Fig. 8 describes another scenario where a tenant NMS 62 sends an SNMP message that the open access NMS 60 finds violates privileges and blocks the message Here,

1. Tenant NMS 62 has a MIB 61 that defines valid SNMP GETs and SETs;
2. Tenant NMS 62 creates an SNMP message that does not fit one of the MIB entries 61; for example the tenant NMS 62 may be originating a message that requests status information for a RAN slice in which it has not leased space;
3. The tenant NMS 62 send the SNMP message to the open access statefull NMS 60;
4. The open access statefull NMS 60 receives the SNMP message with its SNMP agent;
5. The incoming message is identified with IP address of the originating tenant NMS 62;
6. The SNMP agent uses the tenant identification and SNMP address in the message to look up the validity of message in its MIB 63;
7. The message is determined to be invalid; the SNMP agent in the open access statefull NMS 60 then sends an SNMP error message to back to the originating tenant NMS 62; and
8. The open access statefull NMS60 writes a system log message noting an access privilege violation.

A "caching firewall" function may be implemented in the open access NMS 60 as a means to reduce SNMP network traffic on the open access system 10, such as may be due to several tenant NMS 62 making SNMP queries for the same information. The caching firewall functionality of the open access NMS 60 looks like an SNMP agent for the whole open access network 10. Where the statefull firewall feature described above forwards an SNMP message to the open access Hub/RANs, the caching firewall function may first attempt to access information gathered recently in its own database or cache 64, and responds with that data instead of creating additional network traffic to the hubs 35 and RANs 50.

Fig. 9 in particular further describes one scenario where a tenant NMS 62 sends SNMP Get message that the open access NMS 60 actual replies to by using recently cached data stored in its cache 64. The process proceeds as follows.

1. The tenant NMS 62 has a MIB 61that defines valid SNMP GET and SET messages;
2. The tenant NMS 62 creates an SNMP message that fits one of the MIB 61 entries;
3. The tenant NMS 62 sends the SNMP message to open access caching firewall NMS 60;
4. The open access caching firewall NMS 60 receives the SNMP message with its SNMP agent;
5. The incoming message is identified with the IP address of the originating tenant NMS 62;
6. The SNMP agent uses the tenant identification and SNMP address to look up the validity of the message;
7. The message is valid, so the open access SNMP agent 60 then checks for a recent copy of the same information in its data base or cache 62;
8. Noting that the request information exists with a recent update in the cache 62, the open access SNMP agent then formulates an SNMP reply with the information; and
9. The open access caching firewall 60 function then sends the response on to the tenant NMS 62 that originated the transaction.

Fig. 10 illustrates a messaging scenario where tenants 62 may gather large blocks of data from the open access NMS 60 without the overhead of SNMP messaging. In particular, the open access NMS 60 maintains a database of recently gathered SNMP data, such as in its cache 64. This recently gathered data can come from keeping cached copies of SNMP GETS made by tenant NMS 62or by SNMP GETs made by the open access NMS 60. In some cases, the open access NMS 60 will make SNMP requests autonomously, typically solely for the purpose of keeping its cache 64 current.

In the Fig. 10 process:

1. Tenant NMS 62 has database query scripts written to gather data efficiently;
2. Tenant NMS 62 creates a valid database query message;
3. Tenant NMS 62 sends the query message to the open access caching firewall 60;
4. The open access caching firewall 60 receives the query message, such as with a database server 66;
5. The incoming message is identified with the IP address of the originating tenant NMS 62;
6. The database server 66 uses the tenant identification and query to check the validity of the database access message; and
7. If the message is valid, the open access database server 66 sends data back to the tenant NMS 62 that originated the query.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A system comprising:

a first tenant base station operated by a first wireless communication service provider;

a second tenant base station operated by a second wireless communication service provider, and co-located with the first base station;

a transport medium interface for converting radio frequency signals transmitted by the first and second base stations and control messages relating thereto to a common transport medium;

a plurality of remotely located radio access nodes, each radio access node associated with a predetermined portion of a total system coverage area, and each radio access node coupled to receive signals from the common transport medium, with each radio access node containing at least a first and second tenant slice module associated with the respective first and second tenant base stations; and

a first tenant network management system operated by the first wireless communication service provider;

a second tenant network management system operated by the second wireless communication service provider;

a common network management system that forwards control messages from the respective tenant network management system to the intended tenant slice modules associated with respective ones of the radio access nodes using the shared transport medium.

2. A system as in claim 1 where in the common network management system additionally filters forwarded messages to limit access by tenants to

status and control information associated only with radio access node equipment operated by other tenants.

3. A system as in claim 2 wherein the common network management system further comprises:

a statefull firewall configured such that the common network management system appears to be an agent for interfaces ot tenant network management systems, but appears as a client to open access system elements

4. A system as in claim 3 wherein the statefull firewall additionally comprises:

a management information block for maintaining configuration information that defines access privileges that a particular tenant client may have.

5. A system as in claim 1 wherein the common network management system additionally comprises:

a local database store containing information from poll and status information requests that the common network management system originates.

6. A system as in claim 5 wherein the common network management system additionally comprises:

a poll and status request message interceptor, which intercepts messages from the tenant network management systems intended for the radio access nodes and attempts to respond from information contained in the local database.

7. A method for providing multiple wireless communication service providers with access to radio equipment distributed throughout a coverage area, the method comprising the steps of:

accepting requests for distribution service from multiple tenant service providers, the requests specifying a desired air interface for wireless communication from among a plurality of available air interfaces, and an indication of which portions in the coverage area the particular air interface is to be supported;

providing communication network connections to network management system equipment for operating and controlling the base stations equipment as provided by the multiple tenant service providers;

a plurality of remotely located radio access nodes, each radio access node associated with a predetermined portion of a total system coverage area, and each radio access node coupled to receive signals from the common transport medium, with each radio access node containing at least a first and second tenant slice module associated with the respective first and second tenant service providers;

installing, at a central location, a common network management system for intercepting control message traffic from and to the network management systems operated by the multiple wireless service providers intended to control to radio access nodes, and routing such messages to a common control message handler.

8. A method as in claim 7 wherein the common control message handler is a shared transport medium over which control messages are routed to the radio access nodes.

9. A method as in claim 7 wherein the common control message handler is process comprising the steps of:

sending generic status query messages to the radio access nodes;

storing, in a local information database, responses to the generic status query messages; and

in response to control message originating from one of the tenant network management systems, obtaining status information from the local database.

10. A system comprising:

a first tenant network access device specified by a first communication service provider;

a second tenant network access device specified by a second communication service provider;

a transport medium interface for converting radio frequency signals transmitted by the first and second base stations and control messages relating thereto to a common transport medium;

a plurality of remotely located network access nodes, each network access node associated with a predetermined portion of a total network system coverage area, and each network access node coupled to receive signals from the common transport medium, with each network access node containing at least a first and second tenant slice module associated with the respective first and second tenant networks; and

a first tenant network management system operated by the first communication service provider;

a second tenant network management system operated by the second communication service provider;

a common network management system that forwards control messages from the respective tenant network management system to the intended tenant slice modules associated with respective ones of the network access nodes using the shared transport medium.

11. A system as in claim 10 where in the common network management system additionally filters forwarded messages to limit access by tenants to status and control information associated only with network access node equipment operated by other tenants.

12. A system as in claim 10 wherein the common network management system further comprises:

a statefull firewall for filtering messages such that the common network management system appears to be an agent for interfaces of tenant network management systems, but appears as a client to open access system elements.

13. A system as in claim 12 wherein the statefull firewall additionally comprises:

a local data store for maintaining configuration information that defines access privileges that a particular tenant client may have.

14. A system as in claim 10 wherein the common network management system additionally comprises:

a local database for storing data taken from poll and status information requests originated by the common network management system.

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00873

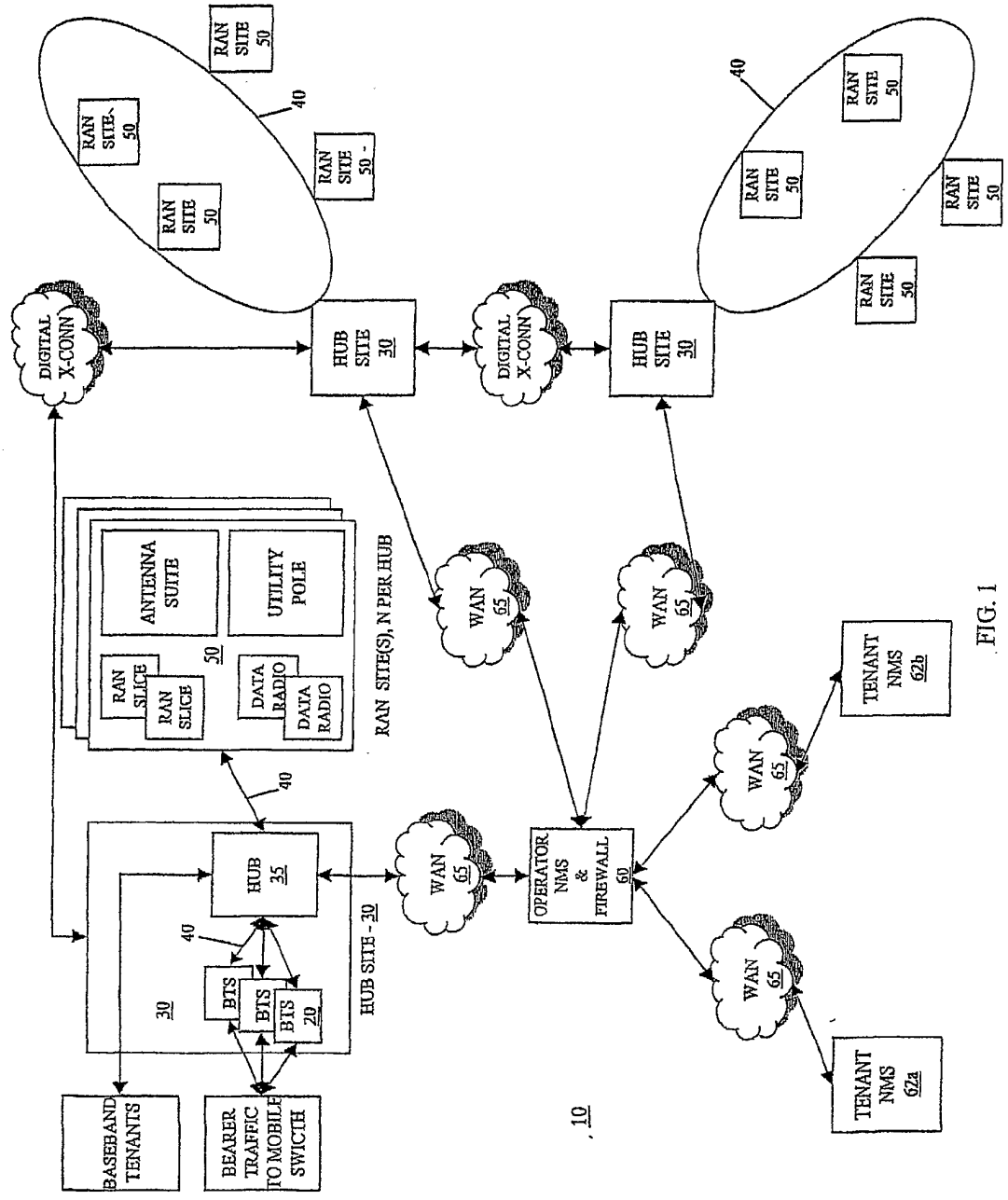


FIG. 1

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00874

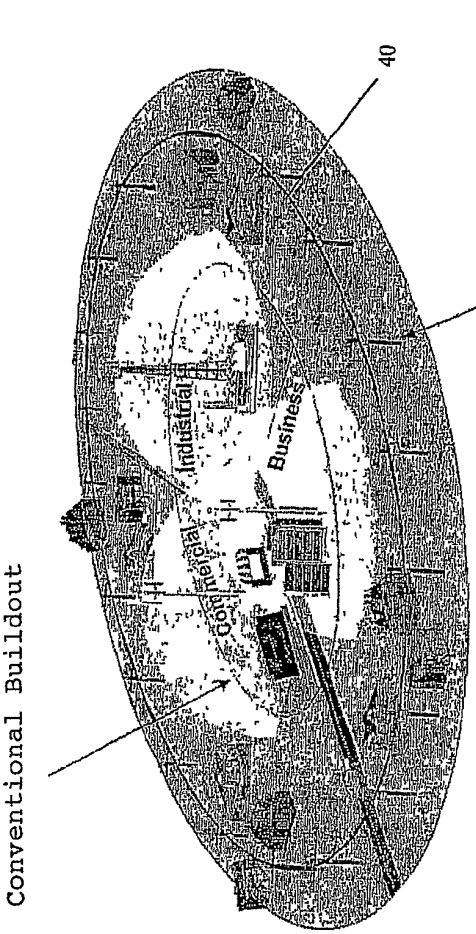


FIG. 2

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00875

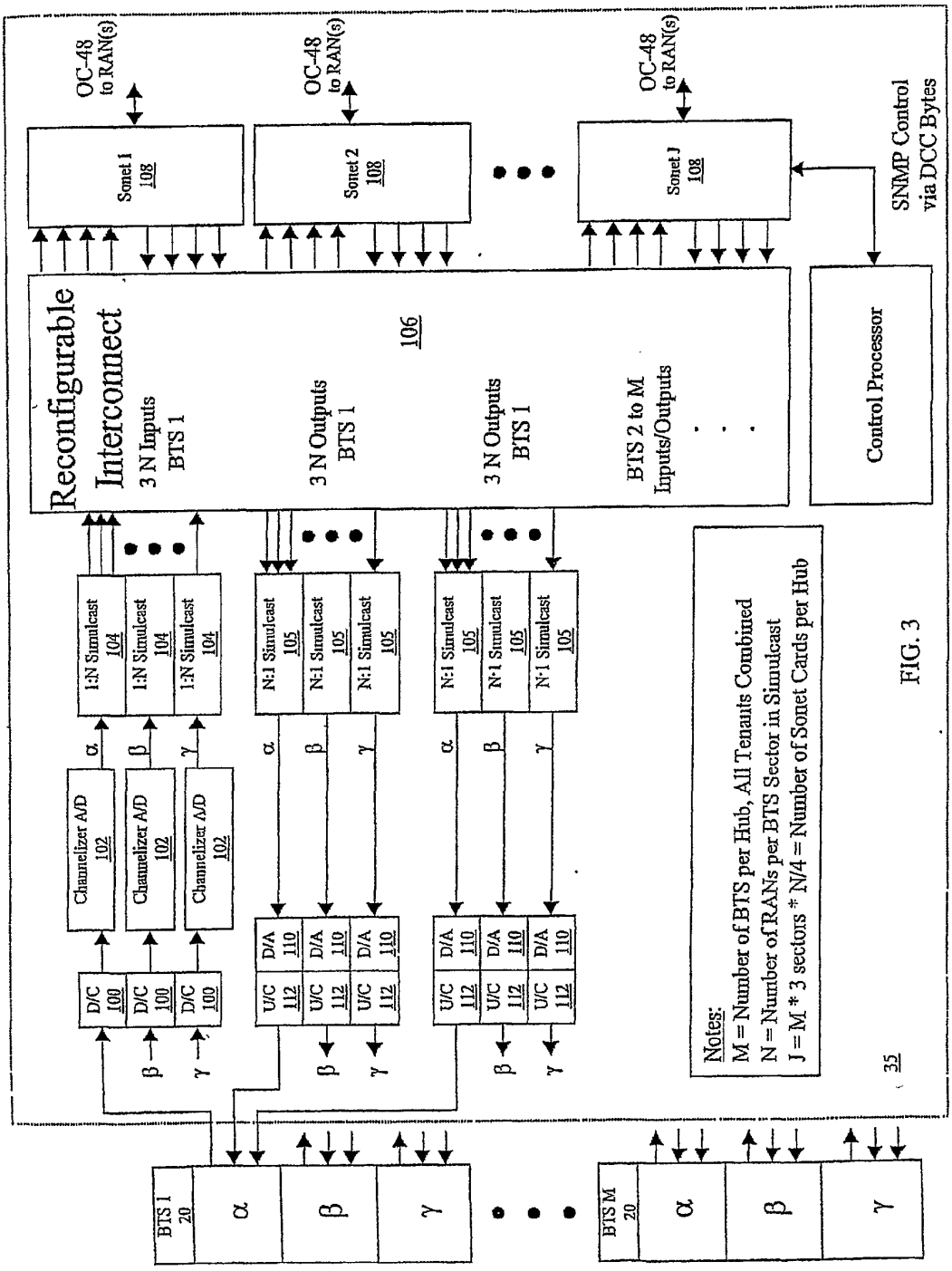


FIG. 3

SUBSTITUTE SHEET (RULE 26)

