph**

As noted above, in the Office Action mailed on March 9, 2009, the Examiner rejected claims 30 and 38 under U.S.C. 112, second paragraph as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. Applicants submit that the rejection is rendered moot by the present amendments, which have clarified the language of claims 30 and 38.

#### **5. Response to Rejections under 35 U.S.C. 103(a)**

As noted above, in the Office Action mailed on March 9, 2009, the Examiner rejected claims 24, 26-34, 36-39, 41, and 44-46 under 35 U.S.C. 103(a) as being unpatentable over Larsson in view of APA.

Applicants have now submitted new claims 24, 32, and 44 and respectfully submit that Larsson, alone or in combination with APA, fails to teach or disclose the subject matter as now set forth in claims 24, 32, and 44.

Specifically, claim 24 recites “generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each comprised of a plurality of samples; cyclically advancing the first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate a shifted version of the first OFDM packet for transmission; and substantially simultaneously transmitting the first OFDM packet and the shifted version of the OFDM packet, wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first ‘n’ samples of the symbol data portion of the first OFDM packet, where



‘n’ is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet.”

The Larsson reference fails to suggest or disclose every element of the claims, as amended. Larsson describes applying a “cyclic delay” to an OFDM symbol by “shifting samples from the end of the OFDM symbol into the beginning of the OFDM symbol and adding a cyclic prefix by copying the last n samples of the OFDM symbol.” See Larsson, column 6, lines 45-49 and Figure 8. Larsson, however, does not appear to suggest the “cyclical advancements” be applied to the OFDM packet as set forth in claim 24 and Fig. 8. In fact, as described in the specification, the “cyclic delay” described by Larsson would cause the legacy receiver to shift the FFT window into the subsequent symbol and thereby cause intersymbol interference since the intentional cyclic delay is “indistinguishable from the sample shifting that occurs in linear delay diversity” from the receiver standpoint.

On the contrary, during the acquisition process of the claimed invention, the cyclical advancement as set forth in claim 24 would cause the impulse responses corresponding to the shifted versions of the OFDM packet to occur before the impulse response of the unshifted OFDM packet, thereby preventing the erroneous alignment of the FFT window. This is due to the directional shift as set forth in Fig. 8, in which the first OFDM packet 804 is left shifted such that a first ‘n’ number of samples (0-3 in Fig. 8) of the OFDM data portion 812 of the first OFDM packet 804 are cyclically shifted such that, during a time period in which the guard interval portion 810 of the first OFDM packet 804 is being transmitted, at least a portion of the first OFDM data portion 812 is being transmitted in the shifted OFDM packet 806.

As set forth in paragraph [0043], “testing has shown that legacy radios show significant performance gains in packet error rate with small advancements...as opposed to large delays.”

As set forth in the specification and Fig. 8, an “advancement” is defined as a left shift of the OFDM packet samples.

Specifically in terms of claim 1 and Fig. 8 of Larsson, Larsson fails to disclose “wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first ‘n’ samples of the symbol data portion of the first OFDM packet, where ‘n’ is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet.”

In fact, Larsson specifically teaches that the samples of the cyclic prefix CP are taken from end of the OFDM symbol data 820.

As set forth on pages 3-4 of the Office Action, the Examiner exclusively relied upon Larsson for every claim element except for the claim element relating to the use of a “legacy OFDM receiver,” the latter of which the Examiner cited APA. For the reasons set forth above, Applicants submit that the claim elements of claim 24 are not disclosed or taught by Larsson. Additionally, APA does not compensate for the failed teachings of Larsson.

Because the Examiner has not provided evidence which as a whole shows that the legal determination sought to be proved (i.e., the reference teachings establish a prima facie case of obviousness) is more probable than not, Applicants submit that the Examiner’s rejection should be withdrawn. *MPEP §2142 rev. 6* (October 2007).

With respect to claims 32 and 44, Applicants point out that they include similar limitations of claim 24 and therefore are not rendered obvious by Larsson and APA for at least the same reasons set forth above. Therefore, Applicants respectfully submit that all claims are now in condition for allowance.

With respect to the remaining claims, Applicants point out that they depend from independent claims 24, 32, and 44 and therefore are not anticipated by Larsson for at least the same reasons set forth above.

**6. Response to the Examiner's Response to Arguments**

Applicants submit that the arguments set forth by the Examiner in the Response to Arguments section are moot in view of the attached Amendments to the Claims. Furthermore, and in light of the forgoing Arguments, Applicants submit that the Larsson reference fails to disclose, teach, or suggest the currently claimed invention, alone or in combination with APA.

**7. Conclusion**

In view of the above, Applicant submits that the application is in condition for allowance and respectfully requests the Examiner pass this application to issue. If, in the opinion of the Examiner, a telephone conference would expedite the prosecution of this application, the Examiner is invited to call the undersigned attorney at 312-913-2125.

Respectfully submitted,

McDONNELL BOEHNEN  
HULBERT & BERGHOFF LLP

Date: June 9, 2009

By: /Daniel R. Bestor/  
Daniel R. Bestor  
Registration No. 58,439

## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 5478987                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | Cyclic diversity systems and methods |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 20306                                |
| <b>Filer:</b>                               | Daniel Robert Bestor                 |
| <b>Filer Authorized By:</b>                 |                                      |
| <b>Attorney Docket Number:</b>              | 08-1424-US                           |
| <b>Receipt Date:</b>                        | 09-JUN-2009                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 12:37:19                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description | File Name               | File Size(Bytes)/<br>Message Digest                               | Multi Part /.zip | Pages (if appl.) |
|-----------------|----------------------|-------------------------|-------------------------------------------------------------------|------------------|------------------|
| 1               |                      | 08-1424-US_Response.pdf | 114250<br><small>654f775aa7a8493178ef82fc75bc882d65821c4b</small> | yes              | 12               |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Multipart Description/PDF files in .zip description   |        |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|--------|-----|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Document Description                                  | Start  | End |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Amendment/Req. Reconsideration-After Non-Final Reject | 1      | 1   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Amendment Copy Claims/Response to Suggested Claims    | 2      | 7   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Applicant Arguments/Remarks Made in an Amendment      | 8      | 12  |
| Warnings:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                       |        |     |
| Information:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                       |        |     |
| Total Files Size (in bytes):                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                       | 114250 |     |
| <p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/>If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/>If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/>If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p> |                                                       |        |     |

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| <b>PATENT APPLICATION FEE DETERMINATION RECORD</b><br>Substitute for Form PTO-875                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                               |                                  |                                    |               | Application or Docket Number<br><b>11/121,661</b> |                     | Filing Date<br><b>05/04/2005</b> |                     | <input type="checkbox"/> To be Mailed |  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|------------------------------------|---------------|---------------------------------------------------|---------------------|----------------------------------|---------------------|---------------------------------------|--|
| <b>APPLICATION AS FILED – PART I</b>                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               | SMALL ENTITY <input type="checkbox"/>             |                     | OR                               |                     | OTHER THAN SMALL ENTITY               |  |
| FOR                                                                                                                                                                                                                                                                                                                                                                                                                                  | NUMBER FILED                                                                                                                                                                                                                  | NUMBER EXTRA                     | RATE (\$)                          | FEE (\$)      | RATE (\$)                                         | FEE (\$)            |                                  |                     |                                       |  |
| <input type="checkbox"/> BASIC FEE<br>(37 CFR 1.16(a), (b), or (c))                                                                                                                                                                                                                                                                                                                                                                  | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               | N/A                                               |                     |                                  |                     |                                       |  |
| <input type="checkbox"/> SEARCH FEE<br>(37 CFR 1.16(k), (l), or (m))                                                                                                                                                                                                                                                                                                                                                                 | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               | N/A                                               |                     |                                  |                     |                                       |  |
| <input type="checkbox"/> EXAMINATION FEE<br>(37 CFR 1.16(o), (p), or (q))                                                                                                                                                                                                                                                                                                                                                            | N/A                                                                                                                                                                                                                           | N/A                              | N/A                                |               | N/A                                               |                     |                                  |                     |                                       |  |
| TOTAL CLAIMS<br>(37 CFR 1.16(i))                                                                                                                                                                                                                                                                                                                                                                                                     | minus 20 =                                                                                                                                                                                                                    | *                                | X \$                               | =             | OR                                                | X \$                | =                                |                     |                                       |  |
| INDEPENDENT CLAIMS<br>(37 CFR 1.16(h))                                                                                                                                                                                                                                                                                                                                                                                               | minus 3 =                                                                                                                                                                                                                     | *                                | X \$                               | =             |                                                   | X \$                | =                                |                     |                                       |  |
| <input type="checkbox"/> APPLICATION SIZE FEE<br>(37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                    | If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
| <input type="checkbox"/> MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
| * If the difference in column 1 is less than zero, enter "0" in column 2.                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                               |                                  | TOTAL                              |               |                                                   | TOTAL               |                                  |                     |                                       |  |
| <b>APPLICATION AS AMENDED – PART II</b>                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               | (Column 3)                                        |                     | SMALL ENTITY                     |                     | OR OTHER THAN SMALL ENTITY            |  |
| AMENDMENT                                                                                                                                                                                                                                                                                                                                                                                                                            | 06/09/2009                                                                                                                                                                                                                    | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE (\$)                                         | ADDITIONAL FEE (\$) | RATE (\$)                        | ADDITIONAL FEE (\$) |                                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Total (37 CFR 1.16(i))                                                                                                                                                                                                        | * 21                             | Minus                              | ** 23         | = 0                                               | X \$ =              | OR                               | X \$52=             | 0                                     |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Independent (37 CFR 1.16(h))                                                                                                                                                                                                  | * 3                              | Minus                              | *** 3         | = 0                                               | X \$ =              | OR                               | X \$220=            | 0                                     |  |
| <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
| <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   | TOTAL ADD'L FEE     | OR                               | TOTAL ADD'L FEE     | 0                                     |  |
| (Column 1)                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                               |                                  | (Column 2)                         |               | (Column 3)                                        |                     | SMALL ENTITY                     |                     | OR OTHER THAN SMALL ENTITY            |  |
| AMENDMENT                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                               | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE (\$)                                         | ADDITIONAL FEE (\$) | RATE (\$)                        | ADDITIONAL FEE (\$) |                                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Total (37 CFR 1.16(i))                                                                                                                                                                                                        | *                                | Minus                              | **            | =                                                 | X \$ =              | OR                               | X \$ =              |                                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      | Independent (37 CFR 1.16(h))                                                                                                                                                                                                  | *                                | Minus                              | ***           | =                                                 | X \$ =              | OR                               | X \$ =              |                                       |  |
| <input type="checkbox"/> Application Size Fee (37 CFR 1.16(s))                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
| <input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   | TOTAL ADD'L FEE     | OR                               | TOTAL ADD'L FEE     |                                       |  |
| <p>* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.</p> <p>** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".</p> <p>*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".</p> <p>The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.</p> |                                                                                                                                                                                                                               |                                  |                                    |               |                                                   |                     |                                  |                     |                                       |  |

