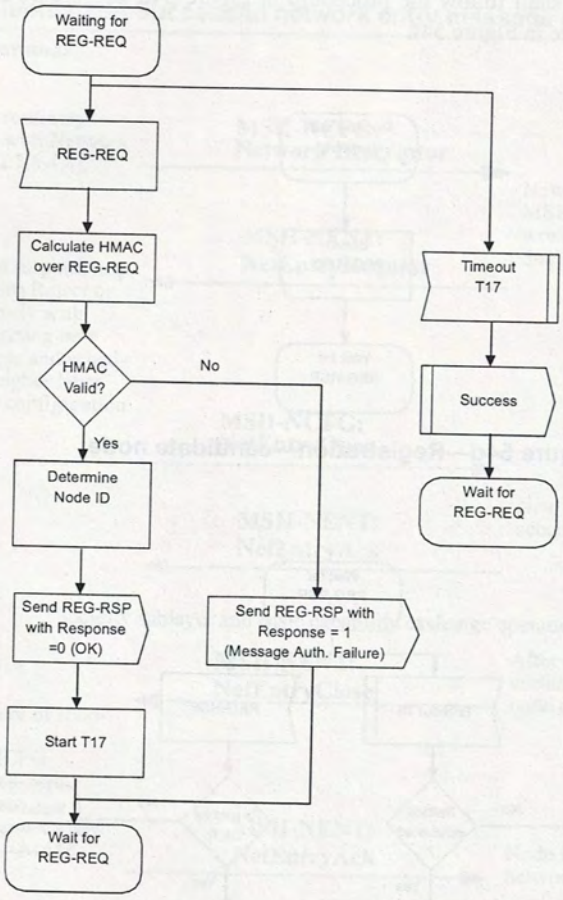


Figure 54f—Registration—registration node

6.2.9.14.7 Establish IP connectivity

The Node shall acquire an IP address using DHCP. The procedure is shown in Table 62 and takes place over the Sponsor Channel.

6.2.9.14.8 Establish time of day

The Nodes in a Mesh network shall retrieve the time of day using the protocol defined in [IETF RFC 868]. The messages shall be carried over UDP in the Sponsor Channel.

6.2.9.14.9 Transfer operational parameters

After successfully acquiring an IP address via DHCP the Node shall download a parameter file using TFTP. The procedure is described in 6.2.9.12. The Node shall instead of the Secondary Management connection use the Sponsor Channel for this purpose.

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6.2.9.14.10 Setup provisioned traffic parameters

Using Mesh, QoS is provisioned on a packet-by-packet basis using the Mesh CID. The connection-based QoS provisioning using the DSx messages defined in 6.2.13 are hence not used. A Mesh node obtains its AuthorizedQoSParamSet during the transfer of operational parameters.

6.2.9.14.11 Establishing links to neighbors

After entering the network, a node can establish links with nodes other than its sponsor by following the secure process as defined in Table 54e. This process uses the MSH-NCFG:Neighbor Link Establishment IE.

a) Node A sends a challenge (action code = 0x0) containing:

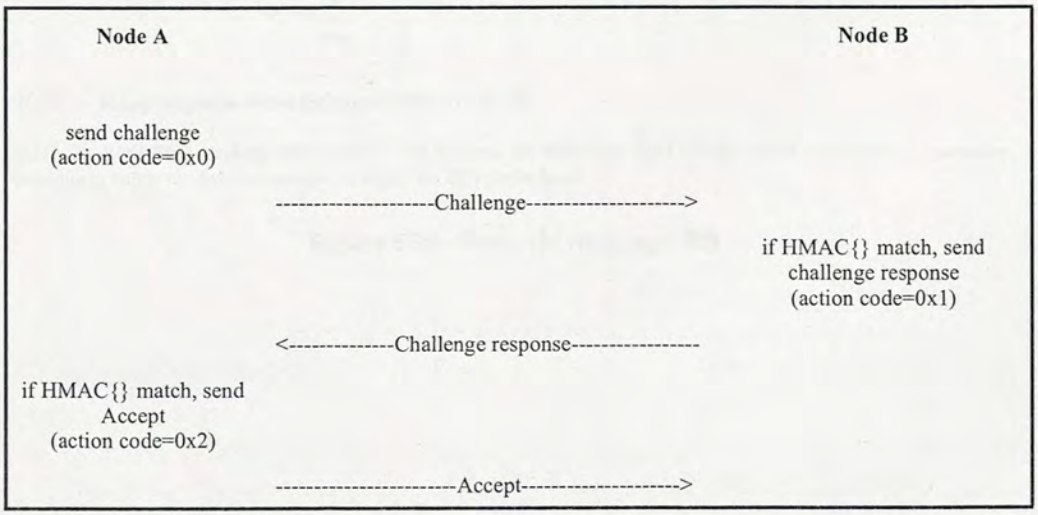
   HMAC{Operator Shared Secret, frame number, Node ID of node A, Node ID of node B}
   where the Operator Shared Secret is a private key obtained from the provider (which is also used to enter the network) and the frame number is the last known frame number in which Node B sent a MSH-NCFG message.

b) Node B, upon reception, computes the same value (it may also attempt some earlier frame numbers where it sent MSH-NCFG messages, in case node A missed the last of its MSH-NCFGs) in item a) and compares. If the values don't match a rejection (action code = 0x3) is returned. If a match is achieved, Node B sends, implicitly accepting the link, a challenge response (action code=0x1) containing:

   HMAC{Operator Shared Secret, frame number, Node ID of node B, Node ID of node A}
   where the frame number is the frame number in which Node A sent the MSH-NCFG message with challenge. It also randomly selects and includes an unused link ID, which shall from this point forward indicate the link from node B to node A.

c) Node A, upon reception, computes the same value in item b) and compares. If the values do not match a rejection (action code = 0x3) is returned. If a match is achieved, Node A sends an Accept. It also randomly selects and includes an unused link ID, which shall from this point forward indicate the link from node A to node B.

Table 54e—Establishing link connectivity



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6.2.10 Ranging

Replace first and second paragraph with the following:

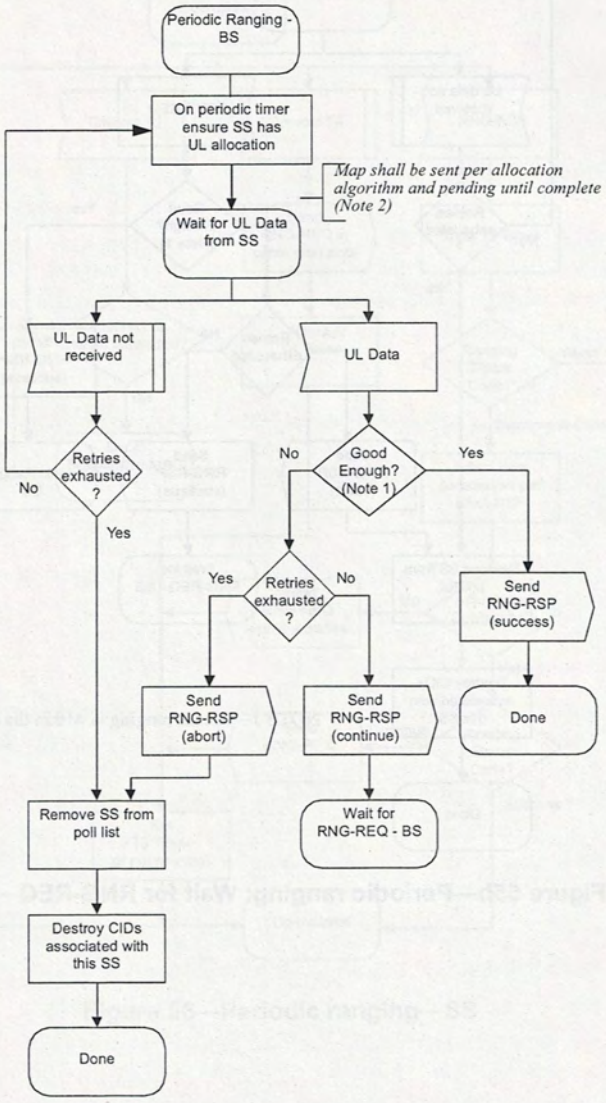
There are two different ranging procedures: initial ranging and periodic ranging. Initial ranging, detailed in 6.2.9.5 is for a new SS to acquire correct transmission parameters, such as time offset and Tx power level, so that the new SS can communicate with the BS properly. Periodic ranging is for the SSs during normal operations to adjust transmission parameters so the SSs can communicate with the BS properly.

The following summarizes the periodic ranging (with exception of CDMA based ranging, which is covered in 6.2.10.2):

1) Both the BS and the SSs shall use a timer T4 for periodic ranging and set the Initial Ranging timer T3 after a RNG-REQ message has been sent.
2) The periodic ranging shall be conducted periodically at an interval sufficiently shorter than T4 that a map could be missed without the SS timing out.
3) A periodic ranging procedure can be originated by either the BS or the SSs.
    i) The BS can originate a periodic ranging procedure by sending an unsolicited RNG-RSP with adjustments based on any UL transmission it received from the SS.
    ii) A SS can originates a periodic ranging procedure by sending a RNG-REQ message in an allocation of UL bandwidth or a contention-based initial ranging slot. Upon receiving this RNG-REQ message, the BS shall send a RNG-RSP to the SS.
4) Upon receiving a RNG-RSP message, the SS shall adjust the indicated transmission parameters accordingly and clear timer T3.
5) The SS shall re-initialize its MAC sublayer (and re-register) when T3 expires and the number of RNG-REQ retries has been exceeded and when the Ranging Status indicates Abort.

Replace Figure 55 with Figure 55a and Figure 55b as follows:

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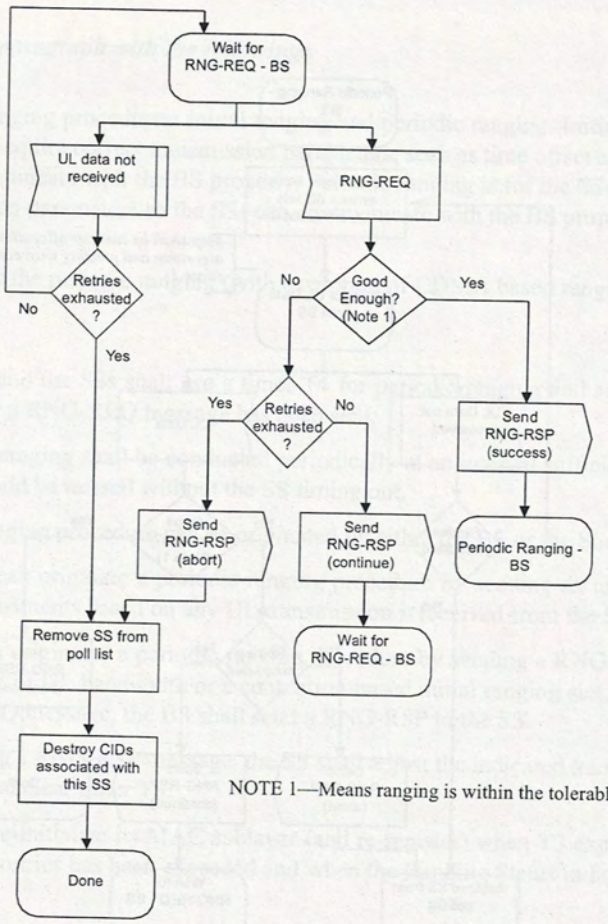


NOTE 1—Means ranging is within the tolerable limits of the BS.

NOTE 2—RNG-REQ pending-until-complete was nonzero, the BS should hold off the station maintenance opportunity accordingly unless needed, for example, to adjust the SS's power level.

Figure 55a—Periodic ranging—BS

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NOTE 1—Means ranging is within the tolerable limits of the BS.

Figure 55b—Periodic ranging: Wait for RNG-REQ—BS

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Replace Figure 56 as follows:

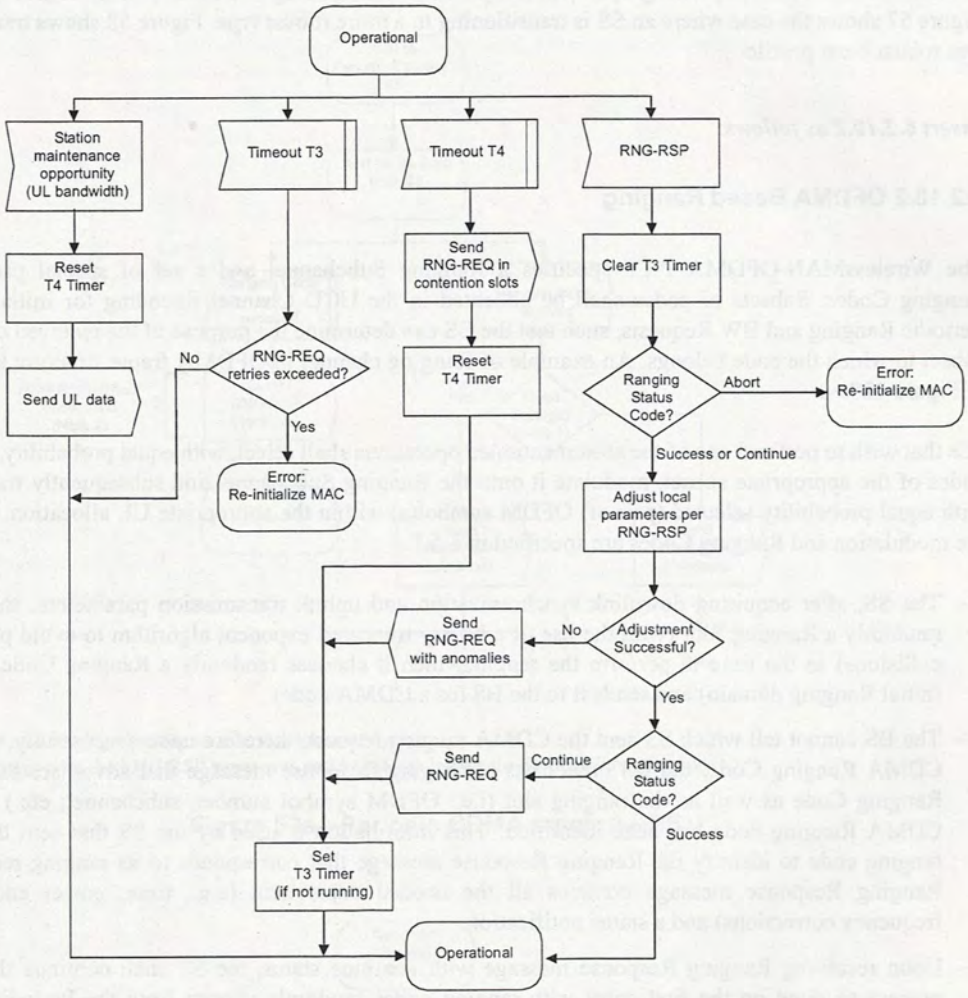


Figure 56—Periodic ranging—SS

6.2.10.1 Downlink burst profile management in framed operation

Change first paragraph to read:

The downlink burst profile is determined by the BS according to the quality of the signal that is received by each SS. To reduce the volume of uplink traffic, the SS monitors the carrier to noise and interference ratio [C/(N+I)] and compares the average value against the allowed range of operation. This region is bounded by threshold levels. If the received C/(N+I) goes outside of the allowed operating region, the SS requests a change to a new burst profile using one of three methods. If the SS has a station maintenance interval available, it shall send a RNG-REQ message to which the BS responds with a RNG-RSP message. Otherwise, the SS shall send a DBPC-REQ message in an uplink allocation addressed to that SS's basic connection ~~(regardless of whether the SS is GPC or GPT)~~. The BS responds with a DBPC-RSP message. If neither of these options is available and the SS requires a more robust burst profile on the downlink, the SS

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shall send a RNG-REQ message in an Initial Maintenance interval. In all three methods, the message is sent using the Basic CID of the SS. The coordination of message transmit and receipt relative to actual change of modulation is different depending upon whether an SS is transitioning to a more or less robust burst profile. Figure 57 shows the case where an SS is transitioning to a more robust type. Figure 58 shows transition to a less robust burst profile.

Insert 6.2.10.2 as follows:

6.2.10.2 OFDMA Based Ranging

The WirelessMAN-OFDMA PHY specifies a Ranging Subchannel and a set of special pseudo-noise Ranging Codes. Subsets of codes shall be allocated in the UCD Channel Encoding for Initial Ranging, Periodic Ranging and BW Requests, such that the BS can determine the purpose of the received code by the subset to which the code belongs. An example of Ranging channel in OFDMA frame structure is specified in Figure 128av.

SSs that wish to perform one of the aforementioned operations shall select, with equal probability, one of the codes of the appropriate subset, modulate it onto the Ranging Subchannel and subsequently transmit in a with equal probability selected (pair of) OFDM symbol(s) within the appropriate UL allocation. Details on the modulation and Ranging Codes are specified in 8.5.7.

— The SS, after acquiring downlink synchronization and uplink transmission parameters, shall choose randomly a Ranging Slot (with the use of a binary truncated exponent algorithm to avoid possible re-collisions) as the time to perform the ranging, then it chooses randomly a Ranging Code (from the Initial Ranging domain) and sends it to the BS (as a CDMA code).

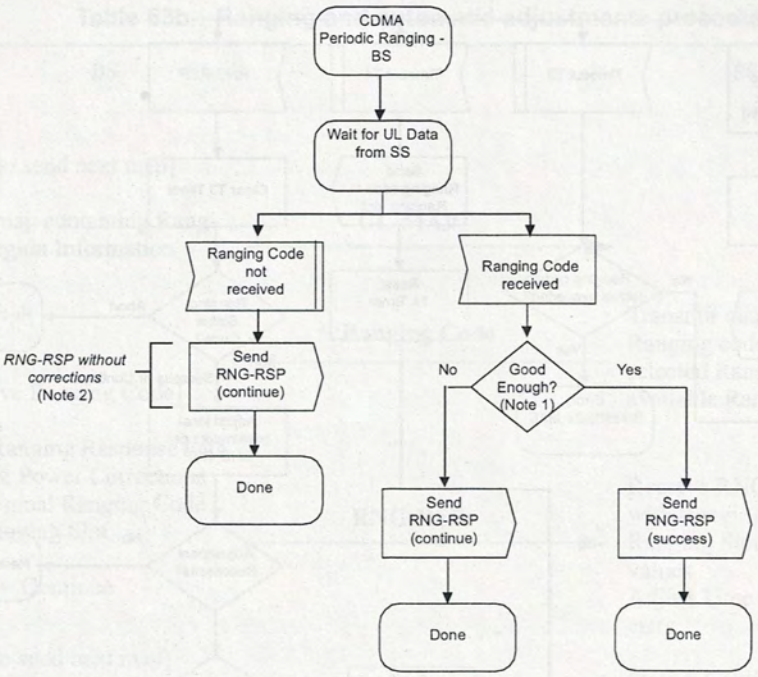
— The BS cannot tell which SS sent the CDMA ranging request, therefore upon successfully receiving a CDMA Ranging Code, the BS broadcasts a Ranging Response message that advertises the received Ranging Code as well as the ranging slot (i.e., OFDM symbol number, subchannel, etc.) where the CDMA Ranging code has been identified. This information is used by the SS that sent the CDMA ranging code to identify the Ranging Response message that corresponds to its ranging request. The Ranging Response message contains all the needed adjustment (e.g., time, power and possibly frequency corrections) and a status notification.

— Upon receiving Ranging Response message with continue status, the SS shall continue the ranging process as done on the first entry with ranging codes randomly chosen from the Periodic Ranging domain.

— Using the OFDMA ranging mechanism, the periodic ranging timer is controlled by the SS, not the BS.

Add Figure 59a, Figure 59b, and Figure 59c.

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NOTE 1—Means ranging is within the tolerable limits of the BS.
NOTE 2—In this case, the RNG-RSP message is sent in order to initiate the SS to send ranging code.

Figure 59a—Periodic CDMA ranging—BS

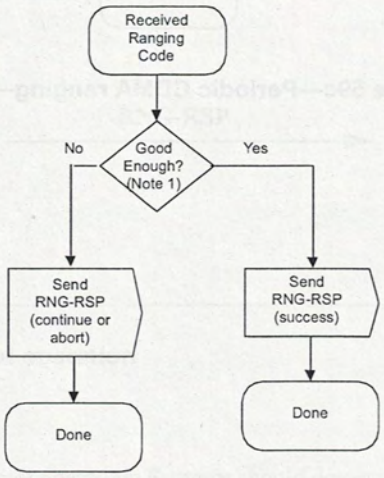


Figure 59b—Periodic ranging—Received ranging code—BS

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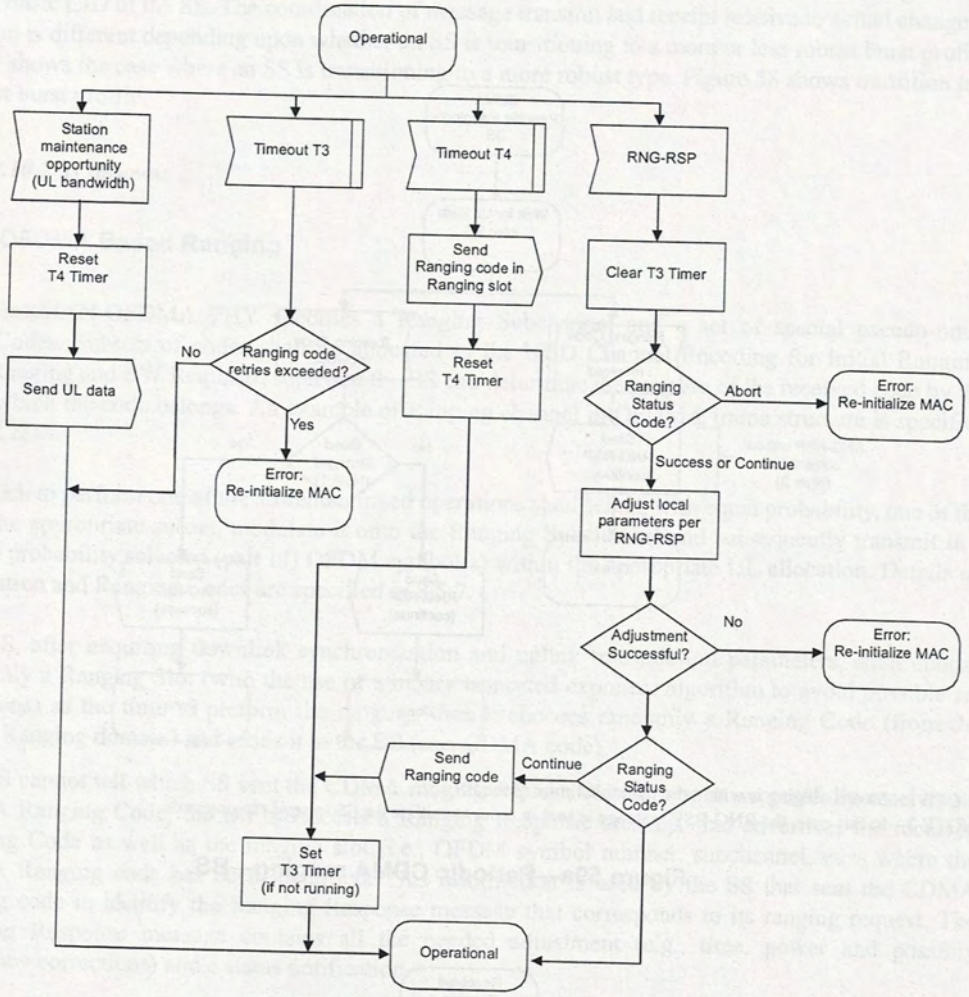
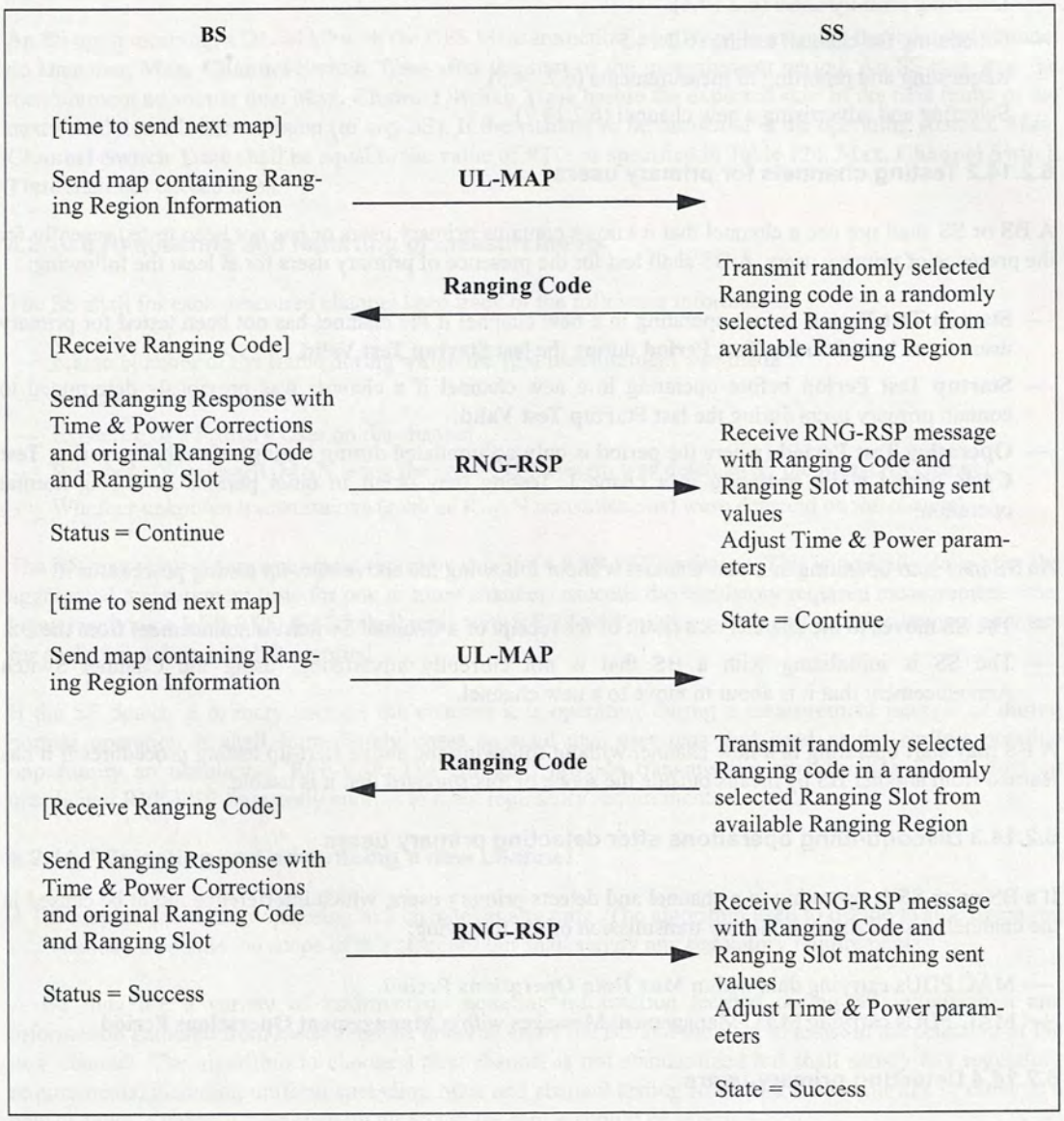


Figure 59c—Periodic CDMA ranging—SS

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Table 63b describes the ranging adjustment process.

Table 63b—Ranging and automatic adjustments procedure



6.2.14 DFS for license-exempt operation

6.2.14.1 Introduction

DFS is mandatory for license-exempt operation. Systems should detect and avoid primary users. Further, the use of channel selection algorithms is required, which result in uniform channel spreading across a minimum number of channels. This specification is intended to be compliant with the regulatory requirements set forth in [B37]. The timing parameters used for DFS are specified by each regulatory administration.

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The DFS procedures provide for:

— Testing channels for primary users (6.2.14.2).
— Discontinuing operations after detecting primary users (6.2.14.3).
— Detecting primary users (6.2.14.4).
— Scheduling for channel testing (6.2.14.5).
— Requesting and reporting of measurements (6.2.14.5).
— Selecting and advertising a new channel (6.2.14.7).

6.2.14.2 Testing channels for primary users

A BS or SS shall not use a channel that it knows contains primary users or has not been tested recently for the presence of primary users. A BS shall test for the presence of primary users for at least the following:

— **Startup Test Period** before operating in a new channel if the channel has not been tested for primary users for at least **Startup Test Period** during the last **Startup Test Valid**.
— **Startup Test Period** before operating in a new channel if a channel was previously determined to contain primary users during the last **Startup Test Valid**.
— **Operating Test Period** (where the period is only accumulated during testing) of each **Operating Test Cycle** period while operating in a channel. Testing may occur in quiet periods or during normal operation.

An SS may start operating in a new channel without following the above start-up testing procedures if:

— The SS moves to the channel as a result of the receipt of a Channel Switch Announcement from the BS.
— The SS is initializing with a BS that is not currently advertising, using the Channel Switch Announcement that it is about to move to a new channel.

A BS may start operating in a new channel without following the above start-up testing procedures if it has learned from another BS by means outside the scope of this standard that it is usable.

6.2.14.3 Discontinuing operations after detecting primary users

If a BS or an SS is operating in a channel and detects primary users, which interference might be caused in the channel, it shall discontinue any transmission of the following:

— MAC PDUs carrying data within **Max Data Operations Period**.
— MAC PDUs carrying MAC Management Messages within **Management Operations Period**.

6.2.14.4 Detecting primary users

Each BS and SS shall use a method to detect primary users operating in a channel that satisfies the regulatory requirements. The particular method used to perform the primary user detection is outside the scope of this specification.

6.2.14.5 Scheduling for channel testing

A BS may measure one or more channels itself and request any SS to measure one or more channels on its behalf, either in a quiet period or during normal operation.

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To request the SSs to measure one channel the BS shall include in the DL-MAP a Report Measurement IE as specified in 8.4.5.2.2. The BS that requests the SSs to perform a measurement shall not transmit MAC PDUs to any SS during the measurement interval. If the channel measured is the operational channel, the BS shall not schedule any UL transmissions from SSs to take place during the measurement period.

An SS upon receiving a DL-MAP with the DFS Measurement IE shall start to measure the indicated channel no later than **Max. Channel Switch Time** after the start of the measurement period. An SS may stop the measurement no sooner than **Max. Channel Switch Time** before the expected start of the next frame or the next scheduled UL transmission (of any SS). If the channel to be measured is the operating channel, **Max. Channel Switch Time** shall be equal to the value of RTG, as specified in Table 124. **Max. Channel Switch Time** shall not exceed 2 ms.

6.2.14.6 Requesting and reporting of measurements

The SS shall for each measured channel keep track of the following information:

— Frame Number of the frame during which the first measurement was made
— Accumulated time measured
— Existence of a Primary User on the channel
— Whether a WirelessHUMAN using the same PHY system was detected on the measures channel
— Whether unknown transmissions (such as RLAN transmissions) were detected on the channel.

The BS may request a measurement report by sending a REP-REQ message. This is typically done after the aggregated measurement time for one or more channels exceeds the regulatory required measurement time. Upon receiving a REP-REQ the SS shall reply with a REP-RSP message and reset its measurement counters for each channel on which it reported.

If the SS detects a primary user on the channel it is operating during a measurement interval or during normal operation it shall immediately cease to send any user data and send at the earliest possible opportunity an unsolicited REP-RSP. The BS shall provide transmission opportunities for sending an unsolicited REP-RSP frequently enough to meet regulatory requirements.

6.2.14.7 Selecting and advertising a new channel

A BS may decide to stop operating in a channel at any time. The algorithm used to decide to stop operating in a channel is outside the scope of this standard but shall satisfy any regulatory requirements.

A BS may use a variety of information, including information learned during SS initialization and information gathered from measurements undertaken by the BS and the SSs, to assist in the selection of the new channel. The algorithm to choose a new channel is not standardized but shall satisfy any regulatory requirements, including uniform spreading rules and channel testing rules. If a BS would like to move to a new channel, a channel supported by all SSs in the sector should be selected.

A BS shall inform its associated SSs of the new channel using the Channel Nr in the DCD message. The new channel shall be used starting from the frame with the number given by the Channel Switch Frame Number in the DCD message. The BS shall not schedule any transmissions during the last **Max. Channel Switch Time** before the channel change is to take place.

The uplink burst profiles used on the old channel defined shall be considered valid also for the new channel, i.e., the BS need not define new UL Burst Profiles when changing channels. When operating in license-exempt bands the BS shall not send the Frequency (Type=3) parameter as a part of UCD message.

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6.2.15 MAC Management Message tunneling in Mesh Mode

In Mesh networks during network entry certain MAC Message protocols take place between entities separated by multiple hops. In these cases the Sponsor Node shall relay the MAC Messages from the New Node acting as the SS to the peer performing the duties of the PMP BS. The sponsor shall also relay the messages from the BS entity to the New Node.

The Sponsor shall tunnel the MAC Messages received from the New Node (SS) listed in Table 71a over UDP as shown in Figure 96a. to the entity performing the BS part of the protocol. The UDP source and destination port used for tunneled messages shall be equal to 80216_UDP_PORT. The sponsor shall also extract the MAC messages from the UDP packets arriving from the BS entity and transmit them over the air to the New Node.

Table 71a—MAC Management Messages tunneled over UDP during network entry

Message	Action of sponsor	Direction of message
PKM-REQ:Auth Request	Tunnel	SS to BS
PKM-REQ:Auth Info	Tunnel	SS to BS
PKM-RSP:Auth Reply	Extract	BS to SS
PKM-RSP:Auth Reject	Extract	BS to SS
REG-REQ	Tunnel	SS to BS
REG-RSP	Extract	BS to SS

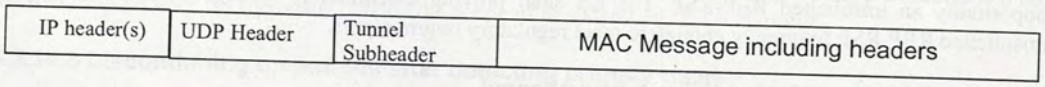


Figure 96a—MAC over UDP/IP tunneling

The format of the Tunnel Subheader is defined in Table 71b.

Table 71b—Tunnel Subheader Format

Syntax	Size	Notes
Tunnel_Subheader(){		
Type	1 byte	0 = Reserved 1 = WirelessMAN MAC header 2–255Reserved
}		

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Also MAC messages may need to be tunneled end to end in cases when the protocol takes place between peers separated by several hops. The packet format in Figure 96a shall be used in these cases with the Tunnel Subheader format defined in Table 71b.

Replace heading numbers 6.A and 6.B with 6.1 and 6.2, respectively, and renumber all remaining headings within Clause 6 subsequently.

7. Privacy sublayer

7.2 Privacy Key Management (PKM) protocol

7.2.2 TEK exchange overview

Insert immediately after header:

7.2.2.1 TEK exchange overview for PMP topology

Insert at end of 7.2.2.1:

7.2.2.2 TEK exchange overview for Mesh Mode

Upon achieving authorization, a Node starts for each Neighbor a separate TEK state machine for each of the SAIDs identified in the Authorization Reply message. Each TEK state machine operating within the Node is responsible for managing the keying material associated with its respective SAID. The Node is responsible for maintaining the TEKs between itself and all nodes it initiates TEK exchange with. Its TEK state machines periodically send Key Request messages to the Neighbors of the node, requesting a refresh of keying material for their respective SAIDs.

The Neighbor replies to a Key Request with a Key Reply message, containing the BS's active keying material for a specific SAID.

The traffic encryption key (TEK) in the Key Reply is encrypted, using the node's public key found in the SS-Certificate attribute.

Note that at all times the node maintains two active sets of keying material per SAID per neighbor. The life-times of the two generations overlap such that each generation becomes active halfway through the life of its predecessor and expires halfway through the life of its successor. A neighbor includes in its Key Replies *both* of an SAID's active generations of keying material.

The Key Reply provides the requesting Node, in addition to the TEK, the remaining lifetime of each of the two sets of keying material. The receiving Node uses these remaining lifetimes to estimate when the Neighbor invalidates a particular TEK, and therefore when to schedule future Key Requests. The transmit regime between the initiating Node and the Neighbor provides for seamless key transition.

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Insert 7.4.1.6, 7.4.2.4 and 7.4.2.5 as follows:

7.4.1.6 Node re-authorization in Mesh Mode during normal operation

When re-authorizing with the network, the re-authorizing node shall tunnel the authorization messages as shown in Figure 96a over UDP.

7.4.2.4 TEK usage in Mesh Mode

For each of its SAIDs, the Neighbor shall transition between active TEKs according to the following rules:

a) At expiration of the older TEK, the Neighbor shall immediately transition to using the newer TEK for encryption.

b) The Neighbor that generated the TEK shall use the older of the two active TEKs for encrypting traffic towards the Node that initiated the TEK exchange.

c) The Neighbor that generated the TEK shall be able to decrypt traffic from each Node using either the older or newer TEK.

For each of its authorized SAIDs, the initiator Node:

a) shall use the newer of its two TEKs to encrypt traffic towards its Neighbors with which it initiated a TEK exchange, and

b) shall be able to decrypt traffic from the Neighbor encrypted with either of the TEKs.

7.4.2.5 Node usage of the Operator Shared Secret in Mesh Nodes

Each node shall be capable of maintaining two active Operator Shared Secrets. A Node shall use the Operator Shared Secret to calculate a HMAC digest for the Key Request and Key Reply messages when exchanging TEKs with its neighboring nodes.

7.5.3 Calculation of HMAC digests

Insert after first paragraph:

In Mesh Mode HMAC digests calculated with the key HMAC_KEY_S shall be supported. When calculating the digest with this key the HMAC sequence Number in the HMAC tuple shall be equal to the Operator Shared Secret Sequence Number.

7.5.4 Derivation of TEKs, KEKs and message authentication keys

7.5.4.3 HMAC Authentication Keys

Insert under HMAC_KEY_U = ...:

HMAC_KEY_S = SHA(H_PAD_D|Operator Shared Secret)

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8. Physical layer

Insert 8.3 through 8.6 as follows:

8.3 WirelessMAN-SCa PHY layer

The WirelessMAN-SCa PHY is based on single carrier technology and designed for NLOS operation in the 2–11 GHz frequency bands (per 1.2.4). For licensed bands, channel bandwidths allowed shall be limited to the regulatory provisioned bandwidth divided by any power of 2 no less than 1.25 MHz.

Elements within this PHY include:

— TDD and FDD support.
— TDMA UL.
— TDM DL.
— Block adaptive modulation and FEC coding for both UL and DL.
— Framing elements that enable improved equalization and channel estimation performance over NLOS and extended delay spread environments.
— Symbol-unit granularity in packet sizes.
— Concatenated FEC using Reed Solomon and Pragmatic TCM with optional interleaving.
— FEC option using BTC and CTC.
— No-FEC option using ARQ for error control.
— STC transmit diversity option.
— Parameter settings and MAC/PHY messages that facilitate optional AAS implementations.

8.3.1 Transmit processing

Figure 128a illustrates the steps involved in transmit processing. Source data shall first be randomized, and then FEC encoded and mapped to QAM symbols. The QAM symbols shall next be framed within a message burst, which typically introduces additional framing symbols. The burst symbols shall then be multiplexed into a duplex frame, which may contain multiple bursts. The I and Q symbols components shall be injected into pulse shaping filters, quadrature modulated up to a carrier frequency, and amplified with power control so that the proper output power is transmitted.

Except where indicated otherwise, transmit processing is the same for both the UL and DL.