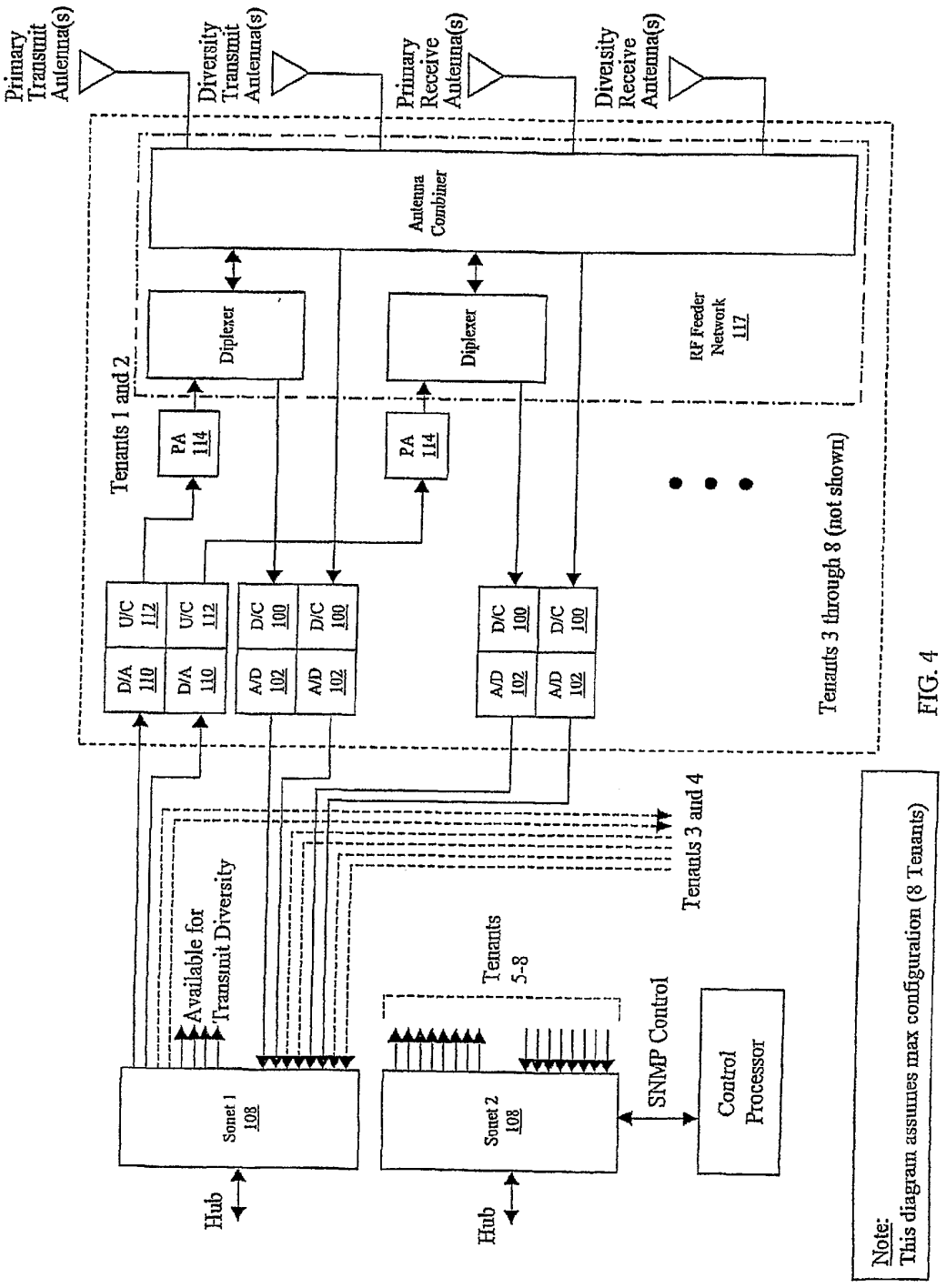


FIG. 4

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00877

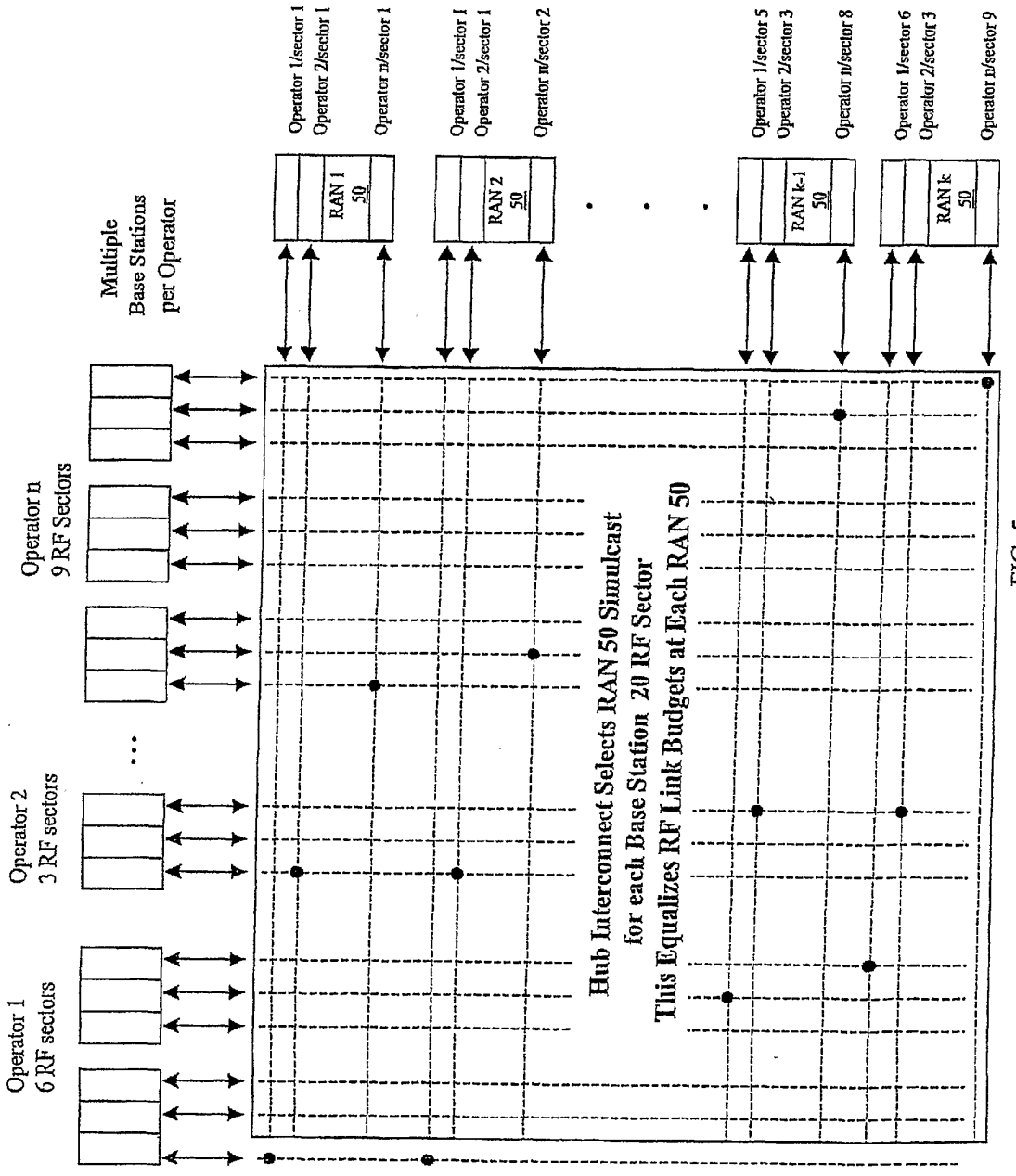


FIG. 5

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00878

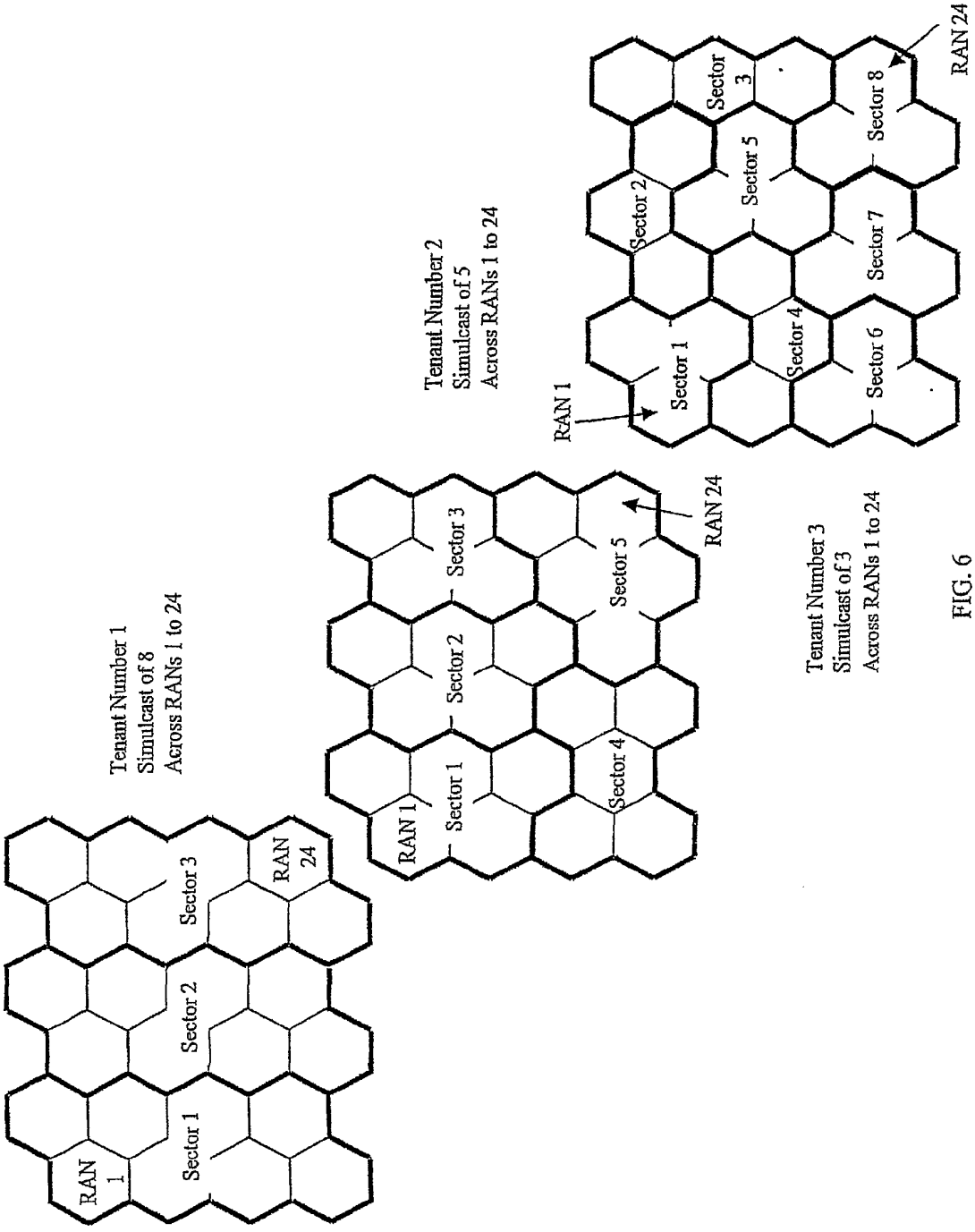


FIG. 6

EX-1002
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00879

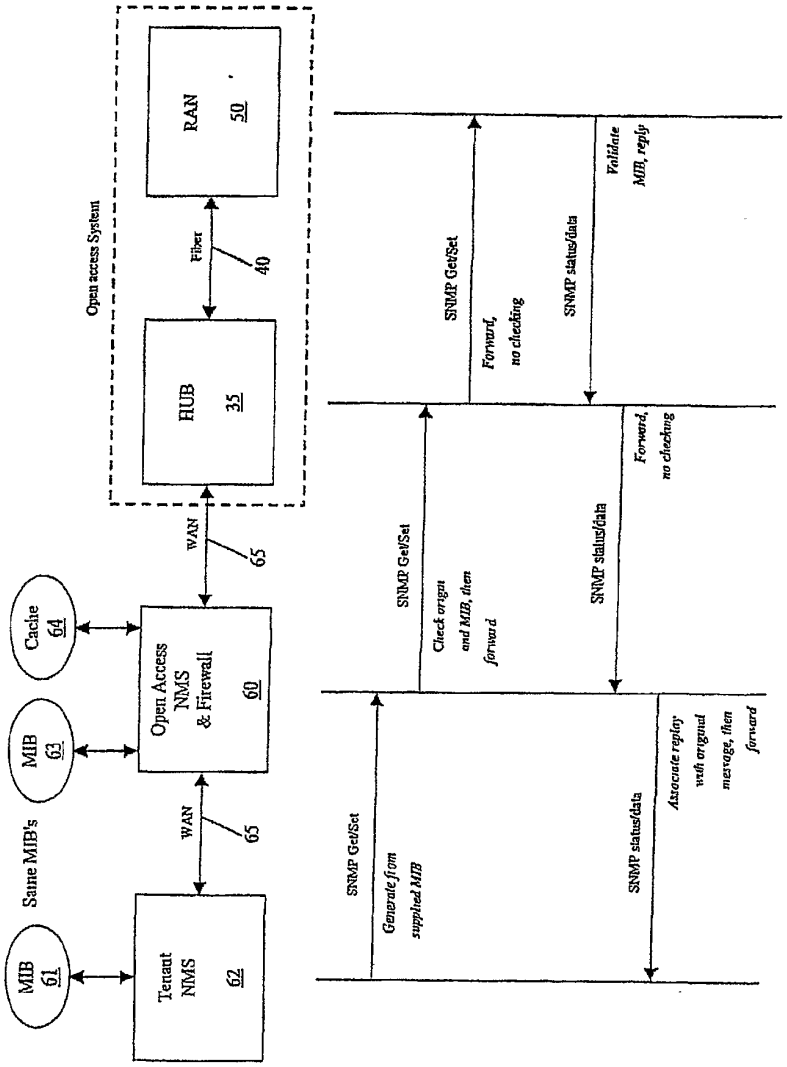


FIG. 7

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00880

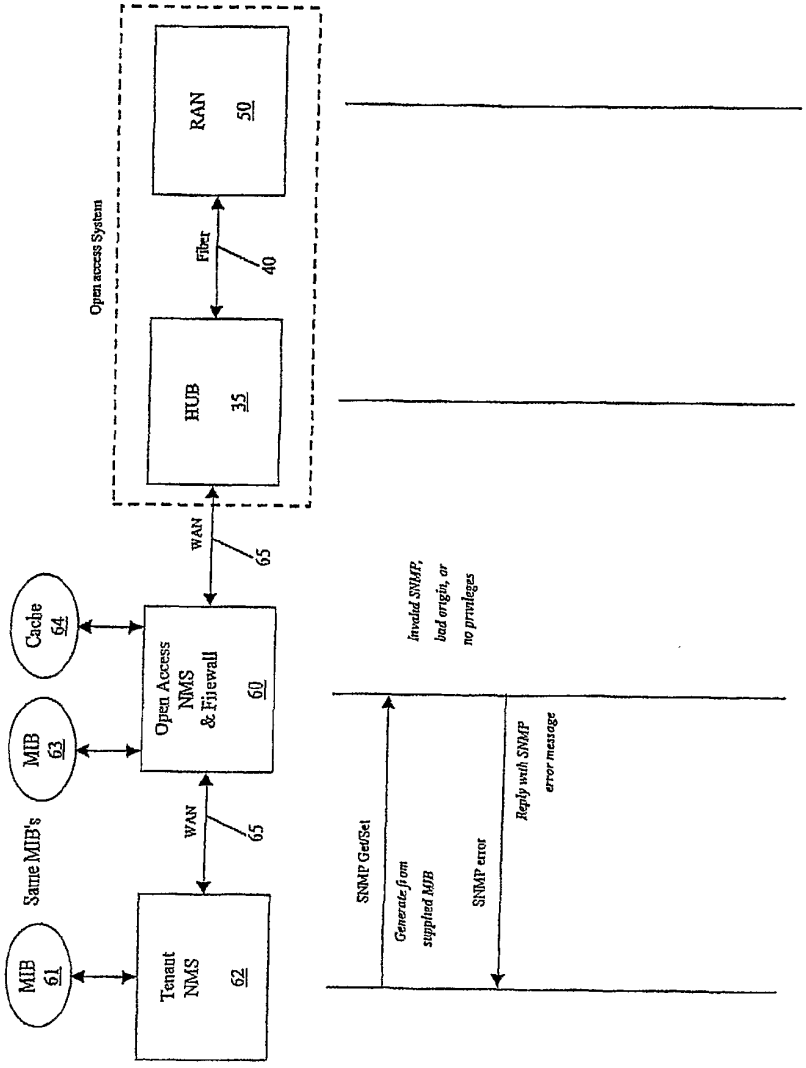


FIG. 8

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00881

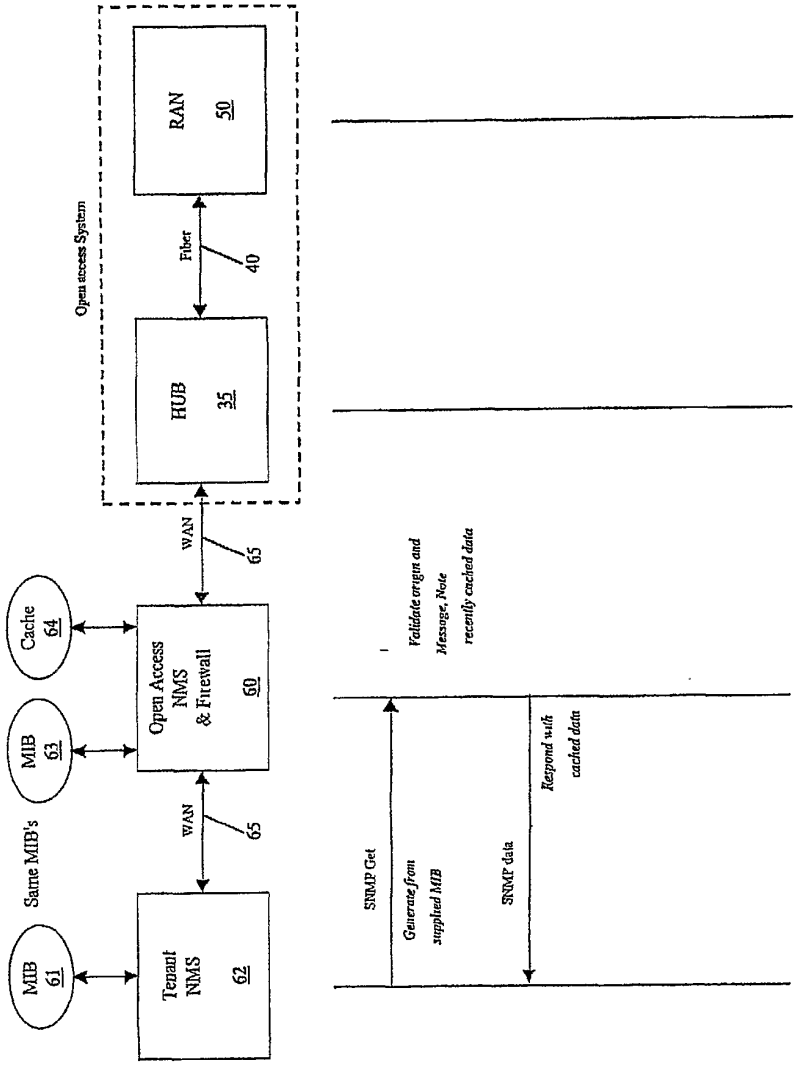


FIG. 9

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00882

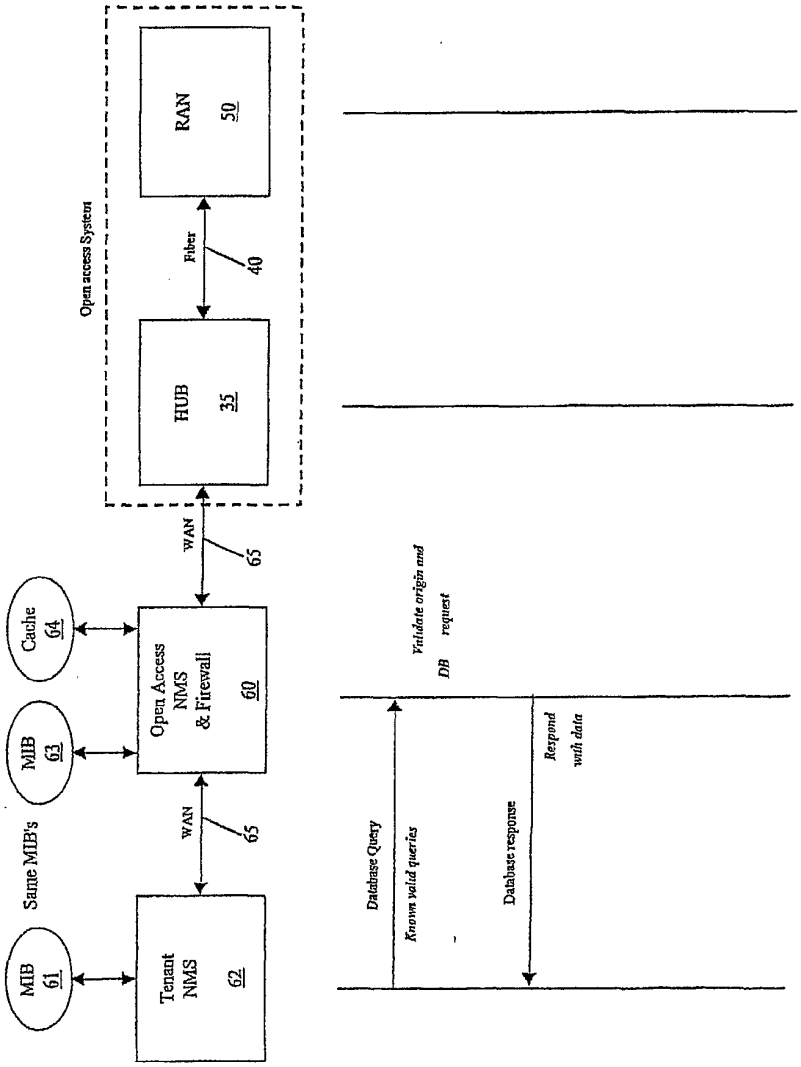


FIG. 10

EX-1002
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00883

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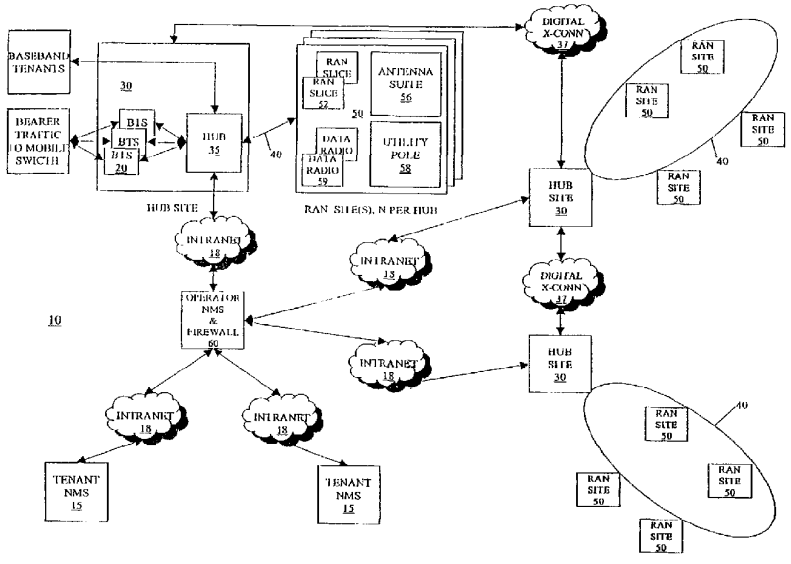
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(54) Title: MULTI-PROTOCOL DISTRIBUTED WIRELESS SYSTEM ARCHITECTURE



(57) Abstract: An open access signal distribution system in which a variety of wireless voice, data and other services and applications are supported. The open access system makes use of a distributed Radio Frequency (RF) distribution network and associated network entities that enable the system operator to employ a wireless infrastructure network that may be easily shared amoung multiple wireless service providers in a given community. The open access system provides the ability for such operators and service providers to share the infrastructure regardless of the specific RF air interface or other signal formatting and/or managing messaging formats that such operators choose to deploy.

WO 01/74100 A1

MULTI-PROTOCOL DISTRIBUTED WIRELESS SYSTEM ARCHITECTURE

BACKGROUND OF THE INVENTION

The wireless telecommunication industry continues to experience significant growth and consolidation. In the United States, market penetration is near 32 % with approximately 86 million users nationwide. In 1999 the total number of subscribers increased 25% over the previous year, with the average Minutes of Use (MOU) also increasing by about 20% per user. If one considers growth in the digital market, in as short as three years, the digital subscriber base has grown to 49 million users, or approximately equal to the installed number of users of analog legacy systems. Even more interesting is an observation by Verizon Mobile that 70% of their busy hour traffic (an important system design parameter) is digital traffic, although only approximately 40% of the total number of their subscribers are digital users. The Verizon Mobile observation indicates the digital subscriber will drive the network design through its increasing usage, whereas the analog user is truly a passive "glovebox" subscriber.

Similar growth has been witnessed in other countries, especially in Northern and Western Europe, where market penetration is even higher, approaching 80% in some areas, and digital service is almost exclusively used.

With the availability of Personal Communications Service (PCS) frequencies in the United States, and additional continuing auctions of spectrum outside of the traditional 800-900 MegaHertz (MHz) radio band, the past few years have also seen increased competition among service providers. For example, it has also been

estimated that 88% of the US population has three or more different wireless service providers from which to choose, 69% have five or more, and about 4% have as many as seven service providers in their local area.

In 1999 total wireless industry revenue increased to $43B, representing an approximate 21% gain over 1998. However, a larger revenue increase would have been expected given the increased subscriber count and usage statistics. It is clear that industry consolidation, the rush to build out a nationwide footprint by multiple competing service providers, and subsequent need to offer competitive pricing plans has had the effect of actually diminishing the dollar-per-minute price that customers are willing to pay for service.

These market realities have placed continuing pressure on system designers to provide system infrastructure at minimum cost. Radio tower construction companies continue to employ several business strategies to serve their target market. One approach, their historical business strategy, is build-to-suit (i.e., at the specific request and location as specified by a wireless operator). But some have now taken speculation approach, where they build a tower and then work with local government authorities to force new service providers to use the already existing towers. This speculation build approach, spawned by the zoning by-law backlash, is actually encouraged by communities to mitigate the "unsightly ugliness" of cellular phone towers. This is seemingly the best alternative, since Federal laws no longer permit local zoning authorities to completely ban the deployment of wireless infrastructure in a community. Often the shared tower facility is zoned far removed from residential areas, in more commercialized areas of town, along heavily traveled roads, or in more sparsely populated rural sections. But providing such out of the way locations for towers often does not fully address each and every wireless operator's capacity or coverage need.

Each of the individual wireless operators compete for the household wireline replacement, and as their dollar-per-MOU is driven down due to competition in the "traditional" wireless space, the "at home" use is one of the last untapped markets.

As the industry continues to consolidate, the wireless operator will look for new ways to offer enhanced services (coverage or products) to maintain and capture new revenue.

Considering the trends that have appeared over recent years, when given the opportunity to displace the household wireline phone with reliable wireless service, a wireless service operator may see their average MOUs increase by a factor of 2 to 4, thereby directly increasing their revenue potential 200 to 400%. In order to achieve this, the wireless operator desires to gain access throughout a community as easily as possible, in both areas where wireless facilities are an allowed use and in where they are not, and blanket the community with strong signal presence.

SUMMARY OF THE INVENTION

Certain solutions are emerging that provide an alternative to the tower build out approach. In particular, wireless signal distribution systems employ a distribution media such as a cable television infrastructure or optical fiber data network to distribute Radio Frequency (RF) signals. This allows the capacity of a single base station to be distributed over an area which is the equivalent of multiple traditional cellular sites without degradation in coverage or call quality.

However, even these systems have a shortcoming in that they are typically built out for one selected over the air protocol and are controlled by a single service provider. Thus, even with such systems as they are presently known, it becomes necessary to build out and overlay multiple base stations and multiple signal distribution networks for multiple service providers.

The present invention is an open access signal distribution system in which a variety of wireless voice, data and other services and applications are supported. The open access systems makes use of a distributed Radio Frequency (RF) distribution network and associated network entities that enable the system operator

to employ a wireless infrastructure network that may be easily shared among multiple wireless service providers in a given community. The open access system provides the ability for such operators and service providers to share the infrastructure regardless of the specific RF air interface or other signal formatting and/or managing messaging formats that such operators choose to deploy.

In one configuration, the present invention consists of a system in which a base station interface located at a central hub location converts radio frequency signals associated with multiple base stations, of the same or even different wireless service providers, to and from a transport signaling format. A shared transport medium, such as a fiber optic data network or the like is then used for transporting the converted signals from the hub location to a number of remote access node locations.

The access node locations each have Radio Access Node equipment located therein. The Radio Access Nodes (RANs) are each associated with a particular coverage area. The RANs have within them a number of slice modules, with each slice module containing equipment that converts the radio signals required for a particular service provider to and from the transport signaling format.

In a preferred embodiment, the transport medium may be an optical fiber telecommunications network such as provided through the SONET type digital frame formatting. In such a configuration, the SONET data formatting is arranged so that certain data frames are associated with the slices in a given Radio Access Node on a time slotted basis. In such a configuration, signal down converter modules convert the radio frequency signals associated with each base station to an Intermediate Frequency (IF) signal. Associated analog to digital (A/D) modules also located at the hub then convert the Intermediate Frequency signals to digital signals suitable for handling by a transport formatter that formats the converted digital signals to the proper framing format for the SONET digital transport.

Other transport media may be used such as Internet Protocol (IP) over Digital Wavelength Division Multiplexing (DWDM).

In one other aspect the invention concerns the aggregation of different Radio Frequency (RF) signaling formats onto a common transport mechanism. In this embodiment, a first and second base station operate according to respectively, first and second different wireless system air interfaces. A transport medium interface converts the radio frequency signals transmitted by the first and second base stations to a common transport medium. The first and second base station may optionally also be operated under the control of two different service providers. In this arrangement, a plurality of remotely located Radio Access Nodes (RANs) each provide radio signal coverage to a predetermined portion of a total system coverage area. Each Radio Access Node is coupled to receive signals from the common transport medium. Each Radio Access Node also contains a first and second slice module associated with the respective one of the first and/or second base station. Each slice module contains a suite of radio transmitter, amplifier and antenna equipment as required by its associated air interface.

In another aspect the present invention concerns equalizing power levels of Radio Frequency signals radiated by the Radio Access Nodes at levels appropriate for respectively different air interfaces. In particular, in such a system a first and second base station are located at a central location and operate according to respectively different wireless system air interfaces. A transport medium interface converts the Radio Frequency signals transmitted by the first and second base stations to a common transport medium signaling format. At a plurality of remote locations Radio Access Nodes (RANs) are located. Each Radio Access Node is coupled to receive signals from the common transport medium. Each Radio Access Node contains at least a first and second slice module that is associated with and responsible for converting signals associated with the first and second base stations.

In this instance, the invention includes means for equalizing the receive sensitivities of the Radio Access Nodes at levels for the appropriate for the

respectively different air interfaces, such as by managing the number of RANs in simulcast depending upon the particular air interface.

This configuration permits for example, the deployment for the set of shared RANs at common RAN remote locations without having to deploy multiple RAN locations for different air interfaces even when such air interfaces have different receive sensitivities and coverage distances. Thus the Radio Access Nodes for two or more different air interfaces may be co-located throughout the coverage system area reducing the overall system build out requirements.

In yet another aspect, the present invention is a method for providing access to radio equipment distributed throughout a coverage area to multiple wireless communication service providers. This method involves the steps of accepting requests for radio signal distribution service from the service providers, the request specifying a desired air interface and an indication of which portions of a coverage area the particular air interface is to be supported. The service provider then installs common base station equipment operating with the air interface specified by the service provider at a central location with the base station equipment being co-located with base station equipment specified by other wireless service providers. The commonly located base station equipment is then coupled to receive traffic signals from a signaling network used by the wireless communication service provider, the signaling network carrying such transport formatted Radio Frequency signals over a common transport medium. A data processor then controls the connection of transport signal to specific Radio Access Nodes as specified by the wireless system operator.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The

drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

Fig. 1 is a block diagram of an open access system according to the invention.

Fig. 2 illustrates one possible deployment for the open access system.

Fig. 3 is a more detailed diagram of a hub signal path for the open access system.

Fig. 4 is a more detailed diagram of a Radio Access Node signal path.

Fig. 5 shows one example of a calculation to determine how simulcast operation can be coordinated to equalize a reverse link budget and provide balancing with a forward link budget.

Fig. 6 is a more detailed view of a cross connect providing for the ability to connect multiple base stations for different wireless operators to a network of Radio Access Nodes.

Fig. 7 is a diagram illustrating how RAN slices may be allocated to different tenants and sectors in simulcast.

Fig. 8 is a more detailed view of one possible configuration for the hubs and RANS over which both the transport traffic signals and control signaling may be carried.

Fig. 9 is a detailed view of one possible antenna configuration.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Turning attention now to the drawings more particularly, Fig. 1 is a diagram of an open access system 10. The open access system 10 is an open access network supporting a multitude of wireless voice, data, video services and applications. Wireless Service Providers (WSP) and Wireless Internet Service (WISP) Providers, commonly known as tenants, may use open access system 10 to either enhance or replace existing networks, wired or wireless, or to develop new networks.

Open access system 10 is a multi-frequency, multi-protocol Radio Frequency (RF) access network, providing cellular, Personal Communication Services (PCS), and wireless data coverage via a distributed RF access system. Open access system 10 is comprised of base stations 20, located at hub sites 30. The base stations 20 are connected via high speed datalinks 40 to distributed RF access nodes (RANs) 50. The system 10 is, in effect, a signal distribution network and associated management entities that enable a network operator to deploy a wireless infrastructure network that may easily be shared among multiple wireless system operators in a given community. The open access network may be shared regardless of the specific RF air interface formatting and management messaging formats that each wireless operator chooses to deploy.

Figs. 2 depicts one possible deployment scenario for the open access system 10. As shown, the system consists of a multiple Radio Frequency (RF) Access Node 50 (RAN) units that may be located at relatively lower height locations such as utility poles. The open access network 10 distributes RF signals to and from the RANs, using a shared transport media 40 such as an optical fiber using high speed transport signaling. The physical deployment of the open access system is thus quite different from the higher radio towers required in a conventional system.

Returning attention to Fig. 1, the hub 35 provides the hardware and software interfaces between the high speed data link 40 and the individual wireless carrier base stations 20. The base stations 20 are considered to be original equipment manufacturer (OEM) type equipment to be provided and/or specified by the tenant 15 and are not provided as part of the open access system 10 itself. Hub 35 co-locates with the base stations 20 at a designated hub site 30. In a maximum configuration, a 3-sector base station 20 connects to 24 RAN Units 50, via an open access Hub 35. Hub 35 can be expanded to connect multiple base stations 20 (one or multiple wireless carriers) and their associated RAN Units 50.

RAN units 50 are distributed throughout a given community in accordance with the network operator's RF plan. RAN Units 50, along with associated antennas

56, are typically installed on utility poles 58, and connect to Hub Unit 35 via a fiber optic cable 40.

Network Management System 60 provides remote monitoring and control of the open access network by the network operator via the open access system 10. Network Management System 60 also allows for the network operator to pass selected control or status information concerning the open access network 10 to or from the individual wireless carriers or tenants. By "tenant" it is meant to refer to the wireless carrier, Wireless Service Provider (WSP), or other business entity that desires to provide wireless service to end customers.

The open access system 10 supports essentially any wireless protocol to be an open Access platform. In one configuration, open access system 10 supports the multiple 800/1900 MHz wireless service providers, and wireless data providers who require last mile access to their targeted customers, all at the same time. In another configuration, open access system 10 supports the lower frequency 400 and 700 MHz bands and the WCS/ISM/MMDS, U-NII wireless data bands.

In a preferred configuration, the open access network consists of radio access nodes (RAN) 50 distributed to achieve the desired RF signal presence and a hub 35 and high speed data link 40, which interconnects the base station RF signals with the RANs 50.

The distributed architecture is comprised of multi-protocol, frequency-independent radio access nodes 50. In the preferred embodiment at the present time, each RAN 50 supports from 1 to 8 operators, commonly referred to as tenants 15, of various protocols and frequencies. It should be understood that other configurations could support a smaller or greater number of tenants per RAN 50. Within each RAN 50, the wireless service provider "tenants" have typically leased space for the service provider to install corresponding individual radio elements in a RAN slice 52. RANs 50 connect to a centralized base station locale 30 where the tenants 15 connect to through an open access HUB 35 to the specific tenant's base station electronics. Each HUB 35 can scale to support one to three sectors of a base stations

20. It should be understood that base stations with a greater number of sectors 20 may also be supported.

RANs 50 are interconnected via fiber links 40 to centrally located HUB sites 30 and associated base stations 20. RANs 50 wide area distribution is logically a "horizontal tower" with access provided to a single "tenant" or shared amongst multiple tenants (wireless service providers). The generic architecture supports scaling from a single operator to supporting up to multiple operators across the multiple frequency bands per shelf. Multiple shelves may be stacked to serve additional tenants, as needed.

HUB 35 and RAN 50 network elements incorporate a System Network Management Protocol (SNMP) communication scheme to facilitate integration with the Host operator's network management system 60. This allows easy and complete communication across the open access system 10 with a high level of control and visibility.

Referring now to Fig. 3, an RF signal is transmitted from a BTS 20 to open access hub 35. The RF signal is of any bandwidth up to typically 15 MHz (future bandwidths may be greater) and follows the hub signal path as shown in Fig. 3. The signal is down converted to a 50 MHz (+/- 7.5 MHz) Intermediate Frequency (IF) signal by the down converter (D/C) 100. The IF signal is then converted to a 14 byte stream, at least at 42.953 Msps, by analog-to-digital (A/D) channelizer 102. Two control bits are added to the stream at a field programmable gate array (FPGA) within the A/D channelizer 102. The 16 byte stream, still at 42.953 Msps, is then serialized using 8B/10B encoding producing a 859 Mbps bit stream or an STS-12 type transport signal. The STS-12 signal is then distributed along a number of paths equal to the number of RANs in simulcast for each BTS sector. The STS-12 signal is preferably transmitted to the designated RAN Units 50 by interconnect 106 cross-connecting the STS-12 signal to a 4:1 multiplexer 108 that converts the STS-12 signal to an OC-48 signal. In a preferred embodiment, as shown in Fig. 1, a base station 20 located at any hub site 30 can transmit its associated signal to any RAN

Unit 50 using a digital cross-connect 37 connected between Hubs 35. In one example, lower rate signals (STS-3, 4, etc.) may be combined into higher rate shared transport signals (e.g. OC-192).

Referring to Fig. 4, the OC-48 signal enters a multiplexer 108 where the signal is converted from an OC-48 signal back to a STS-12 signal. The STS-12 signal is then digital-to-analog (D/A) converted to a 50 MHz (+/- 7.5 MHz) signal by the D/A Channelizer 110. The 50 MHz (+/- 7.5 MHz) signal is up converted 112 (U/C) to the required RF signal between. The RF signal is then power amplified (PA) 114 at its associated RF frequency and transmitted through diplexer 116 that couples transmit and receive signals to the same antenna. The RF signal is then radiated by the antenna.

Referring to Fig. 4, an RF signal is received by an antenna or antenna array and the signal is then down converted (D/C) 100 to a 50 MHz (+/- 7.5 MHz) signal. The RF signal is then converted to a 14 bit stream, at least at 42.953 Msps, in the (A/D) channelizer 102. Two control bits are added to the bit stream at a digital filter implemented in a Field Programmable Gate Array (FPGA) within the A/D channelizer 102. The 16 byte stream, at least at 42.953 Msps, is serialized using 8B/10B encoding producing a 859 Mbps bit stream or STS-12 signal. The STS-12 signal is then combined with the other tenant signals by a 4:1 multiplexer 108 that converts the STS-12 signal to an OC-48 signal. This signal is then transmitted to the designated open access hub 35.

Referring to Fig. 3, the OC-48 signal is received at the open access hub 35 at the multiplexer 108 that converts the OC-48 signal to a STS-12 signal. The STS-12 signal is then cross-connected through interconnect 106 to a designated BTS 20. The STS-12 signal is summed up to 8:, 1 with signals from other RANs in the same simulcast and is then D/A converted 110 to a 50 MHz (+/- 7.5MHz) IF signal. It should be understood that in other configurations, more than 8 signals could be summed together. The 50 MHz signal IF signal is the up converted (U/C) 112 to the

desired radio carrier and forwarded to the BTS 20. Providing for two receive paths in the system 10 allows for receive diversity.

The location of the RANs will be selected to typically support radio link reliability of at least 90% area, 75% at cell edge, as a minimum, for low antenna centerline heights in a microcellular architecture. The radio link budgets, associated with each proposed tenant 70, will be a function of the selected air protocol and the RAN 50 spacing design will need to balance these parameters, to guarantee a level of coverage reliability.

Because of differences in air interface performance and mobile unit transmit powers/receive sensitivities the open access system 10 requires additional design considerations. For example, an optimal RAN location grid spacing for an IS-136 TDMA protocol is not the same as for an IS-95 CDMA protocol.