Legal Instrument Examiner:  
/BRENDA HARRISON/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

## NOTICE OF ALLOWANCE AND FEE(S) DUE

20306 7590 08/21/2009

MCDONNELL BOEHNNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606

EXAMINER

LEVITAN, DMITRY

ART UNIT

PAPER NUMBER

2416

DATE MAILED: 08/21/2009

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
|-----------------|-------------|----------------------|---------------------|------------------|

11/121,661

05/04/2005

Mark A. Webster

08-1424-US

3553

TITLE OF INVENTION: CYCLIC DIVERSITY SYSTEMS AND METHODS

| APPLN. TYPE    | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE   |
|----------------|--------------|---------------|---------------------|----------------------|------------------|------------|
| nonprovisional | NO           | \$1510        | \$300               | \$0                  | \$1810           | 11/23/2009 |

**THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.**

**THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.**

### HOW TO REPLY TO THIS NOTICE:

#### I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

**IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.**

# **PART B - FEE(S) TRANSMITTAL**

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
or Fax (571)-273-2885**

**INSTRUCTIONS:** This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20306 7590 08/21/2009

**MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP**  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

## **Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

|                    |
|--------------------|
| (Depositor's name) |
| (Signature)        |
| (Date)             |

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
|-----------------|-------------|----------------------|---------------------|------------------|

11/121,661 05/04/2005 Mark A. Webster 08-1424-US 3553

TITLE OF INVENTION: CYCLIC DIVERSITY SYSTEMS AND METHODS

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|-------------|--------------|---------------|---------------------|----------------------|------------------|----------|
|-------------|--------------|---------------|---------------------|----------------------|------------------|----------|

nonprovisional NO \$1510 \$300 \$0 \$1810 11/23/2009

| EXAMINER | ART UNIT | CLASS-SUBCLASS |
|----------|----------|----------------|
|----------|----------|----------------|

LEVITAN, DMITRY 2416 370-203000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

- (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, 1 \_\_\_\_\_
- (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 \_\_\_\_\_
- 3 \_\_\_\_\_

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY AND STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies \_\_\_\_\_

4b. Payment of Fee(s); (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number \_\_\_\_\_ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature \_\_\_\_\_

Date \_\_\_\_\_

Typed or printed name \_\_\_\_\_

Registration No. \_\_\_\_\_

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.





# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NO.                                                                                    | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|----------------------------------------------------------------------------------------------------|-------------|----------------------|---------------------|------------------|
| 11/121,661                                                                                         | 05/04/2005  | Mark A. Webster      | 08-1424-US          | 3553             |
| 20306                                                                                              | 7590        | 08/21/2009           | EXAMINER            |                  |
| MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP<br>300 S. WACKER DRIVE<br>32ND FLOOR<br>CHICAGO, IL 60606 |             |                      | LEVITAN, DMITRY     |                  |
|                                                                                                    |             |                      | ART UNIT            | PAPER NUMBER     |
|                                                                                                    |             |                      | 2416                |                  |
| DATE MAILED: 08/21/2009                                                                            |             |                      |                     |                  |

## Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 686 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 686 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

|                               |                        |                     |  |
|-------------------------------|------------------------|---------------------|--|
| <b>Notice of Allowability</b> | <b>Application No.</b> | <b>Applicant(s)</b> |  |
|                               | 11/121,661             | WEBSTER ET AL.      |  |
|                               | <b>Examiner</b>        | <b>Art Unit</b>     |  |
|                               | Dmitry Levitan         | 2416                |  |

**-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--**

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to 6/09/09.
2. ☒ The allowed claim(s) is/are 24-26, 28-38 and 40-46, renumbered as 1-21.
3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
  - a) ☐ All    b) ☐ Some\*    c) ☐ None    of the:
    1. ☐ Certified copies of the priority documents have been received.
    2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
    3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).
  - \* Certified copies not received: \_\_\_\_\_.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.

**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
5. ☐ CORRECTED DRAWINGS ( as "replacement sheets") must be submitted.
  - (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review ( PTO-948) attached
    - 1) ☐ hereto or 2) ☐ to Paper No./Mail Date \_\_\_\_\_.
  - (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date \_\_\_\_\_.

**Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).**
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachment(s)**

- |                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ol style="list-style-type: none"> <li>1. <input type="checkbox"/> Notice of References Cited (PTO-892)</li> <li>2. <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)</li> <li>3. <input type="checkbox"/> Information Disclosure Statements (PTO/SB/08),<br/>Paper No./Mail Date _____</li> <li>4. <input type="checkbox"/> Examiner's Comment Regarding Requirement for Deposit<br/>of Biological Material</li> </ol> | <ol style="list-style-type: none"> <li>5. <input type="checkbox"/> Notice of Informal Patent Application</li> <li>6. <input type="checkbox"/> Interview Summary (PTO-413),<br/>Paper No./Mail Date _____.</li> <li>7. <input checked="" type="checkbox"/> Examiner's Amendment/Comment</li> <li>8. <input type="checkbox"/> Examiner's Statement of Reasons for Allowance</li> <li>9. <input checked="" type="checkbox"/> Other <u>Attachment A</u>.</li> </ol> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Art Unit: 2416

Amendment, filed 6/09/09, has been entered.

### **EXAMINER'S AMENDMENT**

1. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Daniel R. Bestor on 7/31/09.

The application has been amended as follows:

Claims 24, 32 and 44 have been amended per Attachment A.

Note. Claims have been amended to avoid reading on Larsson (US 6,842,487).

### ***Allowable Subject Matter***

2. Claims 24-26, 28-38 and 40-46 are allowed.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Dmitry Levitan whose telephone number is (571) 272-3093. The examiner can normally be reached on 8:30 to 4:30.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Huy Vu can be reached on (571) 272-3155. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Art Unit: 2416

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Dmitry Levitan  
Primary Examiner  
Art Unit 2416

/Dmitry Levitan/  
Primary Examiner, Art Unit 2416

|                                                                                                                    |                                            |                                                                  |
|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------|------------------------------------------------------------------|
| <b><i>Index of Claims</i></b><br> | <b>Application/Control No.</b><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br>WEBSTER ET AL. |
|                                                                                                                    | <b>Examiner</b><br>Dmitry Levitan          | <b>Art Unit</b><br>2416                                          |

|   |                 |   |                   |   |                     |   |                 |
|---|-----------------|---|-------------------|---|---------------------|---|-----------------|
| ✓ | <b>Rejected</b> | - | <b>Cancelled</b>  | N | <b>Non-Elected</b>  | A | <b>Appeal</b>   |
| = | <b>Allowed</b>  | ÷ | <b>Restricted</b> | I | <b>Interference</b> | O | <b>Objected</b> |

| <input type="checkbox"/> Claims renumbered in the same order as presented by applicant |          | <input type="checkbox"/> CPA |            | <input type="checkbox"/> T.D. |            | <input type="checkbox"/> R.1.47 |  |  |  |
|----------------------------------------------------------------------------------------|----------|------------------------------|------------|-------------------------------|------------|---------------------------------|--|--|--|
| CLAIM                                                                                  |          | DATE                         |            |                               |            |                                 |  |  |  |
| Final                                                                                  | Original | 05/16/2008                   | 10/23/2008 | 02/27/2009                    | 08/03/2009 |                                 |  |  |  |
|                                                                                        | 1        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 2        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 3        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 4        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 5        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 6        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 7        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 8        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 9        | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 10       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 11       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 12       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 13       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 14       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 15       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 16       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 17       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 18       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 19       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 20       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 21       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 22       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
|                                                                                        | 23       | ✓                            | ✓          | -                             | -          |                                 |  |  |  |
| 1                                                                                      | 24       |                              |            | ✓                             | =          |                                 |  |  |  |
| 2                                                                                      | 25       |                              |            | ✓                             | =          |                                 |  |  |  |
| 3                                                                                      | 26       |                              |            | ✓                             | =          |                                 |  |  |  |
|                                                                                        | 27       |                              |            | ✓                             | -          |                                 |  |  |  |
| 4                                                                                      | 28       |                              |            | ✓                             | =          |                                 |  |  |  |
| 7                                                                                      | 29       |                              |            | ✓                             | =          |                                 |  |  |  |
| 5                                                                                      | 30       |                              |            | ✓                             | =          |                                 |  |  |  |
| 6                                                                                      | 31       |                              |            | ✓                             | =          |                                 |  |  |  |
| 8                                                                                      | 32       |                              |            | ✓                             | =          |                                 |  |  |  |
| 9                                                                                      | 33       |                              |            | ✓                             | =          |                                 |  |  |  |
| 10                                                                                     | 34       |                              |            | ✓                             | =          |                                 |  |  |  |
| 11                                                                                     | 35       |                              |            | ✓                             | =          |                                 |  |  |  |
| 12                                                                                     | 36       |                              |            | ✓                             | =          |                                 |  |  |  |