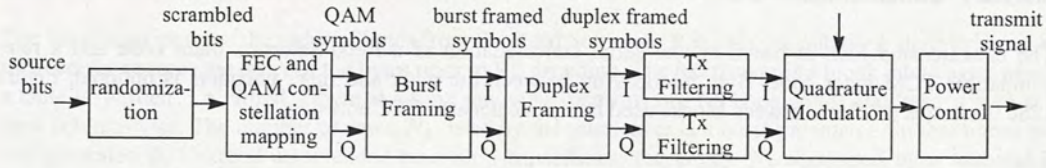


Figure 128a—Transmit processing

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8.3.1.1 Source Bit Randomization

Source bits, i.e., the original information bits prior to FEC encoding, shall be randomized during transmissions.

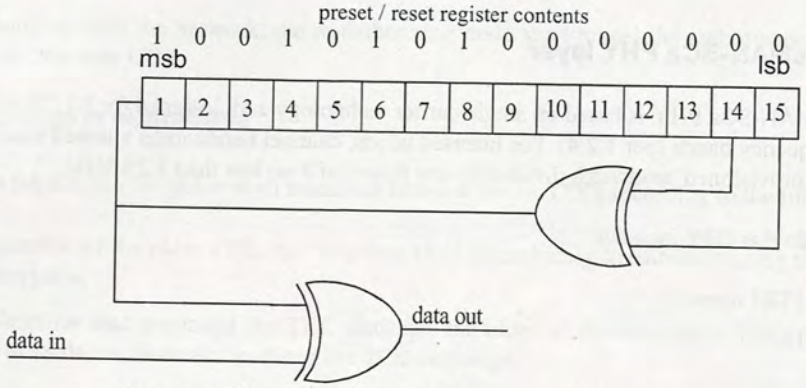


Figure 128b—Randomizer for energy dispersal

As Figure 128b illustrates, source bit randomization shall be performed by modulo-2 addition (XOR-ing) source (information) data with the output of Linear-Feedback Shift Register (LFSR) possessing characteristic polynomial $1 + X^{14} + X^{15}$. The LFSR shall be preset at the beginning of each burst (i.e., directly following the preamble) to the value 100101010000000, and shall be clocked once per processed bit. This implies that the LFSR is not preset between time division multiplexed allocations that may reside within a single burst.

Note that only source bits are randomized. This includes source payloads, plus uncoded null (zero) bits that may be used to fill empty payload segments. Only the source bits are randomized. Elements that are not a part of the source data, such as framing elements and pilot symbols shall not be randomized. Null (zero) bits used to complete a QAM symbol (when an allocation does not fill an entire QAM symbol) shall not be scrambled.

8.3.1.2 FEC

Broadcast messages shall use QPSK and the concatenated FEC of 8.3.1.2.1 with a rate 1/2 convolutional inner code. Adaptive modulation and the concatenated FEC of 8.3.1.2.1 shall be supported for non-broadcast messages. The support of 8.3.1.2.3 as FEC as well as omitting the FEC and relying solely on ARQ for error control (see 8.3.1.2.2) is optional for non-broadcast messages.

8.3.1.2.1 Concatenated FEC

The concatenated FEC is based on the serial concatenation of a Reed-Solomon outer code and a rate-compatible TCM inner code. Byte interleaving between the outer and inner encoders is optional. Figure 128c illustrates the flow between blocks used by a concatenated FEC encoder.

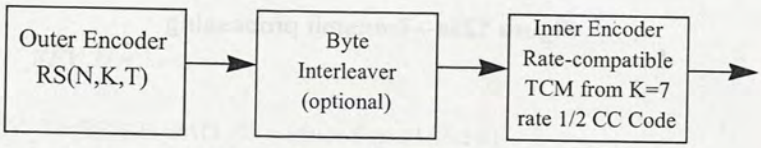


Figure 128c—Concatenated FEC encoder blocks

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8.3.1.2.1.1 Outer code

The outer code consists of a Reed Solomon code.

This Reed-Solomon code shall be derived from a systematic RS (*N=255, K=239*) code using GF(2^8). The following polynomials are used for the systematic code:

Code Generator Polynomial: $g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)..(x+\lambda^{2T-1}),\ \lambda = 02_{HEX}$

Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

The bit/byte conversion shall be msb first.

This RS code may be shortened and punctured to enable variable block sizes and variable error-correction capability,

where

N	is the number of overall bytes after encoding
K	is the number of data bytes before encoding
$R=N-K$	is the number of parity bytes.

When a block is shortened to K' data bytes, the first $239-K'$ data bytes of the block to be encoded shall be set to zero, but shall not be transmitted. When a codeword is punctured to R' parity bytes, only the first R' of the total $R=16$ parity bytes shall be transmitted.

Support of shortening K of the base code to values smaller than 239 bytes while maintaining $R=16$ is mandatory, and is governed by the burst profile specification for K (see 11.1.1.2 or 11.1.2.2). The capability to also puncture, such that $R \leq 16$, is optional, and is governed by the burst profile specification for R.

When a source allocation does not divide into an integer number of K-byte Reed-Solomon code words, the last (fractional) RS code word shall be shortened to a smaller value $1<=K'<K$ that accommodates the remainder bytes. All code words, including the shortened last codeword, shall use the R specified by the burst profile (see Table 123a and Table 125a) for the RS code words within that allocation.

8.3.1.2.1.2 Block Interleaver (optional)

Support of interleaving between the inner and outer code is optional. Interleaving shall not be used in broadcast burst profiles. When interleaving is used, its usage and parameters shall be specified within a burst profile.

The interleaver changes the order of bytes from the Reed Solomon (RS) encoder output. A de-interleaver in the receiver restores the order of the bytes prior to RS decoding. The interleaver is a block interleaver, where a table is 'written', i.e., filled, a byte at a time row-wise (one row per RS code word) and 'read' a byte at a time column-wise. The number of rows, N_R, used by the interleaver is a burst parameter. So that bursts are not generated that exceed an intended receiver's capabilities, the largest N_R supported by a terminal is communicated during SS basic capability negotiation.

Operating parameters for the interleaver are summarized in Table 116c.

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Table 116c—Operating parameters for block interleaver

Parameter	Description
C	Interleaver Width (number of columns), in bytes. Equivalent to the nominal Reed Solomon codeword length, N.
N_R	Maximum Interleaver Depth (number of rows), in bytes. Equals the maximum number of RS codewords that the block interleaver may store at any given time.
B	Nominal Interleaver Block Size, in bytes. $B = C\,N_R$.
P	RS-encoded Size of Packet, in bytes, to be interleaved.

When $P \leq B$ and/or a RS codeword is shortened (so that not all of the columns within its row are filled), the interleaver shall be read column by column (taking a byte from each column), skipping empty elements within the table.

When $P > B$, data shall be parcelled into sub-blocks, and interleaving performed within each of the sub-blocks. The depth of these sub-blocks shall be chosen such that all sub-blocks have approximately the same depth (number of rows) using the following calculations:

Total RS codewords in packet: $T = \left\lceil \frac{P}{C} \right\rceil$

Number of sub-blocks: $S = \left\lceil \frac{P}{B} \right\rceil$

Interleaver depth of longest sub-blocks: $C_{max} = \left\lceil \frac{T}{S} \right\rceil$

Number of blocks with depth C_{max}: $Q_{C_{max}} = T - S(C_{max} - 1)$

Number of blocks with depth $C_{min} = C_{max} - 1$: $Q_{C_{min}} = S - Q_{C_{max}}$.

The first $Q_{C_{max}}$ sub-blocks within a packet shall use a (dynamic) interleaver depth C_{max}, and the remainder of the sub-blocks shall use an interleaver depth $C_{min} = C_{max} - 1$.

8.3.1.2.1.3 Inner code

The inner code is a rate-compatible pragmatic TCM code [B27], [B28] derived from a rate 1/2 constraint length K=7, binary convolutional code.

The encoder for the rate 1/2 binary code shall use the following polynomials to generate its two code bit outputs, denoted X and Y:

$$\begin{aligned} G_1 &= 171_{OCT} \qquad For\ X \\ G_2 &= 133_{OCT} \qquad For\ Y \end{aligned} \tag{10}$$

A binary encoder that implements this rate 1/2 code is depicted in Figure 128d.

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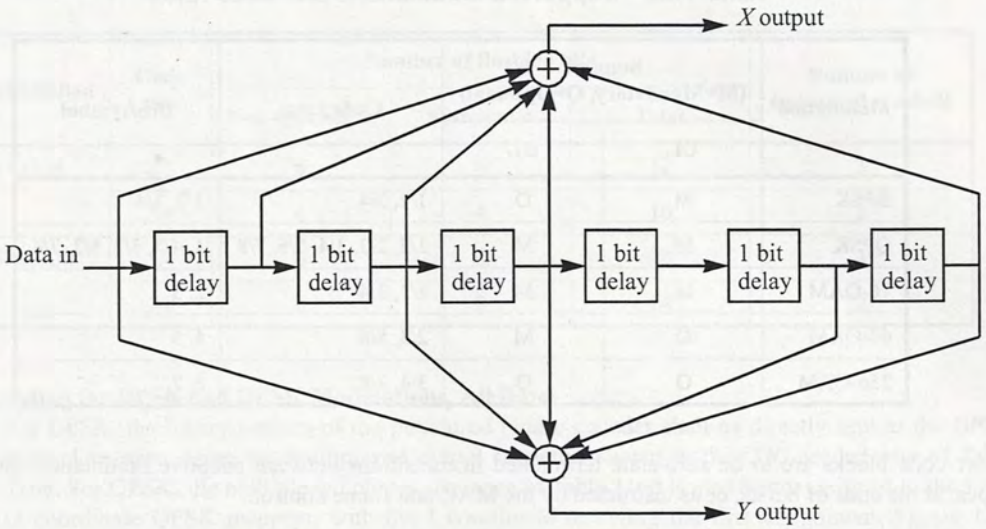


Figure 128d—Binary rate 1/2 convolutional encoder

To generate binary code rates of 2/3, 3/4, 5/6, and 7/8, the rate 1/2 encoder outputs shall be punctured. The puncturing patterns and serialization order for the *X* and *Y* outputs are defined in Table 116d. In the puncture patterns, a '1' denotes a transmitted output bit and a '0' denotes a non-transmitted (punctured) bit.

Table 116d—Puncture patterns and serialization for convolution code

	Code Rates				
Rate	1/2	2/3	3/4	5/6	7/8
X Output Puncture pattern	1	10	101	10101	1000101
Y Output Puncture pattern	1	11	110	11010	1111010
Punctured *XY* serialization	X_1Y_1	$X_1Y_1Y_2$	$X_1Y_1Y_2X_3$	$X_1Y_1Y_2X_3Y_4X_5$	$X_1Y_1Y_2Y_3Y_4X_5Y_6X_7$

The pragmatic TCM code is constructed from both non-systematic coded bits (that are taken from the outputs of the rate 1/2 binary convolutional encoder) and systematic uncoded bits (that are taken directly from the encoder input). The resulting coded bits are then mapped to symbol constellations. Supported modulations and code rates for UL and DL transmissions are listed in Table 116e. The choice of a particular code rate and modulation is made via burst profile parameters.

Since the RS outer code generates byte-denominated records but the inner code generates symbol-denominated outputs, some RS record sizes could require a fractional QAM symbol at the end of the data record. When this occurs, sufficient (non-randomized) zero-valued (null) bits shall be appended to the end of the inner encoder's input record to complete the final symbol. A receiver shall discard these null bits after inner decoding.

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Table 116e—Supported modulations and code rates

Modulation	Support (M=Mandatory, O=Optional)		Code rates	Bits/symbol
	UL	DL		
BPSK	M	O	1/2, 3/4	1/2, 3/4
QPSK	M	M	1/2, 2/3, 3/4, 5/6, 7/8	1, 4/3, 3/2, 5/3, 7/4
16-QAM	M	M	1/2, 3/4	2, 3
64-QAM	O	M	2/3, 5/6	4, 5
256-QAM	O	O	3/4, 7/8	6, 7

Inner code blocks are to be zero-state terminated in transitions between adaptive modulation (and FEC) types, at the ends of bursts, or as instructed by the MAC and frame control.

When using zero state termination, the baseline rate 1/2 convolutional encoder shall be initialized with its registers in the all-zeros state. Inner encoding shall begin from this state, by accepting bit inputs. To terminate the inner code (and return the encoder to the all-zeros state) at the end of a code block, at least 6 zero inputs shall be fed into the baseline rate 1/2 binary convolutional encoder to ensure its register memory is flushed, i.e., its state memory is driven to zero. Once the first flushing zero bit is introduced into the convolutional encoder memory, all input bits, including the systematic input bits that are parallel to the binary convolutional encoder inputs, shall have zero value.

Table 116f specifies the exact number of systematic and non-systematic bits that shall be used to flush a pragmatic TCM encoder. It also tabulates the number of symbols consumed in the code termination process.

Table 116f—Flushing bit requirements for inner code termination

Modulation	Code rate	Number of flushing bits			Number of consumed symbols
		Non-systematic	Systematic	Total	
BPSK	1/2	6	0	6	12
	3/4	6	0	6	8
QPSK	1/2	6	0	6	6
	2/3	7	0	7	5
	3/4	6	0	6	4
	5/6	6	0	6	4
	7/8	7	0	7	4
16-QAM	1/2	6	0	6	3
	3/4	6	12	18	6

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Table 116f—Flushing bit requirements for inner code termination *(continued)*

Modulation	Code rate	Number of flushing bits			Number of consumed symbols
		Non-systematic	Systematic	Total	
64-QAM	2/3	6	6	12	3
	5/6	6	4	10	2
256-QAM	3/4	6	12	18	3
	7/8	6	8	14	2

— **Encoding for BPSK and QPSK Modulations, All Rates**

For BPSK, the binary outputs of the punctured binary encoder shall be directly sent to the BPSK symbol mapper, using the multiplexed output sequence shown in the 'XY'-headed row of Table 116d. For QPSK, the multiplexed output sequence in Table 116d is alternately assigned to the I and Q coordinate QPSK mappers, with the I coordinate receiving the first assignment. Figure 128l depicts bits-to-symbol-constellation maps that shall be used for BPSK and QPSK.

— **Encoding for Rate 1/2 16-QAM**

Figure 128e illustrates the rate 1/2 pragmatic TCM encoder for 16-QAM. The baseline rate 1/2 binary convolutional encoder first generates a two-bit constellation index, b_3b_2, associated with the I symbol coordinate. Provided the next encoder input, it generates a two bit constellation index, b_1b_0, for the Q symbol coordinate. The I index generation shall precede the Q index generation. Note that this encoder should be interpreted as a rate 2/4 encoder, because it generates one four-bit code symbol per two input bits. For this reason, input records of lengths divisible by two shall be fed to this encoder.

Figure 128l depicts the bits-to-constellation map that shall be applied to the rate 1/2 16-QAM encoder output. This is a Gray code map.

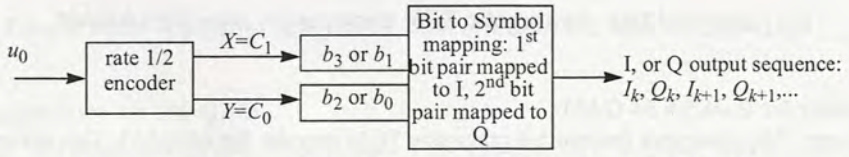


Figure 128e—Pragmatic TCM encoder for rate 1/2 16-QAM

— **Encoding for Rate 3/4 16-QAM**

Figure 128f illustrates the rate 3/4 pragmatic TCM encoder for 16-QAM. This encoder uses the baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. With this structure, the encoder is capable of simultaneously generating 4 output bits per three input bits. The sequence of arrival for the $u_2u_1u_0$ input into the encoder is u_2 arrives first, u_1 second, u_0 last. During the encoding process, the encoder generates a two bit constellation index, b_3b_2, for the I symbol coordinate, and simultaneously generates another two bit constellation index, designated b_1b_0, for the Q symbol coordinate. Note that whole symbols shall be transmitted, so input records of lengths divisible by three shall be fed to this encoder.

Figure 128m depicts the bits-to-symbol-constellation map that shall be applied to the rate 3/4 16-QAM encoder output. This is pragmatic TCM map.

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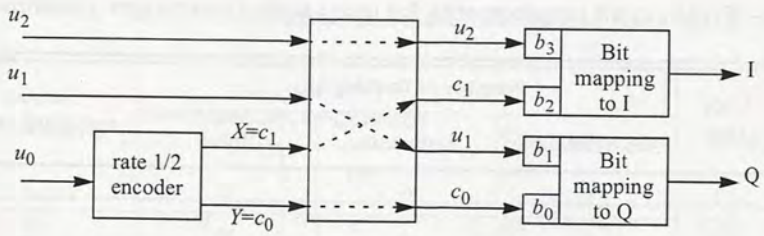


Figure 128f—Pragmatic TCM encoder for rate 3/4 16-QAM

— **Encoding for Rate 2/3 64-QAM**

Figure 128g illustrates the rate 2/3 pragmatic TCM encoder for 64-QAM. This encoder uses the baseline rate 1/2 binary convolutional encoder, along with one systematic bit that is passed directly from the encoder input to the encoder output. The sequence of arrival for the u_1u_0 input into the encoder is u_1 arrives first, u_0 last. The encoder (as a whole) then generates a three-bit constellation index, $b_5b_4b_3$, which is associated with the I symbol coordinate. Provided another two-bit encoder input, the encoder generates another three-bit constellation index, $b_2b_1b_0$, which is associated with the Q symbol coordinate. The I index generation should precede the Q index generation. Note that this encoder should be interpreted as a rate 4/6 encoder, because it generates one six-bit code symbol per four input bits. For this reason, input records of lengths divisible by four shall be fed to this encoder.

Figure 128m depicts the bits-to-symbol-constellation map that shall be applied to the rate 2/3 64-QAM encoder output. This is a pragmatic TCM map.

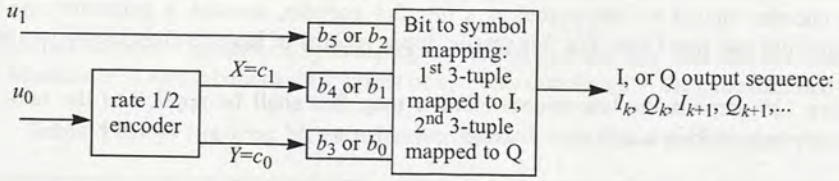


Figure 128g—Pragmatic TCM encoder for rate 2/3 64-QAM

— **Encoding for Rate 5/6 64-QAM**

Figure 128h illustrates the rate 5/6 pragmatic TCM encoder for 64-QAM. This encoder uses a rate 3/4 punctured version of the rate baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. The rate 3/4 punctured code is generated from the baseline rate 1/2 code using the rate 3/4 puncture mask definition in Table 116d. Puncture samples are sequenced c_3 first, c_2 second, c_1 third, and c_0 last. The sequence of arrival for the $u_4u_3u_2u_1u_0$ input into the encoder is u_4 arrives first, u_3 arrives second, u_2 arrives third, u_1 arrives next to last, and u_0 arrives last. During the encoding process, the pragmatic encoder generates a three-bit constellation index, $b_5b_4b_3$, for the I symbol coordinate, and simultaneously generates another three-bit constellation index, $b_2b_1b_0$, for the Q symbol coordinate. Note that whole symbols shall be transmitted, so input records of lengths divisible by five shall be fed to this encoder.

Figure 128m depicts the bits-to-symbol-constellation map that shall be applied to the rate 5/6 64-QAM encoder output. This is a pragmatic TCM map.

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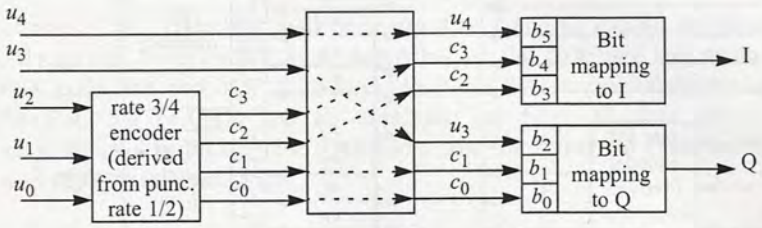


Figure 128h—Pragmatic TCM encoder for rate 5/6 64-QAM

— **Encoding for Rate 3/4 256-QAM**

Figure 128i illustrates the rate 3/4 pragmatic TCM encoder for 256-QAM. This encoder uses the baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. The sequence of arrival for the $u_2u_1u_0$ input into the encoder is u_2 arrives first, u_1 next, u_0 last. Note that the encoder (as a whole) first generates a four-bit constellation index, $b_7b_6b_5b_4$, which is associated with the I symbol coordinate. Provided another four-bit encoder input, it generates a four-bit constellation index, $b_3b_2b_1b_0$, which is associated with the Q symbol coordinate. The I index generation should precede the Q index generation. Note that this encoder should be interpreted as a rate 6/8 encoder, because it generates one eight-bit code symbol per six input bits. For this reason, input records of lengths divisible by six shall be fed to this encoder.

Figure 128k depicts the bits-to-symbol-constellation map that shall be applied to the rate 3/4 256-QAM encoder output. This is a pragmatic TCM map.

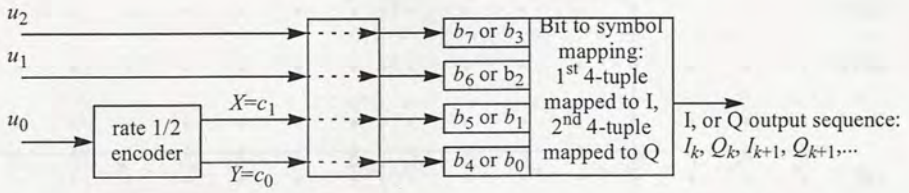


Figure 128i—Optional pragmatic TCM encoder for rate 3/4 256-QAM

— **Encoding for Rate 7/8 256-QAM**

Figure 128j illustrates the rate 7/8 pragmatic TCM encoder for 256-QAM. This encoder uses a rate 3/4 punctured version of the rate baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. The rate 3/4 punctured code is generated from the baseline rate 1/2 code using the rate 3/4 puncture mask definition in Table 116d. Puncture samples are sequenced c_3 first, c_2 second, c_1 third, and c_0 last. The sequence of arrival for the $u_6u_5u_4u_3u_2u_1u_0$ input into the encoder (as a whole) is u_6 arrives first, u_5 arrives second, u_4 arrives third, u_3 arrives fourth, u_2 arrives fifth, u_1 arrives next to last, and u_0 arrives last. During the encoding process, the encoder generates a four-bit constellation index, $b_7b_6b_5b_4$, for the I symbol coordinate, and simultaneously generates another four-bit constellation index, $b_3b_2b_1b_0$, for the Q symbol coordinate. Note that whole 256-QAM symbols should be transmitted, so input records of lengths divisible by seven shall be fed to this encoder.

Figure 128k depicts the bits-to-symbol-constellation map that shall be applied to the rate 7/8 256-QAM encoder output. This is a pragmatic TCM map.

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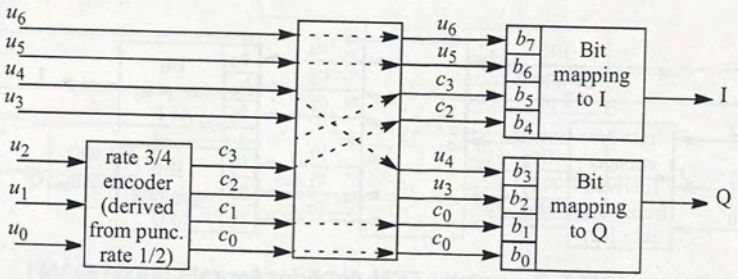


Figure 128j—Optional pragmatic TCM encoder for rate 7/8 256-QAM

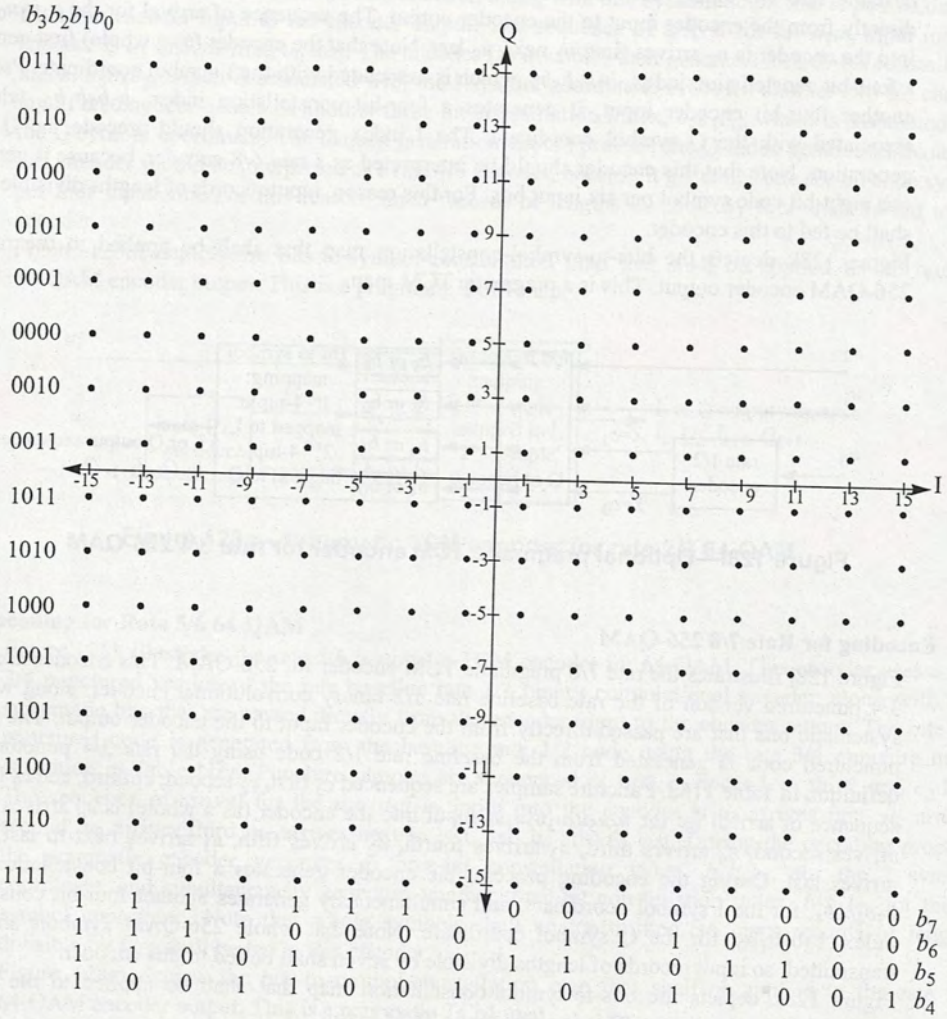


Figure 128k—Pragmatic map for 256-QAM constellation

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8.3.1.2.1.4 Constellation mapping

For the concatenated FEC, code bits shall be mapped to I and Q symbol coordinates using either a pragmatic TCM or Gray code symbol map, depending on the code rate and modulation scheme. All BPSK and QPSK code rates and rate 1/2 16-QAM shall use the Gray coded constellation maps depicted in Figure 128l. Rate 3/4 16-QAM and all code rates for 64-QAM shall use the pragmatic TCM constellation map depicted in Figure 128m. All code rates for 256-QAM shall use the pragmatic TCM constellation map depicted in Figure 128k.

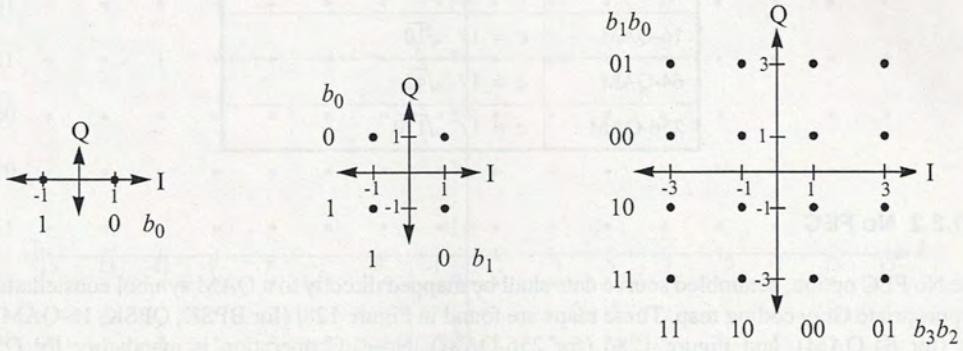


Figure 128l—Gray maps for BPSK, QPSK and 16-QAM constellations

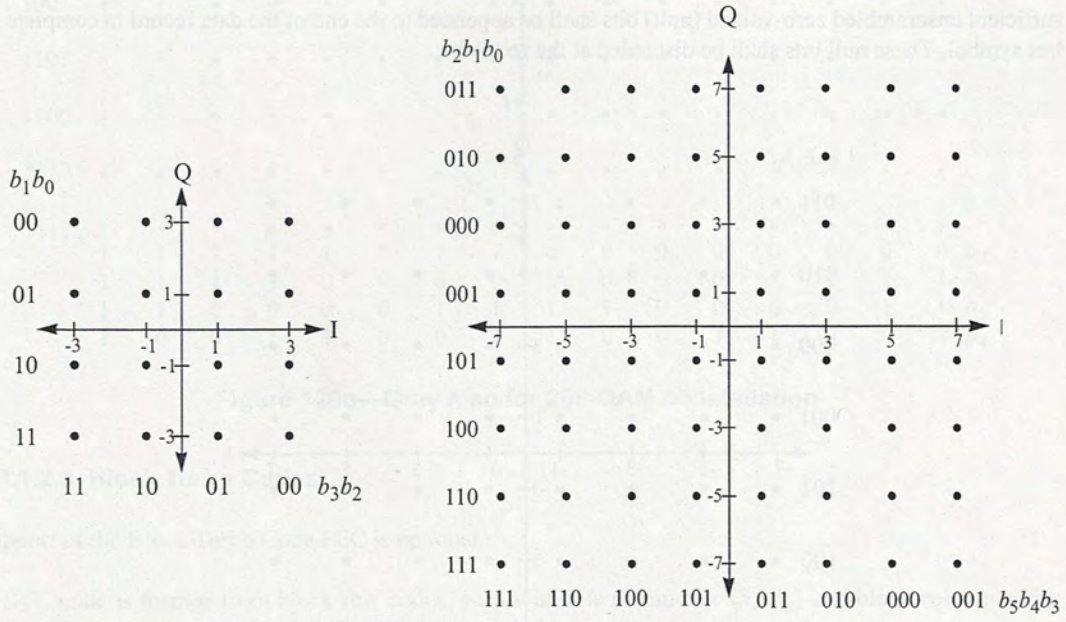


Figure 128m—Pragmatic maps for 16-QAM and 64-QAM constellations

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To obtain unity average power of transmitted sequences, I and Q coordinates of constellation points are multiplied by the appropriate factor for c listed in Table 116g.

Table 116g—Unity average power normalization factors

Modulation scheme	Normalization constant for unity average power
QPSK	$c = 1/\sqrt{2}$
16-QAM	$c = 1/\sqrt{10}$
64-QAM	$c = 1/\sqrt{42}$
256-QAM	$c = 1/\sqrt{170}$

8.3.1.2.2 No FEC

In the No FEC option, scrambled source data shall be mapped directly to a QAM symbol constellation, using the appropriate Gray coding map. These maps are found in Figure 128l (for BPSK, QPSK, 16-QAM), Figure 128n (for 64-QAM), and Figure 128o (for 256-QAM). No-FEC operation is mandatory for QPSK but optional for other modulation methods.

In the event that the source record size in bytes does not divide into an integral number of QAM symbols, sufficient unscrambled zero-valued (null) bits shall be appended to the end of the data record to complete the last symbol. These null bits shall be discarded at the receiver.

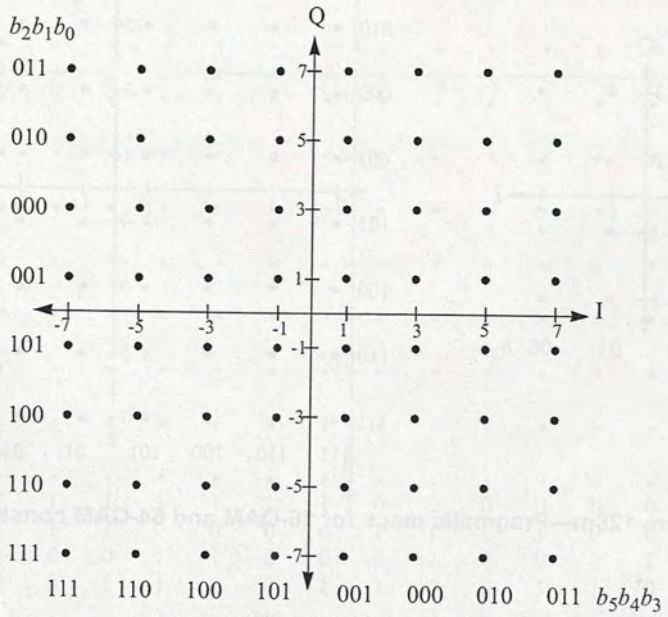


Figure 128n—Gray map for 64-QAM constellation

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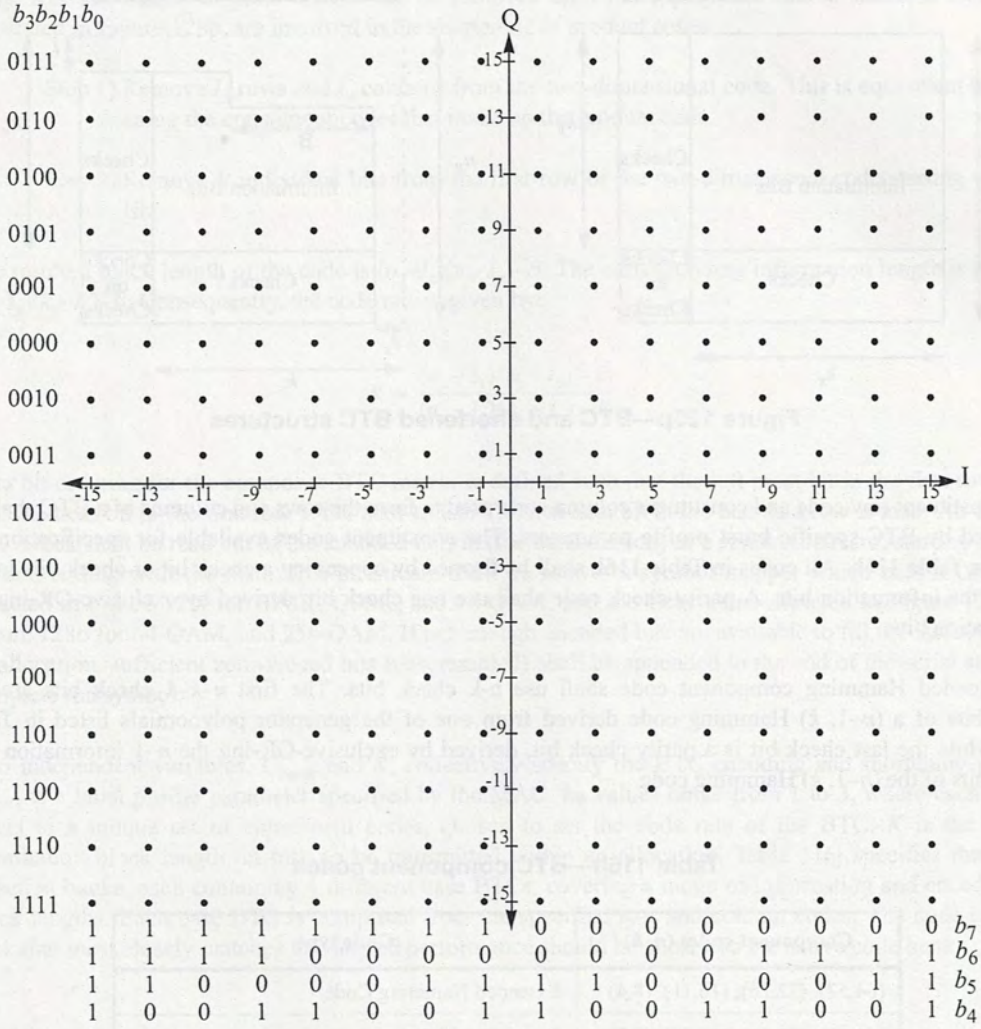


Figure 128o—Gray map for 256-QAM constellation

8.3.1.2.3 Block Turbo Codes

Support of the Block Turbo Code FEC is optional.

A BTC code is formed from block row codes, each with rate parameters (n_x, k_x) and block column codes, each with rate parameters (n_y, k_y). The BTC is encoded by writing data bits row by row into a two-dimensional matrix as illustrated in Figure 128p. The k_x information bits in each row are encoded into n_x bits by using a constituent block (n_x, k_x) row code. The k_y information bits in each column are encoded into n_y bits by using a constituent block (n_y, k_y) column code, where the checkbits of the rows are also encoded. The resulting BTC shall have block length $n = n_x \times n_y$ bits and information length $k = k_x \times k_y$.

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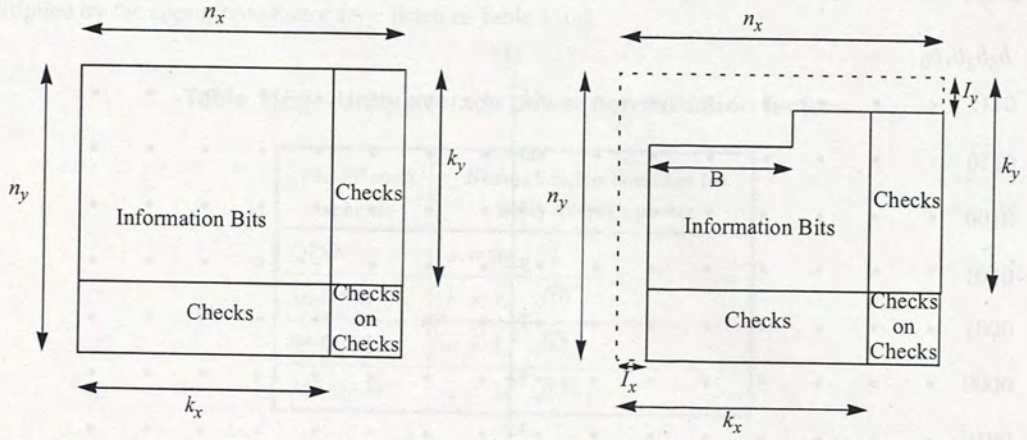


Figure 128p—BTC and shortened BTC structures

The constituent row code and constituent column code used to form the rows and columns of a BTC shall be specified by BTC-specific burst profile parameters. The constituent codes available for specification are listed in Table 116h. All codes in Table 116h shall be formed by appending a check bit or check bits to the end of the information bits. A parity check code shall use one check bit, derived by exclusive-OR-ing the information bits.

An extended Hamming component code shall use n-k check bits. The first $n–k–1$ check bits are the check bits of a $(n–1, k)$ Hamming code derived from one of the generator polynomials listed in Table 116i, while the last check bit is a parity check bit, derived by exclusive-OR-ing the $n–1$ information and parity bits of the $(n–1, k)$ Hamming code.

Table 116h—BTC component codes

Component codes (n, k)	Code type
(64,57), (32,26), (16,11), (8,4)	Extended Hamming Code
(64,63), (32,31), (16,15), (8,7)	Parity Check Code

Table 116i—(n-1,k) Hamming code generator polynomials

$n–1$	k	Generator polynomial
7	4	X^3+X^1+1
15	11	X^4+X^1+1
31	26	X^5+X^2+1
63	57	X^6+X+1

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To match an arbitrary required packet size, BTCs may be shortened by removing symbols from the BTC array. Rows, columns or parts thereof can be removed until the appropriate size is reached. Two steps, illustrated in Figure 128p, are involved in the shortening of product codes:

Step 1) Remove I_x rows and I_y columns from the two-dimensional code. This is equivalent to shortening the constituent codes that make up the product code.