To minimize the number of RANs 50, open access multi-protocol wireless infrastructure requires that all the participating wireless protocols share common geographic transmit/receive locations. These locations are referred to as shared RANs 50, and the distance at which they can be located from any serviceable mobile unit sets the nodes' maximum separation. However, this distance limit is different for each wireless protocol due to performance differences in their respective air interface power or link budgets. A simple, but non-optimum, approach is to determine the RAN 50 locations on the wireless protocol requiring the closest spacing (i.e. smallest RF link budget). The base stations 20 located at the central hub sites 30 are then optically connected to the co-located RAN sites 50 giving each protocol the same coverage footprint per base station sector. This approach is highly non-optimum for those protocols having larger link budgets and will yield heavily overlapped coverage areas. Similarly, basing RAN spacing on the larger link budget will yield coverage gaps for the weaker link protocols.

According to the present invention, differences between the wireless protocols' link budgets are equalized through simulcasting of multiple RANs sites

50. Simulcasting allows a wireless infrastructure provider to reduce the link budget of the RAN 50 for higher power protocols to match those of the others, while increasing the net coverage range of the associated base station sectors 20. A reduction in a RANs 50 link budget (and therefore coverage range) is offset by the increase in the number of RAN's 50 that can be simultaneously served by the associated base station sectors 20. This maintains the base station 20 coverage area for the protocols with a large link budget while maintaining the closer RAN 50 spacing required for those protocols with a small link budget. At the same time, the reverse link can be brought into balance with the forward link for a wide variety of forward RF carrier power levels.

Fig. 5 shows a simplified link budget for three example collocated protocols: IS-136 (TDMA), GSM 1900 and CDMA. It should be understood that the same principles apply to other wireless air interfaces such as: PEN, GSM, 3G (GPRS/EDGE), CDMA 2000, W-CDMA, etc. The protocol with the lowest intrinsic reverse link budget (IS-136) is balanced with the CDMA protocol through the use of a larger number of RANs in the simulcast group for CDMA. All of the protocols' simulcast is also collectively scaled to balance with the forward link. For a higher-power deployment than is shown in Fig. 5 (similar to that of a large tower) the least robust air interface typically uses a simulcast of one and all other air interfaces scale up from there. Since the illustrated scenario is for is a lower power microcellular build-out, all protocols use a non-unity simulcast. The forward transmit powers for each RF carrier are properly scaled to equalize the forward link budgets of the various protocols. Call capacity per geographic area is finally established by selecting the number of RF carriers based upon the final simulcast ratio.

The determination of parameters may proceed as follows.

Forward and reverse RF link budgets are first established for each of the wireless protocols of interest. At this point, simulcast is not entered as a factor into the analysis.

The wireless protocol with the smallest link budget is then identified and its coverage area and capacity are optimized.

The system build-out, lower power (and smaller size) power amplifiers are used to minimize cost and size of the installation. Simulcast of multiple RANs 50 is used to bring the forward and reverse paths in balance for the above identified wireless protocol. This establishes the allowable RF path loss and therefore the physical spacing for the shared RANs 50.

For each of the other collocated protocols, the number RANs 50 in simulcast are selected to match the baseline link budget established above. Each protocol will have a different simulcast number. The sensitivity at each RAN 50 will change as

$$10\log_{10} \text{(the number of RANs 50 in simulcast)}.$$

The forward transmit power levels are then adjusted to bring the forward and reverse paths into agreement.

The number of simultaneous RF carriers is selected for each protocol based upon the call capacity required in the geographic coverage area. Changing the number of carriers does not affect the link balance or the number of RANs 50 in simulcast.

Referring to Fig. 6, this type of infrastructure build-out requires a distributed RF system capable of cross-connecting multiple base stations 20 from different tenants or Wireless Service Providers (WSPs) to a network of RANs 50 using distribution ratios that differ for each wireless protocol. A network that does not support this aspect of the invention would simply connect the base station sectors for all the WSPs to the same complement of RANs 50. Sector 1/ WSP 1 through sector 1/ WSP n would all connect to the same RANs 50. Similarly, sector 2/ WSP 1 through sector 2/ WSP n connect to a different but common group of RANs 50.

Referring to Figs. 6 and 7, the system described by this invention selects a different simulcast scheme for each individual sector of each wireless operator and the total collection of RANs 50 distributed through a geographic coverage area. For example: Sector1/WSP1 does not necessarily connect to the same complement of RANs 50 as sector 1/WSP 2 through sector 1/WSP n. There may be only partial or even no overlap between the connectivity assignments due to the variable simulcast ratios across the differing protocols. Sector 2/WSP 1 not only does not fully overlap with sector 2/(WSP 2 through n) but also may also partially overlap with sector 1/ (2 though n) in RAN assignments.

Referring in particular to the example shown in Figs. 6 and 7, WSP or tenant 1 is operating with a CDMA protocol and therefore is simulcasting a group of 8 RANs within a total number of 24 RANs 50. Each RF sector is connected to a different grouping of 8 RANs. The illustrated drawing in Fig. 8 is for a group of 24 contiguous cells showing how the three tenants may share them.

Tenant 2 is operating with a simulcast group size of 5. Thus 5 different RANs are allocated to each of the 5 sectors for this tenant. Note that since simulcast number of 5 is not an integer divisor of the number of cells in the RAN group, that number being 24 in this example, sector 3 has only 4 cells allocated to it. Tenant 3 is operating with the simulcast group size of 3 and thus is operating with 8 sectors, each having 3 RANs associated with it.

The hub interconnect in Fig. 6 then selects RAN 50 simulcast groupings for each sector based upon the desired groupings desired for each tenant. This permits for equalization of the radio frequency link budgets in each RAN 50 group.

NMS 60 distributes individual alarms to the appropriate tenants, and maintains secure transmission for each tenant, whereas each tenant 15 is provided access to only their own respective system, for monitoring and control purposes. The open access product allows an operator to customize the RAN 50 RF parameter

settings to control the radio link environment, such as signal attenuation, gain, and other methods for strong signal mitigation.

In sector configuration of the system, the Hub/RAN ratio is configurable from 1 to 8 RANs per BTS sector. The RANs 50 is remote configurable through the open access operator's NMS 60, to support what is commonly referred to as sector re-allocation. The sector allocation is defined by the hosted wireless service provider's traffic loading analysis and controlled by the inputs from the specific tenant's NMS 15 via the open access system 10 intranet 18.

The actual RAN 50 cell radius will be largely a function of final antenna radiation center above ground.

Returning attention now to Figs. 1 and 2 briefly, in general, the data link uses one or more fiber optic connections between a hub 35 and one or more RAN's 50. Data link uses a mix of electrical multiplexing, wavelength multiplexing, and multiple fibers to support the bandwidth requirements of the configuration in a cost-effective manner. Data link design should optimize its cost by using the best combination of different multiplexing schemes based on physical fiber costs, leased fiber costs and technology evolution. Data link supports whole RF band transportation (digitized RF), IP packets, and other traffic as need for open access data transmission, system management and control.

The data link 40 connects a Hub 35 and multiple RAN's 50 using either a Ring or Star network topology, or possibly a mix of the two. In one configuration, open access system 10 should support up to, for either a ring or star topology, at least several miles of fiber length. The actual fiber lengths will be guided by optical path link budgets and specific RF protocol limits.

Referring to Fig. 8, in addition to combining digitized RF for common transport, this invention allows the combination of digitized RF with conventional packet data (e.g. IP Packets). This allows the concurrent support of packet driver

wireless radios 59 co-located at the RANs with RAN slices 52, the latter which support BTSs 20. The data radios 59 do not require a BTS 20 at the hub.

The data link is available to support connecting fixed wireless data radios 59 fitted in a RAN 50 to a centrally located router in HUB site 30. In one configuration, IP packet traffic provides 10Mbps, scalable up to 100 Mbps, to be shared amongst the multiple RAN data tenants. Networking architecture supports modularity and scalability for increased data rates. The data link supports multiple data radios at 1 to 25 Mbps data rates per data radio tenant.

Referring to Fig. 9, a utility pole antenna 86 is preferred as being unobtrusive and similar in dimension to the utility pole 80. Antenna 86 at least blends in with its immediate surroundings. The utility pole multi-band antenna 86 typically fits at least within a 12" diameter by 72" tall volume. The minimum pole height to the antenna base is typically at least 31 ft. agl.

In the system the multi-band antenna capability addresses 800, 1900, and at least provides volume for wireless data bands. In a preferred configuration, the antenna is multi-band and provides radiating aperture to cover all the listed bands such as, 800, 1900, WCS/ISM/MMDS and U-NII. Antenna design, antenna sizing and performance is specific for each deployment configuration.

The system configurations are modular and scalable from a single WSP application to a multi-WSP tenancy, for both the RF transceiver assemblies and the data link configurations. The system configurations have the ability to add tenants after initial install in one-tenant steps.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A system for distributing radio frequency signals in a physical area in which multiple wireless service providers wish to provide service, the system comprising:

a first plurality of wireless base stations collocated at a hub location, the base stations receiving and transmitted radio frequency signals, with at least two of such base stations operating with radio frequency signals according to two different air interfaces;

a base station interface, also located at the hub, for converting the radio frequency signals associated with the base stations to and from a transport signaling format;

a shared transport medium, for transporting the converted signals from the hub location to a plurality of remote access node locations;

a plurality of radio access nodes located at the remote access node locations, the radio access nodes each associated with a partial coverage area corresponding to only a portion of a total system coverage area, and the radio access nodes connected to the transport medium; and

the radio access nodes further each comprising:

a plurality of slice modules, with each slice module containing equipment for converting received radio frequency signals formatting according to a selected one of the air interfaces to the transport signal format and from the transport signal format to the selected one of the air interfaces.

2. A method as in claim 1 wherein the number of slice modules located in each partial system coverage area corresponding to the number of different service providers for which wireless communication service is to be provided in the respective partial system coverage area.

3. A system as in claim 1 wherein at least two of the base stations collocated at the hub are operated by wireless system service providers.

4. A system as in claim 1 wherein at least two of the base stations operate in respective different radio frequency bands.

5. A system as in claim 1 wherein at least two of the transmitted radio frequency signals are of two different bandwidths.

6. A system as in claim 1 wherein the shared transport medium is an optical fiber.

7. A system as in claim 6 wherein the shared transport medium uses a time slotted framing scheme.

8. A system as in claim 6 wherein the shared transport medium uses SONET formatting.

9. A system as in claim 8 wherein corresponding connection between a base station and a slice module is allocated a unique SONET frame.

10. A system as in claim 8 wherein the radio access nodes are arranged in a logical ring, and wherein the data frames associated with the slices in a given radio access node are dropped and added to the ring at the respective slice.

11. A system as in claim 7 wherein the time slotted frames are allocated to specific service providers.

12. A system for distributing radio frequency signals in a physical area in which multiple types of wireless communication service is to be provided, the system comprising:

a plurality of wireless base stations collocated at a hub location, the base stations receiving and transmitted radio frequency signals, with at least two of such base stations operating with radio frequency signals according to two different air interfaces as specified by at least two difference wireless service types;

a plurality of down-converter (D/C) modules, a down-converter associated with each of the collocated base stations, each down-converter converting the radio frequency signals transmitted by the respective base station to an intermediate frequency carrier signal;

a plurality of analog to digital (A/D) modules, also located at the hub, for converting the intermediate frequency signals to digital signals;

a simulcast transport formatter, for receiving digital signals from the A/D modules and converting them to a transport formatted signals;

a plurality of transport media, for carrying the transport formatted signals to remote access node locations;

a transport media distribution network, for coupling each of the transport formatted signals to a selected sub-set of the remote access node locations;

a plurality of radio access nodes located at the remote access node locations, the radio access nodes each associated with a partial coverage area corresponding to only a portion of a total system coverage area, and the radio access nodes connected to the transport medium, the remote access nodes arranged in a plurality of sub-networks; and

wherein a least one of the radio access nodes further comprises:

a plurality of slice modules, with each slice module containing equipment for converting received signals from the transport signal format to a selected one of the air interfaces.

13. A system as in claim 12 wherein

the number of slice modules located in at least one of the radio access nodes corresponds to a number of different service providers which are to provide service in the corresponding partial coverage area.

14. A system as in claim 12 wherein at least two of the base stations collocated at the hub are operated by two different wireless system service providers.

15. A system as in claim 13 wherein at least two of the slice modules in at least one of the radio access nodes contain equipment as specified by an air interface used by two different wireless system service providers.

16. A system as in claim 12 wherein at least two of the base stations operate in respective different radio frequency bands.

17. A system as in claim 12 wherein at least two of the transmitted radio frequency signals are of two different bandwidths.

18. A system as in claim 12 wherein the shared transport medium is an optical fiber.

19. A system as in claim 18 wherein the shared transport medium uses SONET formatting.

20. A system as in claim 19 wherein a corresponding transport connection between a base station and a slice module is allocated a unique SONET frame.

21. A system comprising:

a first base station generating radio frequency signals according to a first wireless system air interface;

a second base station generating radio frequency signals according to a second wireless system air interface;

a transport medium interface for converting radio frequency signals transmitted by the first and second base stations to a common transport medium format;

a shared transport medium, for transporting the converted radio frequency signals transmitted by the first and second base stations;

a plurality of remotely located radio access nodes, each radio access node associated with a predetermined portion of a total system coverage area, and each radio access node coupled to receive signals from the common transport medium, each radio access node containing at least a first and second slice module associated with the respective first and second base stations;

a first slice module containing a suite of radio transmitter, amplifier, and antenna equipment as specified by the first air interface; and

a second slice module containing a suite of radio transmitter, amplifier, and antenna equipment as specified by the second air interface.

22. A system as in claim 21 wherein at least two of the base stations operate in respective different radio frequency bands.

23. A system as in claim 21 wherein at least two of the transmitted radio frequency signals are of two different bandwidths.

24. A system as in claim 21 wherein the shared transport medium is an optical fiber.

25. A system as in claim 24 wherein the shared transport medium uses SONET formatting.

26. A system as in claim 25 wherein a corresponding transport connection between a base station and a slice module is allocated a unique SONET frame.

27. A system comprising:

a first base station operating according to a first wireless system air interfaces;

a second base station operated according to a second wireless system air interface;

a transport medium interface for converting radio frequency signals transmitted by the first and second base stations to a common transport medium;

a plurality of remotely located radio access nodes, each radio access node associated with a predetermined sub-area portion of a total system coverage area, and each radio access node coupled to receive signals from the common transport medium, each radio access node containing at least a first and second slice module associated with the respective first and second base stations; and

means for equalizing sensitivity levels of radio frequency signals radiated by the radio access nodes at levels appropriate for the respective different air interfaces.

28. A system as in claim 27 wherein the air interfaces are selected from the group consisting of AMPS, CDMA, and TDMA.

29. A system as in claim 27 wherein the means for equalizing sensitivity levels is a balanced simulcast such that radio access nodes for two different air interfaces may be collocated throughout the system coverage area.

30. A system as in claim 27 wherein the means for equalizing sensitivity levels further comprises:

means for determining which of the respective air interfaces requires a lowest intrinsic link budget level;

means for setting transmit power levels in a selected one of the radio access nodes depending upon such lowest intrinsic link budget level; and

means for simulcasting signals associated with other air interfaces for radio access nodes in adjacent sub-areas.

31. A system as in claim 27 wherein the radio access nodes further each comprise:

a plurality of slice modules, with each slice module containing equipment for converting received radio frequency signals formatting according to a selected one of the air interfaces to the transport signal format and from the transport signal format to the selected one of the air interfaces.

32. A method as in claim 27 wherein the number of slice modules located in each partial system coverage area corresponding to the number of different service providers for which wireless communication service is to be provided in the respective partial system coverage area.

33. A system as in claim 27 wherein the first and second base stations are operated by two different wireless system service providers.

34. A system as in claim 27 wherein the first and second base stations operate in respective different radio frequency bands.

35. A system as in claim 27 wherein the first and second base stations provide transmitted radio frequency signals of two different bandwidths.

36. A method for providing multiple wireless communication service providers with access to radio equipment distributed throughout a coverage area, the method comprising the steps of:

accepting requests for distribution service from the multiple service providers, the requests specifying a desired air interface for wireless communication from among a plurality of available air interfaces, and an indication of which portions in the coverage area the particular air interface is to be supported;

installing base station equipment operating with the air interface specified by the service provider at a central location, the base station equipment being collocated with base station equipment specified by other wireless service providers;

coupling the base station equipment to receive traffic signals from a signaling network used by the wireless communication service provider;

converting the signals transmitted by the base station to a common signaling format;

coupling the common signaling format signals to a common transport medium;

locating a plurality of radio access nodes through the system coverage area, with at least one radio access node located in each portion of the system coverage

area, the radio access nodes further containing radio equipment for receiving signals from the common transport medium and converting such signals to radio frequency signals; and

controlling, with a data processor, the connection of transport signals to specific radio access nodes as specified by the plurality of wireless system operators.

37. A system as in claim 36 wherein at least one of the radio access nodes further comprises:

a plurality of slice modules corresponds to a number of different service providers which are to provide service in the corresponding partial coverage area.

38. A system as in claim 36 wherein at least two of the slice modules in at least one of the radio access nodes contain equipment as specified by an air interface used by two different wireless system service providers.

39. A system as in claim 36 wherein at least two of the base stations operate in respective different radio frequency bands.

40. A system as in claim 36 wherein at least two of the transmitted radio frequency signals are of two different bandwidths.

41. A system as in claim 36 wherein the shared transport medium is an optical fiber.

42. A system as in claim 41 wherein the shared transport medium uses SONET formatting.

43. A system as in claim 42 wherein a corresponding transport connection between a base station and a slice module is allocated a unique SONET frame.

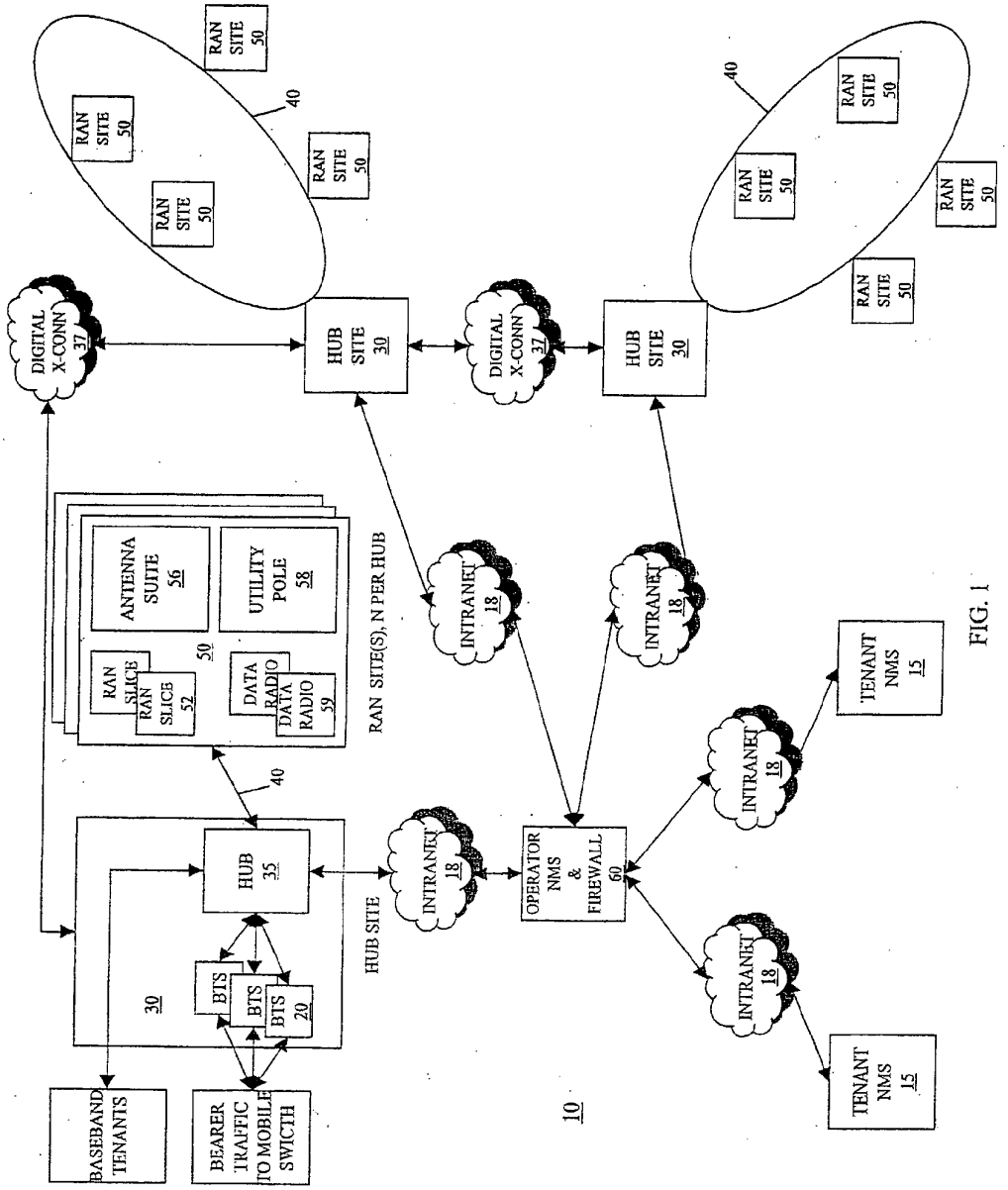


FIG. 1

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00910

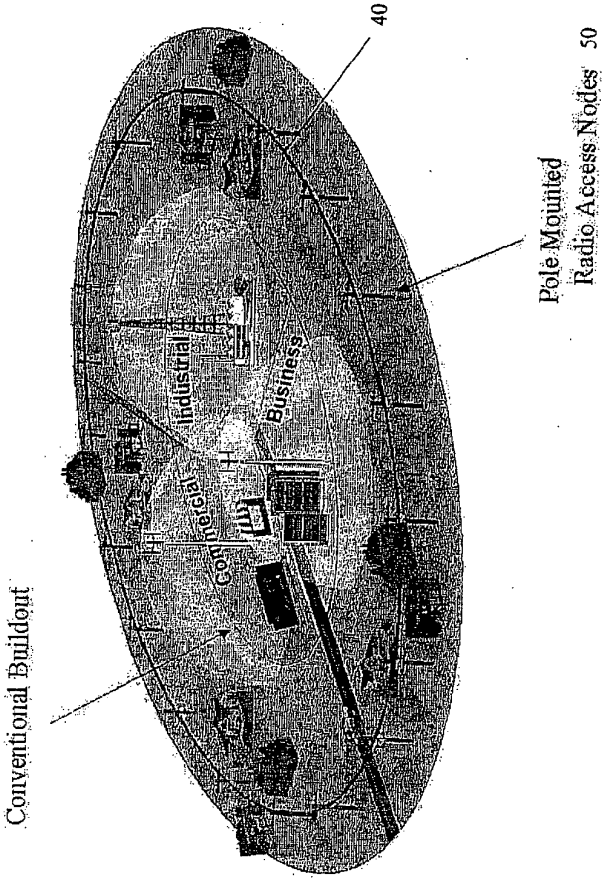


FIG. 2

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00911

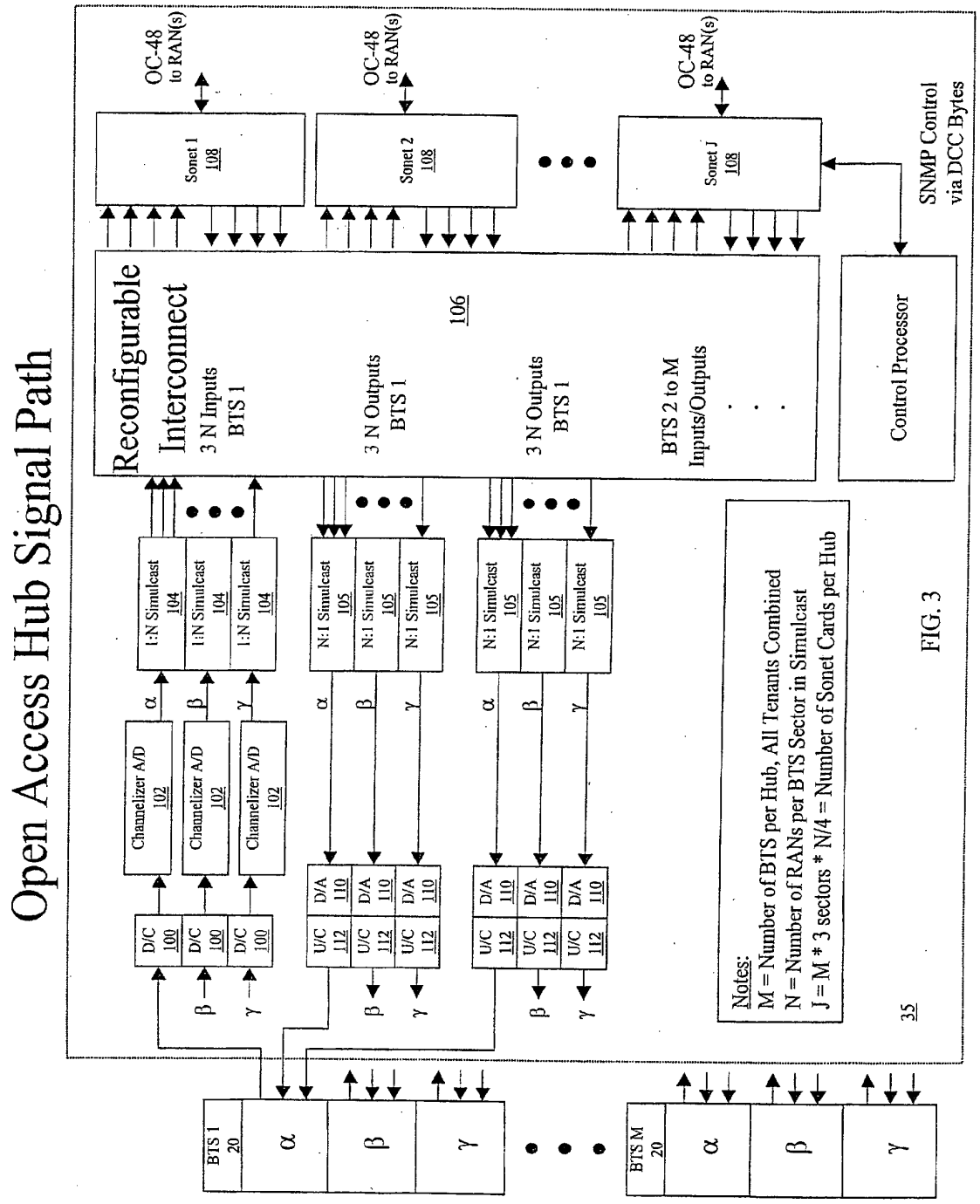


FIG. 3

SUBSTITUTE SHEET (RULE 26)

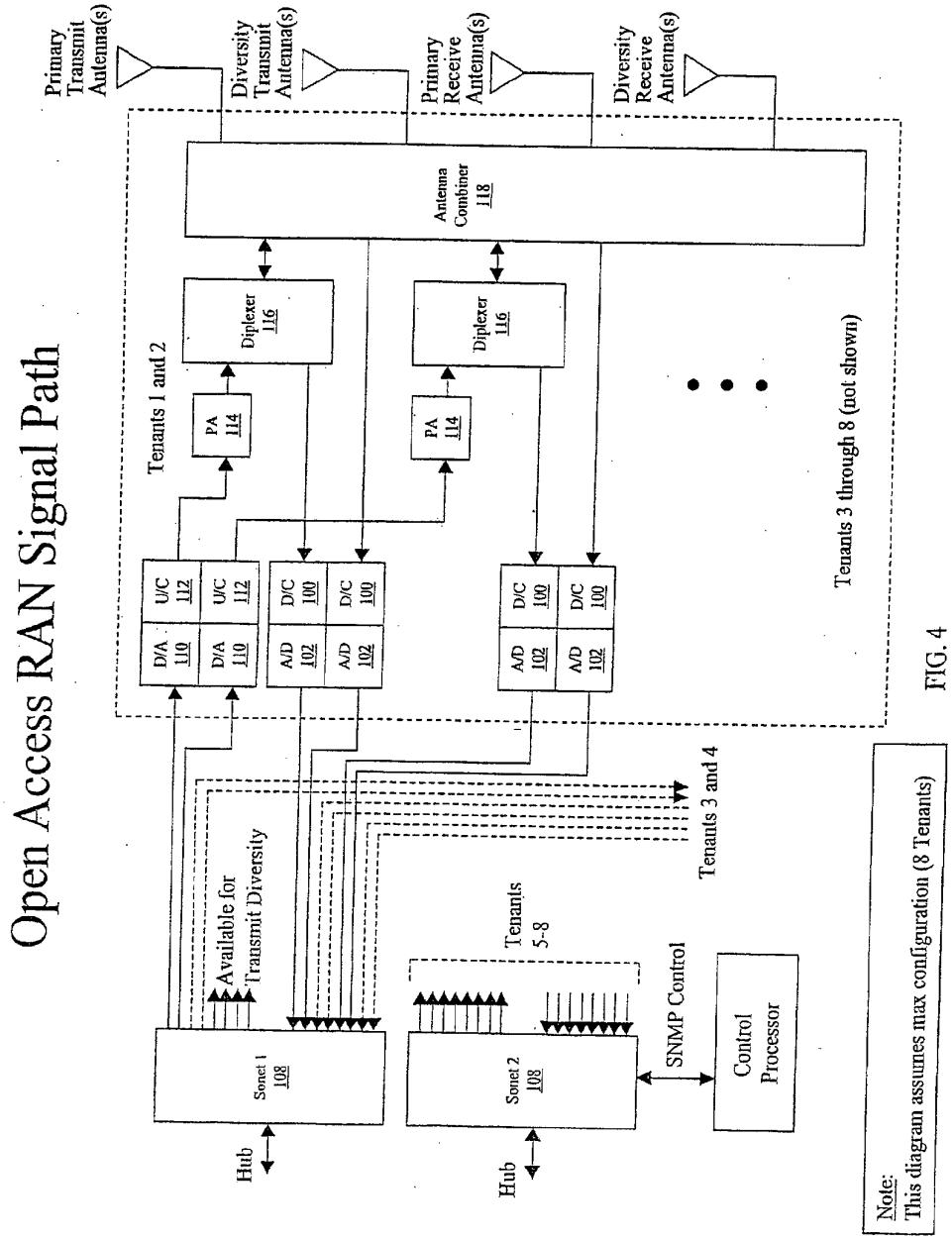


FIG. 4

EX-1002
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00913

Simulcast Varied to Equalize Reverse Link Budgets
and to Balance With Forward Link Budget