|                                                                                                                        |                                                |                                                                      |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b><i>Index of Claims</i></b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                                        | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2416                                          |

|   |                 |   |                   |   |                     |   |                 |
|---|-----------------|---|-------------------|---|---------------------|---|-----------------|
| ✓ | <b>Rejected</b> | - | <b>Cancelled</b>  | N | <b>Non-Elected</b>  | A | <b>Appeal</b>   |
| = | <b>Allowed</b>  | ÷ | <b>Restricted</b> | I | <b>Interference</b> | O | <b>Objected</b> |

| <input type="checkbox"/> Claims renumbered in the same order as presented by applicant |          |            |            |            |            | <input type="checkbox"/> CPA |  | <input type="checkbox"/> T.D. |  | <input type="checkbox"/> R.1.47 |  |
|----------------------------------------------------------------------------------------|----------|------------|------------|------------|------------|------------------------------|--|-------------------------------|--|---------------------------------|--|
| CLAIM                                                                                  |          | DATE       |            |            |            |                              |  |                               |  |                                 |  |
| Final                                                                                  | Original | 05/16/2008 | 10/23/2008 | 02/27/2009 | 08/03/2009 |                              |  |                               |  |                                 |  |
| 13                                                                                     | 37       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
| 14                                                                                     | 38       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
|                                                                                        | 39       |            |            | ✓          | -          |                              |  |                               |  |                                 |  |
| 15                                                                                     | 40       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
| 16                                                                                     | 41       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
| 17                                                                                     | 42       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
| 18                                                                                     | 43       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
| 19                                                                                     | 44       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
| 20                                                                                     | 45       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |
| 21                                                                                     | 46       |            |            | ✓          | =          |                              |  |                               |  |                                 |  |



|                                                                                                              |                                                |                                                                      |
|--------------------------------------------------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|
| <b>Search Notes</b><br><br> | <b>Application/Control No.</b><br><br>11121661 | <b>Applicant(s)/Patent Under Reexamination</b><br><br>WEBSTER ET AL. |
|                                                                                                              | <b>Examiner</b><br><br>Dmitry Levitan          | <b>Art Unit</b><br><br>2416                                          |

| SEARCHED |                       |         |          |
|----------|-----------------------|---------|----------|
| Class    | Subclass              | Date    | Examiner |
| 370      | 203-210, 310, 342-345 | 8/03/09 | DL       |
| 455      | 562, 101              | 8/03/09 | DL       |

| SEARCH NOTES |         |          |
|--------------|---------|----------|
| Search Notes | Date    | Examiner |
| IEEE, EAST   | 8/03/09 | DL       |

| INTERFERENCE SEARCH |          |         |          |
|---------------------|----------|---------|----------|
| Class               | Subclass | Date    | Examiner |
| 370                 | 203      | 8/03/09 | DL       |

|  |  |
|--|--|
|  |  |
|--|--|



**EAST Search History****EAST Search History (Prior Art)**

| <b>Ref #</b> | <b>Hits</b> | <b>Search Query</b>                                                                                                                                                                                                      | <b>DBs</b>             | <b>Default Operator</b> | <b>Plurals</b> | <b>Time Stamp</b>   |
|--------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|-------------------------|----------------|---------------------|
| L2           | 26          | ofdm and<br>((shift\$5 or<br>advanc\$5)<br>near2<br>(samples or<br>symbols) and<br>(guard near2<br>interval)).clm.                                                                                                       | US-<br>PGPUB;<br>USPAT | OR                      | ON             | 2009/08/03<br>14:16 |
| L4           | 39          | ofdm and<br>((shift\$5 or<br>advanc\$5 or<br>mov\$5 or dela<br>\$6) near2<br>(samples or<br>symbols) and<br>((sample or<br>symbol)<br>near2 (length<br>or duration or<br>timing)) and<br>(guard near2<br>interval)).clm. | US-<br>PGPUB;<br>USPAT | OR                      | ON             | 2009/08/03<br>14:23 |

**8/ 3/ 09 2:27:55 PM**
**C:\ Documents and Settings\ DLevitan\ My Documents\ EAST\ Workspaces  
 \ 11121661.wsp**

**AMENDMENTS TO CLAIMS**

1-23. (Canceled)

24. (Currently Amended) A method for transmitting orthogonal frequency division multiplexing (OFDM) signals comprising:

generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each comprised of a plurality of samples;

cyclically advancing the first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate a shifted version of the first OFDM packet for transmission in which at least a non-zero number of the samples from the symbol data portion of the first OFDM packet are shifted into the guard interval portion of the shifted version and a same non-zero number of samples from the guard interval portion of the first OFDM packet are shifted out of the guard interval portion of the shifted version; and

substantially simultaneously transmitting the first OFDM packet and the shifted version of the OFDM packet ~~,-wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first 'n' samples of the symbol data portion of the first OFDM packet, where 'n' is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet.~~

25. (Previously Presented) The method of claim 24, further comprising cyclically advancing the OFDM packet for a duration of less than approximately 800 nanoseconds.

26. (Previously Presented) The method of claim 24, further comprising cyclically advancing the OFDM packet for a duration of less than one half of the sample duration of the guard interval portion.

27. (Canceled)

28. (Previously Presented) The method of claim 24, further comprising a legacy receiver, and wherein the cyclical advancements of the shifted version of the OFDM packet cause the legacy receiver to produce a plurality of impulse responses in an acquisition process, and wherein each of the first OFDM packet and the shifted version of the OFDM packet corresponds to one of the plurality of impulse responses.

29. (Previously Presented) The method of claim 24, further comprising transmitting the first OFDM packet and the shifted version of the OFDM packet from a multiple-antenna transmitter device.

30. (Previously Presented) The method of claim 28, wherein an impulse response corresponding to the shifted version of the OFDM packet occurs earlier in time than an impulse response corresponding to the first OFDM packet.

31. (Previously Presented) The method of claim 28, wherein the legacy OFDM receiver is a single-input, single-output (SISO) receiver device.

32. (Currently Amended) A signal transmitting system for transmitting orthogonal frequency division multiplexing (OFDM) signals comprising:

a first transmit processor for generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each compromised of a plurality of samples;

a second transmit processor for cyclically advancing the first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate a shifted version of the first OFDM packet for transmission in which at least a non-zero number of the samples from the symbol data portion of the first OFDM packet are shifted into the guard interval portion of the shifted version and a same non-zero number of samples from the guard interval portion of the first OFDM packet are shifted out of the guard interval portion of the shifted version;

a plurality of radio transmitters for converting the OFDM packet and the shifted version of the OFDM packet to corresponding radio signals; and

a plurality of radio antennas correspondingly coupled to the plurality of radio transmitters for transmitting the radio signals;

wherein the first transmit processor and the second transmit processor are configured to substantially simultaneously cause the transmission of the first OFDM packet and the shifted version of the OFDM packet via corresponding transmitters and antennas ~~; wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first 'n' samples of the symbol data portion of the first OFDM packet, where 'n' is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet.~~

33. (Previously Presented) The system of claim 32, wherein each of the first and second transmit processors includes a cyclic extension module for performing cyclical advancements.

34. (Previously Presented) The system of claim 33, wherein each of the cyclic extension modules is configured to cyclically advance the OFDM packet for a duration of less than one half of sample duration of the guard interval.

35. (Previously Presented) The system of claim 33, wherein each of the cyclic extension modules is configured to cyclically advance the OFDM packet for a duration of less than approximately 800 nanoseconds.

36. (Previously Presented) The system of claim 32, wherein the first transmit processor is configured to receive incoming data and interleave the received data into a plurality of sub-carrier channels.

37. (Previously Presented) The system of claim 32, wherein each of the plurality of transmit processors further includes an Inverse Fast Fourier (IFFT) module for generating OFDM symbols from incoming data.

38. (Previously Presented) The system of claim 32, wherein the first and second transmit processors perform the cyclical advancements on baseband signals.

39. (Canceled)

40. (Previously Presented) The system of claim 32, wherein the first and second transmit processors include application specific integrated circuits (ASICs).

41. (Previously Presented) The system of claim 32, wherein the transmitter is an 802.11 compliant device.

42. (Previously Presented) The system of claim 32, wherein the first and second transmit processors include field programmable gate arrays (FPGAs).

43. (Previously Presented) The system of claim 32, wherein the first and second transmit processors include firmware stored in a memory device and executed by a suitable instruction execution system.

44. (Currently Amended) A signal transmitting system for transmitting orthogonal frequency division multiplexing (OFDM) signals comprising:

means for generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each compromised of a plurality of samples;

means for cyclically advancing the first OFDM packet including a guard interval portion and a symbol data portion each compromised of a plurality of samples by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate a shifted version of the first OFDM packet for transmission in which at least a non-zero number of the samples from the symbol data portion of the first OFDM packet are shifted into the guard

interval portion of the shifted version and a same non-zero number of samples from the guard interval portion of the first OFDM packet are shifted out of the guard interval portion of the shifted version;

means for converting the first OFDM packet and the shifted version of the OFDM packet to corresponding radio signals; and

means for substantially simultaneously causing the transmission of the first OFDM packet and the shifted version of the OFDM packet, ~~wherein during a period in which the guard interval portion of the first OFDM packet is being transmitted, the shifted version of the OFDM packet transmits the first 'n' samples of the symbol data portion of the first OFDM packet, where 'n' is equal to the amount of shift of the shifted version of the OFDM packet relative to the first OFDM packet.~~

45. (Previously Presented) The system of claim 44, wherein the cyclic advance has a duration less than one of half of sample duration of the guard interval of the OFDM packet.