Step 2) Remove B individual bits from the first row of the two-dimensional code starting with the lsb.

The resulted block length of the code is $(n_x–I_x)(n_y–I_y)–B$. The corresponding information length is given as $(k_x–I_x)(k_y–I_y)–B$. Consequently, the code rate is given by:

$$R = \frac{(k_x - I_x)(k_y - I_y) - B}{(n_x - I_x)(n_y - I_y) - B} \tag{11}$$

Data bit ordering for the composite BTC matrix is defined such that the left most bit in the first row is the lsb. The next bit in the first row is the next-to-lsb. The last data bit in the last data row is msb. An encoded BTC block shall be read out of the encoded matrix (for transmission) as a serial bit stream, starting with the lsb and ending with the msb. This bit stream shall be sent to a symbol mapper which uses a Gray map depicted in Figure 128l for BPSK, QPSK, and 16-QAM, and the Gray maps depicted in Figure 128n and Figure 128o for 64-QAM, and 256-QAM. If not enough encoded bits are available to fill the last symbol of an allocation, sufficient zero-valued bits (unscrambled) shall be appended to the end of the serial stream to complete the symbol.

Two independent variables, C_{bank} and K, collectively specify the BTC encoding and shortening process. C_{bank} is a burst profile parameter specified by the MAC. Its values range from 1 to 3, where each integer refers to a unique set of constituent codes, chosen to set the code rate of the BTC. K is the desired information block length, in bits, to be transmitted within an allocation. Table 116j specifies three code selection banks, each containing 4 different base BTCs, covering a range of information and encoded data block lengths. Each base BTC is composed from the specified row and column codes. The code selection bank that most closely matches the desired performance should be chosen as the active code bank.

Table 116j—BTC code banks

	Component row code (n_x,k_x) bits	Component column code (n_y,k_y) bits	Base BTC block $(n_y n_x,k_y k_x)$ bits
C_{bank}=1 $R \cong 0.94$	(64,63)	(64,63)	(4096,3969)
	(32,31)	(32,31)	(1024,961)
	(16,15)	(16,15)	(256,225)
	(8,7)	(8,7)	(64,49)
C_{bank}=2 $R \cong 0.80$	(64,63)	(64,57)	(4096,3591)
	(32,31)	(32,26)	(1024,806)
	(16,15)	(16,11)	(256,165)
	(8,7)	(8,4)	(64,28)

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Table 116j—BTC code banks *(continued)*

	Component row code (n_x,k_x) bits	Component column code (n_y,k_y) bits	Base BTC block $(n_y n_x,k_y k_x)$ bits
C_{bank}=3 $R \cong 0.69$	(64,57)	(64,57)	(4096,3249)
	(32,26)	(32,26)	(1024,676)
	(16,11)	(16,11)	(256,121)
	(8,4)	(8,4)	(64,16)

From the selected C_{bank}, a corresponding row and column constituent code shall be chosen that best matches the total number of information bits, K, to be encoded. Then the result shall be shortened to the exact information block size. The procedure for doing so shall be as follows:

Step 1: Determine the row and column component codes.

Select the base BTC with the smallest $k_x \times k_y$, such that $K \leq k_x \times k_y$. Should K exceed the largest information block length available in the code selection bank, the K information bits shall be split across N_{blocks} = ceil(K/(8 * maxInfoBlock)), where maxInfoBlock is the number of information bytes in the largest BTC in the code selection bank. The first $N_{blocks} - 1$ blocks shall encode ceil(K/8/N_{blocks}) bytes. The final block shall encode the remaining (K/8)–($N_{blocks} - 1$)*ceil(K/8/N_{blocks}) bytes. Each of the N_{blocks} blocks is encoded according to Step 2, substituting for K the number of information bits assigned to that block. Shortening of the BTC may be required for all N_{blocks} blocks. The code selection bank shall remain unchanged for the duration of the N_{blocks} blocks.

Step 2: Determine the row and column component codes for remnant bits

Select the base BTC with the smallest $k_x \times k_y$, such that $K \leq k_x \times k_y$.

Should K be equal to $k_x \times k_y$, then K fits exactly into the base BTC and the information bits are encoded without shortening. If this is not the case, then the $(n_y \times n_x, k_y \times k_x)$ BTC shall be shortened according to Step 3 after which the K bits are encoded.

Step 3: Determine shortening parameters

Select i such that:

$$\arg\min_i \left[\left(\left(k_x - \left\lfloor \frac{i+1}{2} \right\rfloor \right) \cdot \left(k_y - \left\lfloor \frac{i}{2} \right\rfloor \right) - K \right) > 0 \right] \qquad 0 \leq i < 2k_y - 1 . \tag{12}$$

The obtained i specifies the shortening parameters: $I_x = \lfloor (i+1)/2 \rfloor$, $I_y = \lfloor i/2 \rfloor$ and $B = (k_x - I_x) \times (k_y - I_y) - K$.

8.3.1.2.4 Convolutional Turbo Codes

Support of the Convolutional Turbo Code FEC is optional.

8.3.1.2.4.1 CTC encoder

The Convolutional Turbo Code encoder, including its constituent encoder, is depicted in Figure 128q. It uses a double binary Circular Recursive Systematic Convolutional code. The bits of the data to be encoded are alternately fed to A and B, starting with the msb of the first byte being fed to A. The encoder is fed by blocks of k bits or N couples (k = 2*N bits). For all the frame sizes k is a multiple of 8 and N is a multiple of 4. Further N shall be limited to: $8 \leq N/4 \leq 256$. Zero padding should be used for block sizes less than 32 bytes. For allocations longer than 256 bytes (i.e., 512 nibbles), the allocation (in units of nibbles), A_n determines the number of interleaver code blocks, n_B, that shall be transmitted. The first n_F of these blocks shall each

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use an interleaver of length N_F nibbles, whereas the remainder shall each use an interleaver of length $N_F + 1$ nibbles.

$$n_B = \left\lceil \frac{A_n}{512} \right\rceil$$
$$N_F = \left\lfloor \frac{A_n}{n_B} \right\rfloor \quad (13)$$
$$n_F = n_B(N_F + 1) - A_n$$

The polynomials defining the connections are described in octal and symbol notations as follows:

— for the feedback branch: 0xB, equivalently $1+D+D^3$ (in symbolic notation)
— for the Y parity bit: 0xD, equivalently $1+D^2+D^3$

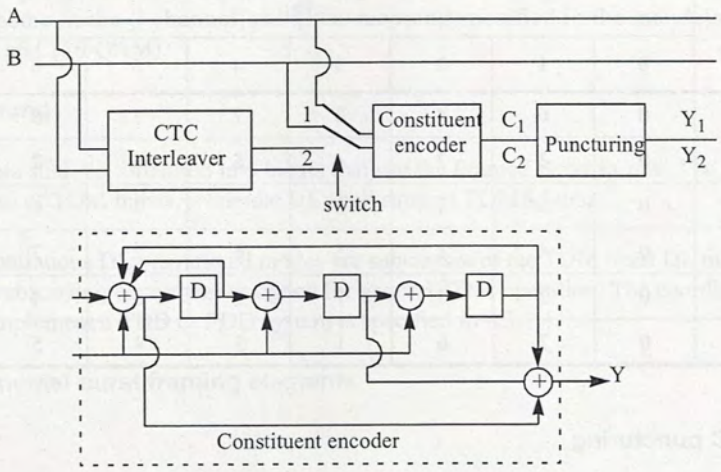


Figure 128q—CTC encoder

First, the encoder (after initialization by the circulation state Sc_1, see subclause 8.3.1.2.4.2) is fed the sequence in the natural order (position 1) with the incremental address $i = 0,...,N-1$. This first encoding is called C_1 encoding. Then the encoder (after initialization by the circulation state Sc_2, see in subclause 8.3.1.2.4.2) is fed by the interleaved sequence (switch in position 2) with incremental address $j = 0,\ldots,N-1$. This second encoding is called C_2 encoding.

8.3.1.2.4.2 CTC interleaver

The interleaver requires the parameters P_0, which shall be the nearest prime number greater than $\sqrt{N/2}$, with $P_0 \geq 3$, which is dependent on the block size N. The two-step interleaver shall be performed by:

Step 1: Switch alternate couples

for $j = 1..N$

if $(j_{\mathrm{mod}_2} == 0)$ let $(B,A) = (A,B)$ (i.e. switch the couple)

Step 2: $P_i(j)$

The function $P_i(j)$ provides the interleaved address i of the consider couple j.

for $j = 1..N$

switch j_{mod_4} :

case 0 or 1: $i = (P_0 \cdot j + 1)_{\mathrm{mod}_N}$

case 2 or 3: $i = (P_0 \cdot j + 1 + N/4)_{\mathrm{mod}_N}$

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8.3.1.2.4.3 Determination of CTC circulation states

The state of the encoder is denoted S ($0 <= S == 7$) with S the value read binary (left to right) out of the constituent encoder memory (see Figure 128q). The circulation states Sc_1 and Sc_2 are determined by the following operations:

Step 1) Initialize the encoder with state 0. Encode the sequence in the natural order for the determination of Sc_1 or in the interleaved order for determination of Sc_2. In both cases the final state of the encoder is $S0_{N-1}$;
Step 2) According to the length N of the sequence, use Figure 116k to find Sc_1 or Sc_2.

Table 116k—Circulation state lookup table (*Sc*)

N_{mod_7}	$S0_{N-1}$							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	6	4	2	7	1	3	5
2	0	3	7	4	5	6	2	1
3	0	5	3	6	2	7	1	4
4	0	4	1	5	6	2	7	3
5	0	2	5	7	1	3	4	6
6	0	7	6	1	3	4	5	2

8.3.1.2.4.4 CTC puncturing

The various code-rates are achieved through selectively deleting the parity bits (puncturing). The puncturing patterns are identical for both codes C_1 and C_2.

Table 116l—Circulation state lookup table (*Sc*)

Rate $R_n/(R_n+1)$	Y															
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1/2	1	1														
2/3	1	0	1	0												
3/4	1	0	0	1	0	0										
5/6	1	0	0	0	0	1	0	0	0	0						
7/8	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

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8.3.1.2.4.5 CTC modulation mapping

The encoded bit is fed into the mapper for BPSK and QPSK in the following order:

$$A_0, B_0 .. A_{N-1}, B_{N-1}, Y_{10}, Y_{1,1} .. Y_{1,M}, Y_{20}, Y_{2,1} .. Y_{2,M},$$

where M is the number of parity bits and the I channel is fed first. The order in which the encoded bit are fed into the mapper for 16-QAM, 64-QAM and 265-QAM is:

$$A_0, B_0 .. A_{Rn} B_{Rn}, Y_{1,0}, A_{Rn+1}, B_{Rn+2} .. A_{2Rn}, B_{2Rn}, Y_{2,0} ..$$

Let S be half the number of bits in the modulation symbol. Then if (R_n+1) equals S, the parity bits are mapped to the two least protected locations in the constellation (16-QAM = $\{b_0, b_2\}$, 64-QAM = $\{b_0, b_3\}$, 256-QAM = $\{b_0, b_4\}$). If (R_n+1) equals $2S$, the parity bits are mapped to the least protected bit in the modulation scheme in the Q channel, using the mapping specified in the mandatory mode (b_0 for 16-QAM, 64-QAM and 256-QAM).

8.3.1.3 Burst framing

Both DL and UL data shall be formatted into bursts that use the Framed Burst format. The DL shall support the most general case of TDM bursts, while the UL shall support TDMA bursts.

TDMA burst and continuous DL operational modes are subclasses of the TDM burst DL mode of operation, and should be realizable using equipment designed for general TDM operation. The coordination of UL and DL bursts used to implement a TDD or FDD system is specified in 8.3.1.4.

8.3.1.3.1 Fundamental burst framing elements

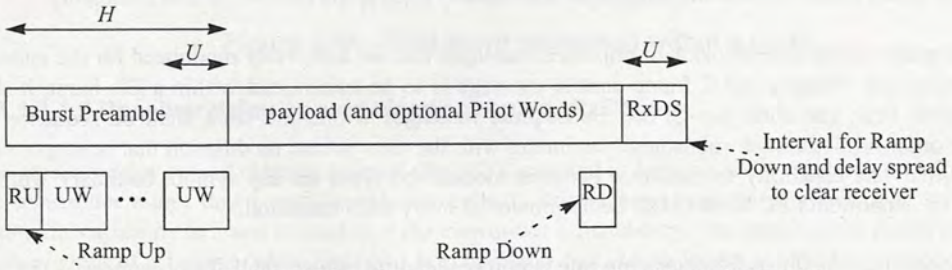


Figure 128r—Fundamental burst framing elements

As Figure 128r illustrates, a burst consists of three fundamental framing elements: a Burst Preamble that includes ramp up; a Payload; and an RxDS interval that includes ramp-down.

8.3.1.3.1.1 Burst preamble

A Burst Preamble shall consist of a ramp up region followed by a preamble body. Burst profile parameters shall specify R_r, the length of the ramp up region in symbols, and m, the number of Unique Words composing the preamble body. The burst profile shall also specify U, the number of symbols in a Unique Word.

A Burst Preamble shall be constructed from the last R symbols of a Unique Word (see Table 116m) followed by an integer multiple $m \geq 0$ of Unique Words, each Unique Word being U symbols in length. Figure 128s illustrates this requirement.

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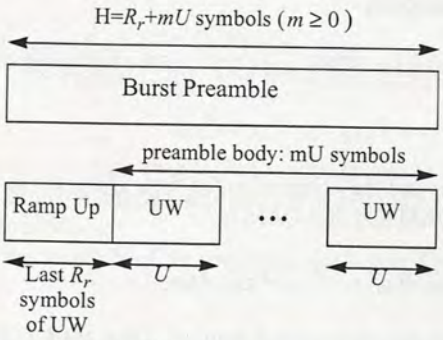


Figure 128s—Burst Preamble composition

For $R_r = 0$, a ramp up element within the Burst Preamble shall not be created.

For $R_r > 0$, a ramp up element shall be created. When creating a ramp up element, the transmit filter memory shall be initialized with zero-valued (null) symbols. R_r ramp up symbols shall then be sequentially fed into the transmit filter input stream. The transient preceding the first ramp up symbol shall be suppressed at the transmit filter output until the symbol period of the first ramp up symbol. A ramped power buildup shall then be achieved by superimposing a multiplicative raised cosine half-window of duration R_r symbols upon the samples leaving the transmit filter.

8.3.1.3.1.2 Burst Payload

The Burst Payload block depicted in Figure 128r contains payload data. The Burst Payload block may also contain periodically inserted Pilot Words (see 8.3.1.3.1.4), if the burst profile specifies their inclusion. The capability to demodulate payloads of arbitrary length and symbol-unit granularity is mandatory. The capability to insert Pilot Words at the transmitter and remove them at the receiver is also mandatory.

A DL burst may contain time division multiplexed messages that are adaptively modulated for the intended message recipients. When a MAC frame control message is to be transmitted within a DL burst, it shall always appear first, and shall use QPSK. Subsequent messages within the burst shall be sequenced in decreasing order of modulation robustness, beginning with the most robust modulation that is supported at the transmitter. The capability to transition between modulation types on any symbol boundary within a burst shall be supported. FEC blocks shall be terminated at every such transition.

One exception to the modulation sequencing rule is null payload fill, which shall always appear as the final message in a burst, and shall be transmitted using QPSK.

An UL burst contains a single message, and uses a single modulation format within a burst. However, different bursts may have different modulation formats. Additional description of MAC / PHY support for adaptive modulation and coding is provided in 6.2.7.

8.3.1.3.1.3 Null payload fill

When additional payload data is necessary to fill the end of a burst frame, e.g., when a continuous DL does not have enough data to fill a MAC frame, null payload fill may be inserted. The capability to insert null payload fill at a transmitter and discard it at a receiver is mandatory.

Null payload fill shall use the null fill data type. A MAC Frame control (map) message treats the null fill data type as an adaptive modulation type, and therefore shall indicate when and for how long this data type

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shall be transmitted within a burst. Null payload fill data shall also be subject to pilot word patterning within a burst.

The null fill data type is defined as zero-valued source bits that are randomized (see 8.3.1.1) and mapped directly to QPSK symbols using the Gray code map in Figure 128l. The randomizer shall run (without reset) through both the preceding burst payload and the null payload fill, but null payload fill shall not be covered (in the MAC) by a CRC code. During null payload fill transmission, a transmitter's output power may be reduced.

8.3.1.3.1.4 Pilot Words

A Pilot Word is a contiguous sequence of symbols composed of an integer $n \geq 0$ multiple of Unique Words, which may periodically pattern a burst. As Figure 128t illustrates, the period of a Pilot Word, F (in symbols), is defined to include the length, P, of the Pilot Word. Both F and n are parameters specified within a burst profile. The setting $n = 0$ indicates that no Pilot words shall be patterned within a burst.

When Pilot Words are patterned within a burst, F for that burst shall be constant, and the first symbol of the first Pilot Word shall commence $F–P+1$ symbols into the burst. As Figure 128t illustrates, Pilot Word patterning shall cease when F-P or less payload data symbols remain in the burst.

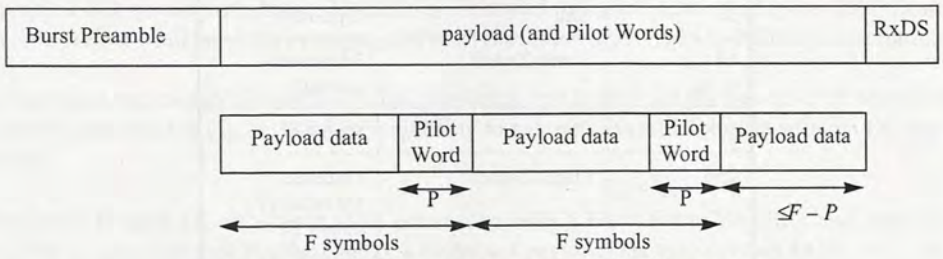


Figure 128t—Pilot Word patterning within a burst

8.3.1.3.1.5 Receiver delay spread clearing region (RxDS)

The receiver delay spread clearing interval (RxDS) illustrated in Figure 128r is a quiet period during which the transmitter ramps down, and the receiver collects delay-spread versions of symbols at the end of the burst. The capability to insert the RxDS at the transmitter is mandatory. The length of the RxDS shall always be the length of a Unique Word, unless it is suppressed (i.e., set to length zero). One instance where the RxDS is automatically suppressed is when bursts are concatenated.

If the RxDS is nonzero in length, a transmitter shall ramp down during this RxDS by inserting zero inputs into the transmit filter memory following the last intended data symbol, and allowing the natural response of the filter to drive the filter output to zero.

8.3.1.3.2 Unique Word

8.3.1.3.2.1 Selection

The length, U, in symbols of a Unique Word (UW) is a burst profile parameter. For best performance, U should be at least as long as the intended channel's span of significant delay spread.

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8.3.1.3.2.2 Definition

Unique Words are derived from Frank-Zadoff [B22] or Chu [B23] sequences, and possess CAZAC (Constant Amplitude Zero [periodic] Auto-Correlation) properties. A burst profile specifies a Unique Word from the options listed in Table 116m. The sequence length $U = 64$ shall be supported and considered a default setting. $U = 16$ shall also be supported for symbol rates below 1.25 Msymb/s, and $U = 256$ shall also be supported for symbol rates above 20 Msymb/s. The other optional sequence lengths listed in Table 116m may be useful for longer or shorter delay spread channels.

Table 116m—UW lengths, types, and support

Length, U (symbols)	Sequence type	Support status
0	–	Optional
8	Chu	Optional
16	Frank-Zadoff	Optional (Mandatory below 1.25 Msymb/s)
32	Chu	Optional
64	Frank-Zadoff	Mandatory (default)
128	Chu	Optional
256	Frank-Zadoff	Optional (Mandatory above 20 Msymb/s)
512	Chu	Optional

The integer n-indexed I and Q components of a length U, $0 \leq n < U$, Unique Word sequence shall be generated from

$$I[n] = \cos(\theta[n])$$
$$Q[n] = \sin(\theta[n]) \quad (14)$$

where $\theta[n] = \theta_{chu}[n]$ when generating a Chu sequence, and $\theta[n] = \theta_{frank}[n]$ when generating a Frank-Zadoff sequence. For a Chu sequence,

$$\theta_{chu}[n] = \frac{\pi n^2}{U} \quad (15)$$

for a Frank-Zadoff sequence,

$$\theta_{frank}[n = p + q\sqrt{U}] = \frac{2\pi pq}{\sqrt{U}}$$
$$p = 0, 1, \ldots, \sqrt{U} - 1 \quad (16)$$
$$q = 0, 1, \ldots, \sqrt{U} - 1$$

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The length $U = 16$, 64, and 256 Unique Word sequences are composed of symbols from QPSK, 8-PSK, and 16-PSK alphabets, respectively. However, the length $U = 8$, 32, 128, and 512 sequences are derived from polyphase symbol alphabets that may require additional care in a hardware implementation. The error vector magnitude (EVM) for Unique Word symbols in a transmitter implementation should conform with the general requirements stated in 8.3.4.4.

8.3.1.4 Duplex framing

Subclause 8.3.1.4.1 specifies FDD operation, while 8.3.1.4.2 specifies TDD operation. Support of at least one of these two duplexing modes is mandatory. FDD SSs may be Half Duplex FDD (H-FDD).

8.3.1.4.1 FDD

Frequency Division Duplexing (FDD) segregates the UL and DL on different-frequency carriers: BSs transmit at the DL carrier frequency, while SSs transmit at the UL carrier frequency.

A SS in a FDD system shall be capable of operation over a burst DL and UL. Moreover, given appropriate parameterization of a burst DL, a SS shall also be capable of continuous DL operation.

8.3.1.4.1.1 FDD with Burst DL

An example FDD system with burst-TDM DL is illustrated in Figure 128u. As Figure 128u illustrates, DL and UL sub-frames shall coincide in length, and shall repeat at regular (MAC-defined) constant intervals.

A DL burst shall not exceed the length of a DL sub-frame, but it need not fill the entire DL sub-frame. Also, although not illustrated in Figure 128u, the capability to support several DL bursts within a DL sub-frame is mandatory.

The first burst in each DL sub-frame shall commence with a Burst Preamble (BP), and shall be directly followed by a Frame Control Header (FCH), a broadcast payload that may contain DCD, UCD and MAPs. Only the first burst in a DL sub-frame shall contain the FCH.

Data within the FCH payload shall use the mandatory FEC with rate 1/2 QPSK inner convolutional code and Reed Solomon outer code. The inner convolutional code shall be zero-state terminated at the end of the FCH. During the FCH, no byte interleaving between the inner and outer code shall be used.

The first X_{FCH} source bytes of the FCH shall be outer encoded using a shortened RS code word specified by RS($N = X_{FCH} + 16$, $K = X_{FCH}$). This shortened code block shall then be inner encoded, and the inner code terminated at the end of the code block. The remainder of the FCH payload shall be encoded within one or more RS(N=255,K=239) code words, with the last code word shortened to RS(K_{last}+16,K_{last}) if K_{last}<239.

X_{FCH} is constant. Its value shall include the content of the DL-MAP message (including MAC header) up to and including the second DL information element. The decoded content of these X_{FCH} bytes is sufficient to determine of the length and location of a future DL sub-frame's entire FCH.

The first X_{FCH} symbols of the FCH shall contain MAC data that can be used to determine the allocation extent of data containing a future DL sub-frame's entire FCH. These X_{FCH} symbols shall be encapsulated within a 8-byte correcting RS codeword and a convolutional code that terminates at the X_{FCH} symbol point. X_{FCH} is a software system configuration parameter that is downloaded from the SS MAC during SS initialization. It shall not change within a system installation, unless a software update is provided to all current and future users of the system.

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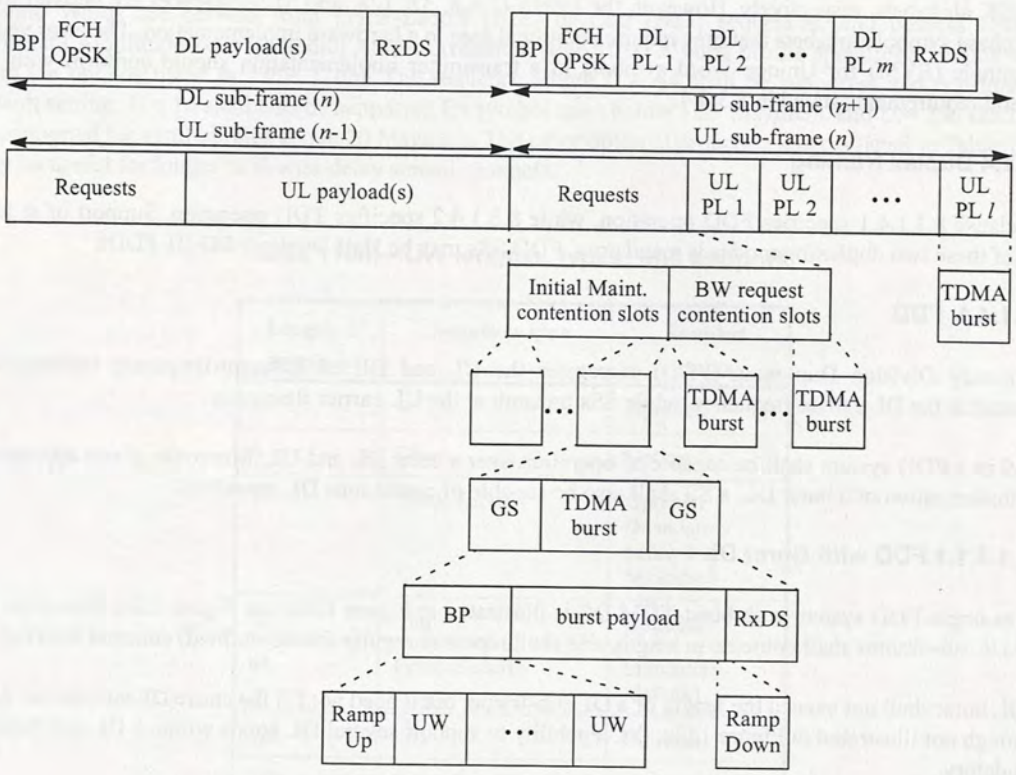


Figure 128u—Example of FDD with burst TDM DL

Time division multiplexed DL payload data may follow the FCH. A DL burst concludes with an RxDS to allow delay spread to clear the receiver. In the event that a DL-MAC frame is entirely filled with data, bursts may be concatenated and the RxDS suppressed. In other words, an RxDS of zero length shall be used, so that no ramp down occurs, and the Preamble of the next MAC frame may immediately commence. The preamble of that next MAC frame shall then use a ramp up parameter R_r of zero, so that no ramp up occurs.

When more than one burst is to be transmitted within a single DL MAC sub-frame, the DL-MAP of the first payload in the follow-up burst shall have a burst profile with its DL Burst Transition Gap (DL-BTG) entry enabled. The DL-BTG is a burst profile parameter. When enabled, the DL-BTG also indicates the length of the gap between bursts. The DL-BTG includes the RxDS terminating such a burst, and thus, when enabled, shall be specified to be at least as long as the RxDS.

An UL sub-frame contains three categories of bursts:

— Initial Maintenance Contention Slots that are transmitted in contention slots reserved for station initial maintenance;

— BW Request Contention Slots that are transmitted in contention slots reserved for response to multicast and broadcast polls for bandwidth needs;

— Grants of BW that are specifically allocated to individual SSs.

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As Figure 128u illustrates, UL bursts are TDMA, and shall be constructed from a Burst Preamble (BP), including ramp up; a Burst Payload; and a receiver delay spread clear interval (RxDS), including ramp down. SS Transition Gaps (SSTGs) separate the burst transmissions of the various SSs using the UL. A SSTG specification includes the length of the RxDS, along with any additional guard symbols that may be inserted between UL bursts to reflect reference time uncertainties.

As shown in the UL sub-frame of Figure 128u, the Initial Maintenance and BW Request Contention Slots shall always be grouped contiguously as Request Slots. To insure interoperability, these request slots shall use UL burst profiles that all BSs and SSs can support. All UL bursts excluding Initial Maintenance slots shall use a SSTG (between bursts) that is specified as a UCD channel descriptor parameter. Since larger time uncertainties may be experienced on the Initial Maintenance slots, a special Initial Maintenance SSTG channel descriptor parameter shall be associated with the Initial Maintenance slots. The Initial Maintenance SSTG specification includes both the length of the RxDS and additional guard symbols. The additional guard symbols used by the Initial Maintenance SSTG are designated by 'GS' in Figure 128u.

The UL-MAP in the DL FCH governs the location, burst size, and burst profiles for exclusive BW grants to SSs. Burst profile selection may be based on the effects of distance, interference and environmental factors on transmission from the SS.

8.3.1.4.1.2 Generating a continuous DL from a burst DL

A continuous DL may be derived from a burst DL by null payload filling the end of a burst, to insure that it spans an entire DL frame. By so doing, a burst DL is forced to suppress both the RxDS and ramp up burst elements, because burst DLs are mandated to suppress these elements when a DL MAC frame is full. To insert null payload fill, the last entry in the DL-MAP of an FCH shall specify the burst profile for the null fill data type. Details on the null payload fill data type can be found in 8.3.1.3.1.3.

8.3.1.4.1.3 FDD Channel and Burst Descriptor field definitions

DL Channel Descriptor Parameters

Each DCD message channel descriptor shall include the following TLV encodings:

- Downlink_Burst_Profile
- BS EIRP
- Frame Duration Code
- DCD Channel ID

DL Burst Descriptor Parameters

Each DCD message burst descriptor shall include the following TLV encodings:

- Modulation Type
- Reed Solomon Information Bytes (K)
- Reed Solomon Parity Bytes (R)
- DIUC Mandatory Exit Threshold
- DIUC Minimum Entry Threshold
- Preamble Length
- CC-specific Parameters
- Unique Word Length
- Pilot Word Parameters
- Transmit Diversity Type
- DL Burst Transition Gap

Each DCD message burst descriptor may include the following additional TLV encodings:

- BTC Code Selector
- CTC Parameters
- Block Interleaver Depth
- STC Parameters

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UL Channel Descriptor Parameters

Each UCD message channel descriptor shall include the following TLV encodings:

Uplink_Burst_Profile
Symbol Rate
Frequency
SS Transition Gap
Roll-Off Factor
Contention-Based Reservation Timeout
Channel Width
Initial Maintenance SSTG

UL Burst Descriptor Parameters

Each UCD message burst descriptor shall include the following TLV encodings:

Modulation Type
Preamble Length
RS Information Bytes (K)
RS Parity Bytes (R)
CC-specific Parameters
Preamble Parameters
Unique Word Length
Pilot Word Parameters
Transmit Diversity Type

Each UCD message burst descriptor may include the following additional TLV encodings:

BTC Code Selector
CTC Parameters
Block Interleaver Depth
STC Parameters

8.3.1.4.2 TDD

TDD multiplexes the UL and DL on the same carrier, over different time intervals within the same MAC frame.

Figure 128v illustrates TDD operation with a single-burst TDM downlink. In TDD, the DL and UL alternate between occupying a shared frame, with the DL sub-frame preceding the UL sub-frame. The size of shared frame shall be constant; however, the DL and UL sub-frame sizes within the shared frame shall vary according to allocations directed by the FCH. Although Figure 128v illustrates a single TDM burst per DL sub-frame, the capability to accommodate several TDM bursts is mandatory, with the first burst in the DL duplex sub-frame containing the FCH.

When more than one burst is to be transmitted within a single DL sub-frame, the DL-MAP of the first payload in the follow-up burst shall have a burst profile with its DL Burst Transition Gap (DL-BTG) entry enabled. The DL-BTG is a burst profile parameter. When enabled, the DL-BTG also indicates the length of the gap between bursts. The DL-BTG includes the RxDS terminating such a burst, and thus, when enabled, shall be specified to be at least as long as the RxDS.

Most framing elements within TDD are found in FDD and perform the same functions; therefore, for descriptions of these elements, consult 8.3.1.4.1.1. The only frame elements in TDD not found in FDD are TTG and RTG.

After the TTG, the BS receiver shall look for the first symbols of uplink burst. This gap is an integer number of PS durations and starts on a PS boundary.

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After the RTG, SS receivers shall look for the first symbols of QPSK modulated data in the downlink burst. This gap is an integer number of physical slot (PS) durations and starts on a PS boundary.

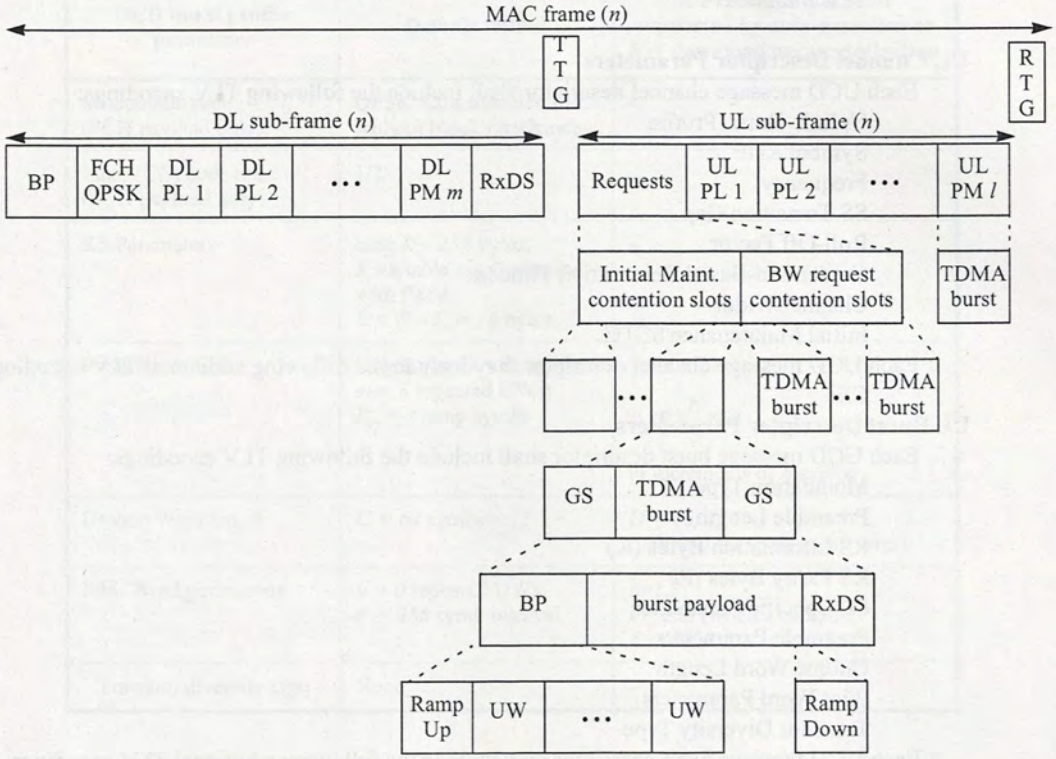


Figure 128v—Example of TDD with single-burst TDM DL sub-frame

8.3.1.4.2.1 TDD Channel Descriptor field definitions

DL Channel Descriptor Parameters

Each DCD message channel descriptor shall include the following TLV encodings:

- Downlink_Burst_Profile
- BS EIRP
- Frame Duration Code
- DCD Channel ID
- TTG

DL Burst Descriptor Parameters

Each DCD message burst descriptor shall include the following TLV encodings:

- Modulation Type
- Reed Solomon Information Bytes (K)
- Reed Solomon Parity Bytes (R)
- DIUC Mandatory Exit Threshold
- DIUC Minimum Entry Threshold
- Preamble Length
- CC-specific Parameters
- Unique Word Length
- Pilot Word Parameters
- Transmit Diversity Type

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Each DCD message burst descriptor may include the following additional TLV encodings:
BTC Code Selector
Block Interleaver Depth
STC Parameters

UL Channel Descriptor Parameters

Each UCD message channel descriptor shall include the following TLV encodings:
Uplink_Burst_Profile
Symbol Rate
Frequency
SS Transition Gap
Roll-Off Factor
Contention-Based Reservation Timeout
Channel Width
Initial Maintenance SSTG

Each UCD message channel descriptor may include the following additional TLV encodings:
CEI

UL Burst Descriptor Parameters

Each UCD message burst descriptor shall include the following TLV encodings:
Modulation Type
Preamble Length
RS Information Bytes (K)
RS Parity Bytes (R)
CC-specific Parameters
Preamble Parameters
Unique Word Length
Pilot Word Parameters
Transmit Diversity Type

Each UCD message burst descriptor may include the following additional TLV encodings:
BTC Code Selector
CTC Parameters
Block Interleaver Depth
STC Parameters

8.3.1.4.3 Burst Profiles for standard bursts

In order to inter-operate with any base station, a SS shall be capable of decoding DL bursts containing a FCH and sending Request messages over a contention channel in a format that the BS is seeking.

8.3.1.4.3.1 DL Bursts containing a Frame Control Header

A compliant SS shall be capable of demodulating a Frame Control Header with the parameters listed in Table 116n and Table 116o; a compliant BS shall be capable of transmitting FCHs using one of these sets.

Table 116n—DCD channel profile setting for Broadcast FCH message

DCD channel profile parameter	Default setting	Alternatives that shall supported by auto-detection or SW initialization
Roll-off factor	0.25	–

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Table 116o—DCD burst profile settings for DL burst containing for Broadcast FCH

DCD burst profile parameter	Default setting	Alternatives that shall supported by auto-detection or SW download parameterization
Modulation type (FCH payload only)	QPSK, Concatenated FEC without block interleaving	–
Inner (CC) code rate (FCH payload only)	1/2	–
RS Parameters	base $K = 239$ bytes; K variable via shortening with fixed $R = N - K = 16$ bytes	–
Preamble length	length = $m\,U + R_r$ symbs; $m = 3$ repeated UWs; $R_r = 4$ ramp symbs	$2 \le m < 11$; $0 \le R \le \frac{U}{2} \le 60$ in increments of 4 symbs
Unique Word length	$U = 64$ symbs	$U = 16, 256$ (optional for some symb rates)
Pilot Word parameters	$n = 0$ repeated UWs; $F = 256$ symb interval	n=1,2; F= 256 (when $U \neq 256$), $F = 1024$
Transmit diversity type	None	–

8.3.1.4.3.2 Bursts on Request Slots

A compliant SS shall be capable of formatting a Request over a Initial Maintenance Slot or BW Request using all combinations of the channel and burst settings listed in Table 116p and Table 116q. A compliant BS shall designate at least one of these combinations as the expected format in its UL MAPs for these slots.

Table 116p—UCD channel profile settings for UL Request Contention Slots

UCD channel profile parameter	Default setting	Alternatives that shall be supported by a SS transmitter
Roll-off factor	0.25	–
SS Transition gap length	0 symbs + RxDS (UW) length	0–50 symbs + RxDS (UW) length
Initial maintenance SSTG	30 symbs + RxDS (UW) length	0–500 symbs + RxDS length

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Table 116q—UCD burst profile settings for UL Contention Slots

UCD burst profile parameter	Default setting	Alternatives that shall be supported by a SS transmitter
Modulation type	QPSK, Concatenated FEC without block interleaving	–
Inner code rate	1/2	–
RS Parameters	base $K = 239$ bytes; K variable via shortening with fixed $R = N - K = 16$ bytes	–
Preamble length	length = $mU + R_r$ symbs; $m = 3$ repeated UWs; $R_r = 4$ ramp symbs	$2 \leq m < 11$; $0 \leq R \leq \frac{U}{2} \leq 60$ in increments of 4 symbs
Unique Word length	$U = 64$ symbs	$U = 16, 256$ (optional for some symb rates)
Pilot Word larameters	$n = 0$ repeated UWs $F = 256$ symb interval	$n = 1,2$; $F = 256$ (when $U \neq 256$), $F = 1024$
Transmit diversity type	None	–

8.3.1.4.4 Burst Profiles for non-broadcast and non-contention messages

Burst profiles for non-broadcast and non-contention messages are adaptive (and potentially negotiable). Such burst profiles are specified by the MAC management encodings of 11.1.