	CDMA	TDMA	GSM1900
Reverse Link			
Mobile Transmit Power	23 dBm	28 dBm	30 dBm
RAN Sensitivity	-120 dBm	-111 dBm	-110 dBm
Allowable Reverse Path Loss without Simulcast	143 dB	139 dB	140 dB
Number in Simulcast	8	3	4
Allowable Reverse Path Loss with Simulcast	134 dB	134 dB	134 dB
Forward Link			
RAN Transmit Power per Traffic Channel	20 dBm	32 dBm	32 dBm
Mobile Sensitivity less Interference Margin	-114 dBm	-102 dBm	-102 dBm
Allowable Forward Path Loss	134 dB	134 dB	134 dB

FIG. 5

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00914

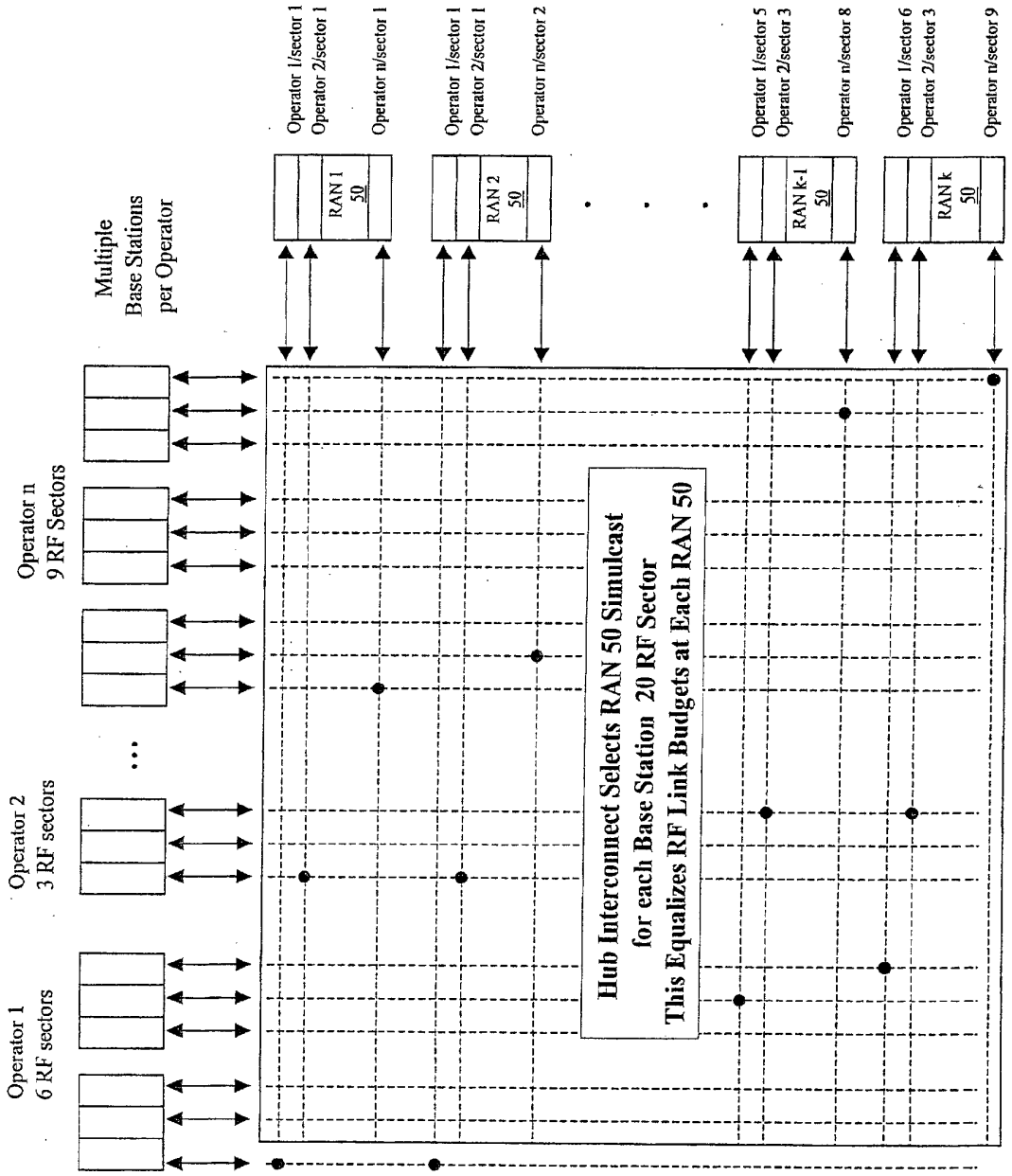


FIG. 6

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00915

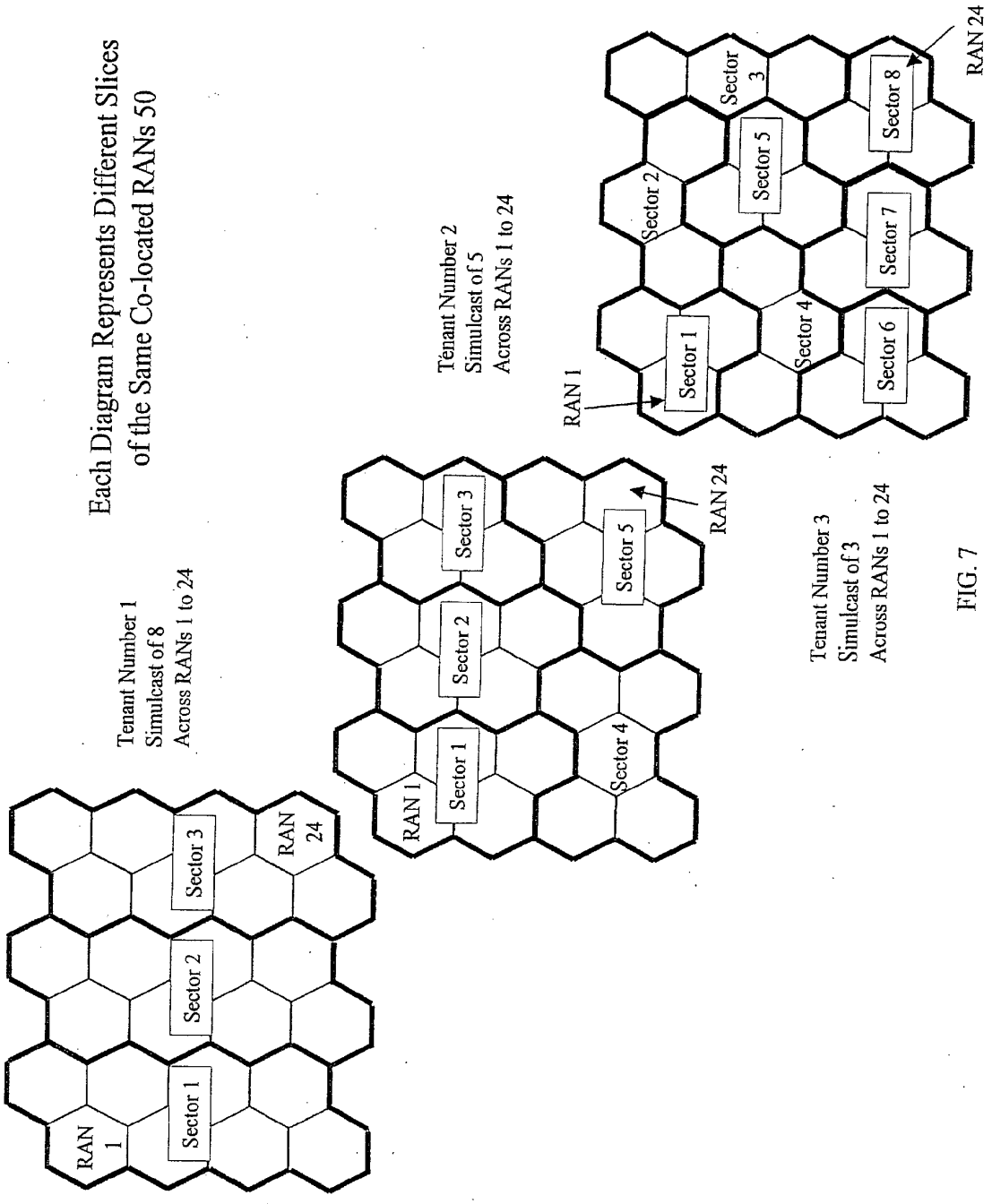


FIG. 7

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00916

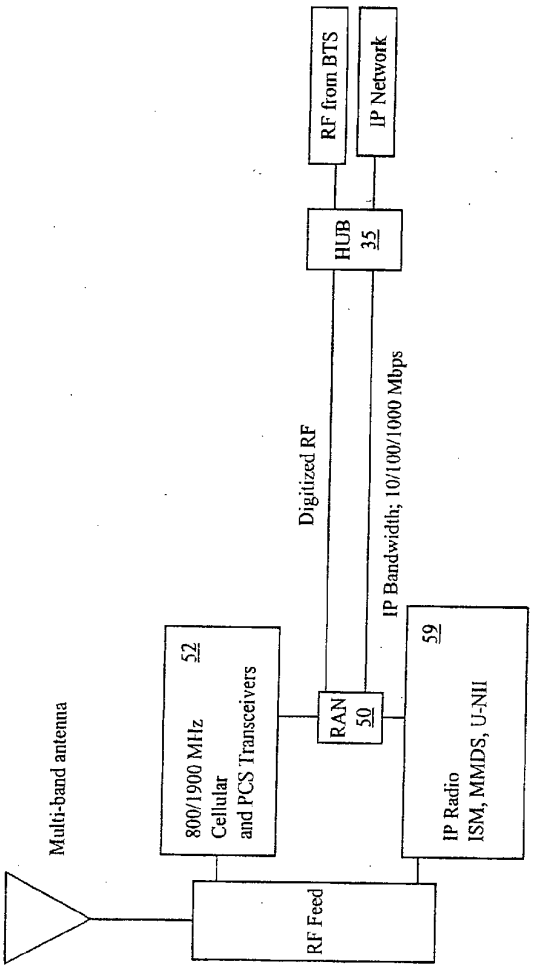


FIG. 8

EX-1002
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00917

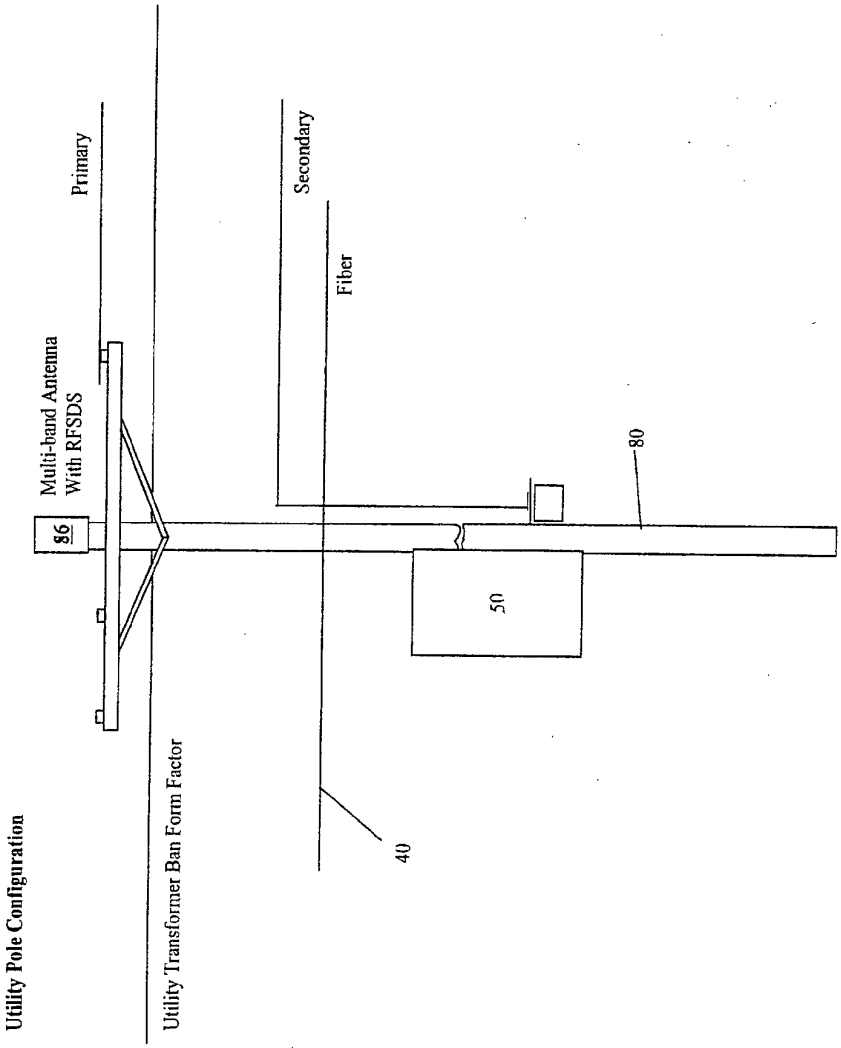


FIG. 9

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00918

INTERNATIONAL SEARCH REPORT

National Application No
PCT/US 01/09724

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 315 959 A (MOTOROLA) 11 February 1998 (1998-02-11)	1,4,5, 21-23, 27, 34-36, 39,40
Y	page 3, line 22 -page 12, line 11; figures	6,8,10, 24,25, 41,42

Y	EP 0 876 073 A (AT&T) 4 November 1998 (1998-11-04) page 3, column 3, line 13 -page 7, column 12, line 32; figures	6,8,10, 24,25, 41,42

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[X] Further documents are listed in the continuation of box C.

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EX-1002
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 33350 A (AIRNET) 7 December 1995 (1995-12-07) page 6, line 34 -page 18, line 37; figures	1,4,5, 21-23, 27,28, 31, 34-36, 39,40
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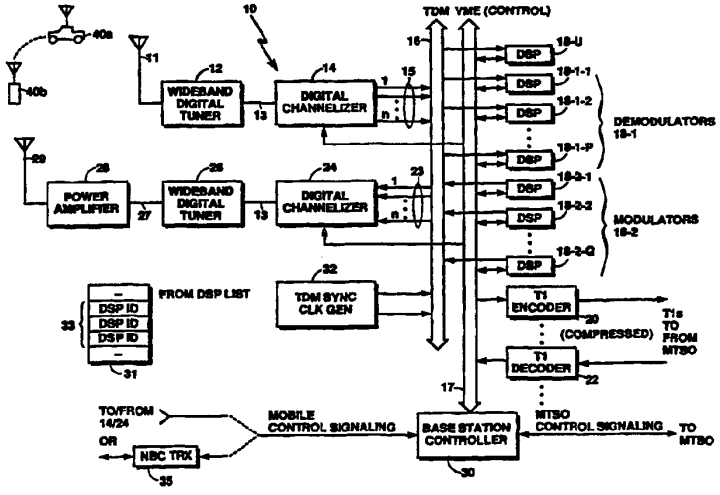
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(54) Title: WIDEBAND WIRELESS BASESTATION MAKING USE OF TIME DIVISION MULTIPLE-ACCESS BUS TO EFFECT SWITCHABLE CONNECTIONS TO MODULATOR/DEMODULATOR RESOURCES



(57) Abstract

A wireless communication system basestation making use of a wideband, multichannel digital transceiver having incorporated therein a time division multiple-access (TDM) bus for providing digital samples of a plurality of wireless communication channels, wherein the TDM bus is used as a crossbar switch to permit dynamic allocation of modulator and demodulator signal processing resources. The invention allows various air interface standards, even those having different channel bandwidths, to be serviced by the same basestation, with automatic redistribution of signal processing resources, eliminating the need to reconfigure the basestation when the loading of different types of wireless signaling traffic changes.

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WIDEBAND WIRELESS BASESTATION MAKING USE OF TIME DIVISION MULTIPLE-ACCESS BUS TO EFFECT SWITCHABLE CONNECTIONS TO MODULATOR/DEMODULATOR RESOURCES

FIELD OF THE INVENTION

This invention relates generally to communication networks, and in particular to a wireless communication system basestation making use of a wideband, multichannel digital transceiver having incorporated therein a time division multiple-access (TDM) bus for providing digital samples of a plurality of wireless communication channels, wherein the TDM bus is used as a cross-bar switch to permit dynamic allocation of modulator and demodulator signal processing resources.

BACKGROUND

The basestations used by the providers of current day multiple channel wireless communication services, such as cellular mobile telephone (CMT) and personal communication systems (PCS), typically designate signal processing equipment for each single receiver channel. This is probably a result of the fact that each basestation is configured to provide communication capability for only a limited predetermined number of channels in the overall frequency spectrum that is available to the service provider.

A typical basestation may thus contain several racks of equipment which house multiple sets of receiver and transmitter signal processing components that service a prescribed subset of the available channels. For example, in an Advanced Mobile Phone Service (AMPS) cellular system, a typical basestation may service a pre-selected number of channels, such as 48, of the total number, such as 416, of the channels available to the service provider.

Certain types of wireless service providers would prefer, however, to employ equipment that would be more flexible, both in terms of where it can be located, as well as in the extent of the available bandwidth coverage provided by a particular transceiver site. This is particularly true in rural areas where cellular coverage may be concentrated along a highway, and for which the limited capacity of a conventional 48 channel transceiver may be inadequate. This may also be true in other instances, where relatively large, secure, and protective structures for multiple racks of equipment are not necessarily available or cost effective, such as for PCS applications.

One way to resolve this difficulty is to implement a basestation transceiver using a high speed analog-to-digital (A/D) converter and equipment which makes use of efficient digital filtering algorithms such as the Fast Fourier Transform (FFT), to separate the incoming signal energy into multiple ones of the desired channels. On the transmit side, this basestation implementation includes an inverse FFT processing combiner which outputs a combined signal representative of the contents of the communication channel signals processed thereby. In this manner, relatively compact, lightweight, inexpensive, and reliable digital integrated circuits may be used to cover the entire channel capacity offered by the service provider, rather than only the subset of the available channels. For a more detailed description of such a system, please refer to our co-pending United States patent application entitled "Transceiver Apparatus Employing Wideband FFT Channelizer with Output Sample Timing Adjustment and Inverse FFT Combiner for a Multichannel Communication Network" filed April 8, 1994 and which is assigned to Overture Systems, Inc., the assignee of this application.

Thus unlike prior art basestations, the wideband digital basestation is capable of receiving any channel. While this provides a certain number of advantages as described above, it also poses a number of unique problems to the service provider.

Perhaps most importantly, there exists a need to efficiently support a varying number of active channels and the

required connections into the public switched telephone network.

These connections should be made in such a way as to simplify call control. Indeed, it would be desirable for as many of the call set up control functions required by such a basestation were handled to the maximum extent possible by the basestation itself.

By so simplifying the network interface, the Mobile Telephone Switching Office (MTSO) and/or Mobile Switching Center (MSC) through which the basestation is connected to the Public Switched Telephone Network (PSTN) may be freed, as much as possible, from the details of maintaining a proper connection from the PSTN to the remote subscriber unit.

Secondly, the basestation should make efficient use of the available resources to process each call. In particular, while the wideband channelizer separates the signals into channels, certain other signal processing resources such as demodulators and modulators are also required.

Using the wideband front end, any channel in the bandwidth available to the service provider is available at any time. However, it is desirable for such a basestation to only activate as many of the other, per-channel resources as is required to support the present call density.

By making the basestation's implementation of call processing resources as modular as possible, the basestation could initially be configured to support a limited number of channels. Then, as the demand for services grows, additional channels could be supported by the addition of the necessary resources.

In other instances, the basestation should be reconfigurable in the event of an interruption or expansion in one type of service. For example, given the emergence of several air interface standards such as code division multiple access (CDMA) as well as time division multiple access (TDMA) standards for cellular, it is desirable for a given wideband basestation to be able to support each such standard, thereby

reducing the number of such basestations that need to be deployed. However, it would be desirable if the resources allocated to one particular air interface, when no longer needed, could then be made available to process signals formatted using the other air interface. That is, as the demands of one type of service or the other come and go, the basestation should be automatically reconfigured.

Thus, several difficulties exist with a wideband digital basestation that can process at any time, any one of many channels in the RF bandwidth available to a service provider.

SUMMARY OF THE INVENTION

Briefly, the invention is a wideband transceiver basestation for a wireless communication system. The receiver portion of the basestation includes a digital channelizer which provides digital samples of multiple wireless channel signals, and a time division multiplexed (TDM) data bus to provide switching functionality between the various channel outputs and other basestation receiver resources such as digital demodulators.

On the transmitter side, basestation signal processing resources such as digital modulators are also connected to a multichannel digital combiner over the TDM bus. Thus, the same flexibility in switching functionality is provided between transmitter signal processing resources and the transmitter channel inputs.

More particularly, the wideband basestation transceiver includes a receive antenna and one or more digital tuners that provide wideband digital signal energy to a digital channelizer. The digital channelizer, in turn, produces a plurality of channel signals, with each channel signal representing the signal energy in one of the radio frequency channels. The channel signals each consist of a series of digital samples.

The digital samples of each channel signal are, in turn, connected to a time division multiplex (TDM) bus. A

basestation controller grants access to the TDM bus by each channel signal in a predetermined timeslot, in a predetermined order.

The samples of the digital channel signals are then forwarded to an available one of the associated receiver resources, such as a demodulator. The demodulators, typically implemented in a digital signal processor (DSP), are then connected to an outgoing landline such as a T1 line to a telephone switching office (MTSO) or mobile switching center (MSC) for further connection into the PSTN.

As a result of the switching functionality provided by the TDM bus, the basestation controller is thus capable of assigning receiver resources dynamically, to any channel, at the time the channel becomes active.

The invention provides other advantages as well.

For example, the invention allows various air interface standards, even those having different channel bandwidths, to be serviced by the same basestation. For example, the basestation may efficiently service both code division multiple access (CDMA) and time division multiple access (TDMA) signals at the same time. In such an arrangement, there are at least two digital channelizers, with one allocated to separating the incoming RF energy into the channel bandwidths required by TDMA, and another channelizer dedicated to separating the energy into the bandwidth required by CDMA. As the channels are activated, they are then serviced by the pool of demodulator resources, by allocating the correct number of additional time slots to accommodate each standard.

If, for example, a wideband CDMA mobile unit goes off line, the timeslots as modulators and demodulators freed thereby can be allocated to processing TDMA signals. This results in automatic on-demand redistribution of basestation resources to one signaling standard or another, without intervention by an MTSO, MSC, or the service provider in any way..

Such a system architecture also exhibits scalability, in the sense that additional DSP processors may be added to

support additional channels as traffic increases, without having to change the RF front configuration. This is unlike the prior art, where each basestation had a fixed channel allocation, and, to add capacity, one must add additional narrowband receivers and transmitters.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the advantages provided by the invention, reference should be had to the following detailed description together with the accompanying drawings, in which:

Fig. 1 is a block diagram of wideband digital basestation making use of a time division multiplex (TDM) bus according to the invention;

Fig. 2 is a more detailed block diagram showing addressable bus drivers and receivers which permits access to the TDM bus;

Fig. 3 is a detailed diagram of an addressable bus driver using a dual-port random access memory (DP-RAM);

Fig. 4 is a detailed diagram of an addressable bus driver using a first-in, first-out (FIFO) memory;

Fig. 5 is a detailed diagram of an addressable bus receiver using a FIFO;

Fig. 6 is a detailed diagram of an addressable bus transmitter using a FIFO;

Fig. 7 is a sequence of operations performed by a basestation control processor in setting up a connection; and

Fig. 8 is an alternate embodiment of the invention making use of multiple tuners and channelizers to support multiple air interface standards while making maximum use of basestation resources.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 is a block diagram of a wideband wireless digital basestation 10 according to the invention. Briefly, the basestation 10 consists of a receive antenna 11, one or more

wideband digital tuners 12, one or more digital channelizers 14, a time division multiplex (TDM) bus 16, a control bus 17, a plurality of digital signal processors (DSPs), a first subset of which are programmed to operate as demodulators 18-1-1, 18-1-2,...,18-1-P (collectively, demodulators 18-1); a second subset of which are programmed to operate as modulators 18-2-1, 18-2-2, ..., 18-2-Q; and a third subset 18-u of which are presently idle, transport signal (T-1) encoder 20, a T-1 decoder 22, one or more digital combiners 24, one or more wideband digital exciters 26, a power amplifier 28, a transmit antenna 29, a basestation control processor (controller) 30, and a TDM synchronization clock generator 32.

More particularly, the basestation exchanges radio frequency (RF) signals with a number of mobile subscriber terminals (mobiles) 40a, 40b. The RF carrier signals are modulated with voice and/or data (channel) signals which are to be coupled to the public switched telephone network (PSTN) by the basestation 10. The particular modulation in used may be any one of a number of different wireless (air interface) standards such as the well known Advanced Mobile Phone Service (AMPS), time division multiple access (TDMA) such as IS-54B, code division multiple access (CDMA) such as IS-95, frequency hopping standards such as the European Groupe Speciale Mobile (GSM), personal communication network (PCN) standards, and the like. Indeed, in a manner that will be described below, the basestation 10 may even be configured to simultaneously process RF signals formatted according to more than one such air interface at the same time.

On the receive side (that is, with respect to the basestation 10), RF modulated signals are first received at the receive antenna 11, and forwarded to the wideband digital tuner 12. The digital tuner 12 downconverts the RF signal received at the antenna to a intermediate frequency (IF) and then performs an analog to digital (A/D) conversion to produce a digital composite signal 13.

Digital tuner 12 is wideband in the sense that it covers a substantial portion of the bandwidth available to the wireless

service provider who is operating the basestation 10. For example, if the air interface implemented by the basestation 10 is IS-54B, the wideband digital tuner may downconvert as much as a 12.5 MegaHertz (MHz) bandwidth in the 800-900 MHz range which contains as many as 416 receive and transmit channel signals, each having an approximately 30 kiloHertz (kHz) bandwidth.

The digital channelizer 14 implements a channel bank to separate the downconverted composite digital signal 13 to a plurality, N, of digital channel signals 15.

This digital sampled signal is then further filtered to separate it into the individual 30 kHz channel signals. The digital channelizer 14 can thus be considered as a bank of digital filters with each filter having a 30 kHz bandwidth. The digital channelizer 14 may implement the filter bank using any of several different filter structures, and no particular digital filter structure is critical to the operation of the invention.

However, our co-pending United States patent application entitled "Transceiver Apparatus Employing Wideband FFT Channelizer with Output Sample Timing Adjustment and Inverse FFT Combiner for a Multichannel Communication Network" filed April 8, 1994 and which is assigned to Overture Systems, Inc. the assignee of this application describes several particular embodiments of the digital tuner 12 and digital channelizer 14 in detail.

In any event, the channelizer 14 provides N individual digital channel signals 15, wherein each of the N outputs represent information in one of the radio frequency channels originated by the mobile 40. Usually, one-half of the channels are used for transmitting signals and one-half for receiving signals. Thus, in the IS-54B example being described, N is 208, and thus there are 208 receive and 208 transmit channels implemented by the basestation 10.

These N digital channel signals are then provided over the time division multiplex (TDM) bus 16 to a plurality of digital

signal processors (DSPs) 18-1-1, 18-1-2, ..., 18-1-P (collectively, demodulator-DSP 18-1). In a manner that will be understood in greater detail shortly, the TDM bus 16 operates as a time division multiplexed cross-bar switch. That is, any one of the N digital channel signals 15 may be connected to any one of the demodulator DSPs 18-1 via the TDM bus 16.

The DSPs 18-1 are each programmed to remove the modulation on each channel signal 15 specified by the air interface standard. There typically is not a one-to-one correspondence between the number of DSPs 18-1 and the number of channel signals, N, provided by the channelizer 14. For example, the DSPs may each process a number, such as 24, of digital channel signals 15 at the same time.