46. (Previously Presented) The system of claim 44, further comprising a legacy receiver, and wherein the cyclical advancements of the shifted version of the OFDM packet cause the legacy receiver to produce a plurality of impulse responses in an acquisition process, and wherein each of the first OFDM packet and the shifted version of the OFDM packet corresponds to one of the plurality of impulse responses.

## PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail Stop ISSUE FEE**  
**Commissioner for Patents**  
**P.O. Box 1450**  
**Alexandria, Virginia 22313-1450**  
 or **Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20306 7590 08/21/2009

MCDONNELL BOEHNNEN HULBERT & BERGHOFF LLP  
 300 S. WACKER DRIVE  
 32ND FLOOR  
 CHICAGO, IL 60606

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

## Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

|                    |
|--------------------|
| (Depositor's name) |
| (Signature)        |
| (Date)             |

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 11/121,661      | 05/04/2005  | Mark A. Webster      | 08-1424-US          | 3553             |

TITLE OF INVENTION: CYCLIC DIVERSITY SYSTEMS AND METHODS

| APPLN. TYPE    | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE   |
|----------------|--------------|---------------|---------------------|----------------------|------------------|------------|
| nonprovisional | NO           | \$1510        | \$300               | \$0                  | \$1810           | 11/23/2009 |

| EXAMINER        | ART UNIT | CLASS-SUBCLASS |
|-----------------|----------|----------------|
| LEVITAN, DMITRY | 2416     | 370-203000     |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

- (1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
- (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

McDonnell Boehnen

1 ~~Hulbert & Berghoff LLP~~

2 \_\_\_\_\_

3 \_\_\_\_\_

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☒ Issue Fee
- ☒ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies -0-

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 13-2490 (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
- ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature /Daniel R. Bestor/

Date October 12, 2009

Typed or printed name Daniel R. Bestor

Registration No. 58,439

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.



| Electronic Patent Application Fee Transmittal |          |                                         |        |                      |
|-----------------------------------------------|----------|-----------------------------------------|--------|----------------------|
| Application Number:                           |          | 11121661                                |        |                      |
| Filing Date:                                  |          | 04-May-2005                             |        |                      |
| Title of Invention:                           |          | CYCLIC DIVERSITY SYSTEMS AND METHODS    |        |                      |
| First Named Inventor/Applicant Name:          |          | Mark A. Webster                         |        |                      |
| Filer:                                        |          | Daniel Robert Bestor/Lucy Ponce de Leon |        |                      |
| Attorney Docket Number:                       |          | 08-1424-US                              |        |                      |
| Filed as Large Entity                         |          |                                         |        |                      |
| Utility under 35 USC 111(a) Filing Fees       |          |                                         |        |                      |
| Description                                   | Fee Code | Quantity                                | Amount | Sub-Total in USD(\$) |
| Basic Filing:                                 |          |                                         |        |                      |
| Pages:                                        |          |                                         |        |                      |
| Claims:                                       |          |                                         |        |                      |
| Miscellaneous-Filing:                         |          |                                         |        |                      |
| Petition:                                     |          |                                         |        |                      |
| Patent-Appeals-and-Interference:              |          |                                         |        |                      |
| Post-Allowance-and-Post-Issuance:             |          |                                         |        |                      |
| Utility Appl issue fee                        | 1501     | 1                                       | 1510   | 1510                 |
| Publ. Fee- early, voluntary, or normal        | 1504     | 1                                       | 300    | 300                  |

| Description        | Fee Code | Quantity | Amount | Sub-Total in USD(\$) |
|--------------------|----------|----------|--------|----------------------|
| Extension-of-Time: |          |          |        |                      |
| Miscellaneous:     |          |          |        |                      |
| Total in USD (\$)  |          |          |        | 1810                 |

## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 6242181                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | CYCLIC DIVERSITY SYSTEMS AND METHODS |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 20306                                |
| <b>Filer:</b>                               | Daniel Robert Bestor                 |
| <b>Filer Authorized By:</b>                 |                                      |
| <b>Attorney Docket Number:</b>              | 08-1424-US                           |
| <b>Receipt Date:</b>                        | 12-OCT-2009                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 15:01:49                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                                          |                 |
|------------------------------------------|-----------------|
| Submitted with Payment                   | yes             |
| Payment Type                             | Deposit Account |
| Payment was successfully received in RAM | \$ 1810         |
| RAM confirmation Number                  | 9565            |
| Deposit Account                          | 132490          |
| Authorized User                          |                 |

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

## File Listing:

| Document Number | Document Description        | File Name                      | File Size(Bytes)/ Message Digest                   | Multi Part /.zip | Pages (if appl.) |
|-----------------|-----------------------------|--------------------------------|----------------------------------------------------|------------------|------------------|
| 1               | Issue Fee Payment (PTO-85B) | 08-1424-US_IssueFeePayment.pdf | 207383<br>21c4f3f1e5eac9f75be3fafa2ff1ccfb7b9e5a11 | no               | 1                |

### Warnings:

### Information:

|   |                         |              |                                                   |    |   |
|---|-------------------------|--------------|---------------------------------------------------|----|---|
| 2 | Fee Worksheet (PTO-875) | fee-info.pdf | 31998<br>83995a913072633ecd71faf57468423ea10b35a4 | no | 2 |
|---|-------------------------|--------------|---------------------------------------------------|----|---|

### Warnings:

### Information:

|                              |  |  |        |
|------------------------------|--|--|--------|
| Total Files Size (in bytes): |  |  | 239381 |
|------------------------------|--|--|--------|

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

#### New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

#### National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

#### New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
[www.uspto.gov](http://www.uspto.gov)

| APPLICATION NO. | ISSUE DATE | PATENT NO. | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|------------|------------|---------------------|------------------|
| 11/121,661      | 11/24/2009 | 7623439    | 08-1424-US          | 3553             |

20306 7590 11/04/2009  
MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606

## ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

### **Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)** (application filed on or after May 29, 2000)

The Patent Term Adjustment is 686 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

Mark A. Webster, Indian Harbor Beach, FL;  
Michael J. Seals, Melbourne, FL;

## REQUEST FOR RECALCULATION OF PATENT TERM ADJUSTMENT IN VIEW OF *WYETH*\*

Attorney Docket  
Number: 08-1424-US

Patent Number: 7,623,439

Filing Date  
(or 371(b) or (f) Date): May 4, 2005

Issue Date: November 24, 2009

First Named  
Inventor: Webster

Title: Cyclic Diversity Systems and Methods

PATENTEE HEREBY REQUESTS RECALCULATION OF THE PATENT TERM ADJUSTMENT (PTA) UNDER 35 USC 154(b) INDICATED ON THE ABOVE-IDENTIFIED PATENT. THE PATENTEE'S SOLE BASIS FOR REQUESTING THE RECALCULATION IS THE USPTO'S PRE-*WYETH* INTERPRETATION OF 35 U.S.C. 154(b)(2)(A).

Note: This form is only for requesting a recalculation of PTA for patents issued before March 2, 2010, if the sole basis for requesting the recalculation is the USPTO's pre-*Wyeth* interpretation of 35 U.S.C. 154(b)(2)(A). See Instruction Sheet on page 2 for more information.

Patentees are reminded that to preserve the right to review in the United States District Court for the District of Columbia of the USPTO's patent term adjustment determination, a patentee must ensure that he or she also takes the steps required under 35 U.S.C. 154(b)(3) and (b)(4) and 37 CFR 1.705 in a timely manner.

\**Wyeth v. Kappos*, No. 2009-1120 (Fed. Cir., Jan. 7, 2010).

Signature /Thomas J. Loos/

Date January 29, 2010

Name  
(Print/Typed) Thomas J. Loos

Registration Number 60161

**Note:** Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required in accordance with 37 CFR 1.33 and 11.18. Please see 37 CFR 1.4(d) for the form of the signature. If necessary, submit multiple forms for more than one signature, see below\*.



\*Total of 1 forms are submitted.

The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 6915020                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | CYCLIC DIVERSITY SYSTEMS AND METHODS |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 20306                                |
| <b>Filer:</b>                               | Thomas J. Loos                       |
| <b>Filer Authorized By:</b>                 |                                      |
| <b>Attorney Docket Number:</b>              | 08-1424-US                           |
| <b>Receipt Date:</b>                        | 29-JAN-2010                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 21:18:06                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description                           | File Name             | File Size(Bytes)/<br>Message Digest                   | Multi Part /.zip | Pages (if appl.) |
|-----------------|------------------------------------------------|-----------------------|-------------------------------------------------------|------------------|------------------|
| 1               | Request for PTA recalculation in view of Wyeth | 08-1424-US_SB_131.pdf | 36393<br>6e5445f71eda61f87a25be49fe2337fcde2ce<br>a99 | no               | 1                |

### Warnings:

### Information:

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

**New Applications Under 35 U.S.C. 111**

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

**National Stage of an International Application under 35 U.S.C. 371**

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

**New International Application Filed with the USPTO as a Receiving Office**

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.





# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606

Mail Date: 04/21/2010

|                      |                   |                                    |
|----------------------|-------------------|------------------------------------|
| <b>Applicant</b>     | : Mark A. Webster | : DECISION ON REQUEST FOR          |
| <b>Patent Number</b> | : 7623439         | : RECALCULATION of PATENT          |
| <b>Issue Date</b>    | : 11/24/2009      | : TERM ADJUSTMENT IN VIEW          |
| <b>Appliction No</b> | : 11/121,661      | : OF WYETH AND NOTICE OF INTENT TO |
| <b>Filed</b>         | : 05/04/2005      | : ISSUE CERTIFICATE OF CORRECTION  |
|                      |                   | :                                  |

The Request for Recalculation is **GRANTED** to the extent indicated.

The patent term adjustment has been determined to be **937** days. The USPTO will *sua sponte* issue a certificate of correction reflecting the amount of PTA days determined by the recalculation.