8.3.1.4.5 MAP message fields and IEs

8.3.1.4.5.1 DL-MAP PHY synchronization field

Table 116r provides the format of the PHY synchronization field of the frame control message described in 6.2.2.3.2.

Table 116r—SCa PHY synchronization field

Syntax	Size	Notes
PHY_synchronization_field() {		
Frame duration code()	8 bits	
Frame number	24 bits	
Allocation_Start_Time	32 bits	
}		

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Frame duration code:

Table 116s indicates the various frame durations that are allowed. The actual frame time used by the DL can be determined by the periodicity of the frame start preambles.

Table 116s—SCa frame duration codes

Code (N)	Nominal frame duration (T_F ms)
0–6	$N/2+2$
7–11	$N-1$
12–255	Reserved

A frame is an integer multiple of PSs long, with the multiple being chosen such that the resulting actual duration is as close as possible to a nominal frame duration listed in Table 116s. For TTD systems, the TTG shall be no less than 5 μs in duration. When using STC encoding, the frame shall contain (in addition to all other requirements) an even number of dual blocks. This requirement shall also be taken into account when choosing an actual frame duration.

Frame number:

The Frame number is incremented by 1 for each frame and eventually wraps around to zero.

Allocation_Start_Time:

Effective start time of the downlink allocation defined by the DL-MAP in units of PSs. This start time is relative to the start of the frame in which the DL-MAP message is transmitted. The minimum value specified for this parameter shall correspond to one frame duration

8.3.1.4.5.2 DL-MAP Information Element formats

The Information Elements of Table 116u are used in DL-MAP messages. The format for these DL-MAP messages is specified in Table 116t.

Table 116t—SCa DL-MAP Information Element format

Syntax	Size	Notes
DL-MAP_Information_Element() {		
DIUC	4 bits	
if (UIUC == 15) {		
Extended UIUC dependent IE	variable	AAS_DL_IE()
} else {		
Offset	12 bits	
}		
}		

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Offset: Offset (in units of minislots) to the start of the data burst from the mini-slot boundary specified by the downlink Allocation_Start_Time.

Table 116u—SCa Downlink interval usage codes

IE name	DIUC	Minislot offset
Fill	0	Start of allocation for uncoded QPSK zero-fill.
Data Grant 1	1	Starting offset of data grant 1 burst type
Data Grant 2	2	Starting offset of data grant 2 burst type.
Data Grant 3	3	Starting offset of data grant 3 burst type
Data Grant 4	4	Starting offset of data grant 4 burst type
Data Grant 5	5	Starting offset of data grant 5 burst type
Data Grant 6	6	Starting offset of data grant 6 burst type
Data Grant 7	7	Starting offset of data grant 7 burst type
Data Grant 8	8	Starting offset of data grant 8 burst type
Data Grant 9	9	Starting offset of data grant 9 burst type
Data Grant 10	10	Starting offset of data grant 10 burst type
Data Grant 11	11	Starting offset of data grant 11 burst type
Data Grant 12	12	Starting offset of data grant 12 burst type
Gap	13	Start offset of an unallocated frame interval
Null	14	Ending offset of the previous grant. Used to bound the length of the last actual interval allocation.
Extended DIUC	15	

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended DIUC = 15 with the AAS_DL_IE() to indicate that the subsequent allocations, until the start of the first UL-MAP allocation using TDD, and until the end of the frame using FDD, shall be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID.

Table 116v—SCa AAS Information Element format

Syntax	Size	Notes
AAS_Information_Element() {		
extended DIUC	4 bits	AAS = 0x02
Offset	12 bits	
Reserved	4 bits	
}		

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When a channel measurement report is needed (see 6.2.14), the extended DIUC = 15 is used with the sub-code 0x00 and with 8-bit Channel Nr value as shown in Table 116w. The Report_IE shall be followed by the Null IE (DIUC=14). When used, the CID of the DL-MAP_IE() shall be set to the broadcast CID.

Table 116w—SCa channel measurement Information Element format

Syntax	Size	Notes
Report_Information_Element() {		
extended DIUC	4 bits	DFS = 0x00
Channel Nr	8 bits	Channel number (see 8.6.1) Set to 0x00 for licensed bands
Offset	12 bits	
Reserved	4 bits	
}		

8.3.1.4.5.3 UL Information Element formats

The Information Elements of Table 116y are used in UL-MAP messages. The format for these UL-MAP messages is specified in Table 116x.

Table 116x—SCa UL-MAP Information Element format

Syntax	Size	Notes
UL-MAP_Information_Element() {		
CID	16 bits	
UIUC	4 bits	
if (UIUC == 15) {		
Extended UIUC dependent IE	variable	AAS_UL_IE()
} else {		
Offset	12 bits	
}		
}		

Connection Identifier (CID):

Represents the assignment of the IE to a unicast, multicast, or broadcast address. When specifically addressed to allocate a bandwidth grant, the CID may be either the Basic CID of the SS or a Traffic CID for one of the connections of the SS.

Uplink Interval Usage Code (UIUC):

A four-bit code used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be included in an UCD message for each Uplink Interval Usage Code that is to be used in the UL-MAP. The UIUC shall be one of the values defined in Table 108 of 8.2.6.1.2.

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Offset:

Indicates the start time, in units of minislots, of the burst relative to the Allocation Start Time given in the UL-MAP message. Consequently, the first IE shall have an offset of 0. The end of the last allocated burst is indicated by allocating a NULL burst (CID = 0 and UIUC = 14) with zero duration. The time instants indicated by offsets are the transmission times of the first symbol of the burst including preamble. .

Table 116y—SCa UL-MAP information elements

IE name	UIUC	CID	Mini-slot offset
Reserved	0	NA	Reserved for future use
Request	1	any	Starting offset of REQ region
Initial maintenance	2	broadcast	Starting offset of MAINT region (used in Initial Ranging)
Data grant burst type 0	3	unicast	Starting offset of Data Grant Burst Type 0 assignment
Data grant burst type 1	4	unicast	Starting offset of Data Grant Burst Type 1 assignment
Data grant burst Type 2	5	unicast	Starting offset of Data Grant Burst Type 2 assignment
Data grant burst type 3	6	unicast	Starting offset of Data Grant Burst Type 3 assignment
Data grant burst type 4	7	unicast	Starting offset of Data Grant Burst Type 4 assignment
Data grant burst type 5	8	unicast	Starting offset of Data Grant Burst Type 5 assignment
Data grant burst type 6	9	unicast	Starting offset of Data Grant Burst Type 6 assignment
Null IE	10	zero	Ending offset of the previous grant. Used to bound the length of the last actual interval allocation.
Empty	11	zero	Used to schedule gaps in transmission
Reserved	12–14	any	Reserved
Extended UIUC	15	extended UIUC	

A BS supporting the AAS option shall allocate at the end of the UL frame an initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but shall be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance.

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended UIUC = 15 with the AAS_UL_IE() to indicate that the subsequent allocation until the end of the frame shall be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID.

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Table 116z—SCa AAS UL information element format

Syntax	Size	Notes
AAS_UL_Information_element() {		
extended UIUC	4 bits	AAS = 0x02
Offset	12 bits	
Reserved	4 bits	
}		

8.3.1.4.5.4 Burst Profile format

Table 116aa defines the format of the Downlink_Burst_Profile, which is used in the DCD message (6.2.2.3.1). The Downlink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit DIUC. The DIUC field is associated with the Downlink Burst Profile and Thresholds. The DIUC value is used in the DL-MAP message to specify the Burst Profile to be used for a specific downlink burst.

Table 116aa—Downlink_burst_profile format

Syntax	Size	Notes
Downlink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
DIUC	4 bits	
TLV encoded information	variable	
}		

Table 116ab defines the format of the Uplink_Burst_Profile, which is used in the UCD message (6.2.2.3.1). The Uplink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit UIUC. The UIUC field is associated with the Uplink Burst Profile and Thresholds. The UIUC value is used in the UL-MAP message to specify the Burst Profile to be used for a specific uplink burst.

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Table 116ab—Uplink_burst_profile format

Syntax	Size	Notes
Uplink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
UIUC	4 bits	
TLV encoded information	variable	
}		

8.3.1.5 Baseband Pulse Shaping

Prior to modulation, I and Q signals shall be filtered by square-root raised cosine. A roll-off factor of $\alpha = 0.25$ shall be supported; 0.15 and 0.18 are optional, but defined settings. The ideal square-root cosine is defined in the frequency domain by the transfer function

$$H(f) = \begin{cases} 1 & |f| < f_N(1-\alpha) \\ \sqrt{\frac{1}{2} + \frac{1}{2}\sin\left(\frac{\pi}{2f_N}\left[\frac{f_N - |f|}{\alpha}\right]\right)} & f_N(1-\alpha) \le |f| \le f_N(1+\alpha) \\ 0 & |f| \ge f_N(1+\alpha) \end{cases} \quad (17)$$

where

$$f_N = \frac{1}{2T_S} = \frac{R_S}{2}, \quad (18)$$

f_N is the Nyquist frequency, T_s is the modulation symbol duration, and R_s is the symbol rate.

8.3.1.6 Quadrature modulation

Define the quadrature modulated transmit waveform $s(t)$ as

$$s(t) = I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t) \quad (19)$$

where $I(t)$ and $Q(t)$ are the filtered baseband signals of the I and Q symbols and f_c is the carrier frequency.

8.3.1.7 Power control

Power control shall be supported on the UL, using both initial calibration and periodic adjustment procedures, and without loss of data. To support this, a BS shall be capable of making accurate power measurements of a received signal burst, nominally using the specifications for measurements found in 8.3.2.2. This measurement can then be compared against a reference level, and the resulting error fed back to a SS in a calibration message from the MAC.

Although its exact implementation is not specified, the power control algorithm shall be designed to respond power fluctuations at rates of no more than 30 dB/second and depths of at least 10 dB. Subclause 8.3.4.5

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provides recommendations on overall power control range, stepsize, and absolute accuracy in an implementation.

A power control algorithm shall also account for the interaction of the RF power amplifier with different burst profiles. For example, when changing from the QAM modulation of one burst profile to another, amplifier back-off margins shall be maintained to prevent peak clipping and violation of emissions masks and/or excessive transmitter EVM.

8.3.2 Channel quality measurements

8.3.2.1 Introduction

RSSI and CINR signal quality measurements and associated statistics can aid in such processes as BS selection/assignment and burst adaptive profile selection. As channel behavior is time-variant, both mean and standard deviation are defined. Implementation of the RSSI and CINR statistics and their reports is mandatory.

The process by which RSSI measurements are taken does not necessarily require receiver demodulation lock; for this reason, RSSI measurements offer reasonably reliable channel strength assessments even at low signal levels. On the other hand, although CINR measurements require receiver lock, they provide information on the actual operating condition of the receiver, including interference and noise levels, and signal strength.

8.3.2.2 RSSI mean and standard deviation

When collection of RSSI measurements is mandated by the BS, a SS shall obtain an RSSI measurement from the DL burst preambles. From a succession of RSSI measurements, the SS shall derive and update estimates of the mean and the standard deviation of the RSSI, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics shall be reported in units of dBm. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from –40 dBm (encoded 0x53) to –123 dBm (encoded 0x00). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the RSSI of a single message is left to individual implementation, but the relative accuracy of a single signal strength measurement, taken from a single message, shall be +/– 2 dB, with an absolute accuracy of +/– 4 dB. This shall be the case over the entire range of input RSSIs. In addition, the range over which these single-message measurements are measured should extend 3 dB on each side beyond the –40 dBm to –123 dBm limits for the final averaged statistics that are reported.

The (linear) mean RSSI statistics (in mW), derived from a multiplicity of single messages, shall be updated using

$$\hat{\mu}_{RSSI}[k] = \begin{cases} R[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{RSSI}[k-1] + \alpha_{avg}R[k] & k > 0 \end{cases} \quad \text{mW} \tag{20}$$

where k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.), $R[k]$ is the RSSI in mW measured during message k, and α_{avg} is an averaging parameter specified by the BS. The mean estimate in dBm shall then be derived from

$$\hat{\mu}_{RSSI\ dBm}[k] = 10\log(\hat{\mu}_{RSSI}[k]) \quad \text{dBm}. \tag{21}$$

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To solve for the standard deviation in dB, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{RSSI}[k] = \begin{cases} |R[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{RSSI}[k-1] + \alpha_{avg}|R[k]|^2 & k > 0 \end{cases} \quad (22)$$

and the result applied to

$$\hat{\sigma}_{RSSI\ dB} = 5\log\left(\left|\hat{x}^2_{RSSI}[k] - (\hat{\mu}_{RSSI}[k])^2\right|\right) \quad \text{dB}. \quad (23)$$

8.3.2.3 CINR mean and standard deviation

When Carrier-to-Interference-and-Noise-Ratio (CINR) measurements are mandated by the BS, a SS shall obtain a CINR measurement from the DL burst preambles. From a succession of these measurements, the SS shall derive and update estimates of the mean and the standard deviation of the CINR, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics for CINR shall be reported in units of dB. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from a minimum of –10 dB (encoded 0x00) to a maximum of 53 dB (encoded 0x3F). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the CINR of a single message is left to individual implementation, but the relative and absolute accuracy of a CINR measurement derived from a single message shall be +/– 1 dB and +/– 2 dB, respectively, for all input CINRs above 0 dB. In addition, the range over which these single-packet measurements are measured should extend 3 dB on each side beyond the –10 dB to 53 dB limits for the final reported, averaged statistics.

One possible method to estimate the CINR of a single message is by normalizing the mean-squared residual error of detected data symbols (and/or pilot symbols) by the average signal power using

$$CINR[k] = \frac{A[k]}{E[k]}, \quad (24)$$

where $CINR[k]$ is the (linear) CINR for message k, $r[k, n]$ is received symbol n within message k; $s[k, n]$ the corresponding detected or pilot symbol corresponding to received symbol n;

$$A[k] = \sum_{n=0}^{N-1} |s[k, n]|^2 \quad (25)$$

is the average signal power, which is normally kept constant within a message by action of AGC; and

$$E[k] = \sum_{n=0}^{N-1} |r[k, n] - s[k, n]|^2. \quad (26)$$

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The mean CINR statistic (in dB) shall be derived from a multiplicity of single messages using

$$\hat{\mu}_{CINR\ dB}[k] = 10\log(\hat{\mu}_{CINR}[k]), \tag{27}$$

where

$$\hat{\mu}_{CINR}[k] = \begin{cases} CINR[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{CINR}[k-1] + \alpha_{avg} CINR[k] & k > 0 \end{cases} \tag{28}$$

k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.); $CINR[k]$ is a linear measurement of CINR (derived by any mechanism that delivers the prescribed accuracy) for message k; and α_{avg} is an averaging parameter specified by the BS.

To solve for the standard deviation, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{CINR}[k] = \begin{cases} |CINR[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{CINR}[k-1] + \alpha_{avg}|CINR[k]|^2 & k > 0 \end{cases} \tag{29}$$

and the result applied to

$$\hat{\sigma}_{CINR\ dB} = 5\log\left(\left|\hat{x}^2_{CINR}[k] - (\hat{\mu}_{CINR}[k])^2\right|\right) \quad \text{dB}. \tag{30}$$

8.3.3 Antenna diversity systems

Diversity techniques are likely to find application in some broadband wireless installations. Receive diversity does not require special considerations on the part of the air interface or framing. With two-way delay transmit diversity, where two transmit antennas are used and the output of the second antenna is delayed with respect to the first, the considerations are minor. Namely, both receiver equalization and framing shall be adequate to accommodate the extra delay spread introduced in the system due to the delayed output of the second transmitter.

However, framing considerations arise when the STC transmit diversity scheme [B26] is to be used. 8.3.3.1 describes the STC transmit diversity scheme for the SCa PHY and specifies framing that shall be used in its implementation.

8.3.3.1 STC transmit diversity

Implementation of STC transmit diversity is optional.

The STC transmit diversity scheme logically pairs blocks of data separated by delay spread guard intervals. These paired blocks are jointly processed at both the transmitter and receiver. The technique to be described is particularly amenable to a frequency domain equalizer implementation.

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8.3.3.1.1 Paired block transmit processing

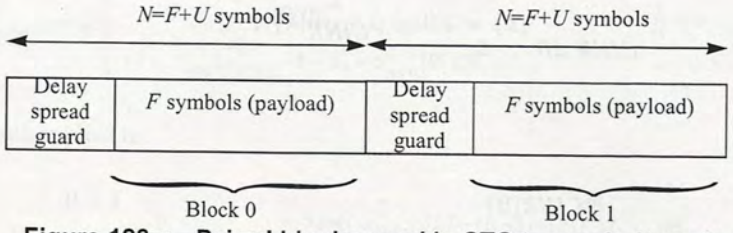


Figure 128w—Paired blocks used in STC transmit diversity combining

Figure 128w illustrates block pairing that shall be used by the STC transmit diversity scheme. Let $\{s_0[n]\}$ and $\{s_1[n]\}$ represent two sequences, each of length F symbols ($0 \le n < F$), which are desired to be delivered to a receiver using the STC transmit diversity scheme. Table 116ac indicates the block multiplexing structure that a two antenna transmitter shall use to transmit the two sequences over the paired blocks illustrated in Figure 128w. As Table 116ac indicates, Transmit Antenna 0 shall transmit its data sequences in order, with no modifications; however, Transmit Antenna 1 shall not only reverse the order in which its blocks are transmitted, but shall also conjugate the transmitted complex symbols and shall also time-reverse—cyclically about zero, modulo-F—the sequence of data symbols within each block. Subclause 8.3.3.1.4 provides details on the composition of the delay spread guard intervals between the blocks illustrated in Figure 128w.

Table 116ac—Multiplexing arrangement for block STC processing

Tx Antenna	Block 0	Block 1
0	$\{s_0[n]\}$	$\{s_1[n]\}$
1	$\{-s_1^*[(F-n) mod (F))]\}$	$\{s_0^*[(F-n) mod (F))]\}$

8.3.3.1.2 Paired block receive processing

If $S_0(e^{j\omega})$, $S_1(e^{j\omega})$, $H_0(e^{j\omega})$, $H_1(e^{j\omega})$, $N_0(e^{j\omega})$, and $N_1(e^{j\omega})$ represent the Discrete-time Fourier transforms, respectively, of the symbol sequences $\{s_0[n]\}$ and $\{s_1[n]\}$, channel impulse responses (for the channels associated with each transmitter antenna) $\{h_0[n]\}$ and $\{h_1[n]\}$, and additive noise sequences (associated with each block) $\{n_0[n]\}$ and $\{n_1[n]\}$, the received signals associated with each block, interpreted in the frequency domain, are as follows:

$$R_0(e^{j\omega}) = H_0(e^{j\omega})S_0(e^{j\omega}) - H_1(e^{j\omega})S_1^*(e^{j\omega}) + N_0(e^{j\omega}) \quad (31)$$

$$R_1(e^{j\omega}) = H_0(e^{j\omega})S_1(e^{j\omega}) + H_1(e^{j\omega})S_0^*(e^{j\omega}) + N_1(e^{j\omega}) \quad (32)$$

Assuming that the channel responses $H_0(e^{j\omega})$ and $H_1(e^{j\omega})$ are known, one shall use the frequency domain combining scheme

$$C_0(e^{j\omega}) = H_0^*(e^{j\omega})R_0(e^{j\omega}) + H_1(e^{j\omega})R_1^*(e^{j\omega}) \quad (33)$$

$$C_1(e^{j\omega}) = -H_1(e^{j\omega})R_0^*(e^{j\omega}) + H_0^*(e^{j\omega})R_1(e^{j\omega}) \quad (34)$$

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to obtain the combiner outputs

$$C_0(e^{j\omega}) = (\left|H_0(e^{j\omega})\right|^2 + \left|H_1(e^{j\omega})\right|^2)S_0(e^{j\omega}) + H_0^*(e^{j\omega})N_0(e^{j\omega}) + H_1(e^{j\omega})N_1^*(e^{j\omega}) \quad (35)$$

$$C_1(e^{j\omega}) = (\left|H_0(e^{j\omega})\right|^2 + \left|H_1(e^{j\omega})\right|^2)S_1(e^{j\omega}) - H_1(e^{j\omega})N_0^*(e^{j\omega}) + H_0^*(e^{j\omega})N_1(e^{j\omega}) \quad (36)$$

The combiner outputs of Equation (35) and Equation (36) can then be independently equalized using frequency domain equalizer techniques (for an example see [B21]) to obtain estimates for $\{s_0[n]\}$ and $\{s_1[n]\}$.

8.3.3.1.3 Channel estimation using pilot symbols

The channel responses used by the equalizer(s) can be estimated using data received during pilot symbol intervals. Under the assumption that pilot symbols are the same in the 0 and 1 blocks, i.e., $S_0^{pilot}(e^{j\omega}) = S_1^{pilot}(e^{j\omega}) = S_{pilot}(e^{j\omega})$, the sum and differences of Equation 6 and Equation 5 can be multiplied by $S_{pilot}^*(e^{j\omega})$ to yield (ignoring noise terms) the following:

$$S_{pilot}^*(e^{j\omega})(R_0^{pilot}(e^{j\omega}) + R_1^{pilot}(e^{j\omega})) = 2\left|S_{pilot}e^{j\omega}\right|^2 H_0(e^{j\omega}) \quad (37)$$

$$S_{pilot}(e^{j\omega})(R_1^{pilot}(e^{j\omega}) - R_0^{pilot}(e^{j\omega})) = 2\left|S_{pilot}e^{j\omega}\right|^2 H_1(e^{j\omega}) \quad (38)$$

The channel estimation task simply involves dividing the left hand sides of Equation (11) and Equation (12) by a constant independent of frequency, since pilot symbols are derived from the Unique Words of 8.3.1.3.2, and these Unique Words have a constant frequency domain magnitude, i.e., $\left|S_{pilot}(e^{j\omega})\right|^2 = \left|S_{UW}(e^{j\omega})\right|^2 = C$.

8.3.3.1.4 Paired block profiles

Figure 128x and Figure 128y illustrate two defined frame (burst) profiles for STC transmit diversity signaling.

Figure 128x illustrates the baseline framing structure for STC transmit multiplexing. This is cyclic-prefix-based frame structure, with U-symbol cyclic prefixes, and F-symbol repetitions chosen to facilitate efficient FFT-based processing at the receiver. Note that although the cyclic prefix is not composed of Unique Words, the length, U, shall be the same as the Unique Word length being used by the burst profile. Observe that the payload portions of Figure 128x reflect the STC antenna multiplexing format described in Table 116ac for Transmit Antennas 0 and 1. Note that a UW may be inserted within Payloads 0 and 1 to facilitate the use of frequency domain equalizers with time-domain decision feedback taps.

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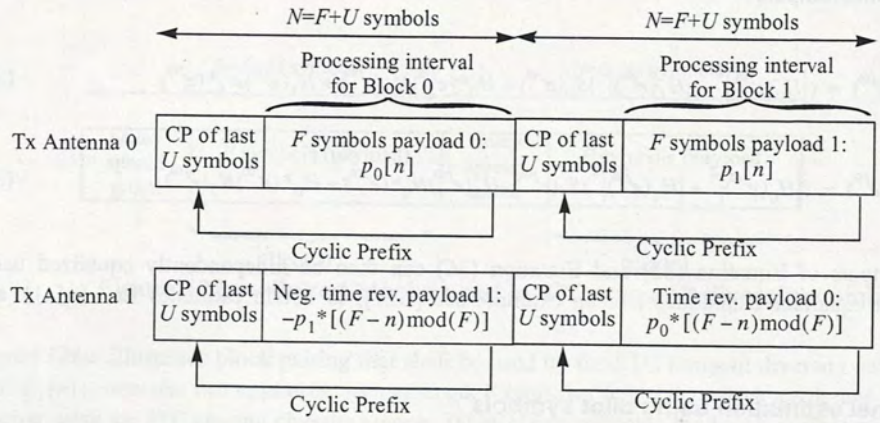


Figure 128x—Cyclic prefix-based STC framing

Figure 128y illustrates another burst profile which explicitly uses Unique Words, rather than a repetition of the payload data, to generate cyclic prefixes.

F, the length of an STC block, is a burst profile parameter. The choice of the burst profile for the paired blocks, i.e., the scheme illustrated in Figure 128x or the scheme illustrated in Figure 128y, is also a burst profile parameter.

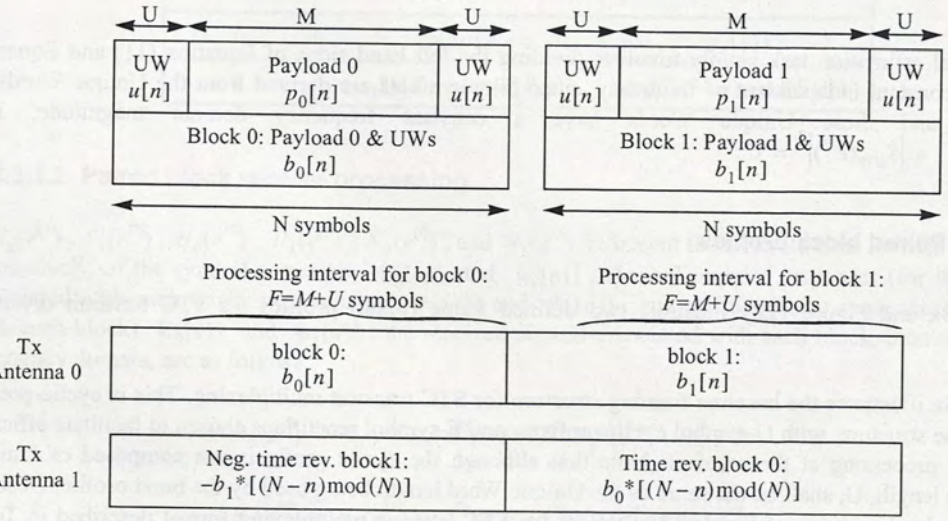


Figure 128y—STC framing using UWs as cyclic prefixes

8.3.3.1.5 STC burst elements

A STC burst shall consist of a preamble, followed by a payload, which may consist of multiple pairs of STC blocks.

Unlike conventional bursts, a RxDS element shall not appear at the conclusion of a STC burst.

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8.3.3.1.5.1 Burst preamble

Figure 128z illustrates that the burst frame preamble shall be used for bursts utilizing STC transmit diversity encoding. The number of UW blocks composing a STC burst preamble is a burst profile paramater, through reuse of the general burst profile encoding for the number of UWs in a preamble. However, since two channels shall be estimated, the total number of UWs used to construct an STC burst preamble shall be twice the number specified in the burst profile encoding.

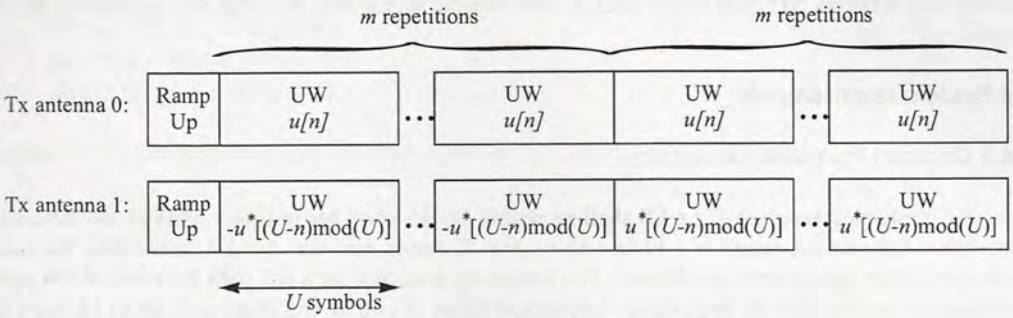


Figure 128z—STC frame preamble

Note that this preamble structure may also be inserted within a transmission as a group of contiguous Pilot Words, to assist in channel estimation and updating within a burst. In such an instance, this contiguous pilot symbol structure is considered external to the paired STC payload data blocks illustrated in Figure 128x, although the pilots may appear after every L^{th} paired payload block, where L is an integer greater than or equal to 1.

Ramp up shall use the same procedure described in 8.3.1.3.1.1, with the exception that the ramp up symbols for each transmit antenna are duplicates of the last R_r symbols of the first length-U data element in the preamble. Note that this implies that the first transmit antenna derives its ramp up symbols from a standard Unique Word sequence $\{u[n]\}$, while the second transmit antenna derives its ramp up symbols from the sequence $\{-u[(U-n)mod(U)]\}$.

8.3.3.1.5.2 Payload data

Payload data within an STC-encoded burst shall be formatted into block pairs, with each block pair possessing one of the block pair profiles described in 8.3.3.1.4. If insufficient data is available to fill the last block pair, then the payload shall be filled with null payload fill, as specified in 8.3.1.3.1.1. Except for the payload fill, modulations are sequenced in terms of decreasing modulation robustness on the Tx Ant 0 channel.

The preamble structure of Figure 128z, minus the ramp up symbols, may also be inserted within a transmission, as a group of contiguous Pilot Words to assist in channel estimation and updates within in a burst. In such an instance, this contiguous pilot symbol structure is considered external to the paired STC payload data blocks illustrated in Figure 128x, although the pilots may appear after every V^{th} paired payload block, where K is an integer greater than or equal to 1. The pilot word repetition interval, and the number of UWs composing a pilot word is a burst profile parameter.

8.3.3.1.5.3 Ramp down

Ramp down follows the end of a burst. A transmitter shall ramp down by inserting zero symbol inputs into the transmit filter memory following the last intended data symbol, and windowing the resulting,

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transmit-filtered output waveform with a multiplicative raised cosine window that diminishes to zero in R_r symbols. The (STC burst) ramp-down interval, R_r, shall be the same as the ramp up interval.

8.3.3.2 Interoperability with non-STC-encoded bursts

For interoperability reasons, STC-encoded data and conventionally-encoded data, shall not be time division multiplexed within the same burst. Instead, the STC data shall be encapsulated within its own burst and preamble.

All bursts with different STC pair block sizes, F, shall also be segregated, although they may share the same preamble.

8.3.4 System requirements

8.3.4.1 Channel frequency accuracy

RF channel frequency accuracy for a SS shall be within +/– 15 parts per million (ppm) of the selected RF carrier over a temperature range of –40 to +65 degrees C operational and up to 5 years from the date of manufacture of the equipment manufacture. The frequency accuracy for a BS shall be within +/– 4 ppm of the selected RF carrier over an operational temperature range of –40 to +65 degrees C, up to 10 years from the date of equipment manufacture.

8.3.4.2 Symbol rate

Utilizing a roll-off factor of $\alpha = 0.25$, the nominal symbol rate for the implemented channel bandwidth(s) BW shall be $(BW)/\ (1+\alpha) - 0.16$.

8.3.4.3 Symbol timing jitter

The minimum-to-maximum difference of symbol timing over a 2 second period shall be less than 2% of the nominal symbol period. This jitter specification shall be maintained over an operational temperature range of –40 to +65 degrees C.

8.3.4.4 Transmitter minimum SNR and EVM

A transmitted signal shall have an SNR of no less than 40 dB at the transmit antenna feed point. The transmitter EVM should be no greater than 3.1%, assuming 64-QAM.

8.3.4.5 Transmitter power level control

A SS transmitter shall provide 50 dB of monotonic power level control with an absolute tolerance of ±3 and a stepsize of 1 dB ±0.5 dB. A BS transmitter shall provide 20 dB of monotonic power level control with an absolute tolerance of ±3 and a stepsize of 1 dB ±0.5 dB.

8.3.4.6 Ramp up/down requirements

Transmit output power shall settle to within the tolerances specified in 8.3.4.5 within 5 μs. Transients due to the transmit filter impulse response shall be factored into settling time calculations.

8.3.4.7 Spurious emissions during burst on/off transients

A transmitter shall control spurious emissions to conform with applicable regulatory requirements. This includes prior to and during ramp up, during and following ramp down, and before and after a burst in a TDM/TDMA scheme.

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8.3.4.8 Out of band spurious emissions

Out of band spurious emissions shall conform with applicable local regulatory spectral masks.

8.3.4.9 Receiver sensitivity

The Receiver sensitivity values shall be better than the values listed below (computed at 10^{-6} uncoded BER, and a total of 7 dB in receiver noise figure plus implementation loss). BW is specified in MHz.

QPSK: –93.4 + 10*log(BW)
16-QAM: –86.6 + 10*log(BW)
64-QAM: 80.4 + 10*log(BW)

Assumed SNR_{req} assumptions (for uncoded signals at 10^{-6} BER) are the following:

QPSK: 13.6 dB
16-QAM: 20.4 dB
64-QAM: 26.6 dB.

8.3.4.10 Receiver maximum input signal

A BS shall be capable of receiving a maximum on-channel operational signal of –40 dBm and should tolerate a maximum input signal of 0 dBm without damage to circuitry. A SS shall be capable of receiving a maximum on-channel operational signal of –20 dBm and should tolerate a maximum input signal of 0 dBm without damage to circuitry.

8.3.4.11 Receiver adjacent channel interference

A system shall achieve the minimum adjacent and alternate adjacent channel interference performance as shown in Table 116ad. All measurements shall be performed uncoded.

Table 116ad—Minimum adjacent and alt. adjacent channel interference performance

	At BER 10–3, for 3 dB degradation	At BER 10–3, for 1 dB degradation	At BER 10–6, for 3 dB degradation	At BER 10–6, for 1 dB degradation
1st adjacent channel interference C/I	BPSK: –12 QPSK: –9 16-QAM: –2 64-QAM: +5 256-QAM: +12	BPSK: –8 QPSK: –5 16-QAM: +2 64-QAM: +9 256-QAM: +16	BPSK: –8 QPSK: –5 16-QAM: +2 64-QAM: +9 256-QAM: +16	BPSK: –4 QPSK: –1 16-QAM: +6 64-QAM: +13 256-QAM: +20
2nd adjacent channel interference C/I	BPSK: –37 QPSK: –34 16-QAM: –27 64-QAM: –20 256-QAM: –13	BPSK: –33 QPSK: –30 16-QAM: –22 64-QAM: –16 256-QAM: –9	BPSK: -33 QPSK: –30 16-QAM: –23 64-QAM: –16 256-QAM: –9	BPSK: –29 QPSK: –26 16-QAM: –20 64-QAM: –12 256-QAM: –5

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8.4 WirelessMAN-OFDM-PHY layer

8.4.1 Introduction

The WirelessMAN-OFDM PHY is based on OFDM modulation and designed for NLOS operation in the 2–11 GHz frequency bands per 1.2.4. For licensed bands, channel bandwidths allowed shall be limited to the regulatory provisioned bandwidth divided by any power of 2 no less than 1.25 MHz.

8.4.1.1 OFDM symbol description

8.4.1.1.1 Time domain

Inverse-Fourier-transforming creates the OFDM waveform; this time duration is referred to as the useful symbol time T_b. A copy of the last T_g μs of the useful symbol period, termed Cyclic Prefix (CP), is used to collect multipath, while maintaining the orthogonality of the tones. The two together are referred to as the symbol time T_s. Figure 128aa illustrates this structure.

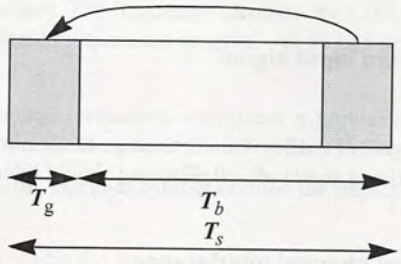


Figure 128aa—OFDM symbol time structure

The transmitter energy increases with the length of the guard time while the receiver energy remains the same (the cyclic extension is discarded), so there is a $10\log(1 - T_g / (T_b + T_g)) / \log(10$ dB loss in SNR. The CP overhead fraction and resultant SNR loss could be reduced by increasing the FFT size, which would however, among other things, adversely affect the sensitivity of the system to phase noise of the oscillators. Using a cyclic extension, the samples required for performing the FFT at the receiver can be taken anywhere over the length of the extended symbol. This provides multipath immunity as well as a tolerance for symbol time synchronization errors.

On initialization, a SS should search all possible values of CP until it finds the CP being used by the BS. The SS shall use the same CP on the UL. Once a specific CP duration has been selected by the BS for operation on the DL, it should not be changed. Changing the CP would force all the SSs to resynchronize to the BS.

8.4.1.1.2 Frequency domain

The frequency domain description includes the basic structure of an OFDM symbol.

An OFDM symbol (see Figure 128ab) is made up from carriers, the number of which determines the FFT size used. There are several carrier types:

— Data carriers: for data transmission
— Pilot carriers: for various estimation purposes
— Null carriers: no transmission at all, for guard bands and DC carrier

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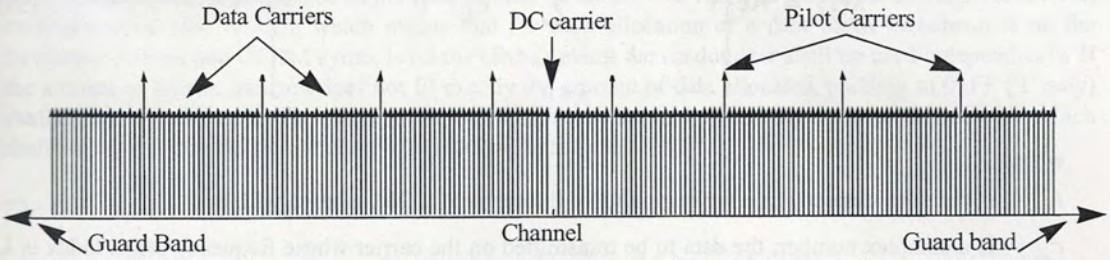


Figure 128ab—OFDM frequency description

The purpose of the guard bands is to enable the signal to naturally decay and create the FFT 'brick Wall' shaping.

8.4.2 OFDM symbol parameters and transmitted signal

8.4.2.1 Primitive parameter definitions

Three primitive parameters characterize the OFDM symbol:

— BW. This is the nominal channel bandwidth.
— (F_s / BW). This is the ratio of "sampling frequency" to the nominal channel bandwidth. Required values of this parameter are specified in 8.4.2.4.
— (T_g / T_b). This is the ratio of CP time to "useful" time. Required values of this parameter are specified in 8.4.2.4.
— N_{FFT}. This is the number of points in the FFT, if an FFT is used in the implementation.

8.4.2.2 Derived parameter definitions

The following parameters are defined in terms of the primitive parameters of 8.4.2.1.

— Sampling Frequency: $F_s = (F_s / BW) \cdot BW$
— Carrier Spacing: $\Delta f = f_s / N_{FFT}$
— Useful Time: $T_b = 1 / \Delta f$
— CP Time: $T_g = (T_g / T_b) \cdot T_b$
— OFDM Symbol Time: $T_s = T_b + T_g$
— Sample Time: $1 / F_s$

8.4.2.3 Transmitted signal

Equation (39) specifies the transmitted signal voltage to the antenna, as a function of time, during any OFDM symbol.

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$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \sum_{\substack{k = -N_{used}/2 \\ k \neq 0}}^{N_{used}/2} c_k \cdot e^{j2\pi k \Delta f (t - T_g)} \right\} \quad (39)$$

where

t is the time, elapsed since the beginning of the subject OFDM symbol, with $0 < t < T_s$.

c_k is a complex number; the data to be transmitted on the carrier whose frequency offset index is k, during the subject OFDM symbol. It specifies a point in a QAM constellation.

8.4.2.4 Parameters of transmitted signal

The parameters of the transmitted OFDM signal, transmitted as in 8.4.2.3, are given in Table 116ae.