The basestation controller 30, using the VME bus and TDM synchronization clock generator 32, manages access by individual digital channel signals 15 to the TDM bus 16, in a manner that will be described shortly.

The outputs of the digital signal processors 18-1, representing demodulated audio or data signals, are then forwarded over the VME bus 17 to the encoder 20. The VME bus 17 is a well known industry standard relatively high frequency bus for interconnecting digital processors and components.

The encoder 20, in turn, reformats the demodulated signals as necessary for transmission to a local Mobile Telephone Switching Office (MTSO). The demodulated signals may be reformatted according to any one of a number of well-known time multiplex telephone signal transport protocols, such as the so-called T1 span (or E1). The T1 signals are then processed by the MTSO in an known fashion, to ultimately complete a telephone call from the subscriber unit 40 to a desired destination, such as another telephone subscriber who is connected to the Public Switched Telephone Network (PSTN).

Since each T1 span has a limited capacity, there may be more than one T1 signal necessary to accommodate all of the channels serviced by the basestation 10. In the example being

discussed, each T1 signal may be formatted to carry up to 96 IS-54B bandwidth-compress signals to the MTSO, assuming that the demodulated signals remain as compressed audio. Thus, as few as five T1 lines can be used to carry all of the 416 transmit and receive channels. When not all of the channels are busy, however, on as many of the T1 line resources as are necessary are connected to the MTSO, in a manner that will be understood shortly.

In other words, the demodulated signals output by the DSPs 18-1 may each be sub-rate (e.g., sub-DS0 frequency signals) which still contain additional encoding other than the air interface standard, such as impressed by a bandwidth compression scheme, which is not removed by the basestation 10. Rather, to minimize the required number of time slots used by the T1 signals, such compression may be removed at the MTSO.

The signal flow on the transmit side of the basestation 10 is analogous. Signals are received from the MTSO and provided to the T1 decoder 22, which removes the T1 formatting.

The unformatted T1 signals are then coupled to the DSPs 18 over the bus 17. A subset of the DSPs 18-2-1, 18-2-2, ..., 18-2-Q (collectively, modulators 18-2) then modulate these signals and presents them to the TDM bus 16. Ultimately, these are then each coupled to one of the N digital channel signals 23 input to the combiner 24. As was true in the receive direction, being a cross-bar swtich, the TDM bus 16 permits any one of the modulator DSPs 18-2 to be connected to any one of the channel signal inputs 23.

Although each modulator DSP 18-2 typically processes multiple channel signals, each such channel signal generated by the modulator DSP 18-2 is typically assigned one or more unique time slots on the TDM bus 16, with no two channel signals thus occupying the same time slot. Similarly, no two channel signals on the receive side ever occupy the same timeslot on the TDM bus 16.

Other DSPs 18-u may be unused at a particular point in time. However, these unused DSPs remain as an available

resource to the basestation 10, should a new mobile 40 request access. The manner in which DSPs are allocated at the time of setting up a call will be described in detail below.

The digital combiner 24 combines the TDM bus outputs to produce a composite IF digital signal 25 representing the N channels to be transmitted. The digital combiner 24 then feeds this combined signal to a digital exciter 26, which generates an RF signal 27. This RF signal 27 is then amplified by the power amplifier 28 and fed to the transmit antenna 29.

A more detailed description of the digital combiner 24 and wideband digital exciter 26 is contained in the above-mentioned co-pending patent application.

In order to set up each call, the basestation control processor 32 must exchange certain control information with the MTSO. For example, when a mobile unit 40 wishes to place a call, the mobile unit 40 indicates this by transmitting on one or more control signal channels. These control signals may be exchanged in one of several ways. As shown, the control signals may be in-band or out of band signals present in one or more of the channel signals output by the channelizer 14 or input to the combiner 24. Alternatively, a separate control signal transceiver 35 may be used to receive and transmit such control signaling.

In either event, the basestation 10 forwards the request for access by the mobile 40 to the MTSO, to set up the end to end connection. Upon receiving an indication from the MTSO that the connection can be made at the remote end, the basestation 10 then performs a number of steps, to insure that the appropriate data path through the TDM bus is then enabled to support communication with between the newly enabled mobile 40 and the MTSO.

For example, the MTSO typically returns a pair of T1 span line and T1 time slot identifiers. These inform the basestation controller 30 on which outgoing T1 line and time slot to place the received signal, and on which incoming T1 line and time slot it can expect to obtain the transmit signal for the mobile 40.

However, before proceeding with a detailed explanation of this call set-up process, a bit more detail of the operation of the TDM bus 16 will be provided. As shown in Fig. 2, the digital channelizer 14 consists of a convolutional digital filter 140, a fast Fourier transform (FFT) 142, as well as a TDM dual port (DP) driver 144.

The operation of the convolutional filter 140 and FFT 142 is not critical to the present invention, and is explained in the co-pending application. It is sufficient here to say that the convolutional filter 140 and FFT 142 make use of multirate digital signal processing techniques, such as overlap and add or polyphase, to efficiently implement a digital filter bank by (1) grouping samples of the downconverted signal 13 together and multiplying them by a weighting function, and then (2) forwarding them to the FFT 142 for conversion into the N individual channel signals.

An exemplary DSP demodulator 18-1-1 and modulator 18-2-1 are also shown in Fig. 2. The demodulator DSP 18-1-1 includes a TDM first-in first-out (FIFO) driver 180-1, a TDM FIFO receiver 182-1, a DSP central processing unit 184-1 and program memory 186-1. Similarly, the modulator DSP 18-2-1 includes a TDM FIFO driver 180-2, a TDM FIFO receiver 182-2, a DSP central processing unit 184-2 and program memory 186-2.

Indeed, the modulator and demodulator DSPs may share the same hardware architecture, with the only difference being the in the program which is enable in the program memory 186, which in turn may control whether the TDM receiver or TDM driver hardware is enabled.

Thus, in the DSP demodulator 18-1-1, only the TDM receiver 182-is enabled (as indicated by the dashed lines around the driver 180-1), since the demodulator 18-1-1 only receives data from the TDM bus 16. Likewise, only the TDM driver 180-2 is enabled in the DSP modulator 18-2-1, since it only transmits data on the TDM bus 16.

On the transmit side, the digital combiner 24 consists of a TDM dual port (DP) receiver 244, an inverse FFT 242, and

deconvolutional digital filter 240. In a manner that is described below, the TDM DP receiver 244 reads each of the data samples off the TDM bus 16 in their assigned time slot, and provides them to the inverse FFT 242 in the required order.

The samples are then operated on by the inverse FFT 242 and deconvolutional filter 240, to provide the composite digital signal 25 (Fig. 1). Again, further details of the operation of the inverse FFT 242 and deconvolutional filter 240 are not necessary here, and they are discussed in the co-pending patent application should the reader be interested.

Returning attention now to the channelizer 14, a detailed diagram of the TDM DP driver 144 is shown in Fig. 3. Briefly, it operates to assert the output samples from the FFT 142 in the proper time slots on the TDM bus 16. In order to simply the implementation of the TDM bus 16, these time slots are fixedly assigned to particular channels (such as in ascending order by frequency and time slot number). Thus, a sample of a given one, k, of the N channel signals, will always appear in a particular time slot, k, when it is active.

The DP driver 144 consists of a TDM slot counter 200, a first Dual Port Random Access Memory (DP-RAM) referred to as the enable DP-RAM 202, a second DP-RAM referred to as the data DP-RAM 204, and a driver 208 having an enable input EN.

As is conventional, each of the DP-RAMs have two separate address and data ports for reading and writing data, namely, input address and data ports AI and DI, and output address and data ports AO and DO.

In operation, the TDM slot counter 200 receives a pair of signals generated by the TDM synchronization circuit 32 (Fig. 1). The first signal, TDM CLK, is a digital clock signal identifying the clock periods, or time slots, on the TDM bus 16. The second signal is a TDM FRAME SYNC signal, indicating when a new frame starts on the TDM bus 16.

The TDM slot counter 200, which is a standard digital counter, receives the TDM FRAME SYNC signal at a reset input R, and the TDM CLK signal at a clock input (denoted by a chevron

in the Figures). Thus, the TDM slot counter 200 continuously keeps track of which consecutively numbered slot on the TDM bus 16 is presently active.

The enable RAM 202 generates an enable signal 203 indicating when the TDM DP driver 144 may assert data on the TDM bus 16. The AI and DI inputs to the enable DP-RAM 202 are typically written into by the basestation controller 30 during the process of setting up a new call. In particular, as shown in the table depicting the contents of the enable DP-RAM 202, a location in the RAM is associated with each time slot on the TDM bus 16 (e.g., if the TDM bus contained 512 time slots, then the RAM 202 has 512 locations).

A logical "0" in the associated enable DP-RAM 202 location indicates that the TDM driver is inactive in the time slot, that is, no data is to be asserted at that time. A logical "1" in the associated location indicates that the time slot has been assigned to this particular TDM driver 144.

Thus, to enable a connection through the TDM bus 16, one step for the basestation controller 30, via the VME bus 17, is to write a logical "1" into the DP-RAM 202 location "x" associated with the newly enabled digital channel signal "x". In the example, shown, a "1" has been written at locations "27" and "30", indicating that this particular TDM driver 144 is now active in timeslot numbers 27 and 30.

The data DP-RAM 204 acts as a buffer, writing the digital channel signal samples output by the FFT at the DI input of the data DP-RAM 204. The DP-RAM 204 then stores the data samples until addressed by the TDM slot counter at the output side.

A data dual port (DP) RAM 204 is as a buffer in the case of processing the FFT output. This is because although the samples do come in bursts, or frames, the samples are not necessarily provided by the FFT 142 in the same order as they must be output onto the TDM bus 16. This is a particular phenomenon of at least one of the channelizer algorithms used. Thus, an address associated with each output sample from the FFT is used to determine at which location each sample is written in the data DP-RAM 204.

However, the input data is already in the correct order for the TDM FIFO driver 180-2 used by the DSP modulator. Such a TDM driver 180-2 can thus use a first-in first out memory (FIFO) 210 in the place of a data DP-RAM. As shown in Fig. 4, the configuration and operation of such as TDM FIFO driver 180-2 is somewhat similar to the DP driver 144.

In particular, the TDM slot counter 200, enable DP-RAM 202 and driver 208 operate in the same way as for the embodiment of Fig.3. The only difference is in the connection of the clock signals to the FIFO 210. On the input side, a clock signal is provided by the data source (e.g., the DSP processor 184-2) to cause data to be stored in the FIFO. The signal from the enable DP-RAM 202 is used to clock the FIFO output, DO.

A detailed diagram of the TDM FIFO receiver 182-1 is shown in Fig. 5. It includes a TDM slot counter 200, enable DP-RAM 202, bus receiver 212, and FIFO 214. The TDM slot counter 200 and enable DP-RAM 202 operate as for the TDM FIFO driver 180-1 shown in Fig. 4, to identify when the receiver 212 is to be active. The FIFO 214 is connected to the output of the receiver 212, having its input port connected to the enable DP-RAM 202 output. The output side of the FIFO is clocked as needed by the destination for the data (such as the DSP processor 184-1 in Fig. 2).

The TDM DP receiver 244 is shown in detail in Fig. 6. As for each of the other driver/receivers, it includes a TDM slot counter 200, enable DP-RAM 202. It includes a data DP-RAM 220 operating similarly to the data DP-RAM in the TDM DP driver 144 (Fig. 3) and bus receiver 218.

With this background in mind, the details of how the basestation control processor 30 effects the switching operation of the TDM bus 16 can now be better understood.

Fig. 7 is a flowchart of these operations. This sequence of steps is initiated (step 300) when the basestation controller 30 receives control signals from the mobile 40 (Fig. 1) indicating that the mobile wishes to have access to the PSTN. The controller 30 then determines whether a free

transmit and receive frequency (step 302) are available among the N channels.

An available modulator DSP and demodulator DSP resource are then identified (step 303) by examining a list 33 of free DSP resources maintained in a memory portion 31 of the basestation controller 30 (Fig. 1). The list 33 is updated by removing the two DSPs once allocated.

Access to an MTSO T1 channel (e.g., access to one or more T1 time slots as needed on a particular T1 span line) is then requested from the MTSO by issuing the appropriate MTSO control signaling (step 304). The MTSO then returns T1 span and time slot identifiers to be used for the transmit and receive channels for this connection.

In the next step (306), the appropriate destination and source information is written into the various TDM bus drivers and receivers.

In particular, given a receive channel identification, a receive channel signal time slot on the TDM bus is thus identified. The corresponding location of the enable DP-RAM 202 in the TDM DP driver 144 associated with this time slot is then set to a logical "1" in the manner already described.

Next, a logical "1" is also written into the enable DP-RAM in the TDM receiver 182-1 associated with the DSP demodulator 18-1 which was identified as being an available resource. If the per-channel bandwidth is greater than that which can be supported by a single timeslot, then a sufficient number of logical "1"s are written into the appropriate locations.

Also, now given a transmit channel identification, the free DSP modulator 18-2 is enabled (step 306) to use the TDM bus 16, by writing a logical "1" into the enable DP-RAM of the TDM driver 180-2 connected to the available one of the DSP modulators 18-2. To complete the connection, a logical "1" is also written into the location of the TDM DP receiver 244 associated with the identified transmit channel.

Finally (step 308), the basestation controller 30 issues control signals to the mobile 40 and MTSO to indicate that the connection has been set up.

The invention can also be used to advantage in implementing a basestation 10 which simultaneously services mobiles 40 which use different air interface standards. That is, the basestation 10 may at the same time process signals from a first mobile 40a which uses TDMA (IS-54B) signaling, as well as a second mobile 40b which uses CDMA signaling (IS-95).

As shown in Fig. 8, to support this implementation, the basestation 10 includes a pair of wideband digital tuners 12-1, 12-2. The first digital tuner 12-1 downconverts a bandwidth, such as 5 MHz, from an RF bandwidth which is occupied by TDMA signals. A second digital tuner section 12-2 downconverters a bandwidth, such as 7.5 MHz, which is occupied by CDMA signals.

Next, the tuners 12-1, 12-2 forward the downconverted signals to respective channelizers 14-1, 14-2. The TDMA channelizer 14-1 is configured to separate the received signal into the 30 kHz bandwidth channels specified by IS-54B. Likewise, the CDMA IS-95 channelizer 14-2 is configured to provide 1.25 MHz channels as specified by that standard.

The modulators and demodulators are then grouped according to the air interface modulation they must deal with. For example, at any given instant in time, a certain number of DSPs 18-1-T will have been allocated to operate as demodulators for the TDMA channels provided by the TDMA channelizer 14-1. A different set of DSP processors 18-1-C will be serving as demodulators for the CDMA channels provided by the CDMA channelizer 14-2. The active modulator DSPs will likewise be so allocated.

Thus, assuming that each of the DSPs 18 can be configured to execute either a TDMA modulation/demodulation program or a CDMA modulation/demodulation program by simply accessing the correct program memory, the available DSP resources are only allocated as needed.

In other words, the DSPs (and associated T1 connections, for that matter) are allocated according to user demand automatically, and without intervention by the service provider. Thus, for example, as more customers migrate to

using CDMA, additional CDMA channels are automatically made available and processed by the DSPs, at the expense of the unused TDMA channels.

A number of advantages can now be see for a basestation 10 configured according to the invention. By disposing the TDM bus 16 between the output of the wideband digital channelizer 14 and the demodulator DSPs 18-1, the demodulator DSPs 18-1 may be allocated only as needed. Similarly, the modulator DSPs 18-2 are allocable as needed, since the TDM bus 16 is disposed between them and the digital combiner 24 as well.

Thus, if the basestation 10 is expected to service only a small number of channels, a correspondingly small number of modulator and demodulator DSPs can be installed in the basestation 10. As the basestation's demands increases, these additional RF channels can be serviced by simply adding more DSPs, and without having to reconfigure the RF front end.

Another advantage is provided in that this switching functionality is distributed at the basestation level as much as possible. In particular, unlike certain prior cellular signal switching techniques, the MTSO need not be concerned with the details of how the mobile units 40 are connected through the basestation. Indeed, the MTSO need not even know or care about which transmit and receive frequencies have been assigned to a particular mobile. All the MTSO need provide is identification of a T1 transport line and time slot on which it expects to receive and provide signals from and to the mobile.

Furthermore, because the basestation may efficiently allocate its demodulator/modulator resources, a number of different air interface standards may be supported by the basestation at the same time, without the need to determine in advance an exact plan for allocating receiver/transmitter resources for each air interface type. Upon detecting a request by a new mobile for access, the basestation simply determines the type of air interface used by the mobile, and then signals the appropriately programmed DSPs, or even initiates the DSPs to run a different modulator/demodulator program, as required to support the additional mobile.

While we have shown and described several embodiments in accordance with the present invention, it is to be understood that the invention is not limited thereto, but is susceptible to numerous changes and modifications as known to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.

CLAIMS

1. A basestation for processing signals in a multiple mobile subscriber unit wireless communication system comprising:

an antenna for receiving signals from a plurality of the mobile units as a composite radio frequency (RF) signal;

wideband digital tuner means, connected to the antenna, for downconverting a selected bandwidth of the RF signal to an intermediate frequency (IF), and for performing an analog to digital conversion on the IF signal, to provide a wideband digital tuner output signal;

digital channelization means, being connected to receive the wideband tuner output signal, and providing multiple digital channel signal outputs, each digital channel signal output having a predetermined channel bandwidth, and each digital channel signal corresponding to one of the signals received from one of the mobile units;

a plurality of digital signal processing means, for providing digitally processed channel signal outputs; and

time division multiplex switching means, disposed between the multiple digital channel signal outputs and the plurality of digital signal processing means, the switching means for interconnecting any one of the multiple digital channel signal outputs to any one of the plurality of digital signal processing means.

2. The basestation of claim 1 wherein the signals received from the mobile units contain air interface modulation, and the digital signal processors include demodulators to remove the air interface modulation.

3. The basestation of claim 1 additionally comprising:

signal-transport encoding means, connected to the output of the digital signal processing means, for encoding the digitally processed channel outputs for further transmission to a mobile telephone switching office (MTSO).

4. The basestation of claim 3 wherein the signal-transport encoding means is a T1 encoder.

5. The basestation of claim 1 additionally comprising:

second digital channelization means, being connected to receive the wideband tuner output signal, and providing a second set of multiple digital channel signal outputs, each one of the second set of the digital channel signal outputs having a predetermined channel bandwidth which is different from the predetermined channel bandwidth of said above mentioned first digital channel signals, and each one of the second set of digital channel signals corresponding to one of the signals received from one of the mobile units.

6. The basestation of claim 1 additionally comprising:

second wideband tuner means, connected to the antenna, for downconverting a second selected bandwidth of the RF signal to a second intermediate frequency (IF), and for performing an analog to digital conversion on the second IF signal, to provide a second wideband digital tuner output signal; and

second digital channelization means, being connected to receive the second wideband tuner output signal, and providing a second set of multiple digital channel signal outputs, each one of the second set of the digital channel signal outputs having a predetermined channel bandwidth which is different from the predetermined channel bandwidth of said above mentioned first digital channel signals, and each one of the second set of digital channel signals corresponding to one of the signals received from one of the mobile units.

7. A basestation as in claim 6 wherein the first and second set of digital channel signals are modulated in accordance with first and second air interface standards, respectively.

8. A basestation as in claim 7 wherein the digital signal processors include a first set of digital signal processor means for demodulating said first set of digital channel signals, and a second set of digital signal processors for demodulating said second set of digital channel signals.

9. A basestation as in claim 7 wherein said first and second air interface standards are each different one of a time division multiplex (TDMA), code division multiplex (CDMA), Advanced Mobile Phone System (AMPS) , Personal Communications System (PCS) or Groupe Especiale Mobile (GSM).

10. A basestation as in claim 1 additionally comprising:

basestation controller means, connected to the time division multiplex switching means and the digital signal processing means, for maintaining a list of unused digital signal processing means that are not presently interconnected through the time division multiplex switching means to one of the digital channel outputs, and for dynamically allocating digital signal processing means from the list of unused digital signal processing means to be interconnected to one of the digital channel outputs only when the digital channel output contains an active signal being transmitted by the mobile unit which has not yet been assigned to one of the digital signal processing means.

11. A basestation as in claim 1 wherein the time division multiplex switching means further comprises:

a time division multiplex (TDM) data bus including data lines;

basestation controller means, connected to the TDM bus, and to generate TDM bus synchronization signals and driver address signals, the TDM bus synchronization signals used to identify access timeslots on the TDM bus; and

TDM bus driver means, connected to the TDM bus, the basestation controller means, and at least one of the digital

channel signals, for receiving the TDM bus synchronization signals and the driver address signals, for storing the driver address signals, and for asserting the digital channel signal on the TDM bus when the value of driver address signals corresponds to the value of the bus synchronization signals, thereby indicating that a timeslot associated with the digital channel signal is currently active.

12. A basestation as in claim 11 wherein the basestation controller means, connected to the TDM bus, additionally generates receiver address signals, and the time division multiplex switching means additionally includes:

TDM bus receiver means, connected to the TDM bus, the basestation controller means, and at least one of the digital signal processor means, for receiving the TDM bus synchronization signals and the receiver address signals, for storing the receiver address signals, and for reading a signal asserted on the TDM bus and providing such asserted signal to the digital signal processor means when the value of receiver address signals corresponds to the value of the bus synchronization signals, indicating that a timeslot associated with the digital signal processor is currently active.

13. A wideband basestation as in claim 6 wherein the first and second channelizers each comprise:

a convolutional digital filter, connected to receive the respective one of the digitized wideband signals; and

a fast Fourier transform (FFT) processor, connected to receive the output of the convolutional digital filter, and to provide the digital channel signals.

14. A basestation as in claim 1 additionally comprising:

a second plurality of digital signal processing means, connected to receive digital input signals from a communication signal source;

a wideband digital combiner, being connected to receive a second plurality of digital channel signals, and to provide a

composite digital signal for transmission;

wherein the time division multiplex switching means is also disposed between the second plurality of digital signal processors and the wideband digital combiner, the switching means connecting any one of the second set of digital signal processors to any one of the digital channel signals input to the combiner;

a wideband digital exciter, connected to receive the composite digital signal and to provide a combined RF signal; and

a transmit antenna, connected to receive the combined RF signal and the radiate the combined RF signal.

15. A basestation as in claim 14 additionally comprising:

basestation controller means, connected to the time division multiplex switching means and the first and second plurality of digital signal processing means, for maintaining a list of all unused digital signal processing means that are not presently interconnected through the time division multiplex switching means to one of the digital channel outputs, and for dynamically allocating digital signal processing means from the list of unused digital signal processing means to function as one of the first or second digital signal processing means only when the digital channel output contains an active signal being transmitted by the mobile unit which has not yet been assigned to one of the digital signal processing means, or when the digital inputs from the communications source are active.

16. A wideband basestation transceiver including:

a wideband digital tuner that provides a wideband digital signal at an output;

a digital channelizer, connected to the wideband tuner, to produce a plurality of sampled channel signals, with each channel signal representing signal energy in one of a plurality of radio frequency channels serviced by the basestation;

a time division multiple-access (TDM) data bus;

means for selectively connecting the digital samples of each channel signal, in turn, to the TDM bus;

basestation controller means, for controlling the means for selectively connecting the digital samples of each channel signal to the TDM bus, by so connecting each channel signal in a predetermined timeslot, in a predetermined order;

means, coupled to the TDM bus, for selecting the digital samples in a particular timeslot; and for generating a reconstructed channel signal thereby;

means for allocating a demodulator to be coupled to the reconstructed channel signal when the associated radio frequency channel is active, the demodulator providing a demodulated channel signal;

means for allocating a T1 line encoder to the demodulated channel signal, to format the demodulated channel signal for transmission over a T1 span line; and

means for coupling the T1 line to a mobile telephone switching office (MTSO) or mobile switching center (MSC) for further connection into the public switched telephone network (PSTN).

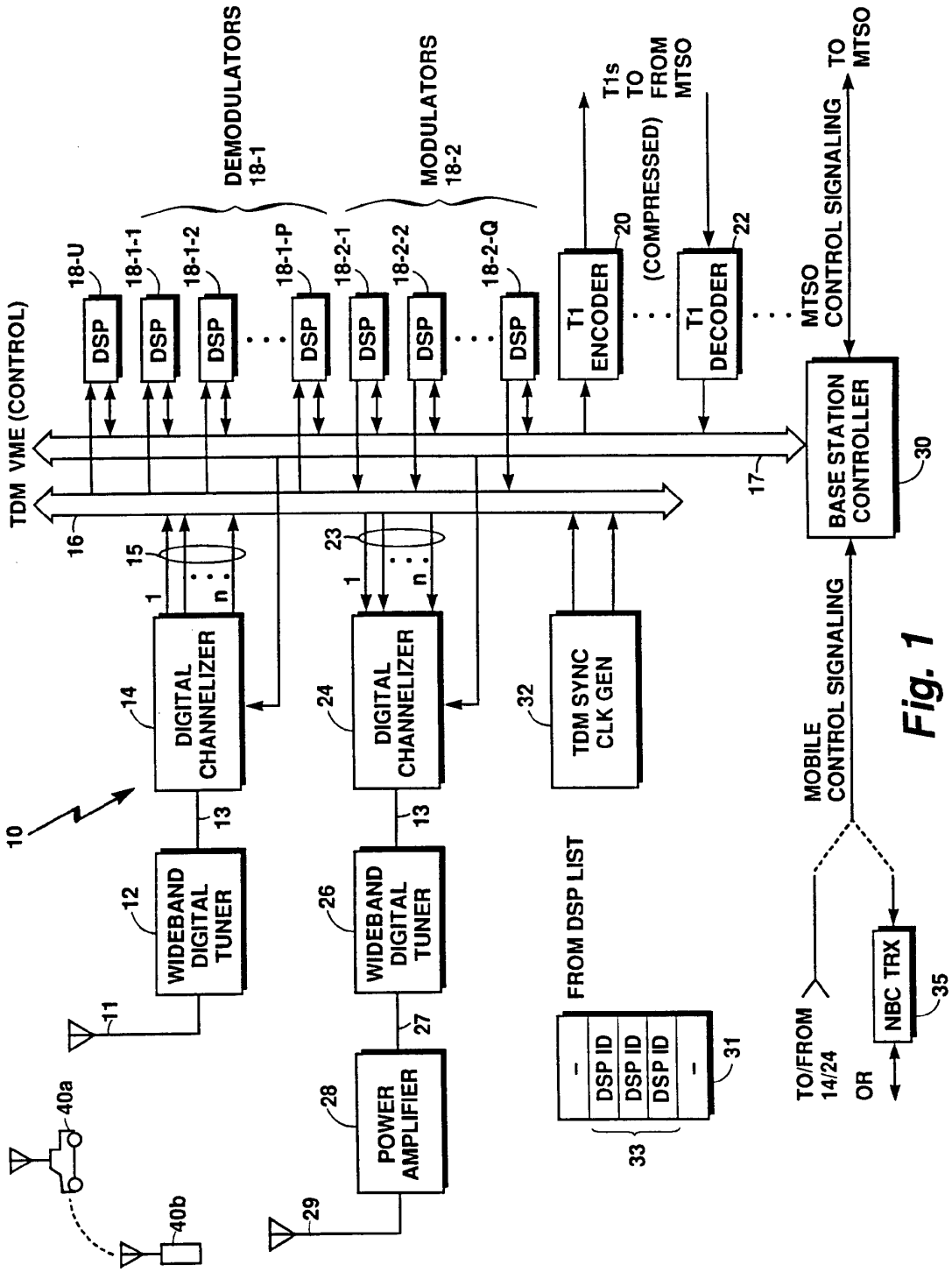

DEMODULATORS 18-1
MODULATORS 18-2
T1s TO FROM MTSO (COMPRESSED)
TO MTSO
18-U
18-1-1
18-1-2
18-1-P
18-2-1
18-2-2
18-2-Q
DSP
T1 ENCODER
T1 DECODER
MTSO CONTROL SIGNALING
TDM VME (CONTROL)
BASE STATION CONTROLLER
DIGITAL CHANNELIZER
TDM SYNC CLK GEN
WIDEBAND DIGITAL TUNER
POWER AMPLIFIER
FROM DSP LIST
DSP ID
MOBILE CONTROL SIGNALING
NBC TRX
TO/FROM 14/24
OR