Prior to the issuance of the certificate of correction, the USPTO will afford patentee an opportunity to be heard and request reconsideration. Accordingly, patentee has **one month or thirty (30) days**, whichever is longer, to file a request for reconsideration of this patent term adjustment calculation. See 35 U.S.C. 154(b)(3)(B)(ii) and 37 CFR 1.322(a)(4). No extensions of time will be granted under 37 CFR 1.136.

Patentee should use document code PET.OP if electronically filing a request for reconsideration of this patent term adjustment calculation. The patentee must also include the information required by 37 CFR 1.705(b)(2) and the fee required by 37 CFR 1.18(e). If patentee does not file a timely request for reconsideration of this patent term adjustment calculation including the information required by 37 CFR 1.705(b)(2) and the fee required by 37 CFR 1.18(e), the USPTO will issue a certificate of correction reflecting the PTA determination noted above.

Patentee should be aware that in order to preserve the right to review in the United States District Court for the District of Columbia of the USPTO patent term adjustment determination, patentee must ensure that he or she also take the steps required under 35 U.S.C. 154(b)(4)(A) in a timely manner. Nothing in the request for recalculation should be construed as providing an alternative time frame for commencing a civil action under 35 U.S.C. 154(b)(4)(A).

Any questions concerning this decision should be directed to the Office of Patent Legal Administration at 571-272-7702.

***IN THE UNITED STATES PATENT AND TRADEMARK OFFICE***

Applicant: Webster, et al.  
Title: CYCLIC DIVERSITY SYSTEMS AND  
METHODS  
Patent. No.: 7,623,439  
Issue Date: 11/24/2009  
Examiner: DMITRY LEVITAN  
Art Unit: 2416  
Confirmation 3553  
Number:

**REQUEST FOR CERTIFICATE OF CORRECTION FOR  
PTO MISTAKE PURSUANT TO 37 C.F.R. § 1.322(a)**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Sir:

Enclosed, is a Certificate of Correction, Form PTO-1050, for United States Patent Number 7,623,439 issued November 24, 2009. The following Patent Office printing errors appear in the issued patent:

**IN THE CLAIMS**

**Claim 8, Col. 10, Line 24:**

Delete the word --die-- and replace with --the--

Applicant submits that the above changes would not constitute new matter, and correction thereof would not require reexamination.

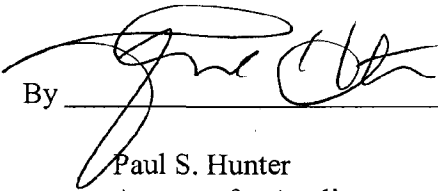
Pursuant to 37 C.F.R. §1.322, Applicant requests that the enclosed Certificate of Correction be approved.

Although Applicant believes that no fee is required for this Request, the Commissioner is hereby authorized to charge any additional fees which may be required for this Request to Deposit Account No. 19-0741.

Respectfully submitted,

Date July 14, 2010

FOLEY & LARDNER LLP  
Customer Number: 23524  
Telephone: (608) 258-4292  
Facsimile: (608) 258-4258

By 

Paul S. Hunter  
Attorney for Applicant  
Registration No. 44,787

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.  
(Also Form PTO-1050)

**UNITED STATES PATENT AND TRADEMARK OFFICE  
CERTIFICATE OF CORRECTION**

PATENT NO. : 7,623,439  
APPLICATION NO. : 11/121,661  
DATED : 11/24/2009  
INVENTOR(S) : Mark A. Webster; Michael J. Seals

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

**IN THE CLAIMS**

**Claim 8, Col. 10, Line 24:**

Delete the word --die-- and replace with --the--

MAILING ADDRESS OF SENDER (Please do not use customer number below):

Verex Plaza  
150 East Gilman Street  
Madison, Wisconsin 53703-1481

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1.0 hour to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer,

U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: **Attention Certificate of Corrections Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 8011598                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | CYCLIC DIVERSITY SYSTEMS AND METHODS |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 20306                                |
| <b>Filer:</b>                               | Paul S. Hunter/Lee Jankoski          |
| <b>Filer Authorized By:</b>                 | Paul S. Hunter                       |
| <b>Attorney Docket Number:</b>              | 08-1424-US                           |
| <b>Receipt Date:</b>                        | 14-JUL-2010                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 12:49:02                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description                  | File Name        | File Size(Bytes)/<br>Message Digest               | Multi Part /.zip | Pages (if appl.) |
|-----------------|---------------------------------------|------------------|---------------------------------------------------|------------------|------------------|
| 1               | Request for Certificate of Correction | 2606COC71410.pdf | 71541<br>a53659b48c0ec3b720991ce9b59e5d01e4e1aa8a | no               | 3                |

### Warnings:

### Information:

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

**New Applications Under 35 U.S.C. 111**

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

**National Stage of an International Application under 35 U.S.C. 371**

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

**New International Application Filed with the USPTO as a Receiving Office**

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO**

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☒ Practitioners associated with the Customer Number:**23524**

OR

☐ Practitioner(s) named below (If more than ten patent practitioners are to be named, then a customer number must be used):

| Name | Registration Number | Name | Registration Number |
|------|---------------------|------|---------------------|
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |
|      |                     |      |                     |

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

☒ The address associated with Customer Number:**23524**

OR

☐ Firm or Individual Name

Address

City

State

Zip

Country

Telephone

Email

Assignee Name and Address:

**XOCYST TRANSFER AG L.L.C.**  
 2711 Centerville Road  
 Suite 400  
 Wilmington, DE 19808  
 USA

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

**SIGNATURE of Assignee of Record**

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

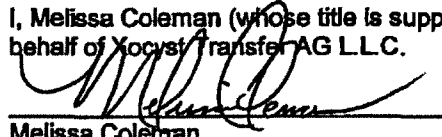
|           |                                                                                     |           |              |
|-----------|-------------------------------------------------------------------------------------|-----------|--------------|
| Signature |  | Date      | May 24, 2010 |
| Name      | Melissa Coleman                                                                     | Telephone |              |
| Title     | Authorized Person for Xocyst Transfer AG L.L.C.                                     |           |              |

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

DECLARATION REGARDING AUTHORITY TO SIGN ON BEHALF OF A LEGAL ENTITY  
(37 C.F.R. 3.73(b)(2)(i))

I, Melissa Coleman (whose title is supplied below), hereby declare that I am authorized to sign on behalf of Xocyst Transfer AG L.L.C.



\_\_\_\_\_  
Melissa Coleman

Authorized Person for Xocyst Transfer AG L.L.C.

May 24, 2010  
[date]



## Electronic Acknowledgement Receipt

|                                             |                                      |
|---------------------------------------------|--------------------------------------|
| <b>EFS ID:</b>                              | 8483396                              |
| <b>Application Number:</b>                  | 11121661                             |
| <b>International Application Number:</b>    |                                      |
| <b>Confirmation Number:</b>                 | 3553                                 |
| <b>Title of Invention:</b>                  | CYCLIC DIVERSITY SYSTEMS AND METHODS |
| <b>First Named Inventor/Applicant Name:</b> | Mark A. Webster                      |
| <b>Customer Number:</b>                     | 20306                                |
| <b>Filer:</b>                               | Paul S. Hunter/Drew Lawson           |
| <b>Filer Authorized By:</b>                 | Paul S. Hunter                       |
| <b>Attorney Docket Number:</b>              | 08-1424-US                           |
| <b>Receipt Date:</b>                        | 24-SEP-2010                          |
| <b>Filing Date:</b>                         | 04-MAY-2005                          |
| <b>Time Stamp:</b>                          | 13:59:58                             |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)          |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description | File Name    | File Size(Bytes)/<br>Message Digest                    | Multi Part /.zip | Pages (if appl.) |
|-----------------|----------------------|--------------|--------------------------------------------------------|------------------|------------------|
| 1               |                      | 2606_POA.pdf | 157948<br>8b8894a3af83c788a493831330423b997c0<br>87e52 | yes              | 3                |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                            |              |            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|--------------|------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Multipart Description/PDF files in .zip description</b> |              |            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Document Description</b>                                | <b>Start</b> | <b>End</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Assignee showing of ownership per 37 CFR 3.73(b).          | 1            | 1          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Power of Attorney                                          | 2            | 3          |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                            |              |            |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                            |              |            |
| <b>Total Files Size (in bytes):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                            | 157948       |            |
| <p><b>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</b></p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/> <b>If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</b></p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/> <b>If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</b></p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/> <b>If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</b></p> |                                                            |              |            |

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**STATEMENT UNDER 37 CFR 3.73(b)**

Applicant/Patent Owner: Mark A. WEBSTER et al

Application No./Patent No.: 11/121,661 / 7,623,439 Filed/Issue Date: 5/4/2005 / 11/24/2009

Attorney Docket Number: 088245-2606

Entitled: Cyclic diversity systems and methods

XOCYST TRANSFER AG L.L.C.  
(Name of Assignee)

LLC  
(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest;
2. ☐ an assignee of less than the entire right, title, and interest  
(The extent (by percentage) of its ownership interest is %); or
3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

in the patent application/patent identified above by virtue of either:

- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel/Frame \_\_\_\_\_ or for which a copy thereof is attached.

**OR**

- B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: Mark A. WEBSTER et al To: CONEXANT SYSTEMS, INC.  
The document was recorded in the United States Patent and Trademark Office at Reel 016541, Frame 0490, or for which a copy thereof is attached.

2. From: CONEXANT SYSTEMS, INC. To: XOCYST TRANSFER AG L.L.C.  
The document was recorded in the United States Patent and Trademark Office at Reel 022043, Frame 0607, or for which a copy thereof is attached.

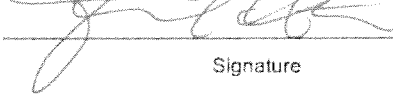
3. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark Office at Reel \_\_\_, Frame \_\_\_, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet.