Table 116ae—OFDM symbol parameters

Parameter	Value
N_{FFT}	256
N_{used}	200
F_s / BW	licensed channel bandwidths which are multiples of 1.75 MHz and license-exempt: 8/7 any other bandwidth: 7/6
(T_g / T_b)	1/4, 1/8, 1/16, 1/32
Number of lower frequency guard carriers	28
Number of higher frequency guard carriers	27
Frequency offset indices of guard carriers	–128,–127...,–101 +101,+102,...,127
Frequency offset indices of BasicFixedLocationPilots	–84,–60,–36,–12,12,36,60,84
Subchannel number: Allocated frequency offset indices of carriers	1:{–88,...,–76},{–50,...,–39},{1,...,13},{64,...,75} 2:{–63,...,–51},{–25,...–14},{26,...,38},{89,...,100} 3:{–100,...,–89},{–38,...,–26},{14,...,25},{51,...,63} 4:{–75,...,–64},{–13,...,–1},{39,...,50},{76,...,88}

8.4.3 Channel coding

Channel coding is composed of three steps: randomizer, forward error correction (FEC) and interleaving. They shall be applied in this order at transmission. The complementary operations shall be applied in reverse order at reception.

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8.4.3.1 Randomization

Data randomization is performed on data transmitted on the DL and UL. The randomization is performed on each allocation (DL or UL), which means that for each allocation of a data block (subchannels on the frequency domain and OFDM symbols on the time domain) the randomizer shall be used independently. If the amount of data to transmit does not fit exactly the amount of data allocated, padding of 0xFF ('1' only) shall be added to the end of the transmission block, up to the amount of data allocated minus one byte, which shall be reserved for the introduction of a 0x00 tail byte by the FEC.

The shift-register of the randomizer shall be initialized for each new allocation.

The Pseudo Random Binary Sequence (PRBS) generator shall be $1 + X^{14} + X^{15}$ as shown in Figure 128ac. Each data byte to be transmitted shall enter sequentially into the randomizer, msb first. Preambles are not randomized. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst. The randomizer sequence is applied only to information bits.

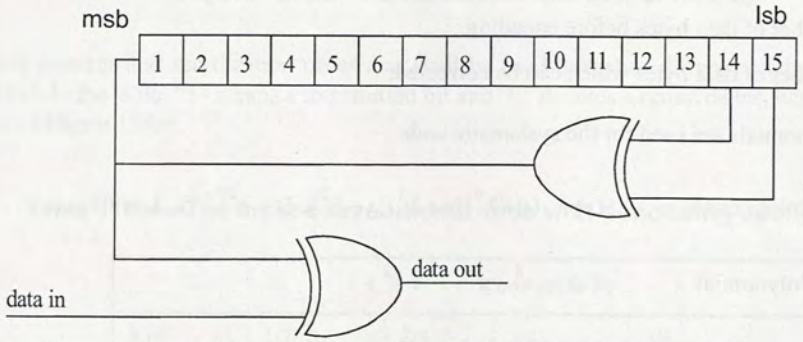


Figure 128ac—PRBS for data randomization

The bits issued from the randomizer shall be applied to the encoder.

In the DL, the scrambler shall be re-initialized at the start of each frame with the sequence: 1 0 0 1 0 1 0 1 0 0 0 0 0 0 0.

On the UL, the scrambler is initialized with the vector shown in Figure 128ad.

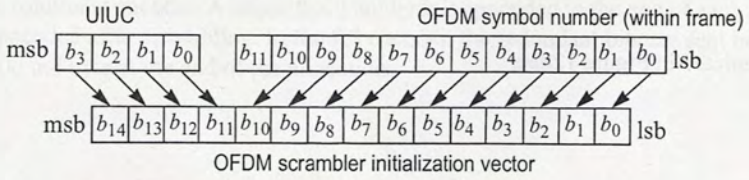


Figure 128ad—OFDM scrambler UL initialization vector

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8.4.3.2 FEC

A FEC, consisting of the concatenation of a Reed-Solomon outer code and a rate-compatible convolutional inner code, shall be supported on both UL and DL. Support of BTC and CTC is optional. The Reed-Solomon-Convolutional coding rate 1/2 shall always be used as the coding mode when requesting access to the network and in the FCH burst.

The encoding is performed by first passing the data in block format through the RS encoder and then passing it through a zero-terminating convolutional encoder.

8.4.3.2.1 Concatenated Reed-Solomon / convolutional code (RS-CC)

The Reed-Solomon encoding shall be derived from a systematic RS (N=255, K=239, T=8) code using GF(28),

where:

N is the number of overall bytes after encoding

K is the number of data bytes before encoding

T is the number of data bytes which can be corrected.

The following polynomials are used for the systematic code:

Code Generator Polynomial: $$g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)..(x+\lambda^{2T-1}),\ \lambda = 02_{HEX} \quad (40)$$

Field Generator Polynomial: $$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \quad (41)$$

This code is shortened and punctured to enable variable block sizes and variable error-correction capability. When a block is shortened to K' data bytes, the first 239-K' bytes of the encoder block shall be zero. When a codeword is punctured to permit T' bytes to be corrected, only the first 2T' of the total 16 codeword bytes shall be employed. The bit/byte conversion shall be msb first.

Each RS block is encoded by the binary convolutional encoder, which shall have native rate of 1/2, a constraint length equal to **7**, and shall use the following generator polynomials codes to derive its two code bits:

$$\begin{aligned} G_1 &= 171_{OCT} \quad FOR\ X \\ G_2 &= 133_{OCT} \quad FOR\ Y \end{aligned} \quad (42)$$

The generator is depicted in Figure 128ae.

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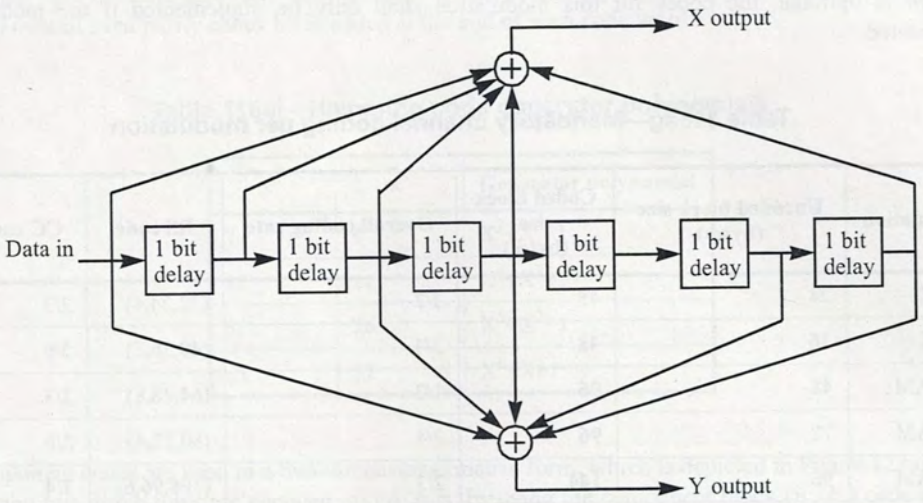


Figure 128ae—Convolutional encoder of rate 1/2

Puncturing patterns and serialization order that shall be used to realize different code rates are defined in Table 116af. In the table, "1" means a transmitted bit and "0" denotes a removed bit, whereas X and Y are in reference to Figure 128ae.

Table 116af—The inner convolutional code with puncturing configuration

	Code rates			
Rate	1/2	2/3	3/4	5/6
d_{free}	10	6	5	4
X	1	10	101	10101
Y	1	11	110	11010
XY	X_1Y_1	$X_1Y_1Y_2$	$X_1Y_1Y_2X_3$	$X_1Y_1Y_2X_3Y_4X_5$

RS-CC rate 1/2 shall always be used as the coding mode when requesting access to the network.

The encoding is performed by first passing the data in block format through the RS encoder and then passing it through a convolutional encoder. A single 0x00 tail byte is appended to the end of each allocation. This tail byte shall be appended after scrambling. In the RS encoder, the redundant bits are sent before the input bits, keeping the 0x00 tail byte at the end of the allocation.

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Table 116ag gives the block sizes and the code rates used for the different modulations and code rates. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ag—Mandatory channel coding per modulation

Modulation	Uncoded block size (bytes)	Coded block size (bytes)	Overall coding rate	RS code	CC code rate
QPSK	24	48	1/2	(32,24,4)	2/3
QPSK	36	48	3/4	(40,36,2)	5/6
16-QAM	48	96	1/2	(64,48,8)	2/3
16-QAM	72	96	3/4	(80,72,4)	5/6
64-QAM	96	144	2/3	(108,96,6)	3/4
64-QAM	108	144	3/4	(120,108,6)	5/6

When subchannelization is active (see 8.4.5.3.5), the FEC shall bypass the RS encoder and use the Overall Coding Rate as indicated in Table 116ag as CC Code Rate. The Uncoded Block Size and Coded Block size may be computed by dividing the values listed in Table 116ag by 4 and 2 for 1 and 2 subchannel allocations respectively.

8.4.3.2.2 Block Turbo Coding (optional)

The BTC is based on the product of two simple component codes, which are binary extended Hamming codes or parity check codes from the set depicted in Table 116ah.

Table 116ah—BTC component codes

Component code (n,k)	Code type
(64,57)	Extended Hamming code
(32,26)	Extended Hamming code
(16,11)	Extended Hamming code
(32,31)	Parity check code
(16,15)	Parity check code
(8,7)	Parity check code

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Table 116ai specifies the generator polynomials for the Hamming codes. To create extended Hamming codes, an overall even parity check bit is added at the end of each code word.

Table 116ai—Hamming code generator polynomials

n'	*k'*	Generator polynomial
7	4	X^3+X^1+1
15	11	X^4+X^1+1
31	26	X^5+X^2+1
63	57	X^6+X+1

The component codes are used in a two-dimensional matrix form, which is depicted in Figure 128ag. The k_x information bits in the rows are encoded into n_x bits, by using the component block (n_x, k_x) code specified for the respective composite code. After encoding the rows, the columns are encoded using a block code (n_y, k_y), where the check bits of the first code are also encoded. The overall block size of such a product code is $n = n_x \times n_y$, the total number of information bits $k = k_x \times k_y$ and the code rate is $R = R_x \times R_y$, where $R_i = k_i / n_i$, $i=x, y$. The Hamming distance of the product code is $d = d_x \times d_y$. Data bit ordering for the composite BTC matrix is defined such that the first bit in the first row is the lsb, and the last data bit in the last data row is the msb.

Figure 128af illustrates an example of a BTC encoded with (8, 4) × (8, 4) extended Hamming component codes.

D_{11}	D_{21}	D_{31}	D_{41}	E_{51}	E_{61}	E_{71}	E_{81}
D_{12}	D_{22}	D_{32}	D_{42}	E_{52}	E_{62}	E_{72}	E_{82}
D_{13}	D_{23}	D_{33}	D_{43}	E_{53}	E_{63}	E_{73}	E_{83}
D_{14}	D_{24}	D_{34}	D_{44}	E_{54}	E_{64}	E_{74}	E_{84}
E_{15}	E_{25}	E_{35}	E_{45}	E_{55}	E_{65}	E_{75}	E_{85}
E_{16}	E_{26}	E_{36}	E_{46}	E_{56}	E_{66}	E_{76}	E_{86}
E_{17}	E_{27}	E_{37}	E_{47}	E_{57}	E_{67}	E_{77}	E_{87}
E_{18}	E_{28}	E_{38}	E_{48}	E_{58}	E_{68}	E_{78}	E_{88}

Figure 128af—Example of an encoded BTC block

Transmission of the block over the channel shall occur in a linear fashion, with all bits of the first row transmitted left to right followed by the second row, and so on. For the (8, 4) × (8, 4) example in Figure 128af, the output order for the 64 encoded bits would be: $D_{11}, D_{21}, D_{31}, D_{41}, E_{51}, E_{61}, E_{71}, E_{81}, D_{12}, D_{22}, \ldots, E_{88}$.

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To match a required packet size, BTCs may be shortened by removing symbols from the BTC array. In the two-dimensional case, rows, columns or parts thereof can be removed until the appropriate size is reached. There are three steps in the process of shortening product codes:

Step 1) Remove I_x rows and I_y columns from the two-dimensional code. This is equivalent to shortening the constituent codes that make up the product code.

Step 2) Remove B individual bits from the first row of the two-dimensional code starting with the lsb.

Step 3) Use if the product code specified from Step 1) and Step 2) has a non-integral number of data bytes. In this case, the Q left over lsb bits are zero filled by the encoder. After decoding at the receive end, the decoder shall strip off these unused bits and only the specified data payload is passed to the next higher level in the physical layer.

The same process is used for shortening the last code word in a message where the available data bytes do not fill the available data bytes in a code block.

These three processes of code shortening are depicted in Figure 128ag. In the first two-dimensional BTC, a non-shortened product code is shown. By comparison, a shortened BTC is shown in the adjacent two-dimensional array. The new coded block length of the code is $(n_x–I_x)(n_y–I_y)–B$. The corresponding information length is given as $(k_x–I_x)(k_y–I_y)–B–Q$. Consequently, the code rate is given by:

$$R = \frac{(k_x - I_x)(k_y - I_y) - B - Q}{(n_x - I_x)(n_y - I_y) - B} \tag{43}$$

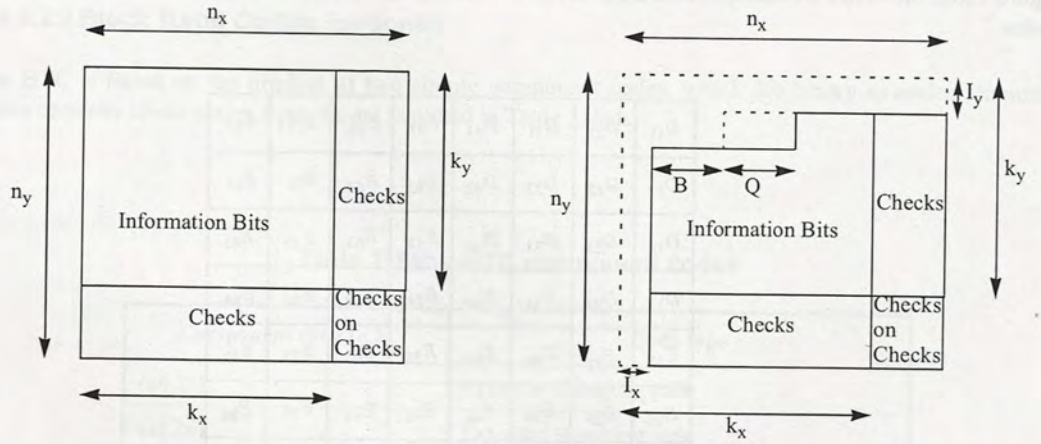


Figure 128ag—BTC and shortened BTC structure

Table 116aj gives the block sizes, code rates, channel efficiency, and code parameters for the different modulation and coding schemes. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

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Table 116aj—Optional BTC channel coding per modulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall code rate	Efficiency (bit/s/Hz)	Constituent codes	Code parameter
QPSK	23	48	~1/2	1.0	(32,26)(16,11)	I_x=4, I_y=2, B=8, Q=6
QPSK	35	48	~3/4	1.5	(32,26)(16,15)	I_x=0, I_y=4, B=0, Q=6
16-QAM	58	96	~3/5	2.4	(32,26)(32,26)	I_x=0, I_y=8, B=0, Q=4
16-QAM	77	96	~4/5	3.3	(64,57)(16,15)	I_x=7, I_y=2, B=30, Q=4
64-QAM	96	144	~2/3	3.8	(64,63)(32,26)	I_x=3, I_y=13, B=7, Q=5
64-QAM	120	144	~5/6	5.0	(32,31)(64,57)	I_x=13, I_y=3, B=7, Q=5

8.4.3.2.3 Convolutional Turbo Codes (optional)

8.4.3.2.3.1 CTC encoder

The Convolutional Turbo Code encoder, including its constituent encoder, is depicted in Figure 128ah. It uses a double binary Circular Recursive Systematic Convolutional code. The bits of the data to be encoded are alternately fed to A and B, starting with the msb of the first byte being fed to A. The encoder is fed by blocks of k bits or N couples ($k = 2*N$ bits). For all the frame sizes k is a multiple of 8 and N is a multiple of 4. N shall be limited to: $8 \leq N/4 \leq 1024$.

The polynomials defining the connections are described in octal and symbol notations as follows:

— for the feedback branch: 0xB, equivalently $1+D+D^3$ (in symbolic notation)
— for the Y parity bit: 0xD, equivalently $1+D^2+D^3$

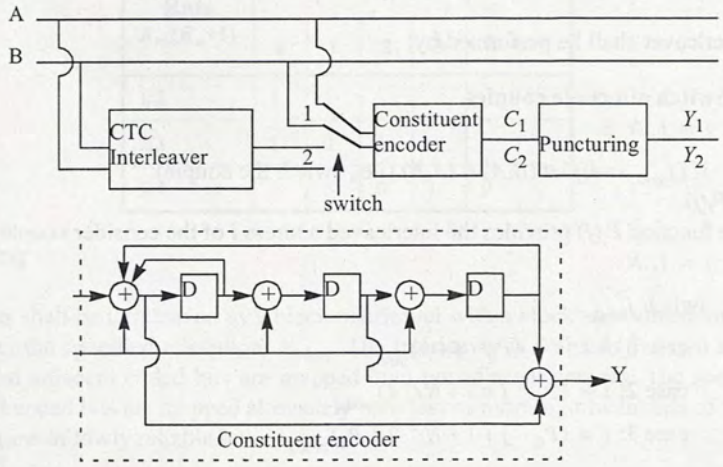


Figure 128ah—CTC encoder

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First, the encoder (after initialization by the circulation state Sc_1, see 8.4.3.2.3.3) is fed the sequence in the natural order (position 1) with the incremental address $i = 0 .. N–1$. This first encoding is called C_1 encoding. Then the encoder (after initialization by the circulation state Sc_2, see 8.4.3.2.3.3) is fed by the interleaved sequence (switch in position 2) with incremental address $j = 0, \ldots N–1$. This second encoding is called C_2 encoding.

The order that the encoded bit shall be fed into the interleaver (8.4.3.3) is as follows:

$$A_0, B_0 .. A_{N-1}, B_{N-1}, Y_{10}, Y_{1,1} .. Y_{1,M}, Y_{20}, Y_{2,1} .. Y_{2,M},$$

where M is the number of parity bits.

Table 116ak gives the block sizes, code rates, channel efficiency, and code parameters for the different modulation and coding schemes. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ak—Optional CTC channel coding per modulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall code rate	N	P_0	P_1
QPSK	24	48	1/2	96	7	3N/4
QPSK	32	48	2/3	128	11	3N/4
QPSK	36	48	3/4	144	17	3N/4
16-QAM	48	96	1/2	192	11	3N/4
16-QAM	72	96	3/4	288	13	3N/4
64-QAM	96	144	2/3	384	17	3N/4
64-QAM	108	144	3/4	432	17	3N/4

8.4.3.2.3.2 CTC Interleaver

The interleaver requires the parameters P_0 and P_1, shown in Table 116ak.

The two-step interleaver shall be performed by:

Step 1: Switch alternate couples

for $j = 1..N$

if $(j_{\mathrm{mod}_2} == 0)$ let $(B,A) = (A,B)$ (i.e., switch the couple)

Step 2: $P_i(j)$

The function $P_i(j)$ provides the interleaved address i of the consider couple j.

for $j = 1..N$

switch j_{mod_4} :

case 0 or 1: $i = (P_0 \cdot j + 1)_{\mathrm{mod}_N}$

case 2: $i = (P_0 \cdot j + 1 + N/4)_{\mathrm{mod}_N}$

case 3: $i = (P_0 \cdot j + 1 + N/2 + P_1)_{\mathrm{mod}_N}$

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8.4.3.2.3.3 Determination of CTC circulation states

The state of the encoder is denoted S ($0 <= S == 7$) with S the value read binary (left to right) out of the constituent encoder memory (see Figure 128ah). The circulation states Sc_1 and Sc_2 are determined by the following operations:

Step 1) Initialize the encoder with state 0. Encode the sequence in the natural order for the determination of Sc_1 or in the interleaved order for determination of Sc_2. In both cases the final state of the encoder is $S0_{N-1}$;

Step 2) According to the length N of the sequence, use Figure 116al to find Sc_1 or Sc_2.

Table 116al—Circulation state lookup table (*Sc*)

N_{mod_7}	$S0_{N-1}$							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	6	4	2	7	1	3	5
2	0	3	7	4	5	6	2	1
3	0	5	3	6	2	7	1	4
4	0	4	1	5	6	2	7	3
5	0	2	5	7	1	3	4	6
6	0	7	6	1	3	4	5	2

8.4.3.2.3.4 CTC puncturing

The three code-rates are achieved through selectively deleting the parity bits (puncturing). The puncturing patterns are identical for both codes C_1 and C_2.

Table 116am—Circulation state lookup table (*Sc*)

Rate $R_n/(R_n+1)$	Y					
	0	**1**	**2**	**3**	**4**	**5**
1/2	1	1				
2/3	1	0	1	0		
3/4	1	0	0	1	0	0

8.4.3.3 Interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the specified allocation, N_{cbps}. The interleaver is defined by a two step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent carriers. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits.

Let N_{cpc} be the number of coded bits per carrier, i.e., 2, 4 or 6 for QPSK, 16-QAM or 64-QAM, respectively. Let $s = N_{cpc}/2$. Let k be the index of the coded bit before the first permutation at transmission; m be the index after the first and before the second permutation; and j be the index after the second permutation, just prior to modulation mapping.

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The first permutation is defined by the rule:

$$m = (N_{cbps}/\ 16) \cdot\ k_{mod(16)} + floor(k/\ 16) \qquad k = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{44}$$

The second permutation is defined by the rule:

$$j = s \cdot\ floor(m/\ s) + (m + N_{cbps} - floor(16 \cdot\ m/\ N_{cbps}))_{mod\ s} \qquad m = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{45}$$

The de-interleaver, which performs the inverse operation, is also defined by two permutations. Let j be the index of the received bit before the first permutation; m be the index after the first and before the second permutation; and k be the index after the second permutation, just prior to delivering the coded bits to the convolutional decoder.

The first permutation is defined by the rule:

$$m = s \cdot\ floor(j/\ s) + (j + floor(16 \cdot\ j/\ N_{cbps}))_{mod\ s} \qquad j = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{46}$$

The second permutation is defined by the rule:

$$k = 16 \cdot\ m - (N_{cbps} - 1) \cdot\ floor(16 \cdot\ m/\ N_{cbps}) \qquad m = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{47}$$

The first permutation in the de-interleaver is the inverse of the second permutation in the interleaver, and conversely.

Table 116an shows the bit interleaver sizes as a function of modulation and coding.

Table 116an—Bit interleaved block sizes

Modulation	Coded bits per bit interleaved block (N_{cbps})		
	Default (4 subchannels)	2 subchannels	1 subchannel
QPSK	384	192	96
16-QAM	768	384	192
64-QAM	1152	576	288

The first bit out of the interleaver shall map to b_0 in the constellation.

8.4.3.4 Modulation

8.4.3.4.1 Data modulation

After bit interleaving, the data bits are entered serially to the constellation mapper. Gray-mapped QPSK and 16-QAM as shown in Figure 128ai shall be supported, whereas the support of 64-QAM is optional. The constellations as shown in Figure 128ai shall be normalized by multiplying the constellation point with the indicated factor c to achieve equal average power.

Per-allocation adaptive modulation and coding shall be supported in the DL. The UL shall support different modulation schemes for each SS based on the MAC burst configuration messages coming from the Base Station. Complete description of the MAC / PHY support of adaptive modulation and coding is provided in 6.2.7.

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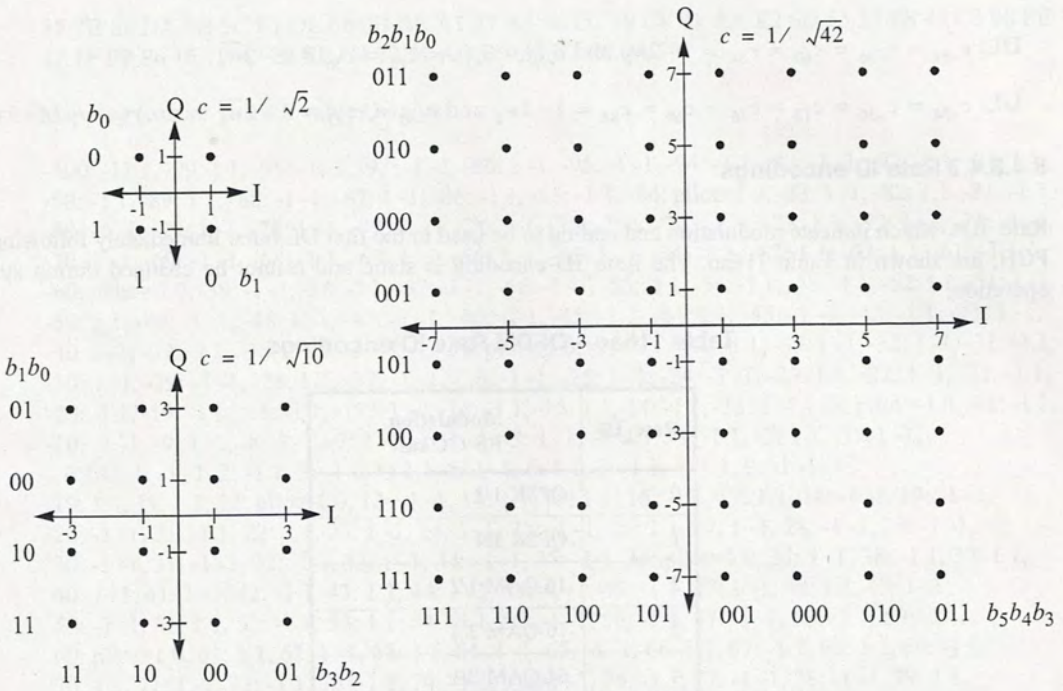


Figure 128ai—QPSK, 16-QAM and 64-QAM constellations

The constellation-mapped data shall be subsequently modulated onto the allocated data carriers. The first symbol out of the data constellation mapping shall be modulated onto frequency offset index $-N_{used}/2$.

8.4.3.4.2 Pilot modulation

Pilot carriers shall be inserted into each data burst in order to constitute the Symbol and they shall be modulated according to their carrier location within the OFDM symbol. The PRBS generator depicted hereafter shall be used to produce a sequence, w_k. The polynomial for the PRBS generator shall be $X^{11} + X^9 + 1$.

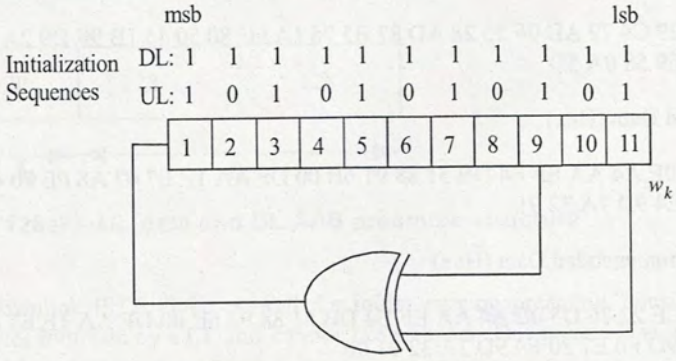


Figure 128aj—PRBS for pilot modulation

The value of the pilot modulation for OFDM symbol k, relative to the beginning of the frame, shall be derived from w_k. The initialization sequences that shall be used on the DL and UL are shown in Figure 128aj. On the DL, this shall result in the sequence 11111111111000000000110... where the 3rd 1, i.e.,

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w_3=1, shall be used in the first OFDM DL symbol following the frame preamble. For each pilot (indicated by frequency offset index), the BPSK modulation shall be derived as follows:

$$\text{DL: } c_{-84} = c_{-36} = c_{60} = c_{84} = 1 - 2w_k \text{ and } c_{-60} = c_{-12} = c_{12} = c_{36} = 1 - 2\overline{w_k} \quad (48)$$

$$\text{UL: } c_{-84} = c_{-36} = c_{12} = c_{36} = c_{60} = c_{84} = 1 - 2w_k \text{ and } c_{-60} = c_{-12} = 1 - 2\overline{w_k} \quad (49)$$

8.4.3.4.3 Rate ID encodings

Rate_IDs, which indicate modulation and coding to be used in the first DL burst immediately following the FCH, are shown in Table 116ao. The Rate_ID encoding is static and cannot be changed during system operation.

Table 116ao—OFDM Rate ID encodings

Rate_ID	Modulation RS-CC rate
0	QPSK 1/2
1	QPSK 3/4
2	16-QAM 1/2
3	16-QAM 3/4
4	64-QAM 2/3
5	64-QAM 3/4
6–15	Reserved

8.4.3.5 Example OFDM UL RS-CC encoding

To illustrate the use of the RS-CC encoding, an example of one frame of OFDM UL data is provided, illustrating each process from randomization through carrier modulation.

Modulation Mode: QPSK, rate 3/4, Slot Offset: 14, UIUC: 7 (decimal values)

Input Data (Hex)

45 29 C4 79 AD 0F 55 28 AD 87 B5 76 1A 9C 80 50 45 1B 9F D9 2A 88 95 EB AE B5 2E 03 4F 09 14 69 58 0A 5D

Randomized Data (Hex)

D5 0E A4 AA EF E4 DB 51 88 91 6B 00 DF AA 1E E7 02 A8 0E 70 4F 7F C9 D8 66 1D 9D F0 E7 20 E4 9D 7A 32 91

Reed-Solomon encoded Data (Hex)

95 CE 22 76 D5 0E A4 AA EF E4 DB 51 88 91 6B 00 DF AA 1E E7 02 A8 0E 70 4F 7F C9 D8 66 1D 9D F0 E7 20 E4 9D 7A 32 91 00

Convolutionally Encoded Data (Hex)

D5 2E 96 38 FE 93 1E 6A AF 17 D3 44 E4 8B 45 8F 13 D6 AF 27 E3 B2 D5 0A 57 C1 2A F1 A9 73 86 71 3F F1 03 95 F8 ED 2D 30 A2 E0 DB D2 F8 8E B3 4C

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Interleaved Data (Hex)

8F 7B 88 DA 4B 5C F1 DE 66 0B BE A1 37 A3 96 D2 59 CF 71 AA E2 6D 55 23 E8 48 C3 08 FE 17 1F F9 E6 16 1E 47 22 EE C4 72 21 AB BC 39 E7 E0 6A 78

Carrier Mapping (carrier index: I value Q value)

-100: -11 1, -99: 1 1, -98: -1 -1, -97: -1 -1, -96: 1 -1, -95: -1 -1, -94: -1 1, -93: -1 -1, -92: -1 1, -91: 1 1,
-90: -1 1, -89: 1 1, -88: -1 -1, -87: 1 -1, -86: -1 1, -85: -1 1, -84: pilot=1 0, -83: 1 -1, -82: 1 1, -81: -1 1,
-80: -1 -1, -79: 1 -1, -78: 1 -1, -77: -1 -1, -76: 1 1, -75: -1 -1, -74: -1 -1, -73: 1 1, -72: 1 -1, -71: -1 -1,
-70: 1 -1, -69: -1 -1, -68: -1 1, -67: 1 -1, -66: 1 -1, -65: 1 -1, -64: -1 1, -63: 1 1, -62: 1 1, -61: -1 1,
-60: pilot=-1 0, -59: -1 -1, -58: -1 1, -57: -1 -1, -56: -1 -1, -55: -1 1, -54: -1 1, -53: -1 1, -52: 1 1, -51: 1 -1,
-50: 1 1, -49: -1 -1, -48: 1 -1, -47: -1 -1, -46: -1 1, -45: -1 1, -44: 1 1, -43: -1 -1, -42: -1 1, -41: 1 -1,
-40: 1 -1, -39: -1 1, -38: -1 -1, -37: 1 -1, -36: pilot=1 0, -35: 1 1, -34: -1 1, -33: 1 -1, -32: 1 -1, -31: -1 1,
-30: 1 -1, -29: -1 -1, -28: 1 1, -27: -1 -1, -26: -1 -1, -25: 1 -1, -24: -1 -1, -23: 1 1, -22: 1 -1, -21: -1 1,
-20: -1 1, -19: -1 1, -18: -1 1, -17: -1 -1, -16: -1 1, -15: 1 1, -14: -1 1, -13: 1 -1, -12: pilot=-1 0, -11: -1 1,
-10: -1 -1, -9: 1 -1, -8: 1 -1, -7: 1 -1, -6: 1 -1, -5: 1 -1, -4: 1 1, -3: -1 1, -2: 1 1, -1: -1 -1,
0:DC, 1: -1 -1, 2: -1 1, 3: -1 1, 4: 1 1, 5: 1 -1, 6: 1 1, 7: -1 1, 8: 1 1, 9: -1 -1,
10: 1 1, 11: 1 1, 12: pilot=1 0, 13: -1 -1, 14: 1 1, 15: 1 1, 16: -1 1, 17: 1 1, 18: -1 -1, 19: -1 -1,
20: -1 -1, 21: -1 1, 22: 1 1, 23: 1 -1, 24: 1 -1, 25: -1 -1, 26: 1 1, 27: 1 -1, 28: -1 -1, 29: -1 -1,
30: -1 -1, 31: -1 -1, 32: -1 1, 33: 1 -1, 34: -1 -1, 35: -1 1, 36: pilot=1 0, 37: 1 -1, 38: -1 1, 39: 1 1,
40: 1 -1, 41: 1 -1, 42: -1 1, 43: 1 1, 44: 1 -1, 45: -1 -1, 46: -1 1, 47: 1 -1, 48: 1 1, 49: 1 -1,
50: -1 -1, 51: 1 1, 52: -1 1, 53: 1 1, 54: -1 1, 55: -1 -1, 56: -1 1, 57: -1 -1, 58: -1 1, 59: -1 -1,
60: pilot=1 0, 61: 1 1, 62: 1 -1, 63: 1 1, 64: 1 -1, 65: -1 -1, 66: 1 1, 67: -1 1, 68: 1 1, 69: -1 1,
70: 1 1, 71: 1 -1, 72: -1 1, 73: -1 1, 74: -1 1, 75: -1 -1, 76: -1 1, 77: -1 -1, 78: -1 -1, 79: 1 1,
80: 1 1, 81: -1 -1, 82: -1 1, 83: 1 -1, 84: pilot=1 0, 85: -1 -1, 86: -1 1, 87: 1 -1, 88: -1 -1, 89: -1 -1,
90: -1 1, 91: 1 1, 92: 1 1, 93: 1 -1, 94: -1 1, 95: -1 1, 96: -1 1, 97: 1 -1, 98: -1 -1, 99: -1 1, 100: 1 1.

Note that the above QPSK values (all values with exception of the BPSK pilots) are to be normalized with a factor as $1/\sqrt{2}$ indicated in Figure 128ai.

8.4.3.6 Preamble structure and modulation

In the uplink, the data preamble consists of 2 times 128 samples preceded by a cyclic prefix whose length is the same as the cyclic prefix in the traffic mode. This preamble is referred to as the short preamble. This preamble shall also precede all allocations during the AAS portion of a frame.

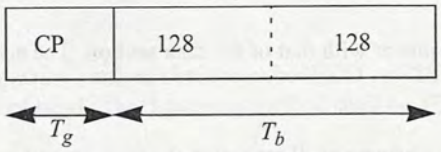


Figure 128ak—UL data and DL AAS preamble structure

The first preamble in the downlink PHY PDU, as well the initial ranging preamble, consists of a CP followed by 4 times 64 samples followed by a CP and 2 times 128 samples. This preamble is referred to as the long preamble.

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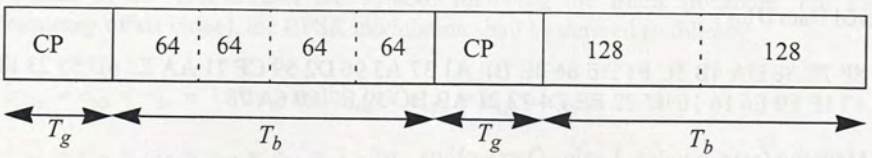


Figure 128al—DL and initial ranging preamble structure

The frequency domain sequence for the 4 times 64 sequence is defined by:

S(-100:100) = {+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 , +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 , 0 , -1-j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , -1+j , (50)
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 , -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}*sqrt(2)*sqrt(2)

The frequency domain sequence for the 2 times 128 sequence is defined by:

P_1(-100:100) = sqrt(2)*sqrt(2)*{

1, 0, -1, 0, -1, 0, -1, 0, 1, 0, 1, 0,	[-100:-89]		
1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1,	[-88:-76]		
0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1,	[-75:-64]		
0,-1, 0, 1, 0, 1, 0, 1, 0, -1, 0, 1, 0,	[-63:-51		
-1, 0, 1, 0, 1, 0, -1, 0, -1, 0, 1, 0,	[-50:-39]		
-1, 0, 1, 0, -1, 0, 1, 0, 1, 0, -1, 0, 1,	[-38:-26]		
0, 1, 0, -1, 0, -1, 0, -1, 0, 1, 0, -1,	[-25:-14]		
0, -1, 0, -1, 0, -1, 0, -1, 0, 1, 0, 1, 0,	[-13:-1]		
0,	[0]	DC	(51)
0, 1, 0, -1, 0, -1, 0, 1, 0, -1, 0, 1, 0,	[1:13]		
1, 0, 1, 0, 1, 0, -1, 0, 1, 0, 1, 0,	[14:25]		
1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1,	[26:38]		
0, -1, 0, 1, 0, 1, 0, -1, 0, 1, 0, -1,	[39:50]		
0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0,	[51:63]		
-1, 0, 1, 0, 1, 0, 1, 0, -1, 0, -1, 0,	[64:75]		
-1, 0, 1, 0, 1, 0, -1, 0, -1, 0, -1, 0, 1,	[76:88]		
0, -1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1}	[89:100]		

The factor of sqrt(2) equates the RMS power with that of the data section. The additional factor of sqrt(2) is related to the 3 dB boost.

Using Mesh, bursts sent in the control subframe shall start with the long preamble. In the data subframe, the bursts shall by default start with the long preamble, but neighbors may negotiate to use the short preamble by setting the preamble flag in the Neighbor Link Info field (see 6.2.2.3.34).

If in the UL the allocation spans only one subchannel, the following preamble vector, P_1, is used in conjunction with subchannelization transmissions, and the preamble carriers that do not fall within the allocated subchannel shall not be transmitted.

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P_1(-100:100) = sqrt(2)*sqrt(2)*{

-1, 0,-1, 0, 1, 0, 1, 0,-1, 0,-1, 0,	[-100:-89]	subchannel 3
-1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1, 0,-1,	[-88:-76]	subchannel 1
0,-1, 0,-1, 0,-1, 0,-1, 0, 1, 0, 1,	[-75:-64]	subchannel 4
0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,	[-63:-51]	subchannel 2
1, 0,-1, 0,-1, 0, 1, 0,-1, 0,-1, 0,	[-50:-39]	subchannel 1
1, 0, 1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1,	[-38:-26]	subchannel 3
0,-1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1,	[-25:-14]	subchannel 2
0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0,	[-13:-1]	subchannel 4
0,	[0]	DC
0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0,	[1:13]	subchannel 1
-1, 0,-1, 0,-1, 0,-1, 0, 1, 0, 1, 0,	[14:25]	subchannel 3
-1, 0, 1, 0,-1, 0,-1, 0, 1, 0,-1, 0,-1,	[26:38]	subchannel 2
0, 1, 0, 1, 0,-1, 0, 1, 0, 1, 0,-1,	[39:50]	subchannel 4
0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,	[51:63]	subchannel 3
-1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1, 0,	[64:75]	subchannel 1
1, 0, 1, 0, 1, 0, 1, 0,-1, 0,-1, 0, 1,	[76:88]	subchannel 4
0, 1, 0, 1, 0,-1, 0,-1, 0, 1, 0, 1}	[89:100]	subchannel 2

(52)

If in the UL the allocation spans two subchannels, the following preamble vector, P_2, is used in conjunction with subchannelization transmissions, and the preamble carriers that do not fall within the allocated subchannels shall not be transmitted.