Fig. 1

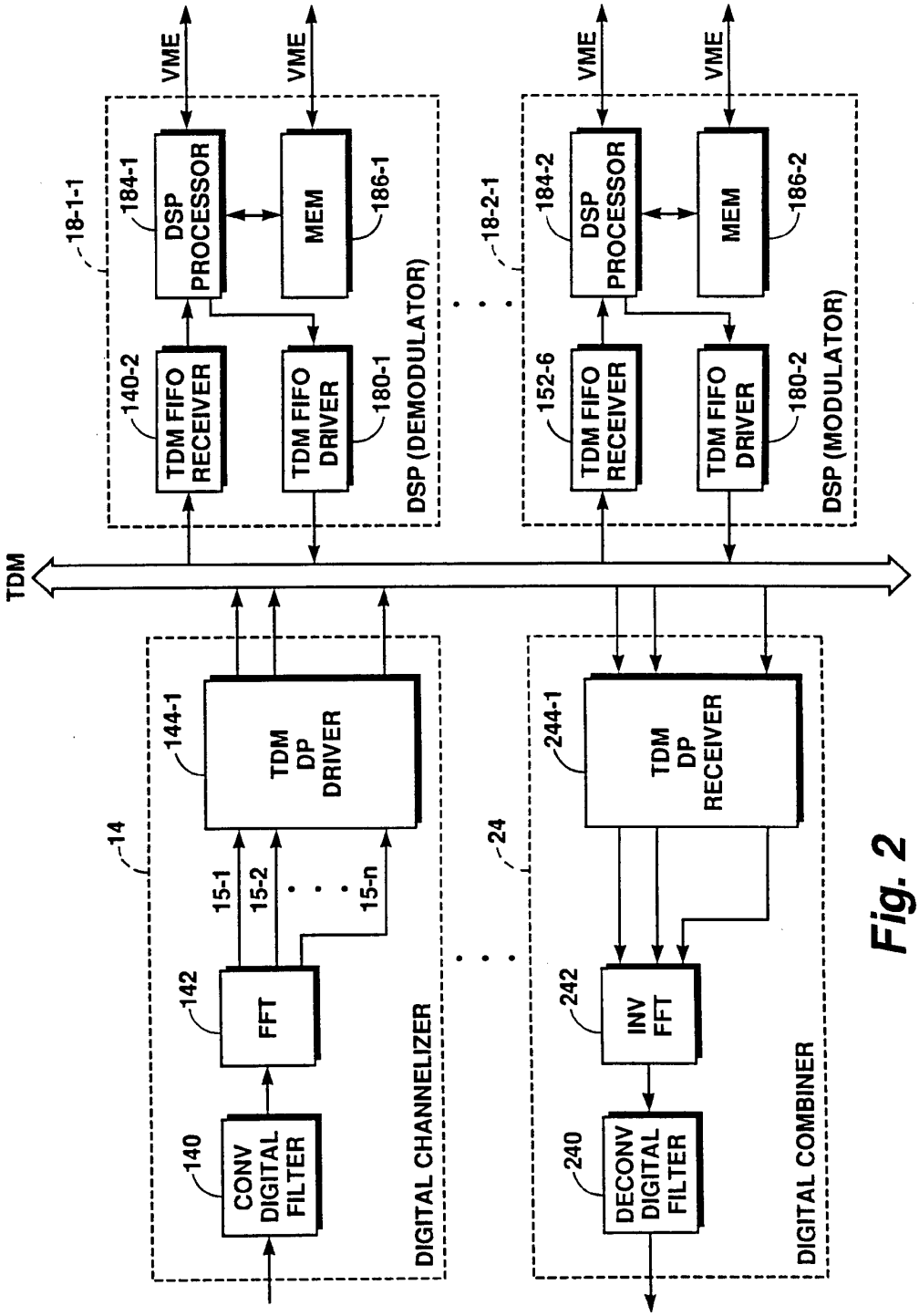

VME
VME
VME
VME
18-1-1
184-1
DSP PROCESSOR
MEM
186-1
140-2
TDM FIFO RECEIVER
TDM FIFO DRIVER
180-1
DSP (DEMODULATOR)
18-2-1
184-2
DSP PROCESSOR
MEM
186-2
152-6
TDM FIFO RECEIVER
TDM FIFO DRIVER
180-2
DSP (MODULATOR)
TDM
14
144-1
TDM DP DRIVER
15-1
15-2
15-n
142
FFT
140
CONV DIGITAL FILTER
DIGITAL CHANNELIZER
24
244-1
TDM DP RECEIVER
242
INV FFT
240
DECONV DIGITAL FILTER
DIGITAL COMBINER

Fig. 2

Fig. 3

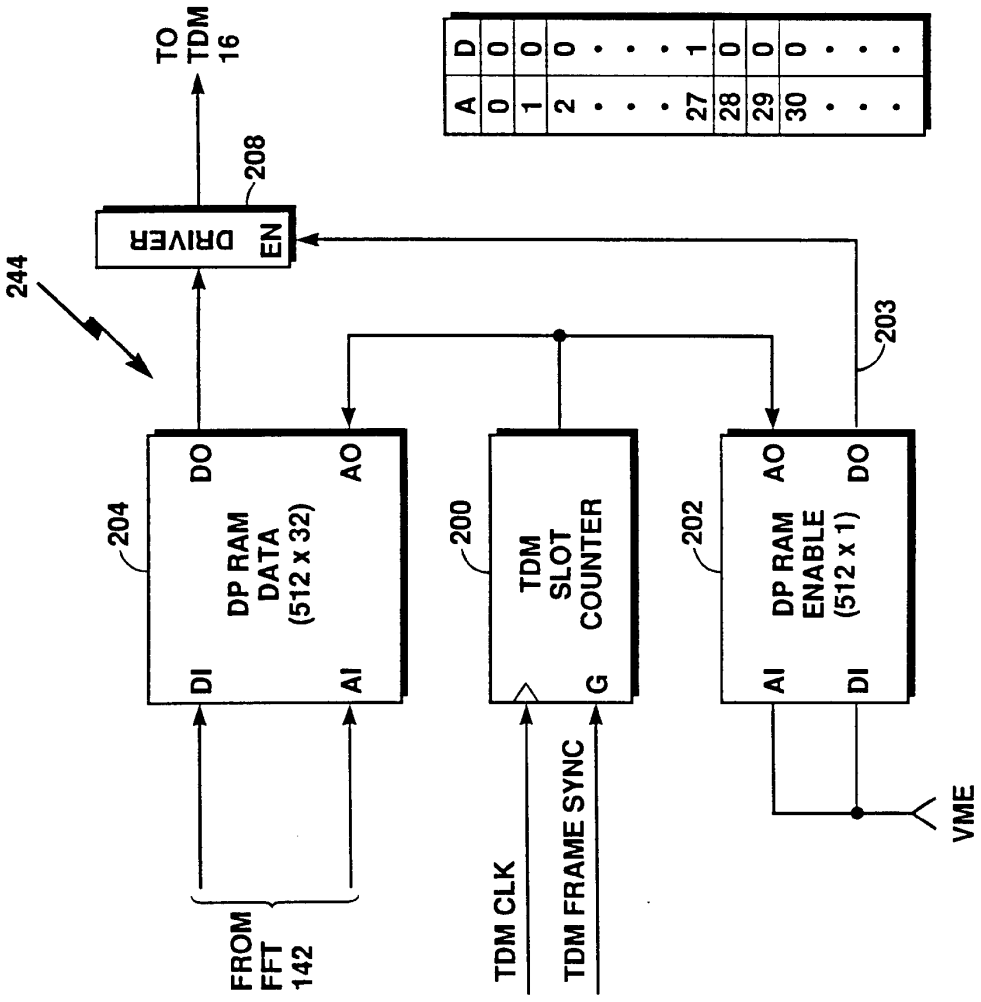
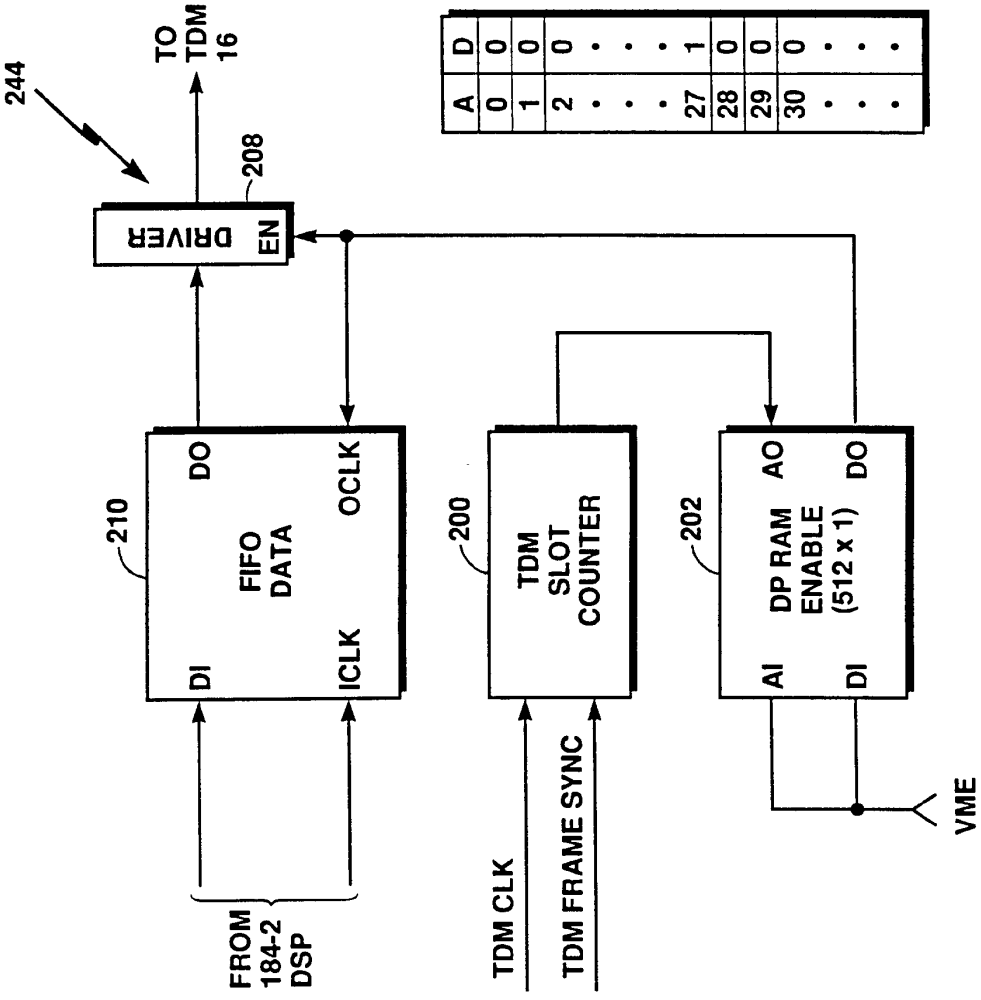

TO TDM 16
208
DRIVER
EN
244
203
204
DP RAM DATA (512 x 32)
DO
AO
DI
AI
200
TDM SLOT COUNTER
G
202
DP RAM ENABLE (512 x 1)
AO
DO
AI
DI
VME
FROM FFT 142
TDM CLK
TDM FRAME SYNC
A
D
0 0 0
1 0
2 0 1
27 0
28 0
29 0
30 0 . . .

Fig.4


A
D
0
0
1
0
2
0
27
1
28
0
29
0
30
0
244
TO TDM 16
208
DRIVER
EN
210
DO
FIFO DATA
OCLK
DI
ICLK
200
TDM SLOT COUNTER
202
AO
DP RAM ENABLE (512 x 1)
DO
AI
DI
VME
FROM 184-2 DSP
TDM CLK
TDM FRAME SYNC

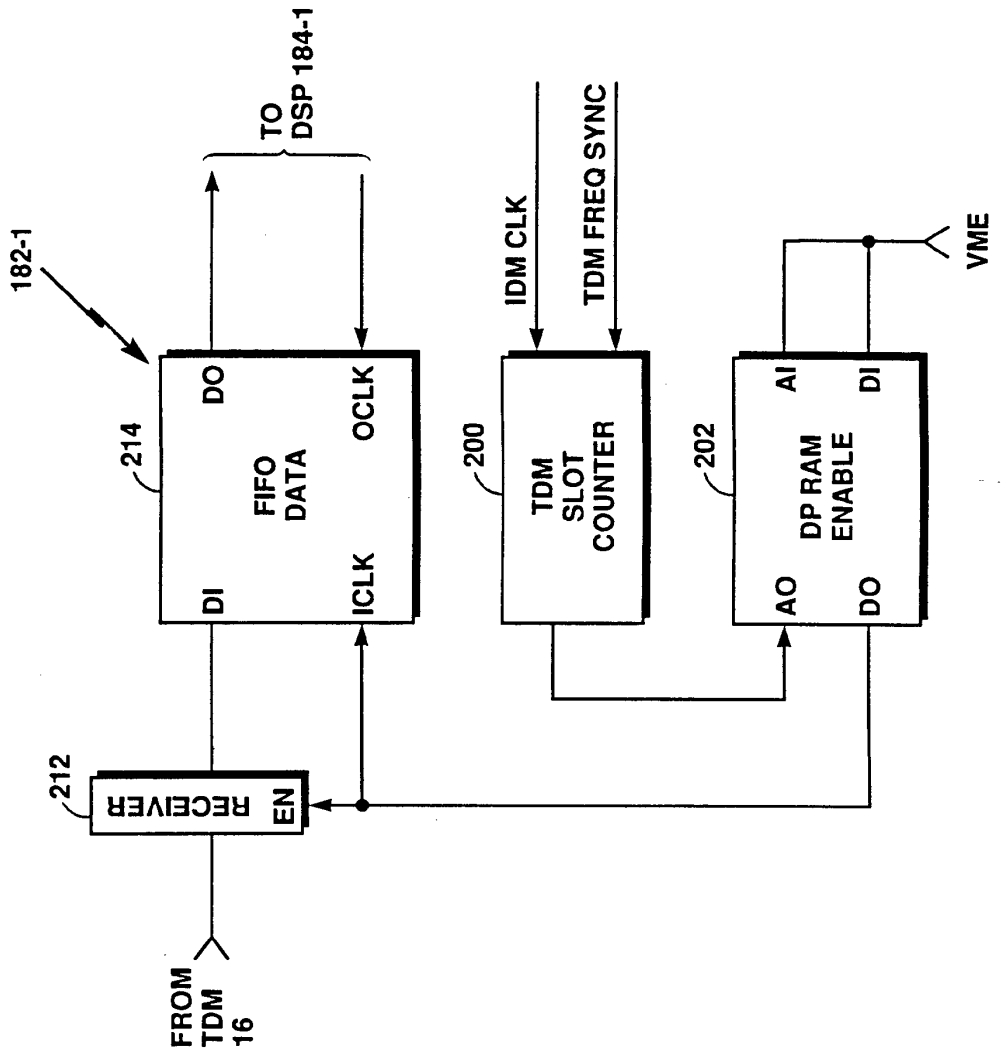
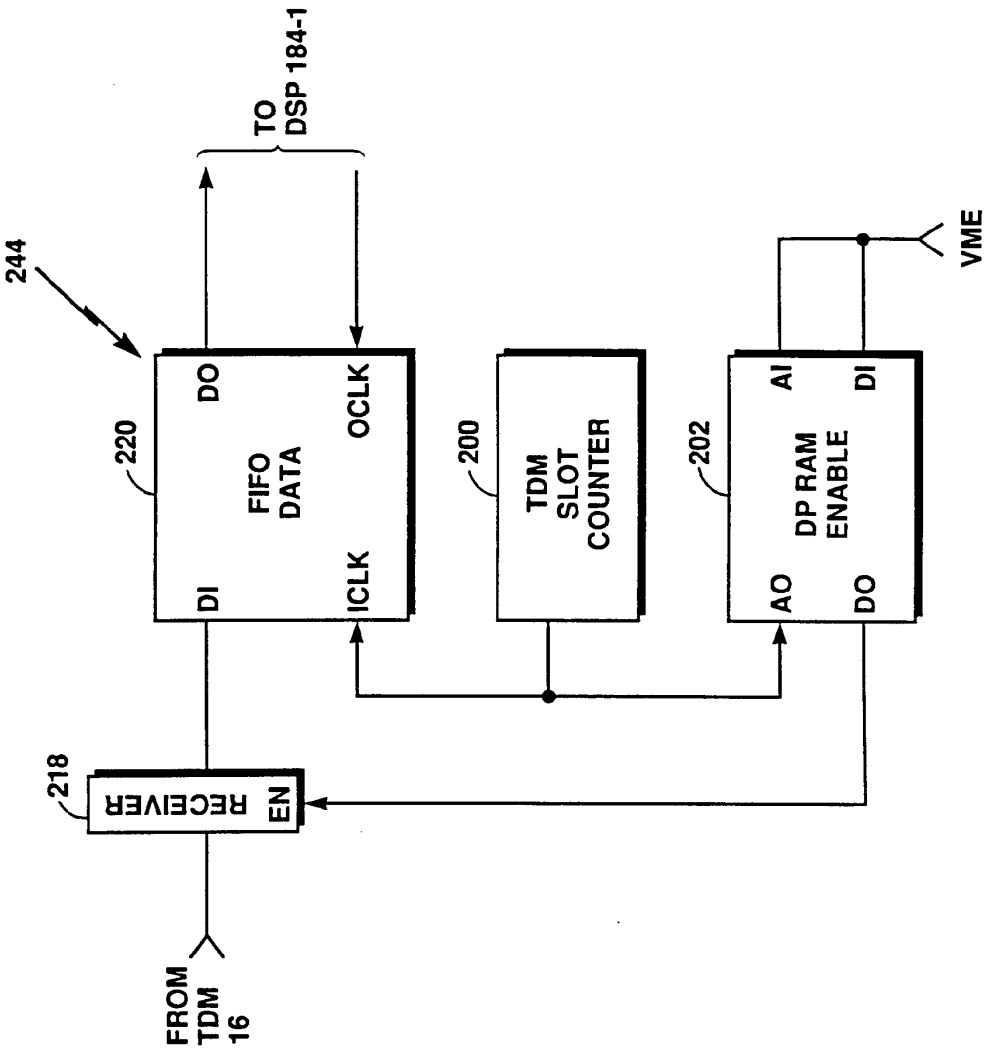

182-1
TO DSP 184-1
IDM CLK
TDM FREQ SYNC
VME
214
FIFO DATA
DO
OCLK
DI
ICLK
200
TDM SLOT COUNTER
202
DP RAM ENABLE
AI
DI
AO
DO
212
RECEIVER
EN
FROM TDM 16

Fig. 5

Fig.6


TO DSP 184-1
244
220
DO
OCLK
FIFO DATA
DI
ICLK
200
TDM SLOT COUNTER
202
AI
DI
DP RAM ENABLE
AO
DO
VME
218
RECEIVER
EN
FROM TDM 16

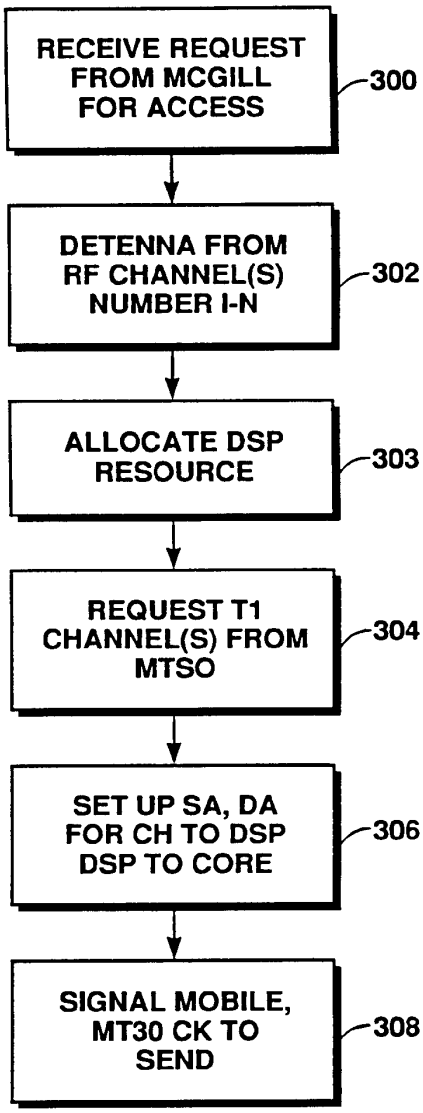

RECEIVE REQUEST FROM MCGILL FOR ACCESS
300
DETENNA FROM RF CHANNEL(S) NUMBER I-N
302
ALLOCATE DSP RESOURCE
303
REQUEST T1 CHANNEL(S) FROM MTSO
304
SET UP SA, DA FOR CH TO DSP DSP TO CORE
306
SIGNAL MOBILE, MT30 CK TO SEND
308

Fig. 7

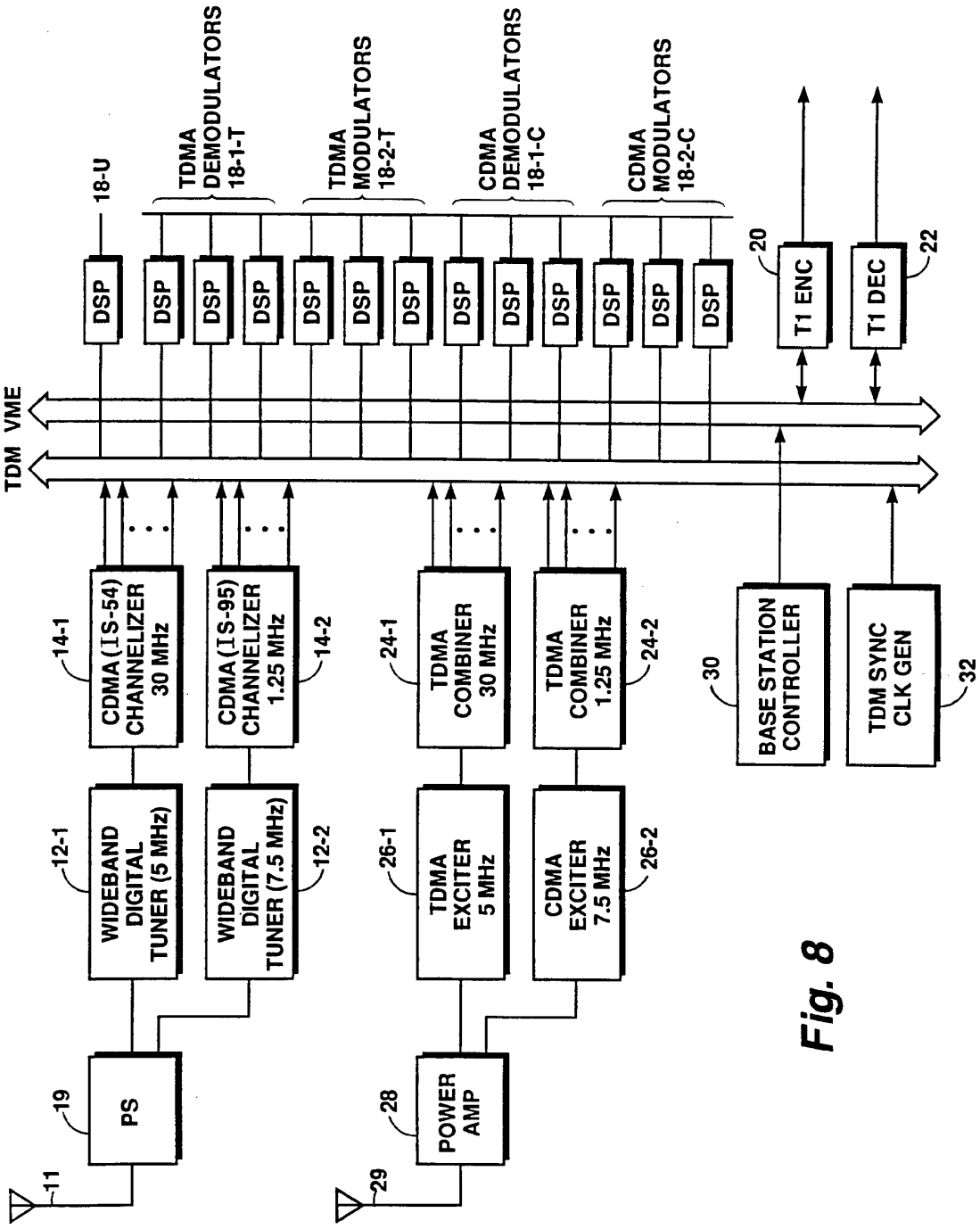

TDM VME
18-U
TDMA DEMODULATORS 18-1-T
TDMA MODULATORS 18-2-T
CDMA DEMODULATORS 18-1-C
CDMA MODULATORS 18-2-C
DSP
T1 ENC
20
T1 DEC
22
CDMA (IS-54) CHANNELIZER 30 MHz
14-1
CDMA (IS-95) CHANNELIZER 1.25 MHz
14-2
TDMA COMBINER 30 MHz
24-1
TDMA COMBINER 1.25 MHz
24-2
BASE STATION CONTROLLER
30
TDM SYNC CLK GEN
32
WIDEBAND DIGITAL TUNER (5 MHz)
12-1
WIDEBAND DIGITAL TUNER (7.5 MHz)
12-2
TDMA EXCITER 5 MHz
26-1
CDMA EXCITER 7.5 MHz
26-2
PS
19
POWER AMP
28
11
29

Fig. 8

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 95/01045

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/30 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A,5 289 464 (WANG) 22 February 1994 see the whole document ---	1-14,16
Y	MOBILE RADIO CONFERENCE, 13 November 1991 - 15 November 1991 VALBONNE, FR, pages 161-168, XP 000444231 BEHAGUE ET AL. 'Modularity and Flexibility: The Keys to Base station System Configuration for the GSM Network' see page 161, right column, line 1 - line 23 see page 163, left column, line 8 - right column, line 6 see page 165, right column, line 1 - page 167, left column, line 10; figures 1,2,6 --- -/--	1-10,13, 14,16

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
29 May 1995	09. 06. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Janyszek, J-M

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EX-1002
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	EP,A,0 590 412 (SIEMENS) 6 April 1994 see column 2, line 3 - line 25 see column 2, line 42 - column 3, line 47 see column 4, line 32 - column 6, line 11; figures ---	1,2,5-14 16
Y A	EP,A,0 189 822 (ANT) 6 August 1986 see page 7, line 21 - page 13, line 29; figures 4,5 ---	1 16
A	VEHICULAR TECHNOLOGY SOCIETY, 10 May 1992 - 13 May 1992 DENVER,US, pages 47-50, XP 000339680 HO 'Architecture Design of a Code Division Multiple Access Cellular System' see paragraph 3 - paragraph 3.1 see paragraph 5; figure 1 ---	1,3-9, 14,16
A	EP,A,0 497 083 (ERICSSON) 5 August 1992 see column 3, line 11 - line 48; figure 2 -----	10

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Information on patent family members

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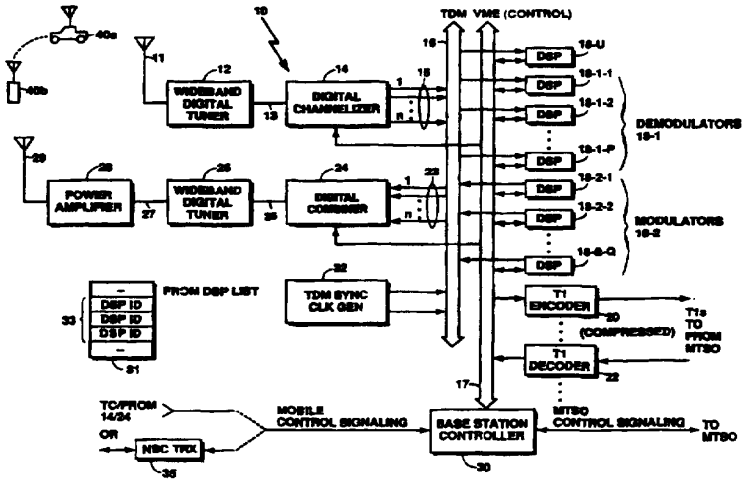
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(57) Abstract

A wireless communication system basestation making use of a wideband, multichannel digital transceiver having incorporated therein a time division multiple-access (TDM) bus for providing digital samples of a plurality of wireless communication channels, wherein the time slot duration and frame rate of the TDM bus may be reconfigured. The invention allows various air interface standards, even those having different channel bandwidths, to be serviced by the same basestation, without having to install additional or different equipment, and by automatically redistributing signal processing resources, eliminating the need to reconfigure the basestation when different types of wireless signalling must be accomodated.

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WIDEBAND WIRELESS BASESTATION MAKING USE OF TIME DIVISION MULTIPLE-ACCESS BUS HAVING SELECTABLE NUMBER OF TIME SLOTS AND FRAME SYNCHRONIZATION TO SUPPORT DIFFERENT MODULATION STANDARDS

FIELD OF THE INVENTION

This invention relates generally to communication networks, and in particular to a wireless communication system basestation making use of a wideband, multichannel digital transceiver having incorporated therein a time division multiple-access (TDM) bus for providing digital samples of a plurality of wireless communication channels, wherein the TDM bus has a selectable number of time slots per frame, and a selectable frame synchronization rate, to permit dynamic allocation of modulator and demodulator signal processing resources, and to support wireless modulation standards of different bandwidths.

BACKGROUND

The basestations used by the providers of current day multiple channel wireless communication services, such as cellular mobile telephone (CMT) and personal communication systems (PCS), typically designate signal processing equipment for each single receiver channel. This is probably a result of the fact that each basestation is configured to provide communication capability for only a limited predetermined number of channels in the overall frequency spectrum that is available to the service provider.

A typical basestation may thus contain several racks of equipment which house multiple sets of receiver and transmitter signal processing components that service a prescribed subset of the available channels. For example, in an Advanced Mobile Phone Service (AMPS) cellular system, a typical basestation may service a pre-selected number of channels, such as 48, of the total number, such as 416, of the channels available to the service provider.