- ☐ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

**[NOTE:** A separate copy (i.e., a true copy of the original document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, if the assignment is to be recorded in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

  
\_\_\_\_\_  
Signature

7-23-10  
\_\_\_\_\_  
Date

Paul S. Hunter (Reg. No. 44,787)  
\_\_\_\_\_  
Printed or Typed Name

(608) 258-4292  
\_\_\_\_\_  
Telephone Number

\_\_\_\_\_  
Attorney for Applicant

\_\_\_\_\_  
Title

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 11/121,661         | 05/04/2005            | Mark A. Webster       | 088245-2606            |

23524  
FOLEY & LARDNER LLP  
150 EAST GILMAN STREET  
P.O. BOX 1497  
MADISON, WI 53701-1497

**CONFIRMATION NO. 3553**  
**POA ACCEPTANCE LETTER**



Date Mailed: 10/04/2010

**NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY**

This is in response to the Power of Attorney filed 09/24/2010.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/ttran/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 11/121,661         | 05/04/2005            | Mark A. Webster       | 08-1424-US             |

**CONFIRMATION NO. 3553**

**POWER OF ATTORNEY NOTICE**



20306  
MCDONNELL BOEHNEN HULBERT & BERGHOFF LLP  
300 S. WACKER DRIVE  
32ND FLOOR  
CHICAGO, IL 60606

Date Mailed: 10/04/2010

**NOTICE REGARDING CHANGE OF POWER OF ATTORNEY**

This is in response to the Power of Attorney filed 09/24/2010.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/ttran/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 7,623,439 B2  
APPLICATION NO. : 11/121661  
DATED : November 24, 2009  
INVENTOR(S) : Webster et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

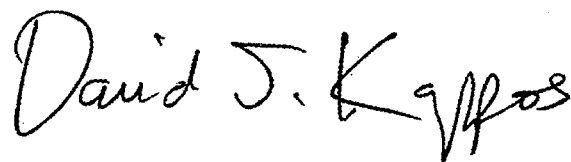
On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b)  
by 937 days.

Signed and Sealed this

Twenty-sixth Day of October, 2010

A handwritten signature in black ink that reads "David J. Kappos". The signature is written in a cursive, flowing style with a large initial "D" and a stylized "K".

David J. Kappos  
*Director of the United States Patent and Trademark Office*

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 7,623,439 B2  
APPLICATION NO. : 11/121661  
DATED : November 24, 2009  
INVENTOR(S) : Mark A. Webster and Michael J. Seals

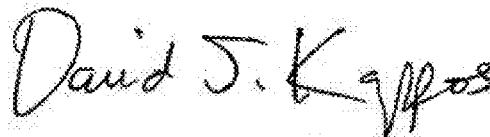
Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

**Claim 8, Col. 10, Line 24:**

Delete the word “die” and replace with --the--

Signed and Sealed this  
Twenty-eighth Day of December, 2010

A handwritten signature in black ink that reads "David J. Kappos". The signature is written in a cursive, flowing style with a large initial "D" and a stylized "K".

David J. Kappos  
*Director of the United States Patent and Trademark Office*

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court District of Delaware on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.):

|                                                                           |                             |                                                 |
|---------------------------------------------------------------------------|-----------------------------|-------------------------------------------------|
| DOCKET NO.                                                                | DATE FILED<br>10/13/2022    | U.S. DISTRICT COURT<br>District of Delaware     |
| PLAINTIFF<br>Intellectual Ventures I LLC and Intellectual Ventures II LLC |                             | DEFENDANT<br>Hewlett Packard Enterprise Company |
| PATENT OR TRADEMARK NO.                                                   | DATE OF PATENT OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                   |
| 1 US 7,623,439 B2                                                         | 11/24/2009                  | Intellectual Ventures I LLC                     |
| 2 US RE44,706 E                                                           | 1/14/2014                   | Intellectual Ventures II LLC                    |
| 3 US 11,265,787 B2                                                        | 3/1/2022                    | Intellectual Ventures II LLC                    |
| 4                                                                         |                             |                                                 |
| 5                                                                         |                             |                                                 |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                         |                                                                                                                                                               |                               |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| DATE INCLUDED           | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |
| PATENT OR TRADEMARK NO. | DATE OF PATENT OR TRADEMARK                                                                                                                                   | HOLDER OF PATENT OR TRADEMARK |
| 1                       |                                                                                                                                                               |                               |
| 2                       |                                                                                                                                                               |                               |
| 3                       |                                                                                                                                                               |                               |
| 4                       |                                                                                                                                                               |                               |
| 5                       |                                                                                                                                                               |                               |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|-------|-------------------|------|

Copy 1—Upon initiation of action, mail this copy to Director Copy 3—Upon termination of action, mail this copy to Director  
 Copy 2—Upon filing document adding patent(s), mail this copy to Director Copy 4—Case file copy



AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been  
filed in the U.S. District Court **Western District of Texas** on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                          |                                |                                                                                     |
|------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------|
| DOCKET NO.<br>6:23-cv-309                | DATE FILED<br>4/26/2023        | U.S. DISTRICT COURT<br>Western District of Texas                                    |
| PLAINTIFF<br>Intellectual Ventures I LLC |                                | DEFENDANT<br>TCL Electronics Holdings Ltd. and<br>TCL Industries Holdings Co., Ltd. |
| PATENT OR<br>TRADEMARK NO.               | DATE OF PATENT<br>OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                                       |
| 1 7,089,443                              | 8/8/2006                       | Intellectual Ventures I                                                             |
| 2 7,623,439                              | 11/24/2009                     | Intellectual Ventures I                                                             |
| 3                                        |                                |                                                                                     |
| 4                                        |                                |                                                                                     |
| 5                                        |                                |                                                                                     |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                            |                                                                                                                                                               |                               |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| DATE INCLUDED              | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |
| PATENT OR<br>TRADEMARK NO. | DATE OF PATENT<br>OR TRADEMARK                                                                                                                                | HOLDER OF PATENT OR TRADEMARK |
| 1                          |                                                                                                                                                               |                               |
| 2                          |                                                                                                                                                               |                               |
| 3                          |                                                                                                                                                               |                               |
| 4                          |                                                                                                                                                               |                               |
| 5                          |                                                                                                                                                               |                               |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|-------|-------------------|------|

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been  
filed in the U.S. District Court **Western District of Texas** on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                                                              |                                |                                                                           |
|------------------------------------------------------------------------------|--------------------------------|---------------------------------------------------------------------------|
| DOCKET NO.<br>6:23-cv-308                                                    | DATE FILED<br>4/26/2023        | U.S. DISTRICT COURT<br>Western District of Texas                          |
| PLAINTIFF<br>Intellectual Ventures I LLC and<br>Intellectual Ventures II LLC |                                | DEFENDANT<br>TP-Link Corporation Limited f/k/a TP-Link International Ltd. |
| PATENT OR<br>TRADEMARK NO.                                                   | DATE OF PATENT<br>OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                             |
| 1 7,623,439                                                                  | 11/24/2009                     | Intellectual Ventures I                                                   |
| 2 US RE44,706                                                                | 1/14/2014                      | Intellectual Ventures II                                                  |
| 3 7,386,036                                                                  | 6/10/2008                      | Intellectual Ventures I                                                   |
| 4                                                                            |                                |                                                                           |
| 5                                                                            |                                |                                                                           |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                            |                                                                                                                                                               |                               |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| DATE INCLUDED              | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |
| PATENT OR<br>TRADEMARK NO. | DATE OF PATENT<br>OR TRADEMARK                                                                                                                                | HOLDER OF PATENT OR TRADEMARK |
| 1                          |                                                                                                                                                               |                               |
| 2                          |                                                                                                                                                               |                               |
| 3                          |                                                                                                                                                               |                               |
| 4                          |                                                                                                                                                               |                               |
| 5                          |                                                                                                                                                               |                               |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|-------|-------------------|------|

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Western District of Texas on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                                                   |                             |                                                                           |
|-------------------------------------------------------------------|-----------------------------|---------------------------------------------------------------------------|
| DOCKET NO.<br>6:23-cv-291                                         | DATE FILED<br>4/20/2023     | U.S. DISTRICT COURT<br>Western District of Texas                          |
| PLAINTIFF<br>Intellectual Ventures I and Intellectual Ventures II |                             | DEFENDANT<br>TP-Link Corporation Limited f/k/a TP-Link International Ltd. |
| PATENT OR TRADEMARK NO.                                           | DATE OF PATENT OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                             |
| 1 7,623,439                                                       | 11/24/2009                  | Intellectual Ventures I                                                   |
| 2 US RE44,706                                                     | 1/14/2014                   | Intellectual Ventures II                                                  |
| 3                                                                 |                             |                                                                           |
| 4                                                                 |                             |                                                                           |
| 5                                                                 |                             |                                                                           |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                         |                                                                                                                                                               |                               |  |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--|
| DATE INCLUDED           | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |  |
| PATENT OR TRADEMARK NO. | DATE OF PATENT OR TRADEMARK                                                                                                                                   | HOLDER OF PATENT OR TRADEMARK |  |
| 1                       |                                                                                                                                                               |                               |  |
| 2                       |                                                                                                                                                               |                               |  |
| 3                       |                                                                                                                                                               |                               |  |
| 4                       |                                                                                                                                                               |                               |  |
| 5                       |                                                                                                                                                               |                               |  |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|       |                   |      |