P_2(-100:100) = sqrt(2)*sqrt(2)*{

1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1, 0,	[-100:-89]	subchannels 3+4
1, 0, 1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1,	[-88:-76]	subchannels 1+2
0, 1, 0, 1, 0, 1, 0,-1, 0, 1, 0, 1,	[-75:-64]	subchannels 3+4
0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1, 0,	[-63:-51]	subchannels 1+2
1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1, 0,	[-50:-39]	subchannels 1+2
-1, 0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1,	[-38:-26]	subchannels 3+4
0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0, 1,	[-25:-14]	subchannels 1+2
0,-1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1, 0,	[-13:-1]	subchannels 3+4
0,	[0]	DC
0, 1, 0,-1, 0,-1, 0, 1, 0, 1, 0, 1, 0,	[1:13]	subchannels 1+2
-1, 0, 1, 0,-1, 0,-1, 0,-1, 0, 1, 0,	[14:25]	subchannels 3+4
-1, 0, 1, 0, 1, 0,-1, 0,-1, 0, 1, 0,-1,	[26:38]	subchannels 1+2
0, 1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1,	[39:50]	subchannels 3+4
0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1, 0,	[51:63]	subchannels 3+4
-1, 0, 1, 0,-1, 0,-1, 0,-1, 0, 1, 0,	[64:75]	subchannels 1+2
-1, 0,-1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1,	[76:88]	subchannels 3+4
0, 1, 0,-1, 0,-1, 0, 1, 0, 1, 0, 1}	[89:100]	subchannels 1+2

(53)

8.4.4 Frame structure

8.4.4.1 PMP

In licensed bands, the duplexing method shall be either FDD or TDD. FDD SSs may be Half Duplex FDD (H-FDD). In license-exempt bands, the duplexing method shall be TDD.

The frame interval contains transmissions (PHY PDUs) of BS and SSs, gaps and guard intervals.

The OFDM PHY supports a frame-based transmission. A frame consists of a DL sub-frame and an UL sub-frame. A DL sub-frame consists of only one DL PHY PDU. A UL sub-frame consists of contention intervals scheduled for initial ranging and bandwidth request purposes and one or multiple UL PHY PDUs, each transmitted from a different SS.

A UL PHY PDU consists of only one burst, which is made up of a short preamble and an integer number of OFDM symbols. The burst PHY parameters of an UL PHY PDU are specified by a 4-bit UIUC in the UL-MAP. The UIUC encoding is defined in the UCD messages. Note the difference between a PHY PDU and a Burst.

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A DL PHY PDU starts from a long preamble, which is used for PHY synchronization. The preamble is followed by a FCH burst. The FCH burst is one OFDM symbol long and is transmitted using QPSK rate 1/2 with the mandatory coding scheme. The FCH contains DL_Frame_Prefix to specify the burst profile and length of the DL burst #1. The Rate_ID encoding is defined in Table 116ao. The FCH burst may also contain short MAC control messages, such as, DCD and/or UCD. It may also contain (partial) map messages. Although the DL burst #1 contains broadcast MAC control messages, it is not necessary to use the most robust well-know modulation/coding. A more efficient modulation/coding may be used if it is supported and applicable to all the SSs of a BS.

The FCH is followed by one or multiple DL bursts, each transmitted with different burst profiles. Each DL burst consists of an integer number of OFDM symbols, and its burst profiles are specified by a 4-bit DIUC in the DL-MAP. The DIUC encoding is defined in the DCD messages.

With the OFDM PHY, a PHY burst, either a DL PHY burst or an UL PHY burst, consists of an integer number of OFDM symbols, carrying MAC messages, i.e., MAC PDUs. To form an integer number of OFDM symbols, a burst payload may be padded by the bytes 0xFF. Then the payload should be scrambled, encoded, and modulated using the burst PHY parameters specified by this standard.

In each TDD frame (see Figure 128am), the Tx/Rx transition gap (TTG) and Rx/Tx transition gap (RTG) shall be inserted between the DL and UL sub-frame and at the end of each frame respectively to allow the BS to turn around. TTG and RTG shall be at least 5 μs and an integer multiple of the PS in duration, and start on a PS boundary. After the TTG, the BS receiver shall look for the first symbols of a UL burst. After the RTG, the SS receivers shall look for the first symbols of QPSK modulated data in the DL burst.

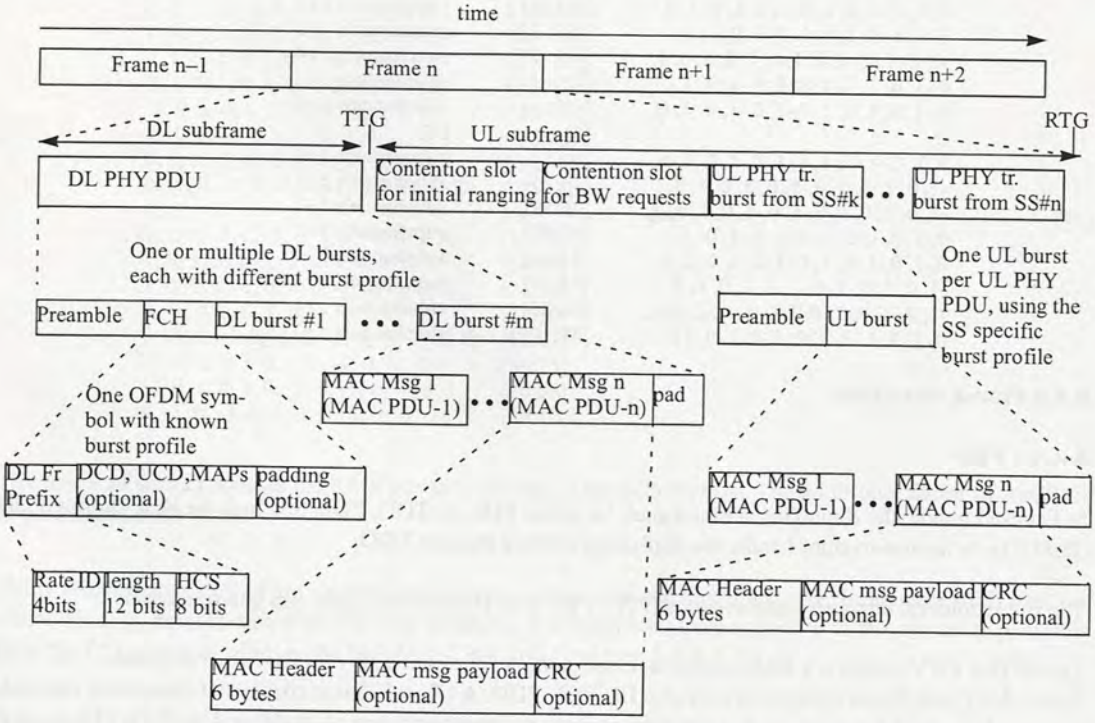


Figure 128am—Example of OFDM frame structure with TDD

In FDD systems (see Figure 128an) TTG and RTG are not needed as the downlink and uplink transmit on independent frequencies. Using FDD, the BS shall, within a frame, not schedule a DL allocation during or after a UL allocation to the same H-FDD terminal.

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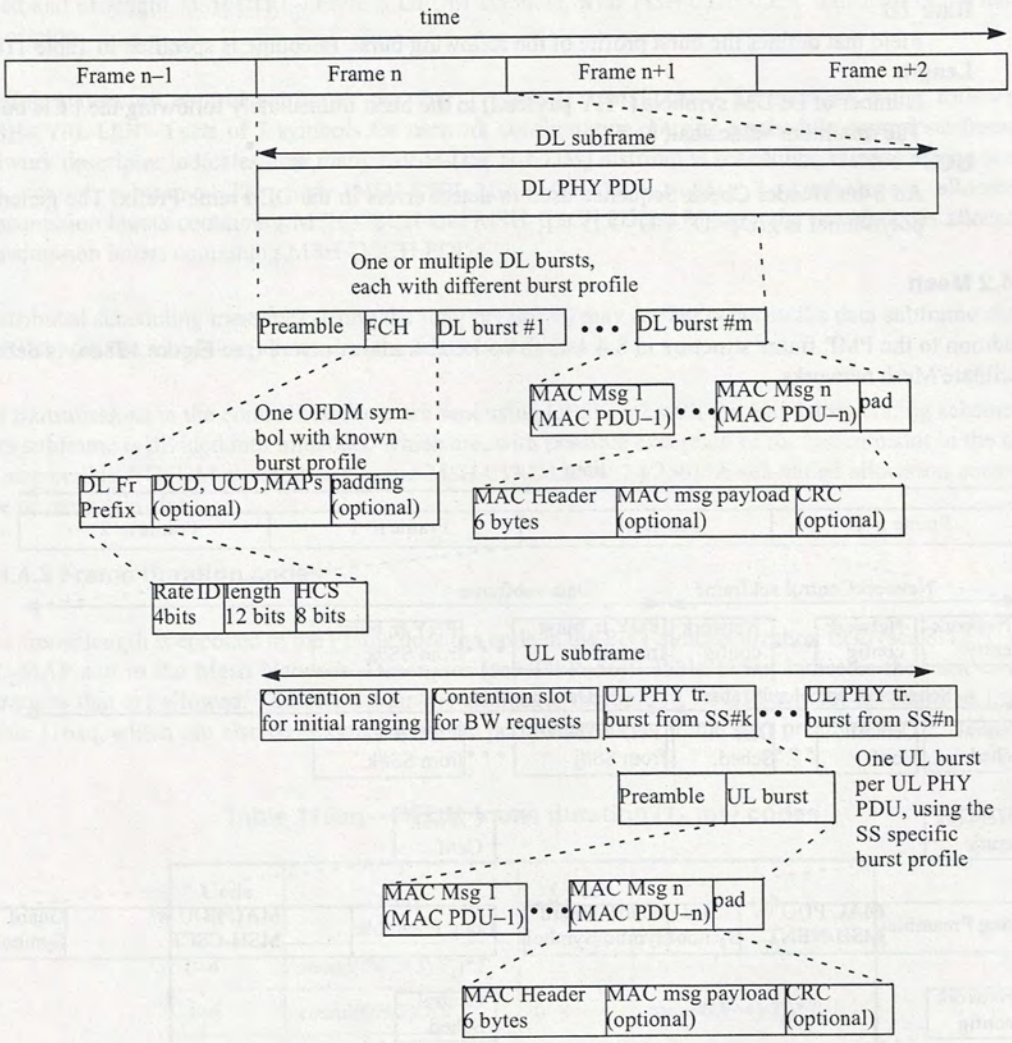


Figure 128an—Example of OFDM frame structure with FDD

Table 116ap—OFDM DL frame prefix format

Syntax	Size	Notes
DL_Frame_Prefix_Format() {		
Rate_ID	4 bits	
Length	12 bits	
HCS	8 bits	
}		

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The following are the fields of DL Frame Prefix:

Rate_ID
Field that defines the burst profile of the following burst. Encoding is specified in Table 116ao.

Length
Number of OFDM symbols (PHY payload) in the burst immediately following the FCH burst. The minimum value shall be 6.

HCS
An 8-bit Header Check Sequence used to detect errors in the DL Frame Prefix. The generator polynomial is $g(D)= D^8 + D^2 + D + 1$.

8.4.4.2 Mesh

In addition to the PMP frame structure in 8.4.4.1, an optional frame structure (see Figure 128ao) is defined to facilitate Mesh networks.

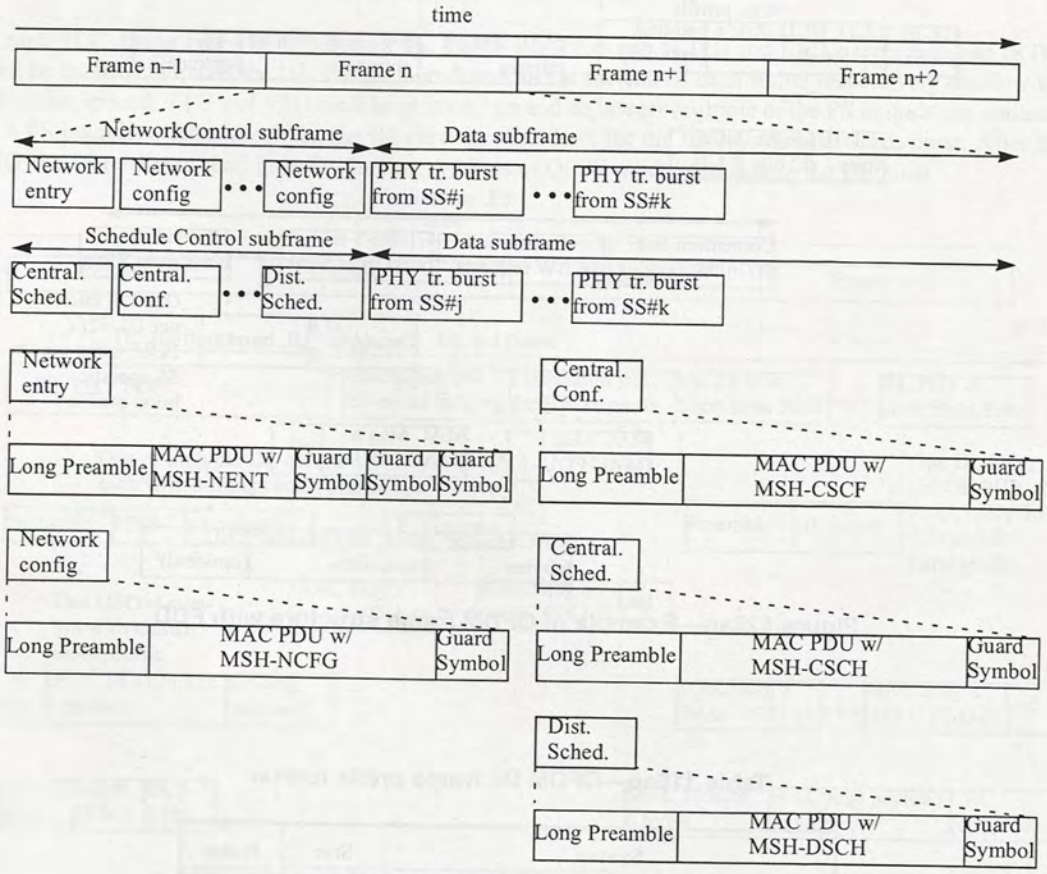


Figure 128ao—Mesh frame structure

A Mesh frame consists of a control and data subframe. The control subframe serves two basic functions. One is the creation and maintenance of cohesion between the different systems, termed "network control" in Figure 128ao. The other is the coordinated scheduling of data-transfers between systems, termed "schedule control" in Figure 128ao. Frames with a network control subframe occur periodically, as indicated in the

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network descriptor. All other frames have a schedule control subframe. The length of the control subframe is fixed and of length MSH-CTRL-LEN × 7 OFDM symbols, with MSH-CTRL-LEN indicated in the network descriptor.

During a network control subframe, the first 7 symbols are allocated for network entry, followed by MSH-CTRL-LEN – 1 sets of 7 symbols for network configuration. During a schedule control subframe, the network descriptor indicates how many (MSH-DSCH-NUM) distributed scheduling messages may occur in the control subframe. The first (MSH-CTRL-LEN - MSH-DSCH-NUM) × 7 symbols are allocated to transmission bursts containing MSH-CSCH and MSH-CSCF PDUs, whereas the remainder is allocated to transmission bursts containing MSH-DSCH PDUs.

Distributed scheduling messages (using the long preamble) may further occur in the data subframe if not in conflict with the scheduling dictated in the control subframe.

All transmissions in the control subframe are sent using QPSK-1/2 with the mandatory coding scheme. The data subframe is divided into minislots, which are, with possible exception of the last minislot in the frame, of size ceiling [(OFDM symbols per frame- MSH-CTRL-LEN × 7)/256]. A scheduled allocation consists of one or more minislots.

8.4.4.3 Frame duration codes

The frame length is encoded in the Frame duration code in the PHY synchronization field (see 8.4.5.1) of the DL-MAP and in the Mesh Network. Descriptor (see Table 56j). Table 116aq indicates the various frame durations that are allowed. The actual frame is an integer multiple of OFDM symbol durations as listed in Table 116aq, which can also be determined by the periodicity of the frame start preambles.

Table 116aq—OFDM frame duration (T_F ms) codes

Code (N)	PMP	Code (N)	Mesh
0–4	round($(N/2+3)/T_s$)*T_s	0–8	round($(N+4)/T_s$)*T_s
5–6	round($(N+2)/T_s$)*T_s		
7–12	round($(2N-4)/T_s$)*T_s		
13–255	Reserved	9–255	Reserved

8.4.4.4 Burst Profile format

Table 116ar defines the format of the Downlink_Burst_Profile, which is used in the DCD message (6.2.2.3.1). The Downlink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit DIUC. The DIUC field is associated with the Downlink Burst Profile and Thresholds. The DIUC value is used in the DL-MAP message to specify the Burst Profile to be used for a specific downlink burst.

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Table 116ar—Downlink_burst_profile format

Syntax	Size	Notes
Downlink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
DIUC	4 bits	
TLV encoded information	variable	
}		

Table 116as defines the format of the Uplink_Burst_Profile, which is used in the UCD message (6.2.2.3.1). The Uplink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit UIUC. The UIUC field is associated with the Uplink Burst Profile and Thresholds. The UIUC value is used in the UL-MAP message to specify the Burst Profile to be used for a specific uplink burst.

Table 116as—Uplink_burst_profile format

Syntax	Size	Notes
Uplink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
UIUC	4 bits	
TLV encoded information	variable	
}		

8.4.5 Map message fields and IEs

8.4.5.1 DL-MAP PHY synchronization field

The PHY synchronization field of the DL-MAP message is structured as follows.

Table 116at—OFDM PHY synchronization field

Syntax	Size	Notes
Synchronization_field {		
Frame Duration Code	8 bits	
Frame Number	24 bits	
Allocation_Start_Time	32 bits	
}		

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Frame Duration Code

The frame duration Code values are specified in Table 116aq.

Frame Number

The frame number is incremented by 1 MOD 2^{24} each frame.

Allocation_Start_Time

Effective start time of the DL allocation defined by the DL-MAP in units of PSs. This start time is relative to the start of the frame in which the DL-MAP message is transmitted. The minimum value specified for this parameter shall correspond to the length of the DL-MAP.

8.4.5.2 DL-MAP Information Element format

DL-MAP Information Elements have the following format:

Table 116au—OFDM DL-MAP Information Element

Syntax	Size	Notes
DL-MAP_Information_Element() {		
DIUC	4 bits	
if (DIUC == 15)		
Extended DIUC dependent IE	variable	Report_IE() or AAS_DL_IE() or STC_IE()
else		
Start Time	12 bits	
}		

Downlink Interval Usage Code

A four-bit Downlink Interval Usage Code (DIUC) shall be used to define the burst type associated with that time interval. Burst Descriptor shall be included into DCD Message for each DIUC used in the DL-MAP except those associated with Gap, End of Map and Extended. The DIUC shall be one of the values defined in Table 116av.

Start Time

Indicates the start time, in units of symbol duration, relative to the start of the first symbol of the PHY PDU (including preamble) where the DL-MAP message is transmitted. The end of the last allocated burst is indicated by allocating a NULL burst (DIUC = 14) with zero duration. The time instants indicated by the Start Time values are the transmission times of the first symbol of the burst including preamble.

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8.4.5.2.1 DIUC allocations

Table 116av contains the DIUC values used in DL-MAP_IE().

Table 116av—OFDM DIUC values

DIUC	Usage
0	Reserved
1–12	Burst Profiles
13	Gap
14	End of Map
15	Extended DIUC

8.4.5.2.2 DL-MAP Report IE format

When a channel measurement report is needed (see 6.2.14 and 8.4.8), the extended DIUC = 15 is used with the sub-code 0x00 and with 8-bit Channel Nr value as shown in Table 116aw. The OFDM Report_IE shall be followed by the End of Map IE (DIUC=14). When used, the CID of the DL-MAP_IE() shall be set to the broadcast CID.

Table 116aw—OFDM Channel measurement Information Element format

Syntax	Size	Notes
Report_Information_Element() {		
extended DIUC	4 bits	DFS = 0x00
Channel Nr	8 bits	Channel number (see 8.6.1) Set to 0x00 for licensed bands
Start Time	12 bits	
Reserved	4 bits	
}		

8.4.5.2.3 DL-MAP AAS IE format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended DIUC = 15 with the AAS_IE() to indicate that the subsequent allocations, until the start of the first UL-MAP allocation using TDD, and until the end of the frame using FDD, shall be for AAS traffic. When used, the CID in the DL-MAP_IE() shall be set to the broadcast CID.

Table 116ax—OFDM AAS DL Information Element format

Syntax	Size	Notes
AAS_DL_Information_Element() {		
extended DIUC	4 bits	AAS = 0x02
}		

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8.4.5.2.4 DL-MAP STC IE format

In the DL-MAP, an STC enabled BS (see 8.4.7) may transmit DIUC=15 with the STC_IE() to indicate that the subsequent allocations shall be STC encoded. No preceding DL allocations shall be STC encoded and all subsequent DL allocations until the end of the frame shall be STC encoded.

Table 116ay—OFDM STC Information Element format

Syntax	Size	Notes
STC_Information_Element() {		
extended DIUC	4 bits	STC = 0x01
}		

The duration of the DIUC=15 STC_IE() allocation is always one OFDM symbol. From the start of the frame up to this allocation, only one antenna shall be used. During this allocation, the short preamble (see 8.4.3.6) shall be transmitted from the other antenna. After this allocation, the BS shall transmit from both antennas until the end of the frame.

8.4.5.3 UL-MAP Information Element format

The UL-MAP Information Element defines the physical parameters and the start time for UL PHY bursts. The format of UL-MAP elements is shown in Table 116az.

Appearance of the Extended UIUC, means that the UL-MAP information element contains an additional byte with UIUC sub-code immediately following the UIUC plus the value of the corresponding parameter.

Table 116az—OFDM UL-MAP Information Element format

Syntax	Size	Notes
UL-MAP_Information_Element() {		
CID	16 bits	
UIUC	4 bits	
if (UIUC == 4)		
Focused_contention_IE()	28 bits	
else if (UIUC == 15)		
Extended UIUC dependent IE	variable	Power_Control_IE() or AAS_UL_IE() subchannelization_IE()
else {		
if (subchannelization[a]) {		
Subchannel Index	3 bits	0x1 = subchannel 1 0x5 = subchannel 1 and 2 0x2 = subchannel 2 0x6 = subchannel 3 and 4 0x3 = subchannel 3 0x0 = reserved 0x4 = subchannel 4 0x7 = reserved

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Table 116az—OFDM UL-MAP Information Element format *(continued)*

Syntax	Size	Notes
Duration	5 bits	in OFDM symbols
Reserved	4 bits	Reserved
} else		
Duration	12 bits	
}		
}		

[a]When subchannelization is active (see 8.4.5.3.5), only UIUCs 5 through 13 shall be used.

Connection Identifier (CID)

Represents the assignment of the IE to a unicast, multicast, or broadcast address. When specifically addressed to allocate a bandwidth grant, the CID may be either the Basic CID of the SS or a Traffic CID for one of the connections of the SS.

Uplink Interval Usage Code (UIUC)

A four-bit Uplink Interval Usage Code (UIUC) shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be included into an UCD message for each Uplink Interval Usage Code that is to be used in the UL-MAP. The UIUC shall be one of the values defined in Table 116ba.

Duration

The Duration indicates the length, in units of OFDM symbols, of the allocation. The start time of the first allocation shall be the Allocation Start Time given in the UL-MAP message. The last allocated burst shall be indicated by allocating a NULL burst (CID = 0 and UIUC = 14) with zero duration.

8.4.5.3.1 UIUC allocations

Table 116ba contains the UIUC values used in the UL-MAP_IE()

Table 116ba—OFDM UIUC values

UIUC	Usage
0	Reserved
1	Initial ranging
2	REQ Region Full
3	REQ Region Focused
4	Focused Contention IE
5–12	Burst Profiles
13	Gap
14	End of Map
15	Extended UIUC

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8.4.5.3.2 UL-MAP Focused Contention IE format

Table 116bb defines the UL-MAP IE for allocation BW for a SS that requested bandwidth using Focused Contention Reservation Requests (see 6.2.2.3.6). This UL-MAP IE is identified by UIUC = 4 (see Table 116ba).

Table 116bb—OFDM Focused Contention Information Element format

Syntax	Size	Notes
Focused_Contention_IE() {		
Duration	12 bits	
Transmit Opportunity Index	6 bits	
Contention Channel Index	6 bits	
Contention Code Index	4 bits	
}		

Duration

Length of the allocation in OFDM symbols.

Transmit Opportunity Index

Index number of the Transmit Opportunity that was used in the Bandwidth Request, which this message is responding to. Focused Contention Reservation Requests Transmit Opportunities are numbered from 0 to 63 backward, starting from the beginning of the frame where the UL-MAP is transmitted.

Contention Channel Index

Index number of the Contention Channel, which was used in the Bandwidth Request, which this message is responding to.

Contention Code Index

Index number of the Contention Code, which was used in the Bandwidth Request, which this message is responding to.

8.4.5.3.3 UL-MAP Power Control IE format

When a power change for the SS is needed, the extended UIUC = 15 is used with the sub-code 0x00 and with 8-bit Power control value as shown in Table 116bc. The power control value is an 8-bit signed integer expressing the change in power level (in 0.25 dB units) that the SS should apply to correct it's current transmission power.

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The CID used in the Information Element should be the Basic CID of the SS.

Table 116bc—OFDM Power Control Information Element format

Syntax	Size	Notes
Power_Control_Information_element() {		
extended UIUC	4 bits	Fast power control = 0x00
Power control	8 bits	Signed integer, which expresses the change in power level (in 0.25 dB units) that the SS should apply to correct its current transmission power.
}		

8.4.5.3.4 UL-MAP AAS IE format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended UIUC = 15 with the AAS_IE() to indicate that the subsequent allocation until the end of the frame shall be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID.

Table 116bd—OFDM AAS UL Information Element format

Syntax	Size	Notes
AAS_Information_Element() {		
extended UIUC	4 bits	AAS = 0x02
}		

8.4.5.3.5 UL-MAP subchannelization IE format

Within a frame, the BS may allocate a portion of the UL allocations to subchannelized traffic.

The UL Subchannelization_IE implicitly indicates the start of the allocation and explicitly indicates the Duration and the Number of Allocations. A SS not capable of subchannelization shall skip the next Number of Allocations UL-MAP_IEs in the UL-MAP and resume interpreting the UL-MAP afterwards with the start of the next allocation Duration OFDM symbols after the last allocation ended.

Table 116be—OFDM subchannelization Information Element format

Syntax	Size	Notes
subchannelization_Information_Element() {		
extended UIUC	4 bits	subchannelization = 0x3x
Duration	12 bits	
Number of allocations	12 bits	
}		

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A SS capable of subchannelization shall decode the subchannelized allocations, whereby the 12 bit Duration field in non-subchannelized UL-MAP messages is replaced by a 3 bit Subchannel Index field, a 5 bit Duration field and 4 reserved bits as shown in Table 116be. A subchannelized allocation shall start when all preceding allocations to the allocated subchannels have terminated.

8.4.6 Control mechanisms

8.4.6.1 Synchronization

8.4.6.1.1 Network synchronization

For TDD and FDD realizations, it is recommended (but not required) that all BSs be time synchronized to a common timing signal. In the event of the loss of the network timing signal, BSs may continue to operate and shall automatically resynchronize to the network timing signal when it is recovered. The synchronizing reference shall be a 1 pps timing pulse and a 10 MHz frequency reference. These signals are typically provided by a GPS receiver.

For both FDD and TDD realizations, frequency references derived from the timing reference may be used to control the frequency accuracy of Base-Stations provided that they meet the frequency accuracy requirements of 8.4.11. This applies during normal operation and during loss of timing reference.

8.4.6.2 Ranging

There are two types of ranging processes: initial ranging (see 6.2.9.5) and periodic ranging (see 6.2.10). Initial ranging (coarse synchronization) and power are performed during two phases of operation; during (re)registration and when synchronization is lost; and secondly, during transmission on a periodic basis. Initial ranging uses the initial ranging contention-based interval, which requires a long preamble. The periodic ranging uses the regular UL burst.

During registration, a new subscriber registers during the random access channel, and if successful it is entered into a ranging process under control of the base station. The ranging process is cyclic in nature where default time and power parameters are used to initiate the process followed by cycles where (re)calculated parameters are used in succession until parameters meet acceptance criteria for the new subscriber. These parameters are monitored, measured and stored at the base station, and transmitted to the subscriber unit for use during normal exchange of data. During normal exchange of data, the stored parameters are updated in a periodic manner based on configurable update intervals to ensure that changes in the channel can be accommodated. The update intervals shall vary in a controlled manner on a subscriber unit by subscriber unit basis. Initial ranging transmissions shall consist of a long preamble and one OFDM symbol using the most robust mandatory burst profile.

Ranging on re-registration follows the same process as new registration.

Regardless of duplexing type, the appropriate duration of the Initial Maintenance slot used for initial system access depends on the intended cell radius.

A BS supporting the AAS option shall allocate at the end of the UL frame a 5 OFDM symbol initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but shall be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance. See 8.4.5.3 for details.

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8.4.6.3 Bandwidth requesting

There may be two types of REQ Regions in a frame. These two types are REQ Region-Full and REQ Region-Focused.

In a REQ Region-Full, each Transmit Opportunity shall consist of a short preamble and one OFDM symbol using the most robust mandatory burst profile.

In a REQ Region-Focused, each Transmit Opportunity shall consist of two OFDM symbols. Each Transmit Opportunity shall be indexed by consecutive Transmit Opportunity Indices. The first occurring Transmit Opportunity shall be indexed 0.

All SS shall be capable of the Full Contention Transmission. Capability of the Focused Contention Transmission is optional. The SS shall follow the backoff procedure as described in 6.2.8.

8.4.6.3.1 Parameter selection

The SS shall examine the UL_MAP message for a future frame and select (in accordance with 6.2.8) a future REQ Region during which to make its request. If Focused Contention Supported = 1 was returned by the BS in SBC-RSP message during SS initialization and if the SS is capable of focused contention, it may choose either a REQ Region-Full or REQ Region-Focused. Otherwise, it shall choose a REQ Region-Full.

If the chosen REQ Region is a REQ Region-Focused, the SS shall also select, at random with equal probability, a *contention code* from Table 116bf and similarly a *contention channel* from Table 116bg. The indices {–100 to +100} in the body of Table 116bg refer to the carrier indices as defined in 8.4.2.4.

If the BS supports subchannelization, the last C_{SE} contention codes shall only be used by subchannelization-enabled SSs that wish to receive a subchannelized allocation. In response, the BS may provide the requested allocation as a subchannelized allocation; and may provide the requested allocation as a full (default) allocation, or may provide no allocation at all. The value of C_{SE} is transmitted in the UCD channel encoding TLV messages. The default value of C_{SE} is 0.

Table 116bf—OFDM Contention codes

Contention code index	bit 0	bit 1	bit 2	bit 3
0	1	1	1	1
1	1	–1	1	–1
2	1	1	–1	–1
3	1	–1	–1	1
4	–1	–1	–1	–1
5	–1	1	–1	1
6	–1	–1	1	1
7	–1	1	1	–1

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Table 116bg—OFDM Contention channels

Contention channel index	Carrier offset index 0	Carrier offset index 1	Carrier offset index 2	Carrier offset index 3
0	–100	–50	+1	+51
1	–99	–49	+2	+52
2	-98	–48	+3	+53
...	...	...	...	...
k	k-100	k-50	k+1	k+51
...	...	...	...	...
48	–52	–2	+49	+99
49	–51	–1	+50	+100

8.4.6.3.2 Full Contention transmission

If the chosen REQ Region is a REQ Region-Full, the SS shall transmit the short preamble as defined in 8.4.3.6, followed by a Bandwidth Request MAC Header as defined in 6.2.2.1.2.

8.4.6.3.3 Focused Contention transmission

The REQ Region-Focused bandwidth requesting mechanism consists of two phases. The Phase-1 is that an SS requesting bandwidth sends a signal to the BS in the UL interval of REQ Region Focused identified by UIUC=3. One REQ Region Focused UL interval with UIUC=3 shall be two OFDM symbols. The Phase-1 bandwidth requesting signal transmission is described in this section. Following the Phase-1, the BS may include in its UL-MAP an allocation for the SS using UIUC=4 and the Focused_contention_IE as defined in Table 116bb. The SS is identified in this Focused_contention_IE by the Transmit Opportunity index, Contention Channel index, and Contention Code index which the SS used to send the Phase-1 bandwidth requesting signal. The Phase-2 is that the SS requesting bandwidth responds to this UL-MAP allocation with a bandwidth request MAC header as defined in 6.2.2.1.2. The Phase-2 UL interval with UIUC=4 shall consists of a short preamble and shall have the Duration indicated in the Focused_Contention_IE, and shall use the most robust mandatory burst profile.

If the chosen REQ Region is a REQ Region-Focused, after choosing its four parameters, the SS shall transmit, during the chosen Transmit Opportunity in the chosen frame, four carriers {carrier index 0, carrier index 1, carrier index 2, carrier index 3}that comprise the chosen contention channel. The amplitude of all other carriers shall be zero.

During both OFDM symbols, the amplitude of each of the four carriers shall be boosted somewhat above its *normal* amplitude, i.e., the amplitude used during a non-contention OFDM symbol, including the current power-control correction. The boost in dB shall equal the value of the Focused Contention Power Boost parameter in the current Uplink Channel Descriptor (UCD).

During the first OFDM symbol of the Transmit Opportunity, the phase of the four carriers is not specified.

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During the second OFDM symbol of the Transmit Opportunity, the phases shall depend on the corresponding bit in the chosen contention code, and the phase transmitted during the first OFDM symbol on the same carrier. If the code bit is +1, the phase shall be the same as that transmitted during the first OFDM symbol. If the code bit is –1, the phase shall be inverted, 180 degrees with respect to the phase transmitted during the first OFDM symbol.

8.4.6.4 Power control

As with frequency control, a power control algorithm shall be supported for the uplink channel with both an initial calibration and periodic adjustment procedure without loss of data. The base station should be capable of providing accurate power measurements of the received burst signal. This value can then be compared against a reference level, and the resulting error can be fed back to the subscriber station in a calibration message coming from the MAC sublayer. The power control algorithm shall be designed to support power attenuation due to distance loss or power fluctuations at rates to 30 dB/second with depths of at least 10 dB. The exact algorithm implementation is vendor-specific. The total power control range consists of both a fixed portion and a portion that is automatically controlled by feedback. The power control algorithm shall take into account the interaction of the RF power amplifier with different burst profiles. For example, when changing from one burst profile to another, margins should be maintained to prevent saturation of the amplifier and to prevent violation of emissions masks.

8.4.7 Transmit diversity: Space-Time Coding (optional)

STC (see [B26]) may be used on the DL to provide 2nd order (Space) transmit diversity.

There are two transmit antennas on the BS side and one reception antenna on the SS side. This scheme requires Multiple Input Single Output channel estimation. Decoding is very similar to maximum ratio combining.

Figure 128ap shows STC insertion into the OFDM chain. Each Tx antenna has its own OFDM chain, but they have the same Local Oscillator for synchronization purposes.

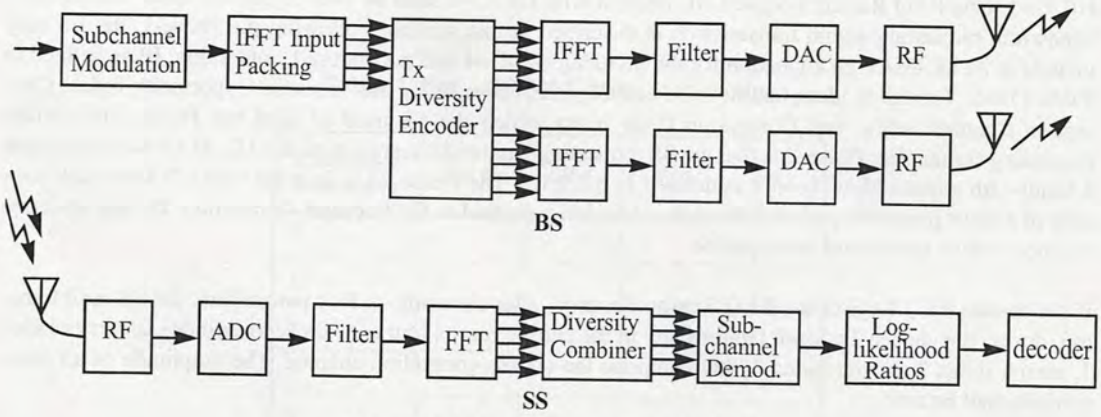


Figure 128ap—Illustration of STC

Both antennas transmit in the same time 2 different OFDM data symbols. Transmission is performed twice to decode and to get 2nd order diversity. Time domain (Space-Time) repetition is used.

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8.4.7.1 Multiple input single output channel estimation and synchronization

Both antennas transmit in the same time, and they share the same Local Oscillator. Thus, the received signal has exactly the same auto-correlation properties as for a single antenna. So, time and frequency coarse and fine estimation can be performed in the same way as for a single antenna. The scheme requires MISO channel estimation, which is provisioned by inserting a short preamble using the STC_IE (see 8.4.5.2.4) to estimate the second antenna's channel.

8.4.7.2 STC encoding

The basic scheme [B26] transmits 2 complex symbols s_0 and s_1, using the multiple input single output channel (two Tx, one Rx) twice with channel vector values h_0 (for antenna 0) and h_1 (for antenna 1).

First channel use: Antenna 0 transmits s_0, antenna 1 transmits s_1.

Second channel use: Antenna 0 transmits $-s_1^*$, antenna 1 transmits s_0^*.

Receiver gets r_0 (first channel use) and r_1 (second channel use) and computes s_0 and s_1 estimates:

$$\hat{s}_0 = h_0^* \cdot r_0 + h_1 \cdot r_1^* \tag{54}$$

$$\hat{s}_1 = h_1^* \cdot r_0 - h_0 \cdot r_1^* \tag{55}$$

These estimates benefit from 2nd order diversity as in the 1Tx-2Rx Maximum Ratio Combining scheme. OFDM symbols are taken by pairs. (Equivalently, 2 Tx symbol duration is twice 1 Tx symbol duration, with twice more data in a symbol.) STC is applied independently on each carrier, in respect to pilot tones positions.

Figure 128aq shows the STC scheme (note that only pilot carrier –84 is depicted).