Certain types of wireless service providers would prefer, however, to employ equipment that would be more flexible, both in terms of where it can be located, as well as in the extent of the available bandwidth coverage provided by a particular transceiver site. This is particularly true in rural areas where cellular coverage may be concentrated along a highway, and for which the limited capacity of a conventional 48 channel

transceiver may be inadequate. This may also be true in other instances, where relatively large, secure, and protective structures for multiple racks of equipment are not necessarily available or cost effective, such as for PCS applications.

One way to resolve this difficulty is to implement a basestation transceiver using a high speed analog-to-digital (A/D) converter and equipment which makes use of efficient digital filtering algorithms such as the Fast Fourier Transform (FFT), to separate the incoming signal energy into multiple ones of the desired channels. On the transmit side, this basestation implementation includes an inverse FFT processing combiner which outputs a combined signal representative of the contents of the communication channel signals processed thereby. In this manner, relatively compact, lightweight, inexpensive, and reliable digital integrated circuits may be used to cover the entire channel capacity offered by the service provider, rather than only the subset of the available channels.

Thus unlike prior art basestations, the wideband digital basestation is capable of receiving any channel. While this provides a certain number of advantages as described above, it also poses a number of unique problems to the service provider.

Perhaps most importantly, there exists a need to efficiently support a varying number of active channels and the required connections into the public switched telephone network.

These connections should be made in such a way as to simplify call control. Indeed, it would be desirable for as many of the call set up control functions required by such a basestation were handled to the maximum extent possible by the basestation itself.

By so simplifying the network interface, the Mobile Telephone Switching Office (MTSO) and/or Mobile Switching Center (MSC) through which the basestation is connected to the Public Switched Telephone Network (PSTN) may be freed, as much as possible, from the details of maintaining a proper connection from the PSTN to the remote subscriber unit.

Secondly, the basestation should make efficient use of the available resources to process each call. In particular, while the wideband channelizer separates the signals into channels, certain other signal processing resources such as demodulators and modulators are also required.

Using the wideband front end, any channel in the bandwidth available to the service provider is available at any time. However, it is desirable for such a basestation

to only activate as many of the other, per-channel resources as is required to support the present call density.

By making the basestation's implementation of call processing resources as modular as possible, the basestation could initially be configured to support a limited number of channels. Then, as the demand for services grows, additional channels could be supported by the addition of the necessary resources.

In other instances, the basestation should be reconfigurable in the event of an change or expansion in one type of service. For example, given the emergence of several air interface standards such as code division multiple access (CDMA) as well as time division multiple access (TDMA) standards for cellular, it is desirable for a given wideband basestation to be able to support each such standard, thereby reducing the number of such basestations that need to be deployed. However, it would be desirable if the resources allocated to one particular air interface, when no longer needed, could then be made available to process signals formatted using the other air interface. That is, as the demands of one type of service or the other come and go, the basestation should be automatically reconfigured, without requiring an investment in new or different basestation resources.

Thus, several difficulties exist with a wideband digital basestation that can process at any time, any one of many channels in the RF bandwidth available to a service provider.

SUMMARY OF THE INVENTION

Briefly, the invention is a wideband transceiver basestation for a wireless communication system. The receiver portion of the basestation includes a digital channelizer which provides digital samples of multiple wireless channel signals, and a time division multiplexed (TDM) data bus, to provide switching functionality between the various channel outputs and other basestation receiver resources such as digital demodulators.

On the transmitter side, basestation signal processing resources such as digital modulators are also connected to a multichannel digital combiner over the TDM bus. Thus, the same flexibility in switching functionality is provided between transmitter signal processing resources and the transmitter channel inputs.

A synchronization and clock generation circuit has the capability of selecting the number of time slots, as well as the bus frame rate, to be used on the TDM bus. The number of time slots and the bus frame rate depend upon, respectively, the number of the channel signals and the bandwidth of each of the channel signals provided by the channelizer.

More particularly, the wideband basestation transceiver includes a receive antenna and one or more digital tuners that provide wideband digital signal energy to a digital channelizer. The digital channelizer, in turn, produces a plurality of channel signals, with each channel signal representing the signal energy in one of the radio frequency channels. The channel signals each consist of a series of digital samples.

The digital samples of each channel signal are, in turn, connected to a time division multiplex (TDM) bus. A basestation controller grants access to the TDM bus by each channel signal in a predetermined timeslot, in a predetermined order.

The samples of the digital channel signals are then forwarded to an available one of the associated receiver resources, such as a demodulator. The demodulators, typically implemented in a digital signal processor (DSP), are then connected to an outgoing landline such as a T1 line to a telephone switching office (MTSO) or mobile switching center (MSC) for further connection into the PSTN.

Accordingly, when the basestation is to support a particular number of channel signals simultaneously, each channel signal having a bandwidth as dictated by a particular modulation or air interface standard to be supported, the TDM bus reconfigured accordingly, to provide the required number of bus time slots, as well as the frame repeat rate required to support the desired per-channel sampling rate.

When it is desired that the basestation support a protocol which has a larger number of narrower bandwidth channels, the bus timing circuits are reconfigured to provide a correpondingly larger number of time slots at a slower frame rate, and, likewise, when the basestation is to support a protocol which has a smaller number of wider bandwidth channels, the bus timing circuits are again reconfigured to provide a smaller numnber of time slots at a higher frame rate.

As a result of the switching functionality provided by the TDM bus, the basestation is thus capable of supporting different signalling protocols, or air interface standards, which have different channel bandwidths.

The invention provides other advantages as well.

For example, the basestation may efficiently service both code division multiple access (CDMA) and time division multiple access (TDMA) signals at the same time. In such an arrangement, there are at least two digital channelizers, with one allocated to separating the incoming RF energy into the channel bandwidths required by TDMA, and another channelizer dedicated to separating the energy into the bandwidth required by CDMA. As the channels are activated, they are then serviced by the pool of demodulator resources, by allocating the correct number of additional time slots to accommodate each standard.

If, for example, a wideband CDMA mobile unit goes off line, the timeslots as modulators and demodulators freed thereby can be allocated to processing TDMA signals. This results in automatic on-demand redistribution of basestation resources to one signaling standard or another, without intervention by an MTSO, MSC, or the service provider in any way.

Such a system architecture also exhibits scalability, in the sense that additional DSP processors may be added to support additional channels as traffic increases, without having to change the RF front configuration. This is unlike the prior art, where each basestation had a fixed channel allocation, and, to add capacity, one must add additional narrowband receivers and transmitters.

As a result, a basestation according to the invention permits a wireless service provider much greater flexibility in planning implementations, as different and even future protocols can be supported.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the advantages provided by the invention, reference should be had to the following detailed description together with the accompanying drawings, in which:

Fig. 1 is a block diagram of wideband digital basestation making use of a time division multiplex (TDM) bus according to the invention;

Fig. 2 is a more detailed block diagram showing addressable bus drivers and receivers which permits access to the TDM bus;

Fig. 3 is a detailed diagram of an addressable bus driver using a dual-port random access memory (DP-RAM);

Figs. 4A and 4B are timing diagrams showing the frame length and number of time slots on the TDM bus for two different channel bandwidths;

Fig. 5 is a detailed diagram of an addressable bus driver using a first-in, first-out (FIFO) memory;

Fig. 6 is a detailed diagram of an addressable bus receiver using a FIFO;

Fig. 7 is a detailed diagram of an addressable bus transmitter using a FIFO;

Fig. 8 is a sequence of operations performed by a basestation control processor in setting up a connection; and

Fig. 9 is an alternate embodiment of the invention making use of multiple tuners and channelizers to support multiple air interface standards while making maximum use of basestation resources.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 is a block diagram of a wideband wireless digital basestation 10 according to the invention. Briefly, the basestation 10 consists of a receive antenna 11, one or more wideband digital tuners 12, one or more digital channelizers 14, a time division multiplex (TDM) bus 16, a control bus 17, a plurality of digital signal processors (DSPs), a first subset of which are programmed to operate as demodulators 18-1-1, 18-1-2,....18-1-P (collectively, demodulators 18-1); a second subset of which are programmed to operate as modulators 18-2-1, 18-2-2, ..., 18-2-Q; and a third subset 18-u of which are presently idle, transport signal (T-1) encoder 20, a T-1 decoder 22, one or more digital combiners 24, one or more wideband digital exciters 26, a power amplifier 28, a transmit antenna 29, a basestation control processor (controller) 30, and a TDM synchronization clock generator 32.

More particularly, the basestation exchanges radio frequency (RF) signals with a number of mobile subscriber terminals (mobiles) 40a, 40b. The RF carrier signals are modulated with voice and/or data (channel) signals which are to be coupled to the public switched telephone network (PSTN) by the basestation 10. The particular modulation in

used may be any one of a number of different wireless (air interface) standards such as the well known Advanced Mobile Phone Service (AMPS), time division multiple access (TDMA) such as IS-54B, code division multiple access (CDMA) such as IS-95, frequency hopping standards such as the European Groupe Speciale Mobile (GSM), personal communication network (PCN) standards, and the like. Indeed, in a manner that will be described below, the basestation 10 may even be configured to simultaneously process RF signals formatted according to more than one such air interface at the same time.

On the receive side (that is, with respect to the basestation 10), RF modulated signals are first received at the receive antenna 11, and forwarded to the wideband digital tuner 12. The digital tuner 12 downconverts the RF signal received at the antenna to a intermediate frequency (IF) and then performs an analog to digital (A/D) conversion to produce a digital composite signal 13.

Digital tuner 12 is wideband in the sense that it covers a substantial portion of the bandwidth available to the wireless service provider who is operating the basestation 10. For example, if the air interface implemented by the basestation 10 is IS-54B, the wideband digital tuner may downconvert as much as a 12.5 MegaHertz (MHz) bandwidth in the 800-900 MHz range which contains as many as 416 receive and transmit channel signals, each having an approximately 30 kiloHertz (kHz) bandwidth.

The digital channelizer 14 implements a channel bank to separate the downconverted composite digital signal 13 to a plurality, N, of digital channel signals 15.

This digital sampled signal is then further filtered to separate it into the individual 30 kHz channel signals. The digital channelizer 14 can thus be considered as a bank of digital filters with each filter having a 30 kHz bandwidth. The digital channelizer 14 may implement the filter bank using any of several different filter structures, and no particular digital filter structure is critical to the operation of the invention. However, in one preferred embodiment, the digital channelizer 14 consists of a set of convolutional digital filters and a Fast Fourier Transform (FFT) processor. The convolutional digital filters make use of multirate digital filter techniques, such as overlap and add, or polyphase, to efficiently implement a digital filter bank by grouping samples of the downconverted signal together, multiplying the sample groups by a convolutional function, and then forwarding the samples to the FFT for conversion into the n individual channel signals. Such filter banks may

implemented using any of the techniques as are described in the textbook by Crochiere, R.E., and Rabiner, L.R., entitled "Multirate Digital Signal Processing" (Englewood Cliffs, New Jersey: Prentice-Hall, 1983), pages 289-399.

In any event, the channelizer 14 provides N individual digital channel signals 15, wherein each of the N outputs represent information in one of the radio frequency channels originated by the mobile 40. Usually, one-half of the channels are used for transmitting signals and one-half for receiving signals. Thus, in the IS-54B example being described, N is 208, and thus there are 208 receive and 208 transmit channels implemented by the basestation 10.

These N digital channel signals are then provided over the time division multiplex (TDM) bus 16 to a plurality of digital signal processors (DSPs) 18-1-1, 18-1-2, ..., 18-1-P (collectively, demodulator-DSP 18-1). In a manner that will be understood in greater detail shortly, the TDM bus 16 operates as a time division multiplexed cross-bar switch. That is, any one of the N digital channel signals 15 may be connected to any one of the demodulator DSPs 18-1 via the TDM bus 16.

The exact nature of the timing of the TDM bus 16, that is, the number of time slots available for eaech frame of data samples output by the digital channelizer 14, and thus the manner in which the N digital channel signals are transferred over the TDM bus 16, changes depending upon the number of channel signals, N. The manner in which the basestation 10 accomodates these changes in the timing of the TDM bus 16 will be decribed in greater detail below.

The DSPs 18-1 are each programmed to remove the modulation on each channel signal 15 as specified by the air interface standard supported by the basestation 10. There typically is not a one-to-one correspondence between the number of DSPs 18-1 and the number of channel signals, N, provided by the channelizer 14. For example, the DSPs may each process a number, such as 24, of digital channel signals 15 at the same time.

The basestation controller 30, using the VME bus and TDM synchronization clock generator 32, manages access by individual digital channel signals 15 to the TDM bus 16, in a manner that will be described shortly.

The outputs of the digital signal processors 18-1, representing demodulated audio or data signals, are then forwarded over the VME bus 17 to the encoder 20. The VME

bus 17 is a well known industry standard relatively high frequency bus for interconnecting digital processors and components.

The encoder 20, in turn, reformats the demodulated signals as necessary for transmission to a local Mobile Telephone Switching Office (MTSO). The demodulated signals may be reformatted according to any one of a number of well-known time multiplex telephone signal transport protocols, such as the so-called T1 span (or E1). The T1 signals are then processed by the MTSO in an known fashion, to ultimately complete a telephone call from the subscriber unit 40 to a desired destination, such as another telephone subscriber who is connected to the Public Switched Telephone Network (PSTN).

Since each T1 span has a limited capacity, there may be more than one T1 signal necessary to accommodate all of the channels serviced by the basestation 10. In the example being discussed, each T1 signal may be formatted to carry up to 96 IS-54B bandwidth-compressed signals to the MTSO, assuming that the demodulated signals remain as compressed audio. Thus, as few as five T1 lines can be used to carry all of the 416 transmit and receive channels. When not all of the channels are busy, however, on as many of the T1 line resources as are necessary are connected to the MTSO, in a manner that will be understood shortly.

In other words, the demodulated signals output by the DSPs 18-1 may each be sub-rate (e.g., sub-DS0 frequency signals) which still contain additional encoding other than the air interface standard, such as impressed by a bandwidth compression scheme, which is not removed by the basestation 10. Rather, to minimize the required number of time slots used by the T1 signals, such compression may be removed at the MTSO.

The signal flow on the transmit side of the basestation 10 is analogous. Signals are received from the MTSO and provided to the T1 decoder 22, which removes the T1 formatting.

The unformatted T1 signals are then coupled to the DSPs 18 over the bus 17. A subset of the DSPs 18-2-1, 18-2-2, ..., 18-2-Q (collectively, modulators 18-2) then modulate these signals and presents them to the TDM bus 16. Ultimately, these are then each coupled to one of the N digital channel signals 23 input to the combiner 24. As was true in the receive direction, being a cross-bar swtich, the TDM bus 16 permits any one of the modulator DSPs 18-2 to be connected to any one of the channel signal inputs 23.

Although each modulator DSP 18-2 typically processes multiple channel signals, each such channel signal generated by the modulator DSP 18-2 is typically assigned one or more unique time slots on the TDM bus 16, with no two channel signals thus occupying the same time slot. Similarly, no two channel signals on the receive side ever occupy the same timeslot on the TDM bus 16.

As for the demodulators DSPs 18-1, the number of time slots assigned per frame on the TDM bus 16 varies, depending upon the channel bandwidth of the moduation standard implemented.

Other DSPs 18-u may be unused at a particular point in time. However, these unused DSPs remain as an available resource to the basestation 10, should a new mobile 40 request access. The manner in which DSPs are allocated at the time of setting up a call will be described in detail below.

The digital combiner 24 combines the TDM bus outputs to produce a composite IF digital signal 25 representing the N channels to be transmitted. The digital combiner 24 then feeds this combined signal to a digital exciter 26, which generates an RF signal 27. This RF signal 27 is then amplified by the power amplifier 28 and fed to the transmit antenna 29.

In order to set up each call, the basestation control processor 32 must exchange certain control information with the MTSO. For example, when a mobile unit 40 wishes to place a call, the mobile unit 40 indicates this by transmitting on one or more control signal channels. These control signals may be exchanged in one of several ways. As shown, the control signals may be in-band or out of band signals present in one or more of the channel signals output by the channelizer 14 or input to the combiner 24. Alternatively, a separate control signal transceiver 35 may be used to receive and transmit such control signaling.

In either event, the basestation 10 forwards the request for access by the mobile 40 to the MTSO, to set up the end to end connection. Upon receiving an indication from the MTSO that the connection can be made at the remote end, the basestation 10 then performs a number of steps, to insure that the appropriate data path through the TDM bus is then enabled to support communication with between the newly enabled mobile 40 and the MTSO.

For example, the MTSO typically returns a pair of T1 span line and T1 time slot identifiers. These inform the basestation controller 30 on which outgoing T1 line and time slot to place the received signal, and on which incoming T1 line and time slot it can expect to obtain the transmit signal for the mobile 40.

However, before proceeding with a detailed explanation of this call set-up process, a bit more detail of the operation of the TDM bus 16 will be provided. As shown in Fig. 2, the digital channelizer 14 consists of a convolutional digital filter 140, a fast Fourier transform (FFT) 142, as well as a TDM dual port (DP) driver 144.

The operation of the convolutional filter 140 and FFT 142 is not critical to the present invention, and is explained in the co-pending application. It is sufficient here to say that the convolutional filter 140 and FFT 142 make use of multirate digital signal processing techniques, such as overlap and add or polyphase, to efficiently implement a digital filter bank by (1) grouping samples of the downconverted signal 13 together and multiplying them by a weighting function, and then (2) forwarding them to the FFT 142 for conversion into the N individual channel signals.

An exemplary DSP demodulator 18-1-1 and modulator 18-2-1 are also shown in Fig. 2. The demodulator DSP 18-1-1 includes a TDM first-in first-out (FIFO) driver 180-1, a TDM FIFO receiver 182-1, a DSP central processing unit 184-1 and program memory 186-1. Similarly, the modulator DSP 18-2-1 includes a TDM FIFO driver 180-2, a TDM FIFO receiver 182-2, a DSP central processing unit 184-2 and program memory 186-2.

Indeed, the modulator and demodulator DSPs may share the same hardware architecture, with the only difference being the in the program which is enable in the program memory 186, which in turn may control whether the TDM receiver or TDM driver hardware is enabled.

Thus, in the DSP demodulator 18-1-1, only the TDM receiver 182-is enabled (as indicated by the dashed lines around the driver 180-1), since the demodulator 18-1-1 only receives data from the TDM bus 16. Likewise, only the TDM driver 180-2 is enabled in the DSP modulator 18-2-1, since it only transmits data on the TDM bus 16.

On the transmit side, the digital combiner 24 consists of a TDM dual port (DP) receiver 244, an inverse FFT 242, and deconvolutional digital filter 240. In a manner that is described below, the TDM DP receiver 244 reads each of the data samples off the

TDM bus 16 in their assigned time slot, and provides them to the inverse FFT 242 in the required order.

The samples are then operated on by the inverse FFT 242 and deconvolutional filter 240, to provide the composite digital signal 25 (Fig. 1).

Returning attention now to the channelizer 14, a detailed diagram of the TDM DP driver 144 is shown in Fig. 3. Briefly, it operates to assert the output samples from the FFT 142 in the proper time slots on the TDM bus 16. In order to simply the implementation of the TDM bus 16, these time slots are fixedly assigned to particular channels (such as in ascending order by frequency and time slot number). Thus, a sample of a given one, k, of the N channel signals, will always appear in a particular time slot, k, when it is active.

The DP driver 144 consists of a TDM slot counter 200, a first Dual Port Random Access Memory (DP-RAM) referred to as the enable DP-RAM 202, a second DP-RAM referred to as the data DP-RAM 204, and a driver 208 having an enable input EN.

As is conventional, each of the DP-RAMs have two separate address and data ports for reading and writing data, namely, input address and data ports AI and DI, and output address and data ports AO and DO.

In operation, the TDM slot counter 200 receives a pair of signals generated by the TDM synchronization circuit 32 (Fig. 1). The first signal, TDM CLK, is a digital clock signal identifying the clock periods, or time slots, on the TDM bus 16. The second signal is a TDM FRAME SYNC signal, indicating when a new frame starts on the TDM bus 16.

The TDM slot counter 200, which is a standard digital counter, receives the TDM FRAME SYNC signal at a reset input R, and the TDM CLK signal at a clock input (denoted by a chevron in the Figures). Thus, the TDM slot counter 200 continuously keeps track of which consecutively numbered slot on the TDM bus 16 is presently active.

According to the invention, the manner in which the signals are multiplexed onto the TDM bus 16 is changed, depending upon the bandwidth of channels in the modulation scheme being supported. In particular, the number of time slots per frame on the TDM bus 16 is adjusted, depending upon the bandwidth of the modulation of the air interface which is implemented.

Thus, for different air interface standards, the TDM slot counter 200 will receive different TDM CLK and different TDM FRAME SYNC signals. Turning attention

briefly to Figs. 4A and 4B, this concept will be better understood. As shown in Fig. 4A, for the IS-54B TDMA standard, the channelizer 14 provides 208 channels, each having a 30kHz bandwidth. The desired complex-valued (e.g., in-phase and quadrature) sampling rate of each TDMA channel is approximately 40kHz, so that the frame rate, that is, the rate at which each group of 208 samples is asserted on the TDM bus 16, is also set to 40kHz.

Accordingly, in order to support IS-54B channels, the TDM FRAME SYNC signal is controlled by the TDM synchronization clock generator 32 to reset the TDM slot counter 200 every 1/40 kHz, or every 25μs, and the TDM CLK signal is set to clock the complex-valued samples, one from each of the 208 channels, every 25 μs / 208; in other words, to provide approximately one TDM time slot every 121 ns.

As shown in Fig. 4B, for the IS-95 CDMA standard, the channelizer provides 10 channels, each having a 1.25 Mhz bandwidth. The desired complex-valued sampling rate of each channel is approximately 1.67 MHz, so that the frame rate is 600 ns.

Accordingly, in order to support IS-95 channels, the TDM FRAME SYNC signal is controlled to reset the TDM slot counter 200 every 600 ns, and the TDM CLK signal is set to clock the complex-valued samples, one from each of the 10 channels, every 600 ns / 10, or to provide approximately one TDM time slot every 60 ns.

As shown in Fig. 1, the TDM synchronization clock generator receives appropriate signals from the basestation controller 30 via the VMS bus 17 indicating the desired TDM CLK and desired TDM FRAME SYNC rate.

The manner in which data may be asserted on the TDM bus 16 in any of the time slots will now be described in detail. In particular, the enable RAM 202 generates an enable signal 203 indicating when the TDM DP driver 144 may assert data on the TDM bus 16. The AI and DI inputs to the enable DP-RAM 202 are typically written into by the basestation controller 30 during the process of setting up a new call. In particular, as shown in the table depicting the contents of the enable DP-RAM 202, a location in the RAM is associated with each time slot on the TDM bus 16 (e.g., if the TDM bus contained 512 time slots, then the RAM 202 has 512 locations).

A logical "0" in the associated enable DP-RAM 202 location indicates that the TDM driver is inactive in the time slot, that is, no data is to be asserted at that time. A

logical "1" in the associated location indicates that the time slot has been assigned to this particular TDM driver 144.

Thus, to enable a connection through the TDM bus 16, one step for the basestation controller 30, via the VME bus 17, is to write a logical "1" into the DP-RAM 202 location "x" associated with the newly enabled digital channel signal "x". In the example, shown, a "1" has been written at locations "27" and "30", indicating that this particular TDM driver 144 is now active in timeslot numbers 27 and 30.

The data DP-RAM 204 acts as a buffer, writing the digital channel signal samples output by the FFT at the DI input of the data DP-RAM 204. The DP-RAM 204 then stores the data samples until addressed by the TDM slot counter at the output side.

A data dual port (DP) RAM 204 is as a buffer in the case of processing the FFT output. This is because although the samples do come in bursts, or frames, the samples are not necessarily provided by the FFT 142 in the same order as they must be output onto the TDM bus 16. This is a particular phenomenon of at least one of the channelizer algorithms used. Thus, an address associated with each output sample from the FFT is used to determine at which location each sample is written in the data DP-RAM 204.

However, the input data is already in the correct order for the TDM FIFO driver 180-2 used by the DSP modulator. Such a TDM driver 180-2 can thus use a first-in first out memory (FIFO) 210 in the place of a data DP-RAM. As shown in Fig. 5, the configuration and operation of such as TDM FIFO driver 180-2 is somewhat similar to the DP driver 144.

In particular, the TDM slot counter 200, enable DP-RAM 202 and driver 208 operate in the same way as for the embodiment of Fig.3. The only difference is in the connection of the clock signals to the FIFO 210. On the input side, a clock signal is provided by the data source (e.g., the DSP processor 184-2) to cause data to be stored in the FIFO. The signal from the enable DP-RAM 202 is used to clock the FIFO output, DO.

A detailed diagram of the TDM FIFO receiver 182-1 is shown in Fig. 6. It includes a TDM slot counter 200, enable DP-RAM 202, bus receiver 212, and FIFO 214. The TDM slot counter 200 and enable DP-RAM 202 operate as for the TDM FIFO driver 180-1 shown in Fig. 5, to identify when the receiver 212 is to be active. The FIFO 214 is connected to the output of the receiver 212, having its input port connected to the enable

DP-RAM 202 output. The output side of the FIFO is clocked as needed by the destination for the data (such as the DSP processor 184-1 in Fig. 2).

The TDM DP receiver 244 is shown in detail in Fig. 7. As for each of the other driver/receivers, it includes a TDM slot counter 200, enable DP-RAM 202. It includes a data DP-RAM 220 operating similarly to the data DP-RAM in the TDM DP driver 144 (Fig. 3) and bus receiver 218.

With this background in mind, the details of how the basestation control processor 30 effects the switching operation of the TDM bus 16 can now be better understood.

Fig. 8 is a flowchart of these operations. This sequence of steps is initiated (step 300) when the basestation controller 30 receives control signals from the mobile 40 (Fig. 1) indicating that the mobile wishes to have access to the PSTN. The controller 30 then determines whether a free transmit and receive frequency (step 302) are available among the N channels.

An available modulator DSP and demodulator DSP resource are then identified (step 303) by examining a list 33 of free DSP resources maintained in a memory portion 31 of the basestation controller 30 (Fig. 1). The list 33 is updated by removing the two DSPs once allocated.

Access to an MTSO T1 channel (e.g., access to one or more T1 time slots as needed on a particular T1 span line) is then requested from the MTSO by issuing the appropriate MTSO control signaling (step 304). The MTSO then returns T1 span and time slot identifiers to be used for the transmit and receive channels for this connection.

In the next step (306), the appropriate destination and source information is written into the various TDM bus drivers and receivers.

In particular, given a receive channel identification, a receive channel signal time slot on the TDM bus is thus identified. The corresponding location of the enable DP-RAM 202 in the TDM DP driver 144 associated with this time slot is then set to a logical "1" in the manner already described.

Next, a logical "1" is also written into the enable DP-RAM in the TDM receiver 182-1 associated with the DSP demodulator 18-1 which was identified as being an available resource. If the per-channel bandwidth is greater than that which can be supported by a single timeslot, then a sufficient number of logical "1"s are written into the appropriate locations.

Also, now given a transmit channel identification, the free DSP modulator 18-2 is enabled (step 306) to use the TDM bus 16, by writing a logical "1" into the enable DP-RAM of the TDM driver 180-2 connected to the available one of the DSP modulators 18-2. To complete the connection, a logical "1" is also written into the location of the TDM DP receiver 244 associated with the identified transmit channel.

Finally (step 308), the basestation controller 30 issues control signals to the mobile 40 and MTSO to indicate that the connection has been set up.

The invention can also be used to advantage in implementing a basestation 10 which simultaneously services mobiles 40 which use different air interface standards. That is, the basestation 10 may at the same time process signals from a first mobile 40a which uses TDMA (IS-54B) signaling, as well as a second mobile 40b which uses CDMA signaling (IS-95).

As shown in Fig. 9, to support this implementation, the basestation 10 includes a pair of wideband digital tuners 12-1, 12-2. The first digital tuner 12-1 downconverts a bandwidth, such as 5 MHz, from an RF bandwidth which is occupied by TDMA signals. A second digital tuner section 12-2 downconverters a bandwidth, such as 7.5 MHz, which is occupied by CDMA signals.

Next, the tuners 12-1, 12-2 forward the downconverted signals to respective channelizers 14-1, 14-2. The TDMA channelizer 14-1 is configured to separate the received signal into the 30 kHz bandwidth channels specified by IS-54B. Likewise, the CDMA IS-95 channelizer 14-2 is configured to provide 1.25 MHz channels as specified by that standard.

The TDM synchronization clock generator 32 is appropriately set to provide a sufficient number of time slots on the TDM bus 16 to permit transmission of both the required number of samples from the TDMA channelizer 14-1 as well as the required number of samples from the CDMA channelizer 14-2.

The modulators and demodulators are then grouped according to the air interface modulation they must deal with. For example, at any given instant in time, a certain number of DSPs 18-1-T will have been allocated to operate as demodulators for the TDMA channels provided by the TDMA channelizer 14-1. A different set of DSP processors 18-1-C will be serving as demodulators for the CDMA channels provided by the CDMA channelizer 14-2. The active modulator DSPs will likewise be so allocated.

Thus, assuming that each of the DSPs 18 can be configured to execute either a TDMA modulation/demodulation program or a CDMA modulation/demodulation program by simply accessing the correct program memory, the available DSP resources and TDM bus time slots are only allocated as needed.