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been  
filed in the U.S. District Court Western District of Texas on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                                                   |                                |                                                     |
|-------------------------------------------------------------------|--------------------------------|-----------------------------------------------------|
| DOCKET NO.<br>6:23-cv-290                                         | DATE FILED<br>4/20/2023        | U.S. DISTRICT COURT<br>Western District of Texas    |
| PLAINTIFF<br>Intellectual Ventures I and Intellectual Ventures II |                                | DEFENDANT<br>OnePlus Technology (Shenzen) Co., Ltd. |
| PATENT OR<br>TRADEMARK NO.                                        | DATE OF PATENT<br>OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                       |
| 1 7,623,439                                                       | 11/24/2009                     | Intellectual Ventures I                             |
| 2 7,646,835                                                       | 1/12/2010                      | Intellectual Ventures II                            |
| 3                                                                 |                                |                                                     |
| 4                                                                 |                                |                                                     |
| 5                                                                 |                                |                                                     |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                            |                                                                                                                                                               |                               |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| DATE INCLUDED              | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |
| PATENT OR<br>TRADEMARK NO. | DATE OF PATENT<br>OR TRADEMARK                                                                                                                                | HOLDER OF PATENT OR TRADEMARK |
| 1                          |                                                                                                                                                               |                               |
| 2                          |                                                                                                                                                               |                               |
| 3                          |                                                                                                                                                               |                               |
| 4                          |                                                                                                                                                               |                               |
| 5                          |                                                                                                                                                               |                               |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|-------|-------------------|------|

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Western District of Texas on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.):

|                                                                   |                                |                                                                                     |
|-------------------------------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------|
| DOCKET NO.<br>6:23-cv-293                                         | DATE FILED<br>4/20/2023        | U.S. DISTRICT COURT<br>Western District of Texas                                    |
| PLAINTIFF<br>Intellectual Ventures I and Intellectual Ventures II |                                | DEFENDANT<br>TCL Electronics Holdings Ltd. and<br>TCL Industries Holdings Co., Ltd. |
| PATENT OR<br>TRADEMARK NO.                                        | DATE OF PATENT<br>OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                                       |
| 1 7,089,443                                                       | 8/8/2006                       | Intellectual Ventures II                                                            |
| 2 7,623,439                                                       | 11/24/2009                     | Intellectual Ventures I                                                             |
| 3                                                                 |                                |                                                                                     |
| 4                                                                 |                                |                                                                                     |
| 5                                                                 |                                |                                                                                     |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                            |                                                                                                                                                               |                               |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| DATE INCLUDED              | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |
| PATENT OR<br>TRADEMARK NO. | DATE OF PATENT<br>OR TRADEMARK                                                                                                                                | HOLDER OF PATENT OR TRADEMARK |
| 1                          |                                                                                                                                                               |                               |
| 2                          |                                                                                                                                                               |                               |
| 3                          |                                                                                                                                                               |                               |
| 4                          |                                                                                                                                                               |                               |
| 5                          |                                                                                                                                                               |                               |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|       |                   |      |

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Western District of Texas on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                                                   |                             |                                                                           |
|-------------------------------------------------------------------|-----------------------------|---------------------------------------------------------------------------|
| DOCKET NO.<br>6:23-cv-291                                         | DATE FILED<br>4/20/2023     | U.S. DISTRICT COURT<br>Western District of Texas                          |
| PLAINTIFF<br>Intellectual Ventures I and Intellectual Ventures II |                             | DEFENDANT<br>TP-Link Corporation Limited f/k/a TP-Link International Ltd. |
| PATENT OR TRADEMARK NO.                                           | DATE OF PATENT OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                             |
| 1 7,623,439                                                       | 11/24/2009                  | Intellectual Ventures I                                                   |
| 2 US RE44,706                                                     | 1/14/2014                   | Intellectual Ventures II                                                  |
| 3                                                                 |                             |                                                                           |
| 4                                                                 |                             |                                                                           |
| 5                                                                 |                             |                                                                           |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                         |                                                                                                                                                               |                               |  |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--|
| DATE INCLUDED           | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |  |
| PATENT OR TRADEMARK NO. | DATE OF PATENT OR TRADEMARK                                                                                                                                   | HOLDER OF PATENT OR TRADEMARK |  |
| 1                       |                                                                                                                                                               |                               |  |
| 2                       |                                                                                                                                                               |                               |  |
| 3                       |                                                                                                                                                               |                               |  |
| 4                       |                                                                                                                                                               |                               |  |
| 5                       |                                                                                                                                                               |                               |  |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|       |                   |      |

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been  
 filed in the U.S. District Court **Western District of Texas** on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                                                              |                                |                                                  |
|------------------------------------------------------------------------------|--------------------------------|--------------------------------------------------|
| DOCKET NO.<br>6:23-cv-307                                                    | DATE FILED<br>4/26/2023        | U.S. DISTRICT COURT<br>Western District of Texas |
| PLAINTIFF<br>Intellectual Ventures I LLC and<br>Intellectual Ventures II LLC |                                | DEFENDANT<br>Lenovo Group Limited                |
| PATENT OR<br>TRADEMARK NO.                                                   | DATE OF PATENT<br>OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                    |
| 1 7,325,140                                                                  | 1/29/2008                      | Intellectual Ventures II LLC                     |
| 2 8,474,016                                                                  | 6/25/2013                      | Intellectual Ventures II LLC                     |
| 3 7,089,443                                                                  | 8/8/2006                       | Intellectual Ventures I LLC                      |
| 4 7,623,439                                                                  | 11/24/2009                     | Intellectual Ventures I LLC                      |
| 5 7,646,835                                                                  | 1/12/2010                      | Intellectual Ventures II LLC                     |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                            |                                                                                                                                                               |                               |  |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--|
| DATE INCLUDED              | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |  |
| PATENT OR<br>TRADEMARK NO. | DATE OF PATENT<br>OR TRADEMARK                                                                                                                                | HOLDER OF PATENT OR TRADEMARK |  |
| 1                          |                                                                                                                                                               |                               |  |
| 2                          |                                                                                                                                                               |                               |  |
| 3                          |                                                                                                                                                               |                               |  |
| 4                          |                                                                                                                                                               |                               |  |
| 5                          |                                                                                                                                                               |                               |  |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|-------|-------------------|------|

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
 Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Western District of Texas on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                                                   |                             |                                                                           |
|-------------------------------------------------------------------|-----------------------------|---------------------------------------------------------------------------|
| DOCKET NO.<br>6:23-cv-291                                         | DATE FILED<br>4/20/2023     | U.S. DISTRICT COURT<br>Western District of Texas                          |
| PLAINTIFF<br>Intellectual Ventures I and Intellectual Ventures II |                             | DEFENDANT<br>TP-Link Corporation Limited f/k/a TP-Link International Ltd. |
| PATENT OR TRADEMARK NO.                                           | DATE OF PATENT OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                             |
| 1 7,623,439                                                       | 11/24/2009                  | Intellectual Ventures I                                                   |
| 2 US RE44,706                                                     | 1/14/2014                   | Intellectual Ventures II                                                  |
| 3                                                                 |                             |                                                                           |
| 4                                                                 |                             |                                                                           |
| 5                                                                 |                             |                                                                           |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                         |                                                                                                                                                               |                               |  |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--|
| DATE INCLUDED           | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |  |
| PATENT OR TRADEMARK NO. | DATE OF PATENT OR TRADEMARK                                                                                                                                   | HOLDER OF PATENT OR TRADEMARK |  |
| 1                       |                                                                                                                                                               |                               |  |
| 2                       |                                                                                                                                                               |                               |  |
| 3                       |                                                                                                                                                               |                               |  |
| 4                       |                                                                                                                                                               |                               |  |
| 5                       |                                                                                                                                                               |                               |  |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|       |                   |      |

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy



|                                                                                                                                                      |                                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b> <b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Eastern District of Virginia on the following

☐ Trademarks or ☒ Patents. ( ☒ the patent action involves 35 U.S.C. § 292.);

|                                                                                          |                             |                                                                                                              |
|------------------------------------------------------------------------------------------|-----------------------------|--------------------------------------------------------------------------------------------------------------|
| DOCKET NO.                                                                               | DATE FILED<br>9/5/2023      | U.S. DISTRICT COURT<br>Eastern District of Virginia                                                          |
| <b>PLAINTIFF</b><br>Peter Christian Hessing-Roper<br><i>U.S. Patent Pending 15658121</i> |                             | <b>DEFENDANT</b><br>Commissioner for Patents, Reginald Tillman Jr Patent Examiner. Patent Trial Appeal Board |
| PATENT OR TRADEMARK NO.                                                                  | DATE OF PATENT OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                                                                |
| 1 Patent Pending 15658121                                                                | 7/24/2017                   | Peter Christian Hessing- Roper                                                                               |
| 2 15658121                                                                               |                             |                                                                                                              |
| 3                                                                                        |                             |                                                                                                              |
| 4                                                                                        |                             |                                                                                                              |
| 5                                                                                        |                             |                                                                                                              |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                                |                                                                                                                                                               |                                |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| DATE INCLUDED                  | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                                |
| PATENT OR TRADEMARK NO.        | DATE OF PATENT OR TRADEMARK                                                                                                                                   | HOLDER OF PATENT OR TRADEMARK  |
| 1 U.S. Patent Pending 15658121 | <del>9/5/2023</del>                                                                                                                                           | Peter Christian Hessing -Roper |
| 2 15658121                     | Filing Date 7/24/2017                                                                                                                                         |                                |
| 3                              |                                                                                                                                                               |                                |
| 4                              |                                                                                                                                                               |                                |
| 5                              |                                                                                                                                                               |                                |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|                    |

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|       |                   |      |

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
 Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

AO 120 (Rev. 08/10)

|                                                                                                                                                         |                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>TO:</b><br><b>Mail Stop 8</b><br><b>Director of the U.S. Patent and Trademark Office</b><br><b>P.O. Box 1450</b><br><b>Alexandria, VA 22313-1450</b> | <b>REPORT ON THE</b><br><b>FILING OR DETERMINATION OF AN</b><br><b>ACTION REGARDING A PATENT OR</b><br><b>TRADEMARK</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Western District of Texas on the following