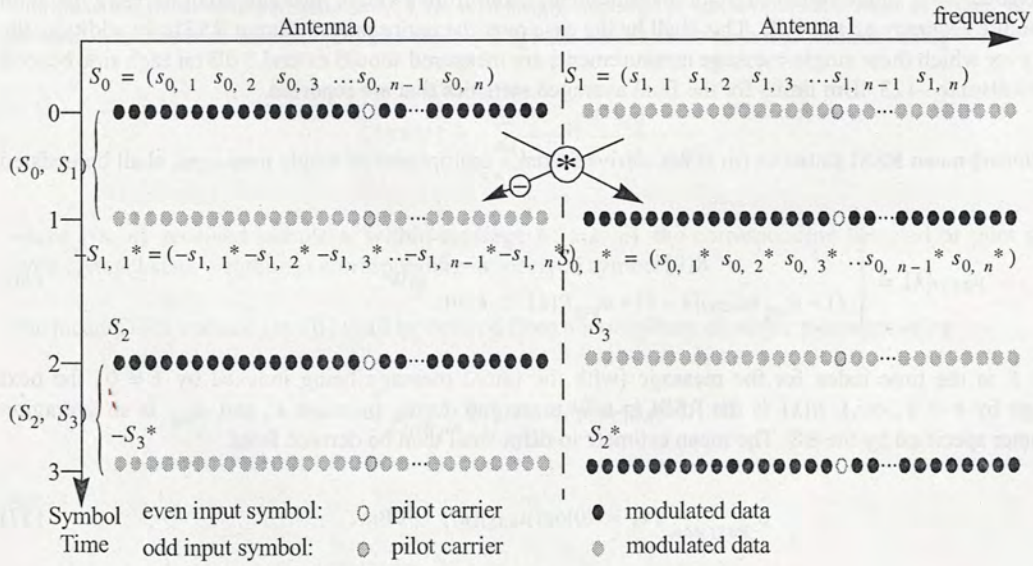


Figure 128aq—STC usage with OFDM

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8.4.7.3 STC decoding

The receiver waits for 2 symbols, and combines them on a carrier basis according to Equation (54) and Equation (55) in 8.4.7.2.

8.4.8 Channel quality measurements

8.4.8.1 Introduction

RSSI and CINR signal quality measurements and associated statistics can aid in such processes as BS selection/assignment and burst adaptive profile selection. As channel behavior is time-variant, both mean and standard deviation are defined. Implementation of the RSSI and CINR statistics and their reports is mandatory.

The process by which RSSI measurements are taken does not necessarily require receiver demodulation lock; for this reason, RSSI measurements offer reasonably reliable channel strength assessments even at low signal levels. On the other hand, although CINR measurements require receiver lock, they provide information on the actual operating condition of the receiver, including interference and noise levels, and signal strength.

8.4.8.2 RSSI mean and standard deviation

When collection of RSSI measurements is mandated by the BS, a SS shall obtain an RSSI measurement from the OFDM DL preambles. From a succession of RSSI measurements, the SS shall derive and update estimates of the mean and the standard deviation of the RSSI, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics shall be reported in units of dBm. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from –40 dBm (encoded 0x53) to –123 dBm (encoded 0x00). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the RSSI of a single message is left to individual implementation, but the relative accuracy of a single signal strength measurement, taken from a single message, shall be +/– 2 dB, with an absolute accuracy of +/– 4 dB. This shall be the case over the entire range of input RSSIs. In addition, the range over which these single-message measurements are measured should extend 3 dB on each side beyond the –40 dBm to –123 dBm limits for the final averaged statistics that are reported.

The (linear) mean RSSI statistics (in mW), derived from a multiplicity of single messages, shall be updated using

$$\hat{\mu}_{RSSI}[k] = \begin{cases} R[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{RSSI}[k-1] + \alpha_{avg}R[k] & k > 0 \end{cases} \text{ mW} \qquad (56)$$

where k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.), $R[k]$ is the RSSI in mW measured during message k, and α_{avg} is an averaging parameter specified by the BS. The mean estimate in dBm shall then be derived from

$$\hat{\mu}_{RSSI\,dBm}[k] = 10\log(\hat{\mu}_{RSSI}[k]) \quad \text{dBm}. \qquad (57)$$

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To solve for the standard deviation in dB, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{RSSI}[k] = \begin{cases} |R[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{RSSI}[k-1] + \alpha_{avg}|R[k]|^2 & k > 0 \end{cases} \quad (58)$$

and the result applied to

$$\hat{\sigma}_{RSSI\ dB} = 5\log(\left|\hat{x}^2_{RSSI}[k] - (\hat{\mu}_{RSSI}[k])^2\right|) \quad \text{dB}. \quad (59)$$

8.4.8.3 CINR mean and standard deviation

When Carrier-to-Interference-and-Noise-Ratio (CINR) measurements are mandated by the BS, a SS shall obtain a CINR measurement from the OFDM DL preamble. From a succession of these measurements, the SS shall derive and update estimates of the mean and the standard deviation of the CINR, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics for CINR shall be reported in units of dB. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from a minimum of –10 dB (encoded 0x00) to a maximum of 53 dB (encoded 0x3F). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the CINR of a single message is left to individual implementation, but the relative and absolute accuracy of a CINR measurement derived from a single message shall be +/– 1 dB and +/– 2 dB, respectively, for all input CINRs above 0 dB. In addition, the range over which these single-packet measurements are measured should extend 3 dB on each side beyond the –10 dB to 53 dB limits for the final reported, averaged statistics.

One possible method to estimate the CINR of a single message is to compute the ratio of signal power to residual error for each data sample, and then average the results from each data sample, using

$$CINR[k] = \sum_{n=0}^{N-1} \frac{|s[k,\ n]|^2}{|r[k,\ n] - s[k,\ n]|^2} \quad (60)$$

where $r[k,\ n]$ received sample n within message k; $s[k,\ n]$ the corresponding detected or pilot sample (with channel state weighting) corresponding to received symbol n.

The mean CINR statistic (in dB) shall be derived from a multiplicity of single messages using

$$\hat{\mu}_{CINR\ dB}[k] = 10\log(\hat{\mu}_{CINR}[k]), \quad (61)$$

where

$$\hat{\mu}_{CINR}[k] = \begin{cases} CINR[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{CINR}[k-1] + \alpha_{avg}CINR[k] & k > 0 \end{cases} \quad (62)$$

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k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.); $CINR[k]$ is a linear measurement of CINR (derived by any mechanism that delivers the prescribed accuracy) for message k; and α_{avg} is an averaging parameter specified by the BS.

To solve for the standard deviation, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{CINR}[k] = \begin{cases} |CINR[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{CINR}[k-1] + \alpha_{avg}|CINR[k]|^2 & k > 0 \end{cases} \quad (63)$$

and the result applied to

$$\hat{\sigma}_{CINR\ dB} = 5\log\left(\left|\hat{x}^2_{CINR}[k] - (\hat{\mu}_{CINR}[k])^2\right|\right) \quad \text{dB}. \quad (64)$$

8.4.9 Transmitter requirements

8.4.9.1 Transmit power level control

The transmitter shall support monotonic power level control of 45 dB (30 dB for license-exempt bands) minimum with a minimum step size of 1 dB and a relative accuracy of +/– 0.5 dB.

8.4.9.1.1 Transmitter spectral flatness

The average energy of the constellations in each of the n spectral lines shall deviate no more than indicated in Table 116bh. The absolute difference between adjacent carriers shall not exceed 0.06 dB.

Table 116bh—OFDM Spectral flatness

Spectral lines	Spectral flatness
Spectral lines from –50 to –1 and +1 to +50	+/– 2dB from the measured energy averaged over all 200 active tones
Spectral lines from –100 to –50 and +50 to +100	+2/– 4dB from the measured energy averaged over all 200 active tones

This data shall be taken from the channel estimation step.

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8.4.9.1.2 Transmitter constellation error and test method

To ensure that the receiver SNR does not degrade more than 0.5 dB due to the transmitter SNR, the relative constellation RMS error, averaged over carriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to Table 116bi.

Table 116bi—Allowed relative constellation error versus data rate

Burst type	Relative constellation error (dB)
QPSK-1/2	–19.4
QPSK-3/4	–21.2
16-QAM-1/2	–26.4
16-QAM-3/4	–28.2
64-QAM-2/3	–32.7
64-QAM-3/4	–34.4

All measurement errors taken together shall be 10dB less than the required noise level, i.e., if a specification is TX S/N = 10dB, the measurement S/N should be at least 20dB. For all PHY modes, measurements shall be taken with all non-guard carriers active.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure [B30]:

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 de-rotated according to estimated frequency offset.
e) The complex channel response coefficients shall be estimated for each of the carriers.
f) For each of the data OFDM symbols: transform the symbol into carrier received values, estimate the phase from the pilot carriers, de-rotate the carrier values according to estimated phase, and divide each carrier value with a complex estimated channel response coefficient.
g) For each data-carrying carrier, 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:

$$\text{Error}_{RMS} = \frac{\sum_{i=1}^{N_f} \frac{\sum_{j=1}^{L_P} \left[\sum_{k=1}^{N_{FFT}} \left\{ (I(i,j,k) - I_0(i,j,k))^2 + (Q(i,j,k) - Q_0(i,j,k))^2 \right\} \right]}{P_0 \cdot L_P \cdot N_{FFT}}}{N_f} \quad (65)$$

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where

L_P is the length of the packet;

N_f is the number of frames for the measurement;

$(I_0(i,j,k), Q_0(i,j,k))$ denotes the ideal symbol point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} carrier of the OFDM symbol in the complex plane;

$(I(i,j,k), Q(i,j,k))$ denotes the observed point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} carrier of the OFDM symbol in the complex plane;

P_0 is the average power of the constellation.

8.4.10 Receiver requirements

8.4.10.1 Receiver sensitivity

The bit error rate (BER) shall be less than 10^{-6} at the power levels shown in Table 116bj for standard message and test conditions. If the implemented bandwidth is not listed, then the values for the nearest smaller listed bandwidth shall apply. The minimum input levels are measured as follows:

— At the antenna connector or through a calibrated radiated test environment,
— Using the defined standardized message packet formats, and
— Using an AWGN channel.

Table 116bj—Receiver minimum input level sensitivity (dBm)

Bandwidth (MHz)	QPSK		16-QAM		64-QAM	
	1/2	3/4	1/2	3/4	2/3	3/4
1.5	–91	–89	–84	–82	–78	–76
1.75	–90	–87	–83	–81	–77	–75
3	–88	–86	–81	–79	–75	–73
3.5	–87	–85	–80	–78	–74	–72
5	–86	–84	–79	–77	–72	–71
6	–85	–83	–78	–76	–72	–70
7	–84	–82	–77	–75	–71	–69
10	–83	–81	–76	–74	–69	–68
12	–82	–80	–75	–73	–69	–67
14	–81	–79	–74	–72	–68	–66
20	–80	–78	–73	–71	–66	–65

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Table 116bj (as well as Table 116bi) are derived assuming 5 dB implementation loss, a Noise Figure of 7 dB and receiver SNR and E_b/N_0 values as listed in Table 116bk.

Table 116bk—Receiver SNR and E_b/N_0 assumptions

Modulation	E_b/N_0 (dB)	Coding rate	Receiver SNR (dB)
QPSK	10.5	1/2	9.4
		3/4	11.2
16-QAM	14.5	1/2	16.4
		3/4	18.2
64-QAM	19.0	2/3	22.7
		3/4	24.4

Test messages for measuring Receiver Sensitivity shall be based on a continuous stream of MAC PDUs, each with a payload consisting of a R times repeated sequence $S_{modulation}$. For each modulation, a different sequence applies:

$$
\begin{aligned}
S_{QPSK} &= [0xE4, 0xB1, 0xE1, 0xB4] \\
S_{16QAM} &= [0xA8, 0x20, 0xB9, 0x31, 0xEC, 0x64, 0xFD, 0x75] \\
S_{64QAM} &= [0xB6, 0x93, 0x49, 0xB2, 0x83, 0x08, 0x96, 0x11, 0x41, 0x92, 0x01, 0x00, \\
&\quad 0xBA, 0xA3, 0x8A, 0x9A, 0x21, 0x82, 0xD7, 0x15, 0x51, 0xD3, 0x05, \\
&\quad 0x10, 0xDB, 0x25, 0x92, 0xF7, 0x97, 0x59, 0xF3, 0x87, 0x18, 0xBE, \\
&\quad 0xB3, 0xCB, 0x9E, 0x31, 0xC3, 0xDF, 0x35, 0xD3, 0xFB, 0xA7, \\
&\quad 0x9A, 0xFF, 0xB7, 0xDB]
\end{aligned}
\tag{66}
$$

For each mandatory test message, the $(R,S_{modulation})$ tuples that shall apply are:

Short length test message payload (288 data bytes): $(72,S_{QPSK})$, $(36,S_{16QAM})$, $(6,S_{64QAM})$
Mid length test message payload (864 data bytes): $(216,S_{QPSK})$, $(108,S_{16QAM})$, $(18,S_{64QAM})$
Long length test message payload (1536 data bytes): $(384,S_{QPSK})$, $(192,S_{16QAM})$, $(32,S_{64QAM})$

The test condition requirements are: ambient room temperature, shielded room, conducted measurement at the RF port if available, radiated measurement in a calibrated test environment if the antenna is integrated, and RS FEC is enabled. The test shall be repeated for each test message length and for each $(R,S_{modulation})$ tuple as identified above, using the mandatory FEC scheme. The results shall meet or exceed the sensitivity requirements set out in Table 116bj.

8.4.10.2 Receiver adjacent and alternate channel rejection

The adjacent channel rejection and alternate channel rejection shall be measured by setting the desired signal's strength 3dB above the rate dependent receiver sensitivity (see Table 116bj) and raising the power

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level of the interfering signal until the specified error rate is obtained. The power difference between the interfering signal and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a conforming OFDM signal, unsynchronized with the signal in the channel under test. For non-adjacent channel testing the test method is identical except the interfering channel shall be any channel other than the adjacent channel or the co-channel. For the PHY to be compliant, the minimum rejection shall exceed the following:

Table 116bl—Adjacent and non-adjacent channel rejection

Modulation/coding	Adjacent channel rejection dB)	Non-adjacent channel rejection (dB)
16-QAM-3/4	11	30
64-QAM-2/3	4	23

8.4.10.3 Receiver maximum input signal

The receiver shall be capable of receiving a maximum on-channel signal of –30 dBm, and shall tolerate a maximum signal of 0 dBm without damage.

8.4.10.4 Receiver linearity

The receiver shall have a minimum Input Intercept Point (IIP3) of –10 dBm.

8.4.11 Frequency and timing requirements

At the BS, the transmitted center frequency, receive center frequency and the symbol clock frequency shall be derived from the same reference oscillator. At the BS the reference frequency tolerance shall be +/– 4 ppm in licensed bands.

At the SS, both the transmitted center frequency and the symbol clock frequency shall be synchronized to the BS with a tolerance of maximum 2% of the carrier spacing.

For Mesh capable devices, all devices shall have a +/– 20 ppm maximum frequency tolerance and achieve synchronization to its neighboring nodes with a tolerance of maximum 3% of the carrier spacing.

During the synchronization period, the SS shall acquire frequency synchronization within the specified tolerance before attempting any uplink transmission. During normal operation, the SS shall track the frequency changes and shall defer any transmission if synchronization is lost.

All SSs shall acquire and adjust their timing such that all uplink OFDM symbols arrive time coincident at the Base-Station to a accuracy of +/– 50% of the minimum guard-interval or better.

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8.5 WirelessMAN-OFDMA PHY layer

8.5.1 Introduction

The WirelessMAN-OFDMA ([B24]) PHY, based on OFDM modulation, is designed for NLOS operation in the 2–11 GHz frequency bands per 1.2.4. For licensed bands, channel bandwidths allowed shall be limited to the regulatory provisioned bandwidth divided by any power of 2 no less than 1.25 MHz.

8.5.1.1 Generic OFDMA symbol description

8.5.2 OFDMA symbol description, symbol parameters and transmitted signal

8.5.2.1 Time domain description

Inverse-Fourier-transforming creates the OFDMA waveform; this time duration is referred to as the useful symbol time T_b. A copy of the last T_g µs of the useful symbol period, termed Cyclic Prefix (CP), is used to collect multipath, while maintaining the orthogonality of the tones. The two together are referred to as the symbol time T_s. Figure 128ar illustrates this structure.

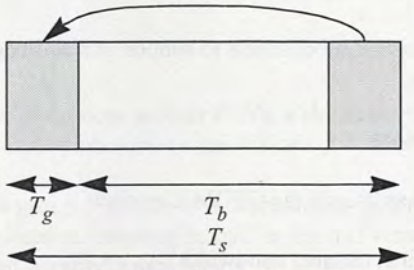


Figure 128ar—OFDM symbol time structure

The transmitter energy increases with the length of the guard time while the receiver energy remains the same (the cyclic extension is discarded), so there is a $0\log(1 - T_g / (T_b + T_g)) / \log(10$ dB loss in SNR. Using a cyclic extension, the samples required for performing the FFT at the receiver can be taken anywhere over the length of the extended symbol. This provides multipath immunity as well as a tolerance for symbol time synchronization errors.

On initialization, a SS should search all possible values of CP until it finds the CP being used by the BS. The SS shall use the same CP on the UL. Once a specific CP duration has been selected by the BS for operation on the DL, it should not be changed. Changing the CP would force all the SSs to resynchronize to the BS.

8.5.2.2 Frequency domain description

The frequency domain description includes the basic structure of an OFDMA symbol.

An OFDMA symbol is made up of carriers, the number of which determines the FFT size used. There are several carrier types:

— Data carriers: for data transmission
— Pilot carriers: for various estimation purposes
— Null carrier: no transmission at all, for guard bands and DC carrier.

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The purpose of the guard bands is to enable the signal to naturally decay and create the FFT 'brick Wall' shaping.

In the OFDMA mode, the active carriers are divided into subsets of carriers, each subset is termed a subchannel. In the DL, a subchannel may be intended for different (groups of) receivers; in the UL, a transmitter may be assigned one or more subchannels, several transmitters may transmit in parallel. The carriers forming one subchannel may, but need not be adjacent. The concept is shown in Figure 128as.

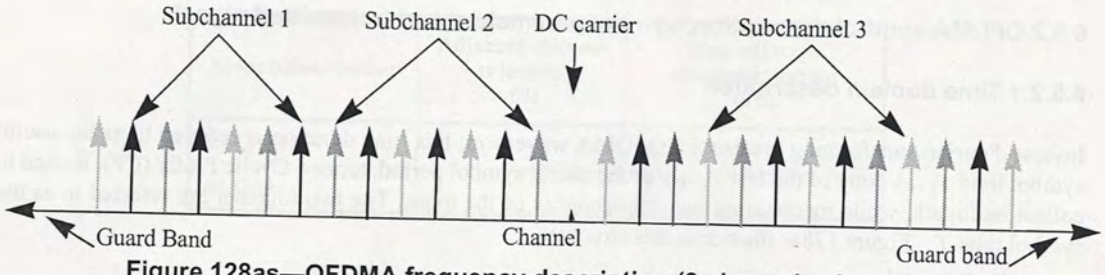


Figure 128as—OFDMA frequency description (3 channel schematic example)

The symbol is divided into logical subchannels to support scalability, multiple access, and advanced antenna array processing capabilities.

8.5.2.3 Primitive parameters

Four primitive parameters characterize the OFDMA symbol:

- BW. This is the nominal channel bandwidth.
- $(F_s/\ BW)$. This is the ratio of "sampling frequency" to the nominal channel bandwidth. This value is set to 8/7.
- $(T_g/\ T_b)$. This is the ratio of CP time to "useful" time. The following values shall be supported: 1/32, 1/16, 1/8, and 1/4.
- N_{FFT}. If an FFT is used in the implementation, this is the number of points in the FFT. The OFDMA PHY defines this value to be equal to 2048.

8.5.2.4 Derived parameters

The following parameters are defined in terms of the primitive parameters of 8.5.2.3.

$F_s = (F_s/\ BW) \cdot\ BW$ is Sampling Frequency

$\Delta f = F_s/\ N_{FFT}$ is the Carrier Spacing

$T_b = 1/\ \Delta f$ is the Useful Time

$T_g = (T_g/\ T_b) \cdot\ T_b$ is the CP Time

$T_s = T_b + T_g$ is the OFDM Symbol Time

$1/\ F_s$ is the Sample Time

8.5.2.5 Transmitted signal

Equation (67) specifies the transmitted signal voltage to the antenna, as a function of time, during any OFDMA symbol.

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$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \sum_{\substack{k=-N_{used}/2 \\ k\neq 0}}^{N_{used}/2} c_k \cdot e^{j2\pi k\Delta f(t-T_g)} \right\} \quad (67)$$

where

t is the time, elapsed since the beginning of the subject OFDM symbol, with $0 < t < T_S$.

c_k is a complex number; the data to be transmitted on the carrier whose frequency offset index is k, during the subject OFDM symbol. It specifies a point in a QAM constellation.

T_g is the guard time.

T_S is the OFDM symbol duration, including guard time.

Δf is the carrier frequency spacing.

8.5.3 OFDMA slot definition

8.5.3.1 Data region and PHY burst

In addition to the time dimension that defines slots in other PHYs, a slot in the OFDMA PHY requires a subchannel dimension for complete definition. (Subchannels are defined in 8.5.6.)

A PHY burst in OFDMA is allocated a group of contiguous subchannels, in a group of contiguous OFDMA symbols. This allocation may be visualized as a rectangle, such as the 4x3 rectangle shown in Figure 128at. This type of two-dimensional allocation is called a data region.

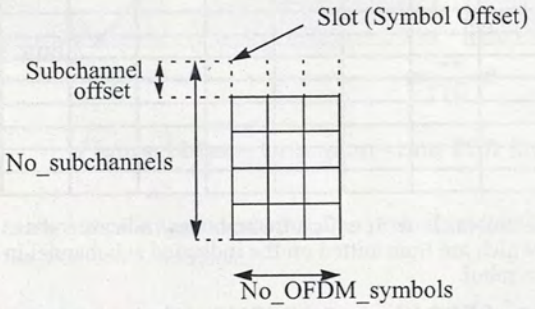


Figure 128at—Example of the data region which defines the OFDMA allocation

Such a data region can be assigned in the UL to a specific SS (or a group of subscribers) or can be transmitted in the DL by the BS as a transmission to a (group of) SS(s).

8.5.3.2 OFDMA data mapping

MAC data shall be processed as described in 8.5.9 and shall be mapped to an OFDMA Data Region (see 8.5.3.1) using the following algorithm:

1) Segment the data into blocks sized to fit into one FEC block.

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2) Each FEC block spans one OFDMA subchannel in the subchannel axis and three OFDM symbols in the time axis (see Figure 128au). Map the FEC blocks such that the lowest numbered FEC block occupies the lowest numbered subchannel in the lowest numbered OFDM symbol.
3) Continue the mapping such that the OFDMA subchannel index is increased for each FEC block mapped. When the edge of the Data Region is reached, continue the mapping from the lowest numbered OFDMA subchannel in the next OFDM symbol.

Figure 128au illustrates the order in which FEC blocks are mapped to OFDMA subchannels and OFDM symbols.

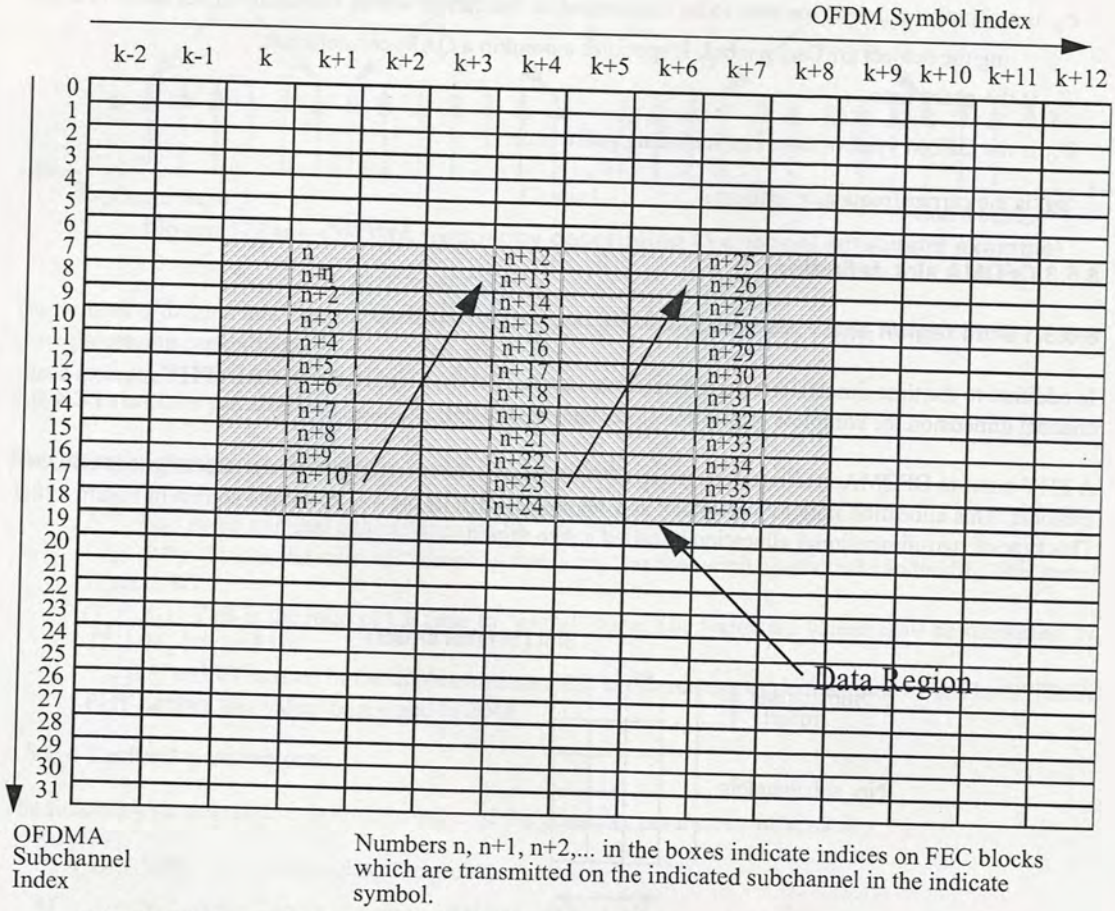


Figure 128au—Mapping of FEC blocks to OFDMA subchannels and symbols

8.5.4 Frame structure

8.5.4.1 Duplexing modes

In licensed bands, the duplexing method shall be either FDD or TDD. FDD SSs may be Half Duplex FDD (H-FDD). In license-exempt bands, the duplexing method shall be TDD.

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8.5.4.2 PMP frame structure

When implementing a TDD system, the frame structure is built from BS and SS transmissions. Each burst transmission consists of multiples of three (or six, if STC used, see 8.5.8) OFDMA symbols. In each frame, the Tx/Rx transition gap (TTG) and Rx/Tx transition gap (RTG) shall be inserted between the downlink and uplink and at the end of each frame respectively to allow the BS to turn around. TTG and RTG shall be at least 5 μs and an integer multiple of the PS in duration, and start on a PS boundary. After the TTG, the BS receiver shall look for the first symbols of a UL burst. After the RTG, the SS receivers shall look for the first symbols of QPSK modulated data in the DL burst.

There is no need for TTG and RTG as the downlink and uplink transmit on independent frequencies in FDD systems.

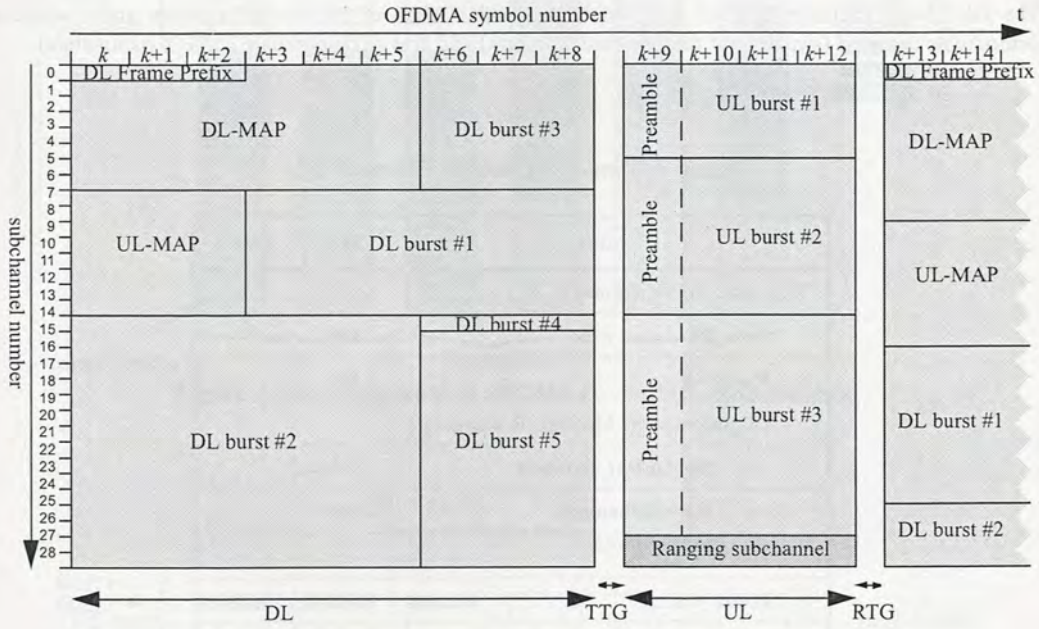


Figure 128av—Time plan - one TDD time frame

Regardless of duplexing type, the appropriate duration of the Initial Maintenance slot used for initial system access depends on the intended cell radius.

The framing structure used for the DL includes the transmission of a FCH, which is transmitted in the most robust burst profile of the system followed by transmission using burst profiles as defined in the FCH. The MAC layer also defines the DL transmission frame length and the length of the different transmission parts.

The transitions between modulations and coding take place on OFDMA symbol boundaries in time domain and on subchannels within an OFDM symbol in frequency domain.

A BS supporting the AAS option shall allocate at the end of the UL frame an initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but shall be marked by a non-used CID to ensure that no non-AAS subscriber (or AAS subscriber can decode the UL-MAP message) uses this interval for initial maintenance.

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8.5.4.3 DL Frame Prefix

The FCH is transmitted at the beginning of each frame. It is a data structure that contains the DL-MAP message and may additionally include the UL-MAP, DCD or UCD messages. The first FEC block of the DL frame shall contain information about the FCH and beginning of the DL-MAP, as shown in Figure 128aw. The DL Frame prefix is always transmitted using the burst profile QPSK-1/2 with the mandatory coding scheme.

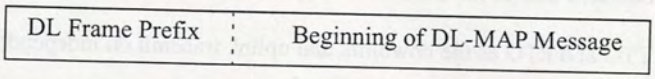


Figure 128aw—Structure of the first FEC block in OFDMA

The DL Frame Prefix is defined in Table 116bm and is used to provide information about where to demodulate the FCH (structure of the transmitted matrix) and how to demodulate it (PHY parameters).

Table 116bm—OFDMA DL Frame Prefix

Syntax	Size	Notes
DL_Frame_Prefix_Format() {		
Rate_ID	4 bits	
Reserved	4 bits	
DL_Information_Message_Rectangle() {		
No_OFDM_Symbols	10 bits	
No_subchannels	6 bits	
}		
Prefix_CS	8 bits	
}		

The fields in Table 116bm are defined as:

Rate_ID:
Enumerated field that describes the modulation/coding of the DL-MAP message. Encoding values of the Rate_ID field are defined in Table 116ao.

No_OFDM_Symbols
Indicates the number of OFDM symbols for the DL_MAP message starting from the first symbol of the frame.

No_subchannels
Indicates the number of subchannels for the DL_MAP message starting from subchannel 0.

Prefix_CS
An 8-bit checksum for the DL-Frame prefix fields, with the generator polynomial: $g(D) = D^8+D^2+D+1$.

The remaining bytes of the first FEC block may contain the beginning of the frame control information (DL-MAP).

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Two specific examples of the usage of the DL_Frame_Prefix are provided below:

1) The frame control information is transmitted at the beginning of the frame, using all or part of the subchannels (see Figure 128ax).

2) Taking advantage of the option of forward power control, the transmission of the frame control information is done by using 1-2 subchannels for the duration of the whole frame while power boosting the used carriers (see Figure 128ay).

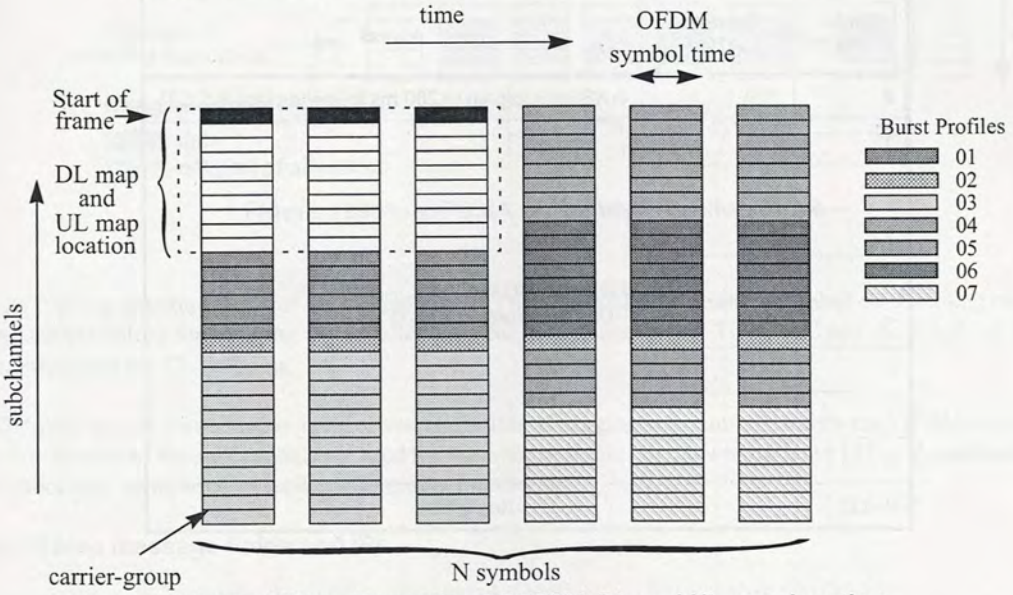


Figure 128ax—Example of OFDMA DL and UL map location

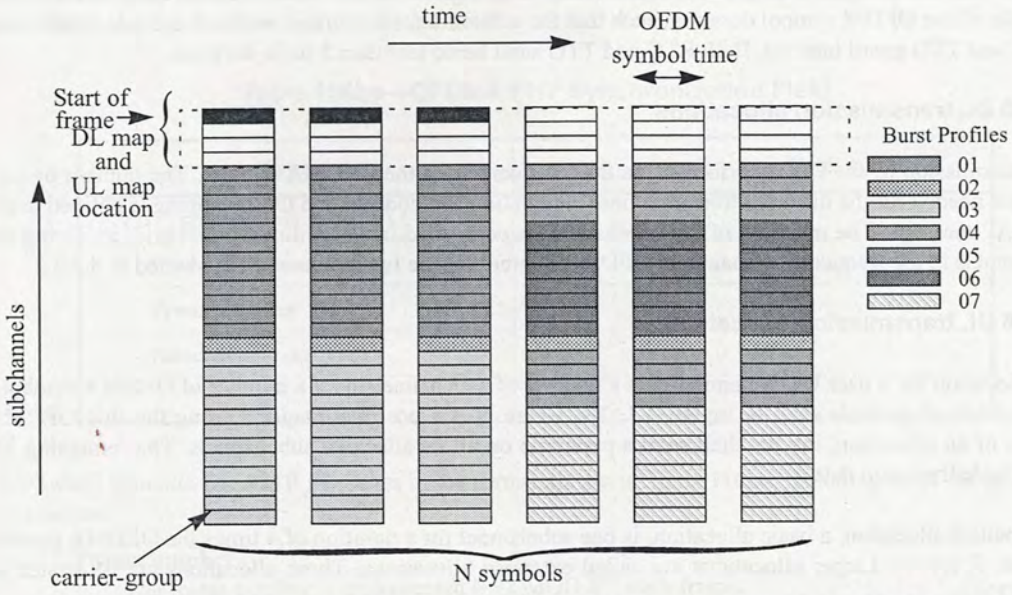


Figure 128ay—Another example of OFDMA DL and UL map location

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8.5.4.4 Frame duration codes

Table 116bn indicates the various frame durations that are allowed. The actual frame duration can be determined by the periodicity of the DL frame start preamble.

Table 116bn—OFDMA frame duration (T_F ms) codes

Code (N)	Nominal (D)	Actual
0	N/A	AAS-only gap up to 200 ms following (see 8.5.6.3)
1	2	FDD: round(D/3T_s)*3T_s TDD: max(round(D/T_s),7)*T_s
2	3.5	
3	5	
4	7	
5	10	
6	14	
7	15	
8	20	
9–255	Reserved	

In an FDD case, the frame duration shall be an integer multiple of three OFDM symbols duration, such that the actual frame duration is as listed in Table 116bn. In a TDD case, the frame duration shall be an integer multiple of one OFDM symbol duration, such that the actual frame duration is as listed in Table 116bn, plus a RTG and TTG guard interval. Both RTG and TTG shall be no less than 5 μs in duration.

8.5.4.5 DL transmission allocations

The transmission of the DL is performed on the subchannels of the OFDMA symbol. The number of subchannels needed for the different transmissions (modulation and coding) and their mapping is defined in the DL-MAP message. The mapping of the subchannels is performed in a two-dimensional grid, involving the subchannels in the frequency domain and OFDMA symbols in the time domain, as explained in 8.5.3.2.

8.5.4.6 UL transmission allocations

The allocation for a user UL transmission is a number of subchannels over a number of OFDMA symbols. The number of symbols shall be equal to 1+3N, where N is a positive integer. During the first OFDMA symbol of an allocation, the SS shall send a preamble on all its allocated subchannels. The remaining 3N symbols shall contain data.

The smallest allocation, a basic allocation, is one subchannel for a duration of 4 times the OFDMA symbol duration T_s (N=1). Larger allocations are called extended allocations. These allocations are illustrated in Figure 128az.

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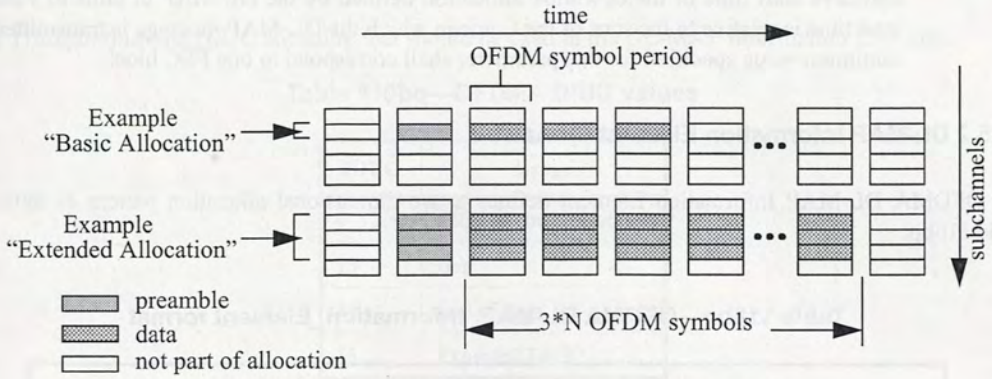


Figure 128az—OFDMA UL bandwidth allocations

The framing structure used for the UL includes the transmission of a possible symbol for Jamming monitoring, an allocation for Ranging and an allocation for data transmission. The MAC sets the length of the UL framing, and the UL mapping.

The framing for these modes involve the allocation of ranging subchannels within the OFDMA symbols, while the rest of the subchannels are used for users transmission, as shown in Figure 128az. An optional Null symbol may be inserted to facilitate Jamming monitoring.

8.5.5 Map message fields and IEs

8.5.5.1 DL-MAP PHY Synchronization Field

The format of the PHY Synchronization Field of the DL-MAP message, as described in 6.2.2.3.2, is given in Table 116bo. The Frame Duration Codes are given in Table 116bn. The Frame number is incremented by 1 each frame and eventually wraps around to zero.

Table 116bo—OFDMA PHY Synchronization Field

Syntax	Size	Notes
PHY_synchronization_field() {		
Frame duration code()	8 bits	
Frame number	24 bits	
Allocation_Start_Time	32 bits	
}		

A BS shall generate DL-MAP messages in the format shown in Table 116bo, including all of the following parameters:

Frame number
The frame number is incremented by 1 MOD 2^{24} each frame.