☐ Trademarks or ☒ Patents. ( ☐ the patent action involves 35 U.S.C. § 292.);

|                                                                   |                             |                                                                           |
|-------------------------------------------------------------------|-----------------------------|---------------------------------------------------------------------------|
| DOCKET NO.<br>6:23-cv-291                                         | DATE FILED<br>4/20/2023     | U.S. DISTRICT COURT<br>Western District of Texas                          |
| PLAINTIFF<br>Intellectual Ventures I and Intellectual Ventures II |                             | DEFENDANT<br>TP-Link Corporation Limited f/k/a TP-Link International Ltd. |
| PATENT OR TRADEMARK NO.                                           | DATE OF PATENT OR TRADEMARK | HOLDER OF PATENT OR TRADEMARK                                             |
| 1 7,623,439                                                       | 11/24/2009                  | Intellectual Ventures I                                                   |
| 2 US RE44,706                                                     | 1/14/2014                   | Intellectual Ventures II                                                  |
| 3                                                                 |                             |                                                                           |
| 4                                                                 |                             |                                                                           |
| 5                                                                 |                             |                                                                           |

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

|                         |                                                                                                                                                               |                               |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| DATE INCLUDED           | INCLUDED BY<br><input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading |                               |
| PATENT OR TRADEMARK NO. | DATE OF PATENT OR TRADEMARK                                                                                                                                   | HOLDER OF PATENT OR TRADEMARK |
| 1                       |                                                                                                                                                               |                               |
| 2                       |                                                                                                                                                               |                               |
| 3                       |                                                                                                                                                               |                               |
| 4                       |                                                                                                                                                               |                               |
| 5                       |                                                                                                                                                               |                               |

In the above—entitled case, the following decision has been rendered or judgement issued:

|                    |
|--------------------|
| DECISION/JUDGEMENT |
|--------------------|

|       |                   |      |
|-------|-------------------|------|
| CLERK | (BY) DEPUTY CLERK | DATE |
|       |                   |      |

Copy 1—Upon initiation of action, mail this copy to Director    Copy 3—Upon termination of action, mail this copy to Director  
Copy 2—Upon filing document adding patent(s), mail this copy to Director    Copy 4—Case file copy

UNITED STATES PATENT AND TRADEMARK OFFICE

---

BEFORE THE PATENT TRIAL AND APPEAL BOARD

---

Zebra Technologies Corporation,  
Petitioner,

v.

Intellectual Ventures I LLC,  
Patent Owner.

---

Case IPR2024-00883  
Patent No. 7,623,439

---

Mailed: May 22, 2024

Before Carrie Johnson, *Trial Paralegal*

NOTICE OF FILING DATE ACCORDED TO PETITION  
AND  
TIME FOR FILING PATENT OWNER PRELIMINARY RESPONSE

The petition for *inter partes* review filed in the above proceeding has been accorded the filing date of May 1, 2024.

Patent Owner may file a preliminary response to the petition no later than three months from the date of this notice. The preliminary response is limited to setting forth the reasons why the requested review should not be instituted. Patent Owner may also file an election to waive the preliminary

response to expedite the proceeding. For more information, please consult the Office Patent Trial Practice Guide, 77 Fed. Reg. 48756 (Aug. 14, 2012), which is available on the Board Web site at <http://www.uspto.gov/PTAB>.

Patent Owner is advised of the requirement to submit mandatory notice information under 37 C.F.R. § 42.8(a)(2) within 21 days of service of the petition. Mandatory notices include identifying any other judicial or administrative matter that would affect, or be affected by, a decision in the proceeding. 37 C.F.R. § 42.8(b)(2). Such administrative matters include requests for certificates of correction.

The parties are encouraged to use the heading on the first page of this Notice for all future filings in the proceeding.

The parties are advised that under 37 C.F.R. § 42.10(c), recognition of counsel *pro hac vice* requires a showing of good cause. The parties are authorized to file motions for *pro hac vice* admission under 37 C.F.R. § 42.10(c). Such motions shall be filed in accordance with the “Order -- Authorizing Motion *for Pro Hac Vice* Admission” in Case IPR2013-00639, Paper 7, a copy of which is available on the Board Web site under “Representative Orders, Decisions, and Notices.”

The parties are reminded that unless otherwise permitted by 37 C.F.R. § 42.6(b)(2), all filings in this proceeding must be made electronically in the Patent Trial Appeal Case Tracking System (P-TACTS), accessible from the Board Web site at <http://www.uspto.gov/PTAB>. To file documents, users must first obtain a user ID by registering with MyUSPTO. Information regarding how to register with MyUSPTO and use P-TACTS is available at the Board Web site at <https://www.uspto.gov/patents/ptab/patent-trial-and-appeal-case-tracking-system-p-tacts>.

The parties may request a conference call as needed. Any email requesting a conference call with the Board should: (a) copy all parties, (b) indicate generally the relief being requested or the subject matter of the conference call, (c) include multiple times when all parties are available, (d) state whether the opposing party opposes any relief requested, and (e) if opposed, either certify that the parties have met and conferred telephonically or in person in an attempt to reach agreement, or explain why such meet and confer did not occur. The email may not contain substantive argument and, unless otherwise authorized, may not include attachments. *See* Trial Practice Guide at 9–10. If practicable, in order to ensure emails are consistent with the above, the parties should send a single, joint email that includes items (a)–(e).

If there are any questions pertaining to this notice, please contact Carrie Johnson at 571-272-5169 or the Patent Trial and Appeal Board at 571-272-7822.

Case IPR2024-00883

Patent No. 7,623,439

PETITIONER:

Michael Morlock

April Isaacson

mmorlock@kilpatricktownsend.com

aisaacson@kilpatricktownsend.com

PATENT OWNER:

Brandon Theiss

Daniel Golub

Ryan O'Donnell

Robert Leonard

Russell Rigby

btheiss@vklaw.com

dgolub@vklaw.com

rodonnell@vklaw.com

rleonard@vklaw.com

rrigby@intven.com

**NOTICE CONCERNING ALTERNATIVE DISPUTE RESOLUTION  
(ADR)**

The Patent Trial and Appeal Board (PTAB) strongly encourages parties who are considering settlement to consider alternative dispute resolution as a means of settling the issues that may be raised in an AIA trial proceeding. Many AIA trials are settled prior to a Final Written Decision. Those considering settlement may wish to consider alternative dispute resolution techniques early in a proceeding to produce a quicker, mutually agreeable resolution of a dispute or to at least narrow the scope of matters in dispute. Alternative dispute resolution has the potential to save parties time and money.

Many non-profit organizations, both inside and outside the intellectual property field, offer alternative dispute resolution services. Listed below are the names and addresses of several such organizations. The listings are provided for the convenience of parties involved in cases before the PTAB; the PTAB does not sponsor or endorse any particular organization's alternative dispute resolution services. In addition, consideration may be given to utilizing independent alternative dispute resolution firms. Such firms may be located through a standard keyword Internet search.

| <b>CPR<br/>INSTITUTE<br/>FOR DISPUTE<br/>RESOLUTION</b> | <b>AMERICAN<br/>INTELLECTUAL<br/>PROPERTY<br/>LAW<br/>ASSOCIATION<br/>(AIPLA)</b> | <b>AMERICAN<br/>ARBITRATION<br/>ASSOCIATION (AAA)</b> | <b>WORLD<br/>INTELLECTUAL<br/>PROPERTY<br/>ORGANIZATION (WIPO)</b> | <b>AMERICAN<br/>BAR<br/>ASSOCIATION<br/>(ABA)</b>            |
|---------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------------------------------|
| Telephone:<br>(212) 949-6490                            | Telephone:<br>(703) 415-0780                                                      | Telephone:<br>(212) 484-3266                          | Telephone:<br>41 22 338 9111                                       | Telephone :<br>(202) 662-1000                                |
| Fax: (212) 949-8859                                     | Fax: (703) 415-0786                                                               | Fax: (212) 307-4387                                   | Fax: 41 22 733 5428                                                | N/A                                                          |
| 575 Lexington Ave<br>New York, NY 10022                 | 241 18th Street, South,<br>Suite 700<br>Arlington, VA 22202                       | 140 West 51st<br>Street<br>New York, NY<br>10020      | 34, chemin des<br>Colombettes<br>CH-1211 Geneva 20,<br>Switzerland | 1050 Connecticut Ave,<br>NW<br>Washington D.C. 20036         |
| <a href="http://www.cpradr.org">www.cpradr.org</a>      | <a href="http://www.aipla.org">www.aipla.org</a>                                  | <a href="http://www.adr.org">www.adr.org</a>          | <a href="http://www.wipo.int">www.wipo.int</a>                     | <a href="http://www.americanbar.org">www.americanbar.org</a> |

If parties to an AIA trial proceeding consider using alternative dispute resolution, the PTAB would like to know whether the parties ultimately decided to engage in alternative dispute resolution and the reasons why or why not. If the parties actually engage in alternative dispute resolution, the PTAB would be interested to learn what mechanism (e.g., arbitration,

mediation, etc.) was used and the general result. Such a statement from the parties is not required but would be helpful to the PTAB in assessing the value of alternative dispute resolution to parties involved in AIA trial proceedings. To report an experience with ADR, please forward a summary of the particulars to the following email address:  
PTAB\_ADR\_Comments@uspto.gov



**The United States Patent and Trademark Office**  
**PATENT TRIAL AND APPEAL BOARD**



A petition has been filed in Patent Number 7623439, Application Number 11/121661  
on 05/01/2024 (Date).

The Case Number is IPR2024-00883.  
(IPR, CBM, PGR, DER #)

To view the documents filed in this petition, go to <https://ptab.uspto.gov>.

Use the Search PTAB tab and enter the Patent Number or the Trial or Case Number and select the Search button.

Questions regarding this notice should be directed to the Patent Trial and Appeal Board at 571-272-7822.