Frame Duration Code
The frame duration Code values are specified in Table 116bn.

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Allocation_Start_Time
Effective start time of the downlink allocation defined by the DL-MAP in units of PSs. This start time is relative to the start of the frame in which the DL-MAP message is transmitted. The minimum value specified for this parameter shall correspond to one FEC block.

8.5.5.2 DL-MAP Information Element format

The OFDMA DL-MAP Information Element defines a two-dimensional allocation pattern as defined in Table 116bp:

Table 116bp—OFDMA DL-MAP_Information_Element format

Syntax	Size	Notes
DL-MAP_Information_Element() {		
DIUC	4 bits	
if (UIUC == 15) {		
Extended DIUC dependent IE	variable	AAS_DL_IE()
} else {		
OFDM Symbol offset	10 bits	
Subchannel offset	6 bits	
No. OFDM Symbols	10 bits	
No. Subchannels	6 bits	
}		
}		

DIUC
Downlink interval usage code used for the burst.
OFDM Symbol offset
The offset of the OFDM symbol in which the burst starts, measured in OFDM symbols from the allocation start time specified by the Allocation_Start_time field in the DL-MAP.
Subchannel offset
The lowest index OFDM subchannel used for carrying the burst, starting from subchannel 0.
No. OFDM Symbols
The number of OFDM symbols that are used (fully or partially) to carry the DL PHY Burst.
No. of subchannels
The number OFDMA subchannels with subsequent indexes, used to carry the burst.

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8.5.5.2.1 DIUC allocation

Table 116bq defines the DIUC encoding that should be used in the DL-MAP Information Elements.

Table 116bq—OFDMA DIUC values

DIUC	Usage
0–12	Different burst profiles
13	Gap
14	End of map
15	Extended DIUC

8.5.5.2.2 AAS Information Element format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended DIUC = 15 with the AAS_DL_IE() to indicate that the subsequent allocations, until the start of the first UL-MAP allocation using TDD, and until the end of the frame using FDD, shall be for AAS traffic. When used, the CID in the DL-MAP_IE() shall be set to the broadcast CID.

Table 116br—OFDMA DL AAS information element

Syntax	Size	Notes
AAS_DL_IE() {		
extended DIUC	4 bits	AAS = 0x02
Permutation	2 bits	0 = distributed-carrier permutation 1 = adjacent-carrier permutation
OFDMA symbol offset	10 bits	
}		

8.5.5.2.3 STC Information Element format

In the DL-MAP, an STC enabled BS (see 8.5.8) may transmit DIUC=15 with the STC_IE() to indicate that the subsequent allocations shall be STC encoded. No preceding DL allocations shall be STC encoded and all subsequent DL allocations until the end of the frame shall be STC encoded. The subsequent DL allocations shall span a multiple of 6 OFDM symbols in time.

Table 116bs—OFDMA DL STC Information Element

Syntax	Size	Notes
STC_IE() {		
extended DIUC	4 bits	AAS = 0x01
OFDMA symbol offset	10 bits	
}		

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The duration of the DIUC=15 STC_IE() allocation shall be zero. From the start of the frame up to this allocation, only one antenna shall be used. The transmission in this allocation will be as specified in 8.5.8.2. After this allocation, the BS shall transmit from both its antennas until the end of the frame.

8.5.5.3 UL-MAP Information Element format

The OFDMA UL-MAP Information Element defines a two-dimensional allocation pattern for the UL bursts. Information Elements define uplink bandwidth allocations. Each UL-MAP message shall contain at least one Information Element that marks the end of the last allocated burst. The Information Elements shall be in strict chronological order within the UL-MAP. The Connection Identifier represents the assignment of the IE to either a unicast, multicast, or broadcast address. A UIUC shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be specified in the UCD for each UIUC to be used in the UL-MAP. The format of the UL-MAP IE is defined in Table 116bt.

Table 116bt—OFDMA UL-MAP Information Element format

Syntax	Size	Notes
UL-MAP_Information_Element() {		
CID	16 bits	
UIUC	4 bits	
if (UIUC == 4) {		
CDMA_Allocation_IE()	52 bits	
else if (UIUC == 15) {		
Extended UIUC dependent IE	variable	Power_Control_IE() or AAS_UL_IE()
} else {		
OFDM Symbol offset	9 bits	
Subchannel offset	5 bits	
Boosting	2 bits	00: normal (not boosted); 01: +6dB; 10: –6dB; 11: not used.
No. OFDM Symbols	9 bits	
No. Subchannels	5 bits	
Reserved	2 bits	
}		
}		

CID (Connection Identifier)
Represents the assignment of the IE.

UIUC
Uplink interval usage code used for the burst.

OFDM Symbol offset
The offset of the OFDM symbol in which the burst starts, the offset value is defined in units of OFDM symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.

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Subchannel offset
The lowest index OFDMA subchannel used for carrying the burst, starting from subchannel 0.
No. OFDM Symbols
The number of OFDM symbols that are used to carry the UL Burst.
No. subchannels
The number OFDMA subchannels with subsequent indexes, used to carry the burst.
Boosting
Indication whether the carriers for this allocation are power boosted.

The end of the last allocated burst is indicated by allocating a NULL burst (CID =0 and UIUC =10) with zero duration. The time instants indicated by the offsets are the transmission times of the first symbol of the burst including preamble.

A BS supporting the AAS option shall allocate subchannels 30 and 31, during the last 4 symbols of the UL frame as initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=12), but shall be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance.

8.5.5.3.1 UIUC Allocation

Table 116bu defines the UIUC encoding that should be used in the UL-MAP_IE().

Table 116bu—OFDMA UIUC values

UIUC	Usage
0	Reserved
1–9	Different burst profiles
10	Null Information Element
11	BW request, periodic ranging
12	Initial ranging
13	Reserved
14	CDMA Allocation Information Element
15	Extended UIUC

8.5.5.3.2 CDMA allocation UL-MAP Information Element format

Table 116bv defines the UL-MAP_IE for allocation BW for a user that requested bandwidth using Request Code. This IE is identified by UIUC =14.

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Table 116bv—CDMA Allocation Information Element format

Syntax	Size	Notes
CDMA_Allocation_IE() {		
Ranging Code	6 bits	
Ranging Symbol	10 bits	
OFDM Symbol offset	8 bits	
Subchannel offset	6 bits	
No. OFDM Symbols	6 bits	
No. Subchannels	6 bits	
Ranging subchannel	6 bits	
BW request mandatory	1 bit	1= yes, 0= no
Reserved	3 bits	
}		

Ranging Code
Indicating the CDMA Code sent by the SS.
Ranging Symbol
Indicating the OFDM symbol used by the SS.
OFDM Symbol offset
The offset of the OFDM symbol in which the burst starts, the offset value is defined in units of OFDM symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.
Subchannel offset
The lowest index OFDMA subchannel used for carrying the burst, starting from subchannel 0.
No. OFDM Symbols.
The number of OFDM symbols that are used to carry the UL Burst.
Number of subchannels
The number OFDMA subchannels with subsequent indexes, used to carry the burst.
Ranging subchannel
Identifies the Ranging subchannel used by the SS to send the CDMA code.
BW request mandatory
Indicates whether the SS shall include a BW request in the allocation.

The end of the last allocated burst is indicated by allocating a NULL burst (CID=0 and UIUC=10) with zero duration.The time instants indicated by the offsets are the transmission times of the first symbol of the burst including preamble.

8.5.5.3.3 Power Control Information Element format

When a power change for the SS is needed, the extended UIUC = 15 may be used with the sub-code 0x00 and with 8-bit Power control value as shown in Table 116bw. The power control value is an 8-bit signed integer expressing the change in power level (in 0.25 dB units) that the SS should apply to correct it's current transmission power.

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The CID used in the Information Element should be the Basic CID of the SS.

Table 116bw—OFDMA Power Control Information Element

Syntax	Size	Notes
Power_Control_IE() {		
extended UIUC	4 bits	Fast power control = 0x00
Power control	8 bits	Signed integer, which expresses the change in power level (in 0.25 dB units) that the SS should apply to correct its current transmission power.
}		

8.5.5.3.4 AAS Information Element format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended UIUC = 15 with the AAS_UL_IE() to indicate that the subsequent allocation until the end of the frame shall be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID.

Table 116bx—OFDMA UL AAS Information Element

Syntax	Size	Notes
AAS_UL_IE() {		
extended UIUC	4 bits	AAS = 0x02
Permutation	2 bits	0 = distributed-carrier permutation 1 = adjacent-carrier permutation
OFDMA symbol offset	10 bits	
Reserved	4 bits	
}		

8.5.5.4 Burst Profile format

Table 116by defines the format of the Downlink_Burst_Profile, which is used in the DCD message (6.2.2.3.1). The Downlink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit DIUC. The DIUC field is associated with the Downlink Burst Profile and Thresholds. The DIUC value is used in the DL-MAP message to specify the Burst Profile to be used for a specific downlink burst.

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Table 116by—Downlink_burst_profile format

Syntax	Size	Notes
Downlink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
DIUC	4 bits	
TLV encoded information	variable	
}		

Table 116bz defines the format of the Uplink_Burst_Profile, which is used in the UCD message (6.2.2.3.1). The Uplink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit UIUC. The UIUC field is associated with the Uplink Burst Profile and Thresholds. The UIUC value is used in the UL-MAP message to specify the Burst Profile to be used for a specific uplink burst.

Table 116bz—Uplink_burst_profile format

Syntax	Size	Notes
Uplink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
UIUC	4 bits	
TLV encoded information	variable	
}		

8.5.6 OFDMA carrier allocations

For OFDMA, $F_s = BW \cdot 8/7$. Subtracting the DC carrier and the guard tones from N_{FFT}, one obtains the set of "used" carriers N_{used}. For both uplink and downlink these used carriers are allocated to pilot carriers and data carriers. However, there is a subtle difference between uplink and downlink. This difference is that, in the downlink, the pilot tones are allocated first; what remains are subchannels that are used exclusively for data. In the uplink, however, the set of used carriers is first partitioned into subchannels, and then the pilot carriers are allocated from within each subchannel. Thus, in the downlink, there is one set of common pilot carriers, but in the uplink, each subchannel contains its own set of pilot carriers. This is necessary since, in OFDMA, the BS downlink is broadcast to all SS, but in the uplink, each subchannel may be transmitted from a different SS.

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In the sequel, carriers are identified by a carrier index; however, in order to construct the OFDMA signal as specified in 8.5.2.5 the frequency offset index is required. The frequency offset index of a particular carrier is specified terms of its carrier index by Equation (68).

$$k_{foi} = \begin{cases} k_{ci} - N_{used}/2, & k_{ci} < N_{used}/2 \\ k_{ci} - N_{used}/2 + 1, & k_{ci} \geq N_{used}/2 \end{cases} \quad (68)$$

where

k_{foi} is the frequency offset index

k_{ci} is the carrier index

N_{used} is the number of used carriers.

8.5.6.1 Downlink

8.5.6.1.1 Assignment of pilots

The N_{used} used carriers are partitioned into fixed-location pilots, variable location pilots, and data subchannels. The carrier indices of the fixed-location pilots never change. These indices are the members of the set BasicFixedLocationPilots. The variable-location pilots shift their location every symbol repeating every 4 symbols, according to the formula:

$$varLocPilot_k = 3L + 12P_k$$

where

$varLocPilot_k$ is the carrier index of a of variable-location pilot

$L \in 0..3$ is a function of the symbol index, modulo 4

$P_k \in \{0, 1, 2, .., N_{varLocPilots} - 1\}$

and $N_{varLocPilots}$ is given in Table 116ca.

L does not simply increment from one symbol to the next, but instead follows the sequence $L = 0, 2, 1, 3, 0...$

In some cases a variable-location pilot will coincide with a fixed-location pilot. The sets of BasicFixedLocationPilots are designed so that the number of coinciding pilots is the same for every L.

There is no all-pilot preamble in the DL.

The allocation of pilot carriers is illustrated in Figure 128ba.

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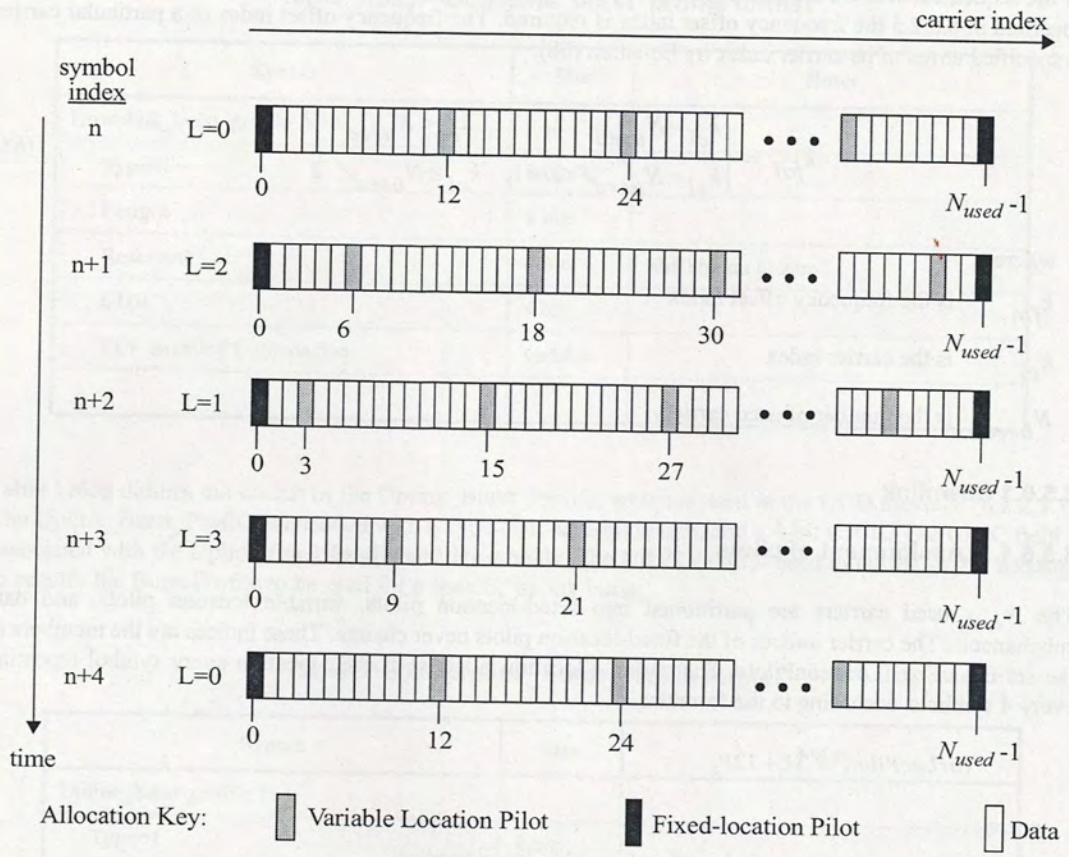


Figure 128ba—Carrier Allocations in the OFDMA DL

8.5.6.1.2 Partitioning of data carriers into subchannels

After mapping the pilots, the remainder of the used carriers are the data subchannels. Note that since the variable location pilots change location in each symbol, repeating every fourth symbol, the locations of the carriers in the data subchannels shall change also.

To allocate the data subchannels, the remaining carriers are partitioned into groups of contiguous carriers. Each subchannel consists of one carrier from each of these groups. The number of groups is therefore equal to the number of carriers per subchannel, and it is denoted $N_{subcarriers}$. The number of the carriers in a group is equal to the number of subchannels, and it is denoted $N_{subchannels}$. The number of data carriers is thus equal to $N_{subcarriers} \cdot N_{subchannels}$.

The exact partitioning into subchannels is according to Equation (69), called a permutation formula. (To clarify the operation of this formula, an example application is given subsequently in 8.5.6.2.1).

$$carrier(n, s) = N_{subchannels} \cdot n + \{p_s[n_{mod(N_{subchannels})}] + ID_{cell} \cdot ceil[(n+1)/N_{subchannels}]\}_{mod(N_{subchannels})} \quad (69)$$

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where

$carrier(n, s)$ is the carrier index of carrier n in subchannel s

s is the index number of a subchannel, from the set $[0..N_{(subchannel)s}-1]$

n is the carrier-in-subchannel index from the set $[0..N_{subcarriers}-1]$

$N_{(subchannel)s}$ is the number of subchannels

$p_s[j]$ is the series obtained by rotating $\{PermutationBase_0\}$ cyclically to the left s times

$ceil[\ ]$ is the function that rounds its argument up to the next integer

ID_{cell} is a positive integer assigned by the MAC to identify this particular BS sector

$X_{mod(k)}$ is the remainder of the quotient X/k (which is at most k–1)

and the numerical parameters are given in Table 116ca.

On initialization, a SS must search for the DL preamble for each possible value of the permutation index to determine the actual index being used for the cell. An AAS-enabled SS may additionally search for preambles based on the permutations (distributed, adjacent or both) it is capable of using for AAS traffic. However, an SS shall perform this search if it intends to initiate AAS-based initial ranging (see 6.2.7.7.4). Note that an AAS-enabled SS, which does not provision the same permutation (distributed or adjacent) for AAS traffic selected by the BS for this purpose, is not capable of using its AAS capabilities with this BS.

Table 116ca—OFDMA DL carrier allocations

Parameter	Value
Number of dc carriers	1
Number of guard carriers, left	173
Number of guard carriers, right	172
N_{used}, Number of used carriers	1702
Total number of carriers	2048
$N_{varLocPilots}$	142
Number of fixed-location pilots	32
Number of variable-location pilots which coincide with fixed-location pilots	8
Total number of pilots[a]	166
Number of data carriers	1536
$N_{subchannels}$	32
$N_{subcarriers}$	48
Number of data carriers per subchannel	48
BasicFixedLocationPilots	{0,39, 261, 330, 342, 351, 522, 636, 645, 651, 708, 726, 756, 792, 849, 855, 918, 1017, 1143, 1155, 1158, 1185, 1206, 1260, 1407, 1419,1428, 1461, 1530,1545, 1572, 1701}
$\{PermutationBase_0\}$	{3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}

[a]Variable Location Pilots which coincide with Fixed-location Pilots are counted only once in this value.

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8.5.6.2 Uplink

The N_{used} used carriers are first partitioned into subchannels, using the same procedure as in 8.5.6.1.2, including Equation (69), except that, for the uplink, the parameters are as given in Table 116cb. Note that since we have not first assigned pilots, $N_{subcarriers}$ in the uplink is 53, instead of 48 as in the downlink.

Table 116cb—OFDMA UL Carrier Allocations

Parameter	Value
Number of dc carriers	1
N_{used}	1696
Guard carriers: left, right	176 | 175
$N_{subchannels}$	32
$N_{subcarriers}$	53
Number of data carriers per subchannel	48
$\{PermutationBase_0\}$	{3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}

Within each subchannel, there are 48 data carriers, 1 fixed-location pilot carrier, and 4 variable-location pilot carriers.

The fixed-location pilot is always at carrier-in-subchannel 26.

The variable-location pilots location changes in each symbol, repeating every 13 symbols, according to L_k where $k = 0$ to 12. The sequence L_k is given by $L_k = \{0,2,4,6,8,10,12,1,3,5,7,9,11\}$. The first symbol (in k=0) is produced after the all-pilot symbols (preamble), which consist of permuted carriers modulated according to 8.5.6.1. For k=0 the variable location pilots are positioned at indices: 0,13,27,40. For other k values these locations change by adding L_k to each index. For example, for k=9, L_k=5, and the variable pilots location are: 5,18, 32, 45.

The variable-location pilot locations just described will never coincide with the fixed-location pilot at carrier-in-subchannel 26.

The remaining 48 carriers are data carriers. Thus, due to the motion of the variable-location pilots, the locations of these data carriers also change with each symbol.

The partitioning of each UL subchannel just described in this subclause is illustrated in Figure 128bb.

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Using Equation (69),

1) The basic series of 32 numbers is {3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}

2) In order to get 32 different permutation the series is rotated to the left (from no rotation at all up to 31 rotations). Since it is assumed s=1, ($permutationbase_{s=1}$) is: {18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3}

3) Repeat the permuted series 2 times and take the first 53 numbers only: {18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3}.

4) The concatenation depends on the ID_{cell} (which characterizes the working cell and can range from 0 to 31). It is assumed s=1 and $ID_{cell} = 2$, the last term in the equation becomes

$$\{p_s[n_{mod(32)}] + 2 \cdot ceil[(n+1)/32]\}_{mod(32)} \quad \text{with } n = 0, 1, \ldots, 52$$

= {20, 4, 10, 18, 12, 13, 17, 28, 24, 8, 11, 29, 22, 27, 3, 31, 9, 23, 7, 30, 1, 25, 19, 6, 26, 2, 15, 14, 21, 16, 0, 5, 22, 6, 12, 20, 14, 15, 19, 30, 26, 10, 13, 31, 24, 29, 5, 1, 11, 25, 9, 0, 3}

5) Finally adding in the first term, the set of carriers is found: *carrier(n,1)* = {20, 36, 74, 114, 140, 173, 209, 252, 280, 296, 331, 381, 406, 443, 451, 511, 521, 567, 583, 638, 641, 697, 723, 742, 794, 802, 847, 878, 917, 944, 960, 997, 1046, 1062, 1100, 1140, 1166, 1199, 1235, 1278, 1306, 1322, 1357, 1407, 1432, 1469, 1477, 1505, 1547, 1593, 1609, 1632, 1667}.

8.5.6.3 Optional permutations for AAS

A BS using the AAS option may change from the "distributed carrier permutation" described in 8.5.6.1 and 8.5.6.2 to the "adjacent carrier permutation" when changing from non-AAS to AAS-enabled traffic to support AAS adjacent carrier user traffic in the cell. After this change, the BS shall only transmit / receive AAS-enabled traffic using the adjacent carrier permutation until the end of the frame. The BS shall always return to the distributed carrier permutation for the broadcast (non-AAS) traffic.

While the BS does not have any SSs registered that are not capable of using the AAS permutation selected by the BS, the BS may employ the AAS superframe structure. Otherwise, it shall always return to the distributed carrier permutation at the end of each frame and provision broadcast traffic at the start of each frame.

The AAS superframe shall have the following structure:

1) The BS shall start each superframe with no less than 20 consecutive frames, which contain both DL and UL broadcast OFDM symbols. Each of these frames shall provision DCD, UCD, DL-MAP and UL-MAP messages, and at least one initial ranging opportunity. The frame duration code in each frame except the last one shall be set to the actual frame duration used. The frame duration code in the last frame shall be set to 0x00.

2) Subsequently, the BS shall transmit up to 200 ms of AAS only frames, followed by a minimum of one frame containing at least one DL broadcast OFDM symbol, which shall provision DCD, UCD and DL-MAP messages. The frame duration code shall be set to 0x00.

3) The BS shall repeat Step 2) of this subclause, up to the AAS superframe duration, which shall be no more than 1s.

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With the adjacent carrier permutation, symbol data within a subchannel is assigned to adjacent carriers and the pilot and data carriers are assigned fixed positions in the frequency domain within an OFDM symbol. This permutation is the same for both UL and DL. Within each frame, the BS shall indicate the switch to the optional permutation in the AAS_DL_IE() and AAS_UL_IE() when switching to AAS traffic. (see 8.5.5.2 and 8.5.5.3).

Table 116cc—OFDMA AAS carrier allocations

Parameter	Value
Number of dc carriers	1
Number of guard carriers, left	176
Number of guard carriers, right	175
N_{used}, Number of used carriers	1696
Total number of carriers	2048
$N_{varLocPilots}$	0
Number of fixed-location pilots	160
Number of variable-location pilots which coincide with fixed-location pilots	0
Total number of pilots (*)	160
Number of data carriers	1536
$N_{subchannels}$	32
$N_{subcarriers}$	48
Number of data carriers per subchannel	48
BasicFixedLocationPilots	{5,16,27,38,49} within each subchannel

8.5.7 OFDMA ranging

When used with the WirelessMAN-OFDMA PHY, the MAC shall define a single ranging channel. This ranging channel is composed of one or more pairs of adjacent subchannels, where the index of the lowest numbered subchannel is even. The indices of the subchannels that compose the ranging channel are specified in the UL-MAP message. Users are allowed to collide on this ranging channel. To effect a ranging transmission, each user randomly chooses one ranging code from a bank of specified binary codes. These codes are then BPSK modulated onto the carriers in the ranging channel, one bit per carrier.

8.5.7.1 Initial-ranging transmissions

The initial ranging transmission shall be used by any SS that wants to synchronize to the system channel for the first time. An initial-ranging transmission shall be performed during two consecutive symbols. The same ranging code is transmitted on the ranging channel during each symbol, with no phase discontinuity between the two symbols. A time-domain illustration of the initial-ranging transmission is shown in Figure 128bc.

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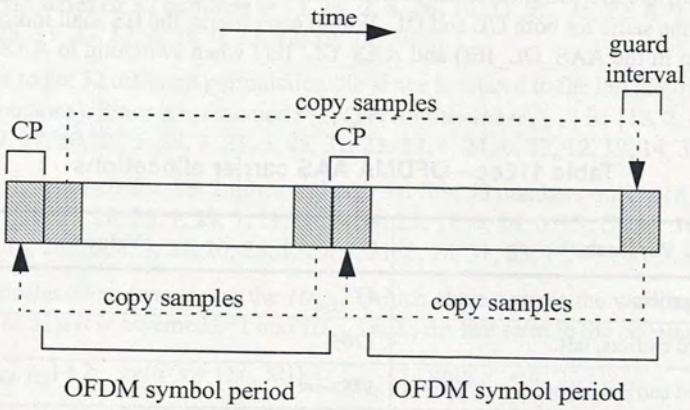


Figure 128bc—Initial-ranging transmission for OFDMA

8.5.7.2 Periodic-ranging and bandwidth-request transmissions

Periodic-ranging transmissions are sent periodically for system periodic ranging. Bandwidth-requests transmissions are for requesting UL allocations from the BS.

These transmissions shall be sent only by SS that have already synchronized to the system.

To perform either a periodic-ranging or bandwidth-request transmission, the SS shall modulate one ranging code on the ranging subchannel for a period of one OFDM symbol. Ranging subchannels are dynamically allocated by the MAC and indicated in the UL-MAP. A time-domain illustration of the periodic-ranging or bandwidth-request transmission is shown in Figure 128bd.

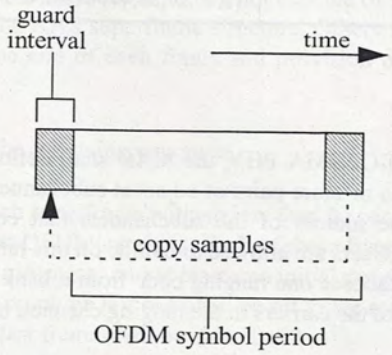


Figure 128bd—Periodic-ranging or bandwidth-request transmission for OFDMA

8.5.7.3 Ranging codes

The binary codes are the pseudo-noise (PN) codes produced by the PRBS described in Figure 128be, which implements the polynomial generator $1 + X^1 + X^4 + X^7 + X^{15}$.

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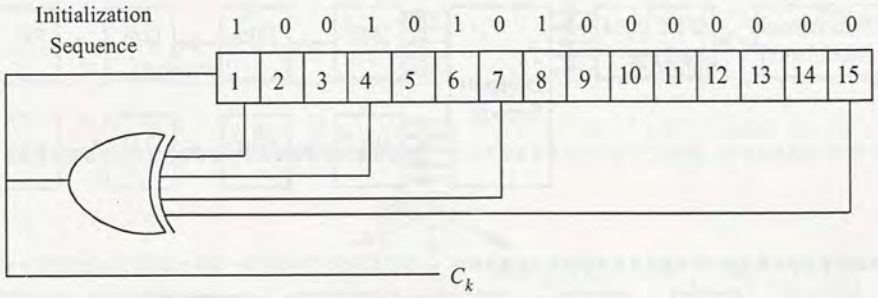


Figure 128be—PRBS for ranging code generation

The binary ranging codes are subsequences of the pseudo-noise sequence appearing at its output C_k. The length of each ranging code is 106 bits. These bits are used to modulate the sub-carriers in a pair of adjacent subchannels. The index of the lowest numbered subchannel in the pair is even. The pair is called a ranging subchannel. The ranging subchannel is referenced in the ranging and BW request messages by the index of lower numbered subchannel. The default allocation for the ranging channel is one ranging subchannel.

For example, if the BS has defined the ranging channel to be the default two subchannels, the first 106-bit code obtained by clocking the PN generator as specified, the first code shall be 011110000011111... The next ranging code is produced by taking the output of the 107th to 212th clock of the PRBS, etc.

The number of available codes is 48, numbered 0..47. These codes are divided in three usage groups (initial-ranging, periodic-ranging and bandwidth-requests). The codes are allocated dynamically to the groups by the BS. The default number of codes for each group is two.

— The first *N* codes produced are for initial-ranging. For example, for the default case of two subchannels in the ranging channel, clock the PRBS *0* times to 106 *x N-1* times.
— The next *M* codes produced are for periodic-ranging. For example, for the default case of two subchannels in the ranging channel, clock the PRBS *106 x N* times to *106 x (N + M)-1* times.
— The next *L* codes produced are for bandwidth-requests. For example, for the default case of two subchannels in the ranging channel, clock the PRBS *106 x (N + M)* times to *106 x (N + M + L)-1* times.

The BS can separate colliding codes and extract timing (ranging) information and power. In the process of user code detection, the BS gets the Channel Impulse Response (CIR) of the code, thus acquiring for the BS vast information about the user channel and condition. The time (ranging) and power measurements allow the system to compensate for the near/far user problems and the propagation delay caused by large cells.

8.5.8 Transmit diversity: Space-Time Coding (optional)

Space-Time Coding (STC) (see [B26]) may be used on the downlink to provide 2nd order (Space) transmit diversity.

There are two transmit antennas on the BS side and one reception antenna on the SS side. This scheme requires multiple input single output channel estimation. Decoding is very similar to maximum ratio combining.

Figure 128bf shows STC insertion into the OFDM chain. Each Tx antenna has its own OFDM chain, but they have the same Local Oscillator for synchronization purposes.

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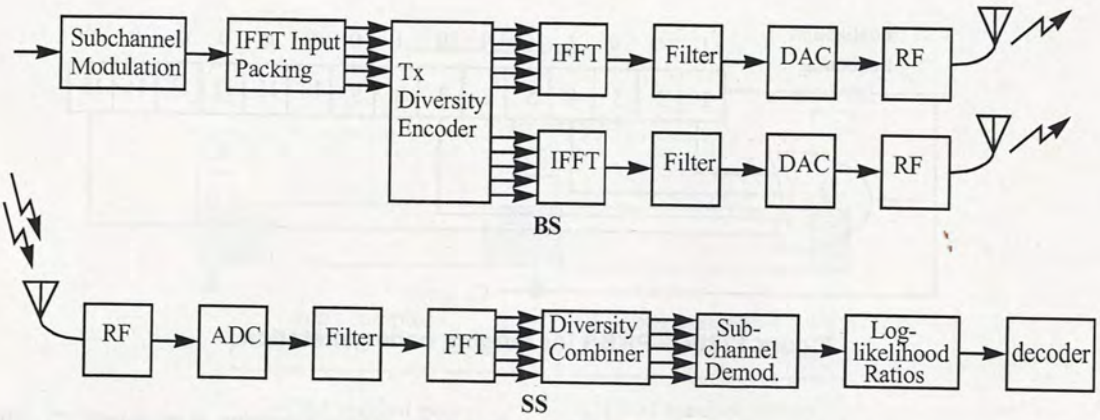


Figure 128bf—Illustration of STC

Both antennas transmit in the same time 2 different OFDM data symbols. Transmission is performed twice to decode and to get 2nd order diversity. Time domain (Space-Time) repetition is used.

8.5.8.1 Multiple in single out channel estimation and synchronization

Both antennas transmit in the same time, and they share the same Local Oscillator. Thus, the received signal has exactly the same auto-correlation properties as for a single antenna. So, time and frequency coarse and fine estimation can be performed in the same way as for a single antenna. The scheme requires multiple input single output channel estimation, which is allowed by splitting some preambles and pilots between the 2 Tx antennas, as described in 8.5.8.2.

8.5.8.2 STC encoding

The basic scheme [B26] transmits 2 complex symbols s_0 and s_1, using the multiple input single output channel (two Tx, one Rx) twice with channel vector values h_0 (for antenna 0) and h_1 (for antenna 1).

First channel use: Antenna0 transmits s_0, antenna1 transmits s_1.

Second channel use: Antenna0 transmits $-s_1^*$, antenna1 transmits s_0^*.

Receiver gets r_0 (first channel use) and r_1 (second channel use) and computes s_0 and s_1 estimates:

$$\hat{s}_0 = h_0^* \cdot r_0 + h_1 \cdot r_1^* \tag{70}$$

$$\hat{s}_1 = h_1^* \cdot r_0 - h_0 \cdot r_1^* \tag{71}$$

These estimates benefit from 2nd order diversity as in the 1Tx-2Rx Maximum Ratio Combining scheme. OFDM symbols are taken by pairs. (Equivalently, 2 Tx symbol duration is twice 1 Tx symbol duration, with twice more data in a symbol.) In the transmission frame, variable location pilots are kept identical for two symbols and L is constant for the duration of two symbols (see 8.5.6.1 for definition of L). STC is applied independently on each carrier, in respect to pilot tones positions.

Figure 128bg shows STC for OFDMA. Note that since pilot positions do not change from even to odd symbols, and pilot modulation is real, conjugation (and inversion) can be applied to a whole symbol (possibly in the time domain).

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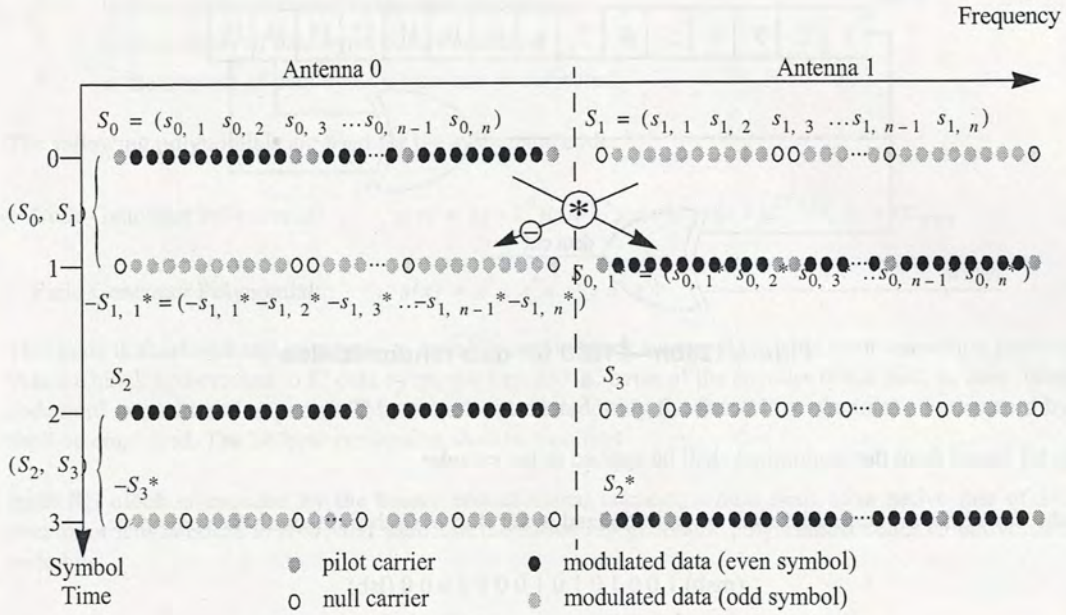


Figure 128bg— STC usage with OFDMA

8.5.8.3 STC decoding

The receiver waits for 2 symbols, and combines them on a carrier basis according to Equation (70) and Equation (71) in 8.5.8.2.

8.5.9 Channel coding

Channel coding procedures include randomization (see 8.5.9.1), FEC encoding (see 8.5.9.2), interleaving (see 8.5.9.3) and modulation (see 8.5.9.4).

8.5.9.1 Randomization

Data randomization is performed on data transmitted on the DL and UL. The randomization is performed on each allocation (DL or UL), which means that for each allocation of a data block (subchannels on the frequency domain and OFDM symbols on the time domain) the randomizer shall be used independently. If the amount of data to transmit does not fit exactly the amount of data allocated, padding of 0xFF ('1' only) shall be added to the end of the transmission block, up to the amount of data allocated.

The shift-register of the randomizer shall be initialized for each new allocation or for every 1250 bytes passed through (if the allocation is larger then 1250 bytes).

The Pseudo Random Binary Sequence (PRBS) generator shall be $1 + X^{14} + X^{15}$ as shown in Figure 128bh. Each data byte to be transmitted shall enter sequentially into the randomizer, msb first. Preambles are not randomized. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst. The randomizer sequence is applied only to information bits.

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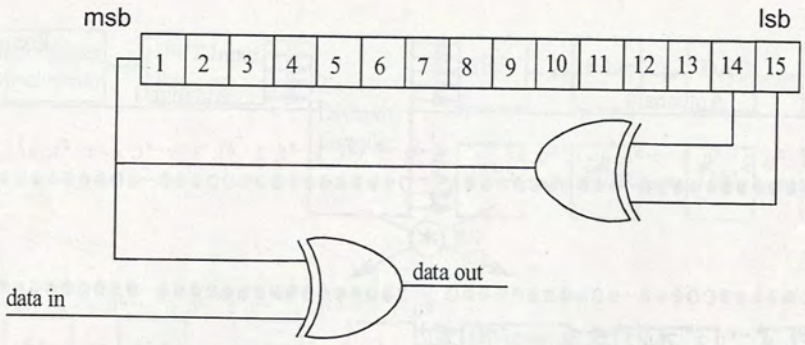


Figure 128bh—PRBS for data randomization

The bit issued from the randomizer shall be applied to the encoder.

In the downlink, the scrambler shall be re-initialized at the start of each frame with the sequence:

(msb) 1 0 0 1 0 1 0 1 0 0 0 0 0 0 0 0 (lsb)

The produced sequence from the PRBS shall start with: 0 0 0 0 0 0 1 1 1 1 1 1 0 1 1 0 ....

In the uplink, the scrambler is initialized with the vector created as shown in Figure 128bi.

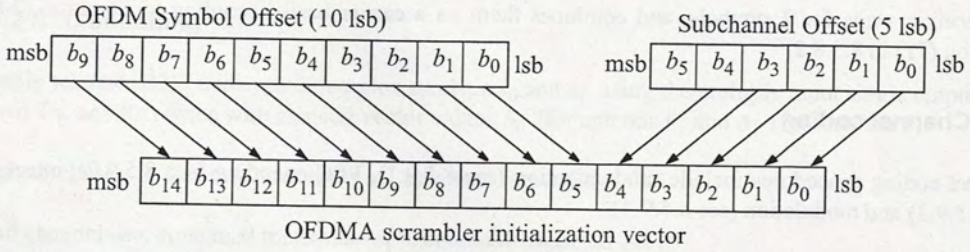


Figure 128bi—Creation of OFDMA scrambler initialization vector

8.5.9.2 FEC

A FEC, consisting of the concatenation of a Reed-Solomon outer code and a rate-compatible convolutional inner code, shall be supported on both UL and DL. Support of BTC and CTC is optional. The Reed-Solomon-Convolutional coding rate 1/2 with QPSK modulation, shall always be used as the default mode when requesting access to the network (except when using CDMA ranging) and in the-DL Frame Prefix.

8.5.9.2.1 Concatenated Reed-Solomon / convolutional code (RS-CC)

The Reed-Solomon encoding shall be derived from a systematic RS (N=255, K=239, T=8) code using GF(2^8),

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