In other words, the DSPs (and associated T1 connections, for that matter) are allocated according to user demand automatically, and without intervention by the service provider. Thus, for example, as more customers migrate to using CDMA, additional CDMA channels are automatically made available and processed by the DSPs, at the expense of the unused TDMA channels.

A number of advantages can now be see for a basestation 10 configured according to the invention.

When the basestation is to receive and transmit channel signals having a bandwidth as dictated by a particular modulation or air interface standard to, the TDM bus is reconfigured accordingly, to provide the required number of bus time slots, as well as to provide a frame repeat rate approraite to support the required per-channel sampling rate.

When, at a different time, the basestation is to support a protocol having a larger number of narrower bandwidth channels, the bus timing circuits are reconfigured to provide a correpondingly larger number of time slots at a slower frame rate. Likewise, when the basestation is to support a protocol which has a smaller number of wider bandwidth channels, the bus timing circuits are again reconfigured to provide a smaller numnber of time slots at the higher required frame rate.

By disposing the TDM bus 16 between the output of the wideband digital channelizer 14 and the demodulator DSPs 18-1, the demodulator DSPs 18-1 may be allocated only as needed. Similarly, the modulator DSPs 18-2 are allocable as needed, since the TDM bus 16 is disposed between them and the digital combiner 24 as well.

Thus, if the basestation 10 is expected to service only a small number of channels, a correspondingly small number of modulator and demodulator DSPs can be installed in the basestation 10. As the basestation's demands increases, these additional RF channels can be serviced by simply adding more DSPs, and without having to reconfigure the RF front end.

Another advantage is provided in that this switching functionality is distributed at the basestation level as much as possible. In particular, unlike certain prior cellular signal switching techniques, the MTSO need not be concerned with the details of how the mobile units 40 are connected through the basestation. Indeed, the MTSO need not even know or care about which transmit and receive frequencies have been assigned to a particular mobile. All the MTSO need provide is identification of a T1 transport line and time slot on which it expects to receive and provide signals from and to the mobile.

Furthermore, because the basestation may efficiently allocate its demodulator/modulator resources, a number of different air interface standards may be supported by the basestation at the same time, without the need to determine in advance an exact plan for allocating receiver/transmitter resources for each air interface type. Upon detecting a request by a new mobile for access, the basestation simply determines the type of air interface used by the mobile, and then signals the appropriately programmed DSPs, or even initiates the DSPs to run a different modulator/demodulator program, as required to support the additional mobile.

While we have shown and described several embodiments in accordance with the present invention, it is to be understood that the invention is not limited thereto, but is susceptible to numerous changes and modifications as known to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.

What is claimed is:

CLAIMS

1. A basestation for processing signals in a multiple mobile subscriber unit wireless communication system comprising:

an antenna for receiving signals from a plurality of the mobile units as a composite radio frequency, RF, signal;

wideband digital tuner means, connected to the antenna, for downconverting a selected bandwidth of the RF signal to an intermediate frequency, IF, signal and for performing an analog to digital conversion on the IF signal, to provide a wideband digital tuner output signal;

digital channelization means, being connected to receive the wideband tuner output signal, and providing multiple digital channel signal outputs, each digital channel signal output having a predetermined channel bandwidth, and each digital channel signal corresponding to one of the signals received from one of the mobile units;

a plurality of digital signal processing means, for providing digitally processed channel signal outputs; and

time division multiplex switching means, disposed between the multiple digital channel signal outputs and the plurality of digital signal processing means, the switching means for interconnecting any one of the multiple digital channel signal outputs to any one of the plurality of digital signal processing means; and

time division multipex synchronization timing means, connected to control the time division multiplex means, to provide, at a frame rate which depends upon the predetermined bandwidth of the channel signals, a plurality of time slots, the numer of time slots depending upon the number of digital channel signals.

2. The basestation of claim 1 wherein the signals received from the mobile units contain modulation, and the digital signal processors include demodulators to remove the modulation.

3. The basestation of claim 1 additionally comprising:

signal-transport encoding means, connected to the output of the digital signal processing means, for encoding the digitally processed channel outputs for further transmission to a mobile telephone switching office, MTSO.

4. The basestation of claim 3 wherein the signal-transport encoding means is a T1 encoder.

5. The basestation of claim 1 additionally comprising:

second digital channelization means, being connected to receive the wideband tuner output signal, and providing a second set of multiple digital channel signal outputs, each one of the second set of the digital channel signal outputs having a predetermined channel bandwidth which is different from the predetermined channel bandwidth of said above mentioned first digital channel signals, and each one of the second set of digital channel signals corresponding to one of the signals received from one of the mobile units.

6. The basestation of claim 1 additionally comprising:

second wideband tuner means, connected to the antenna, for downconverting a second selected bandwidth of the RF signal to a second intermediate frequency, IF, signal, and for performing an analog to digital conversion on the second IF signal, to provide a second wideband digital tuner output signal; and

second digital channelization means, being connected to receive the second wideband tuner output signal, and providing a second set of multiple digital channel signal outputs, each one of the second set of the digital channel signal outputs having a predetermined channel bandwidth which is different from the predetermined channel bandwidth of said above mentioned first digital channel signals, and each one of the second set of digital channel signals corresponding to one of the signals received from one of the mobile units.

7. A basestation as in claim 6 wherein the first and second set of digital channel signals are modulated in accordance with first and second standards, respectively.

8. A basestation as in claim 7 wherein the digital signal processors include a first set of digital signal processor means for demodulating said first set of digital channel signals, and a second set of digital signal processors for demodulating said second set of digital channel signals.

9. A basestation as in claim 7 wherein said first and second standards are each different one of a time division multiplex, TDMA, code division multiplex, CDMA, Advanced Mobile Phone System, AMPS, Personal Communications System , PCS, or Groupe Especiale Mobile, GSM.

10. A basestation as in claim 1 additionally comprising:

basestation controller means, connected to the time division multiplex switching means and the digital signal processing means, for maintaining a list of unused digital signal processing means that are not presently interconnected through the time division multiplex switching means to one of the digital channel outputs, and for dynamically allocating digital signal processing means from the list of unused digital signal processing means to be interconnected to one of the digital channel outputs only when the digital channel output contains an active signal being transmitted by the mobile unit which has not yet been assigned to one of the digital signal processing means.

11. A basestation as in claim 1 wherein the time division multiplex switching means further comprises:

a time division multiplex, TDM, data bus including data lines;

basestation controller means, connected to the TDM bus, and to generate TDM bus synchronization signals and driver address signals, the TDM bus synchronization signals used to identify access timeslots on the TDM bus; and

TDM bus driver means, connected to the TDM bus, the basestation controller means, and at least one of the digital channel signals, for receiving the TDM bus synchronization signals and the driver address signals, for storing the driver address signals, and for asserting the digital channel signal on the TDM bus when the value of driver address signals corresponds to the value of the bus synchronization signals, thereby indicating that a timeslot associated with the digital channel signal is currently active.

12. A basestation as in claim 11 wherein the basestation controller means, connected to the TDM bus, additionally generates receiver address signals, and the time division multiplex switching means additionally includes:

TDM bus receiver means, connected to the TDM bus, the basestation controller means, and at least one of the digital signal processor means, for receiving the TDM bus synchronization signals and the receiver address signals, for storing the receiver address signals, and for reading a signal asserted on the TDM bus and providing such asserted signal to the digital signal processor means when the value of receiver address signals corresponds to the value of the bus synchronization signals, indicating that a timeslot associated with the digital signal processor is currently active.

13. A wideband basestation as in claim 6 wherein the first and second channelizers each comprise:

a convolutional digital filter, connected to receive the respective one of the digitized wideband signals; and

a fast Fourier transform, FFT, processor, connected to receive the output of the convolutional digital filter, and to provide the digital channel signals.

14. A basestation as in claim 1 additionally comprising:

a second plurality of digital signal processing means, connected to receive digital input signals from a communication signal source;

a wideband digital combiner, being connected to receive a second plurality of digital channel signals, and to provide a composite digital signal for transmission;

wherein the time division multiplex switching means is also disposed between the second plurality of digital signal processors and the wideband digital combiner, the switching means connecting any one of the second set of digital signal processors to any one of the digital channel signals input to the combiner:

a wideband digital exciter, connected to receive the composite digital signal and to provide a combined RF signal; and

a transmit antenna, connected to receive the combined RF signal and the radiate the combined RF signal.

15. A basestation as in claim 14 additionally comprising:

basestation controller means, connected to the time division multiplex switching means and the first and second plurality of digital signal processing means, for

maintaining a list of all unused digital signal processing means that are not presently interconnected through the time division multiplex switching means to one of the digital channel outputs, and for dynamically allocating digital signal processing means from the list of unused digital signal processing means to function as one of the first or second digital signal processing means only when the digital channel output contains an active signal being transmitted by the mobile unit which has not yet been assigned to one of the digital signal processing means, or when the digital inputs from the communications source are active.

16. A wideband basestation transceiver including:

a wideband digital tuner that provides a wideband digital signal at an output;

a digital channelizer, connected to the wideband tuner, to produce a plurality of sampled channel signals, with each channel signal representing signal energy in one of a plurality of radio frequency channels serviced by the basestation;

a time division multiple-access, TDM, data bus;

means for selectively connecting the digital samples of each channel signal, in turn, to the TDM bus;

basestation controller means, for controlling the means for selectively connecting the digital samples of each channel signal to the TDM bus, by so connecting each channel signal in a predetermined timeslot, in a predetermined order;

means, coupled to the TDM bus, for selecting the digital samples in a particular timeslot, and for generating a reconstructed channel signal thereby;

means for allocating a demodulator to be coupled to the reconstructed channel signal when the associated radio frequency channel is active, the demodulator providing a demodulated channel signal;

means for allocating a T1 line encoder to the demodulated channel signal, to format the demodulated channel signal for transmission over a T1 span line;

means for coupling the T1 line to a mobile telephone switching office, MTSO, or mobile switching center, MSC, for further connection into the public switched telephone network, PSTN; and

A synchronization and clock generation circuit has the capability of selecting the number of time slots, as well as the bus frame rate, to be used on the TDM bus. The number of time slots and the bus frame rate depend upon, respectively, the number of the channel signals and the bandwidth of each of the channel signals provided by the channelizer.

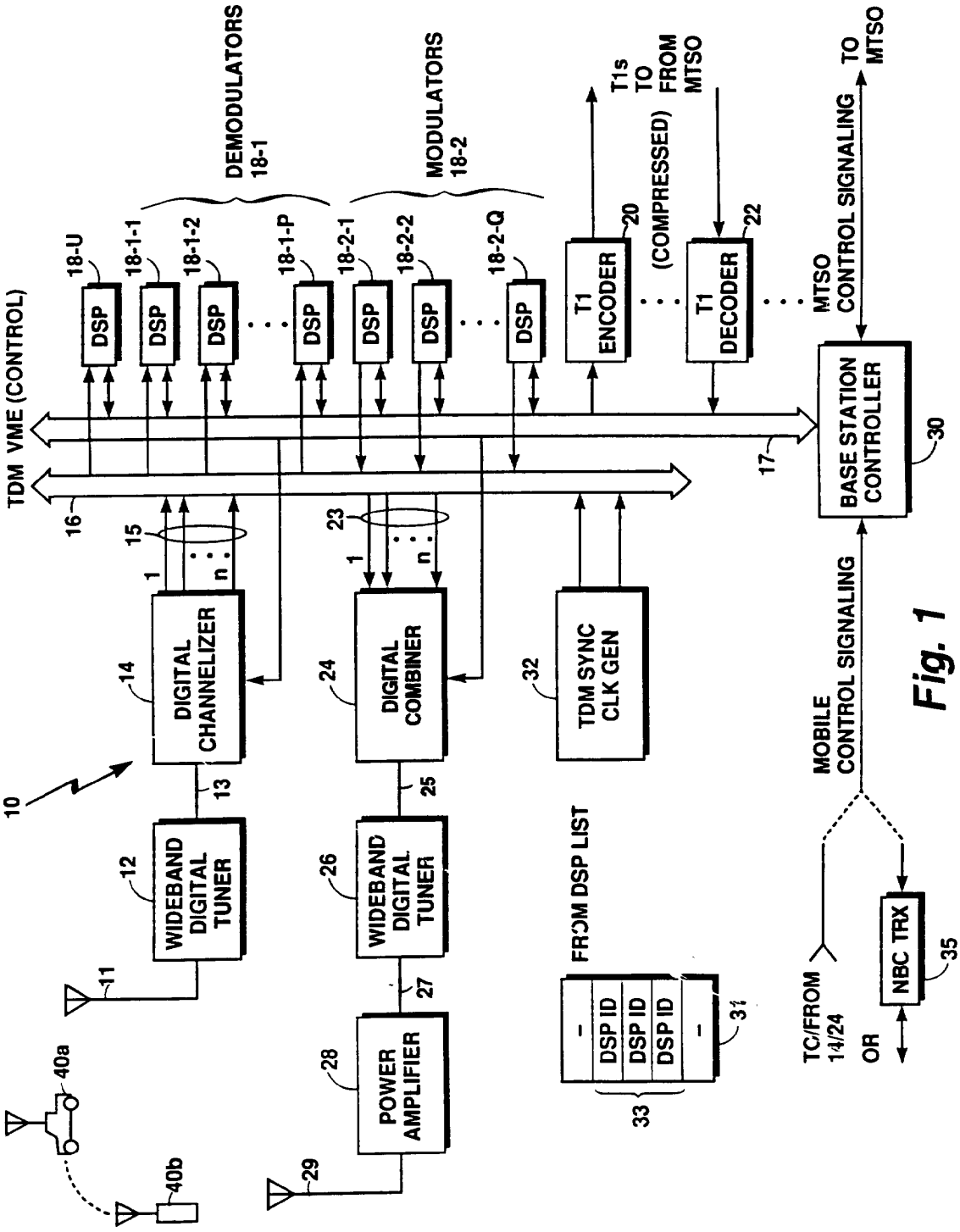


Fig. 1

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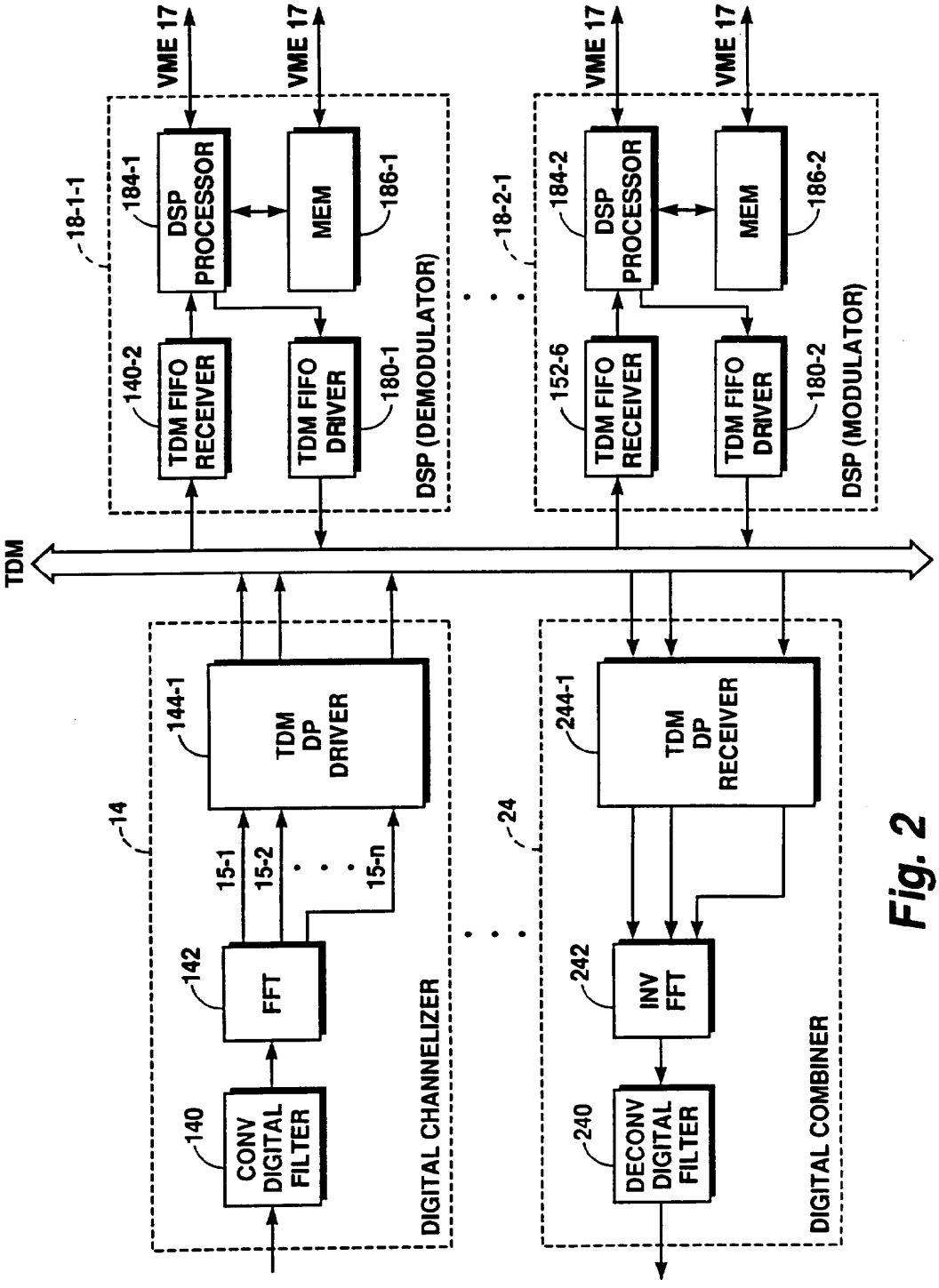
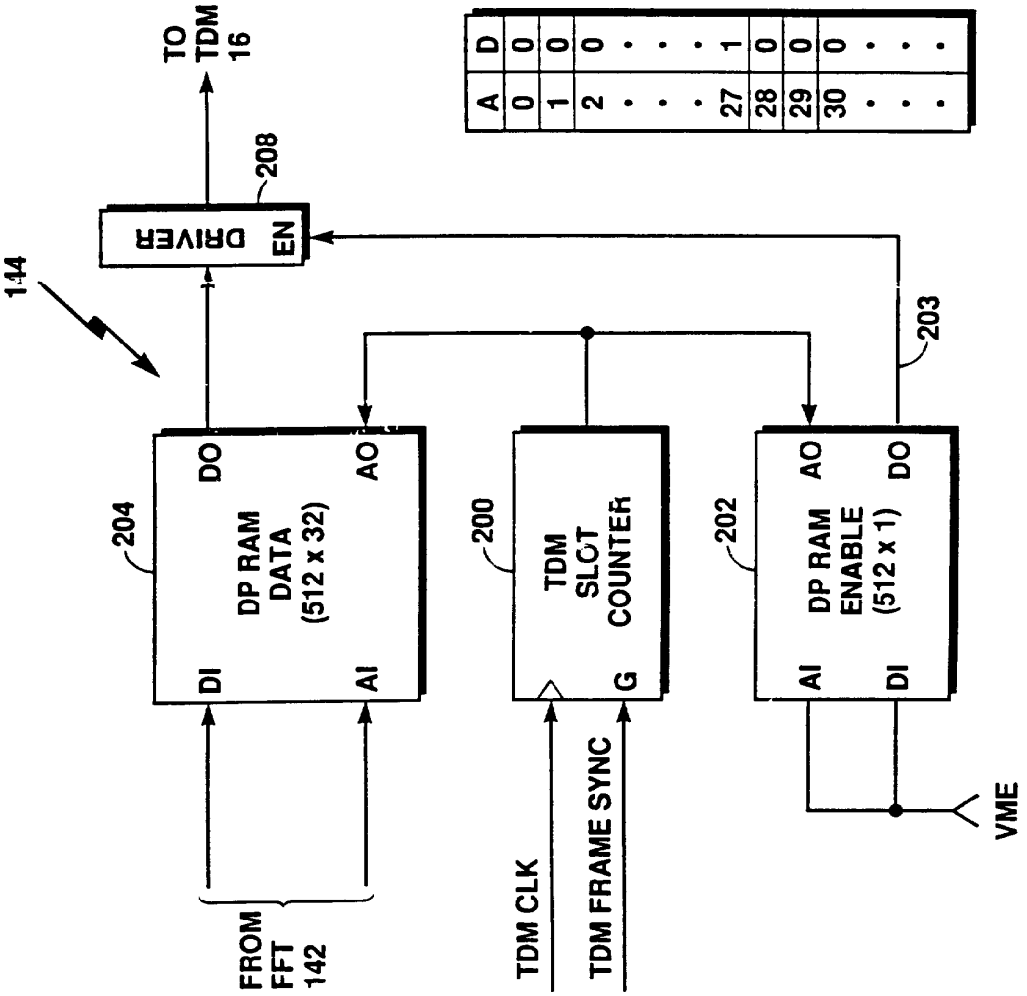


Fig. 2

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Fig. 3



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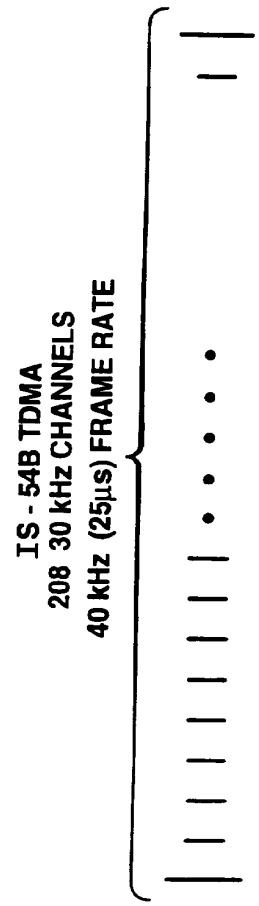


Fig. 4A

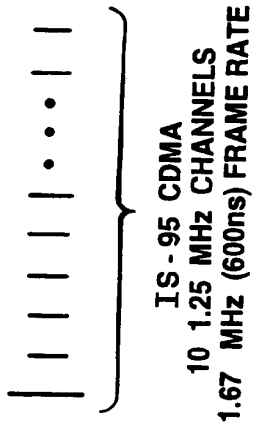
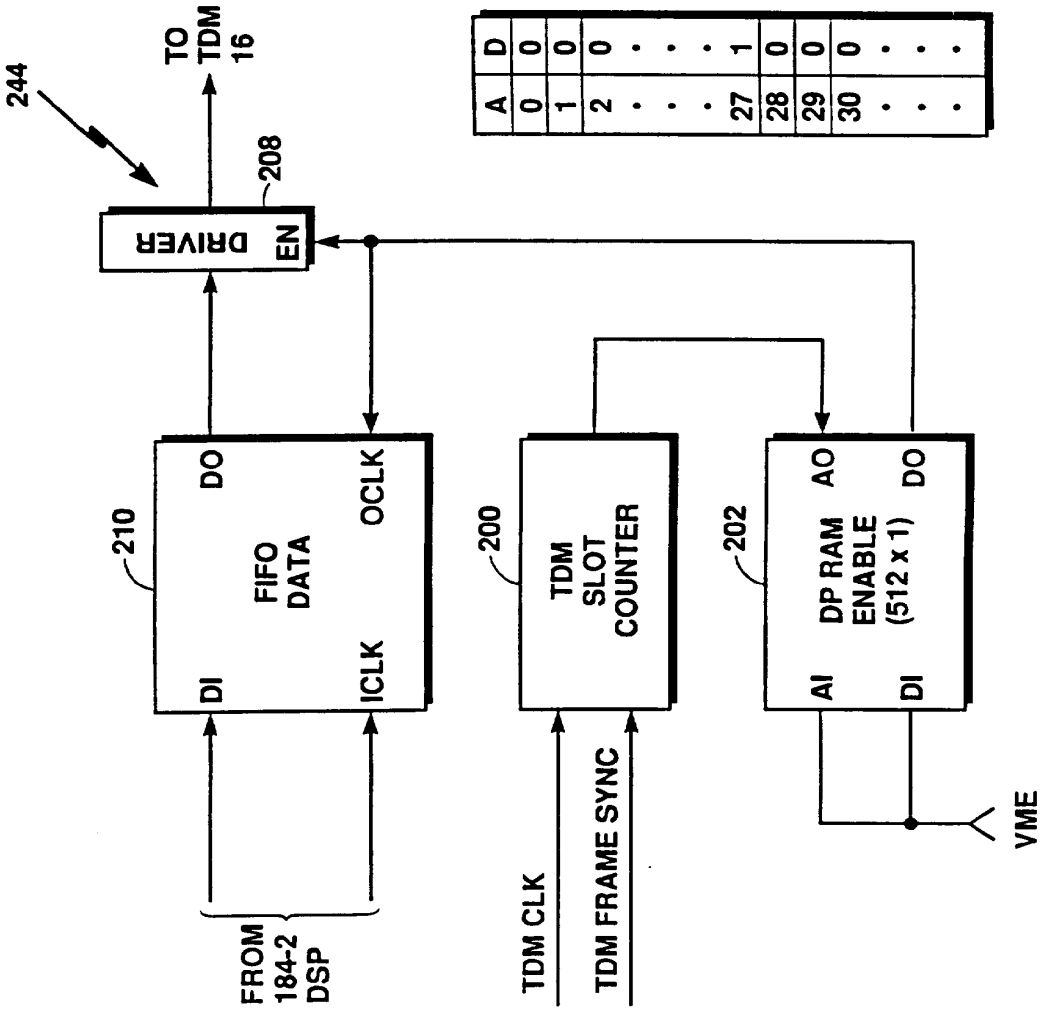


Fig. 4B

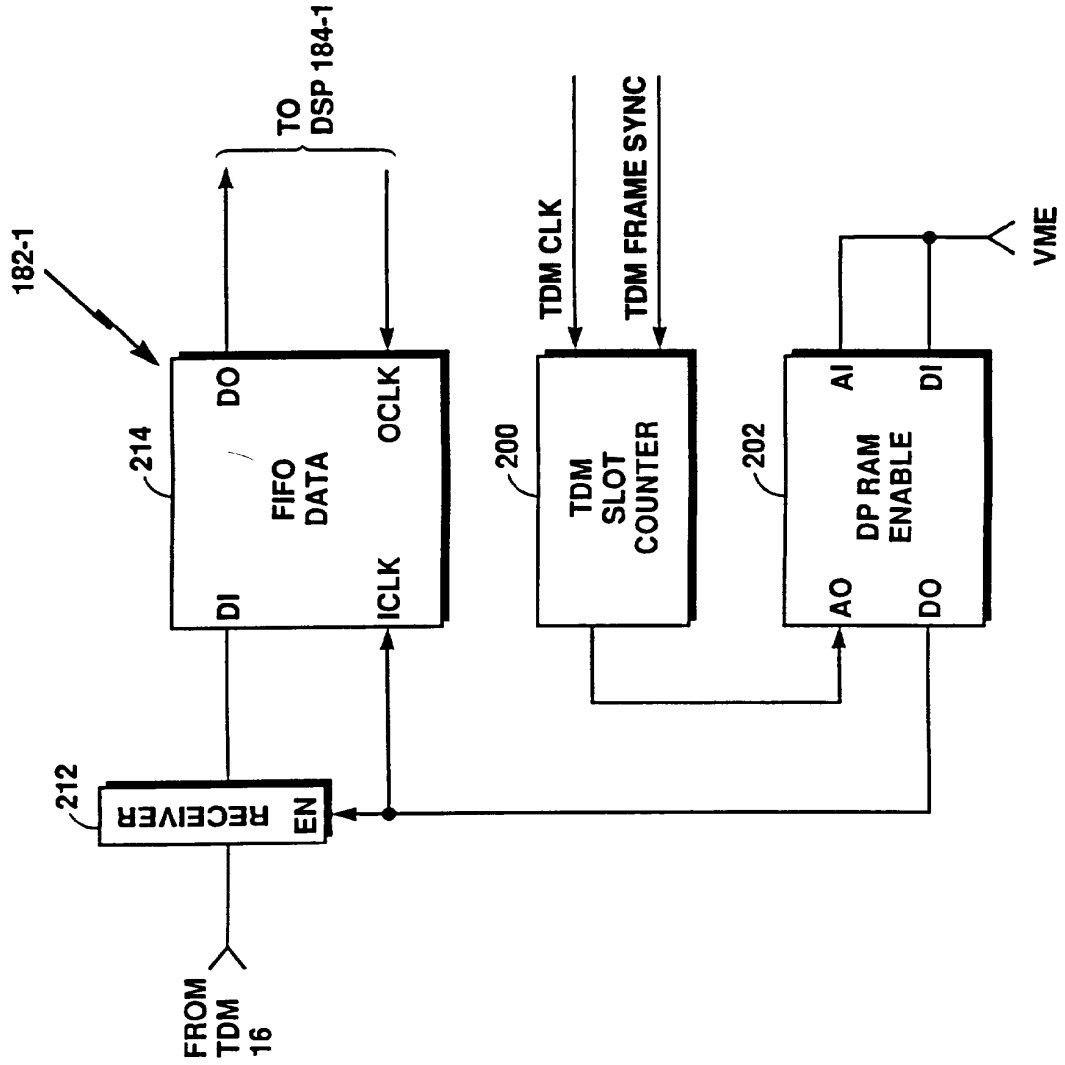
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Fig. 5



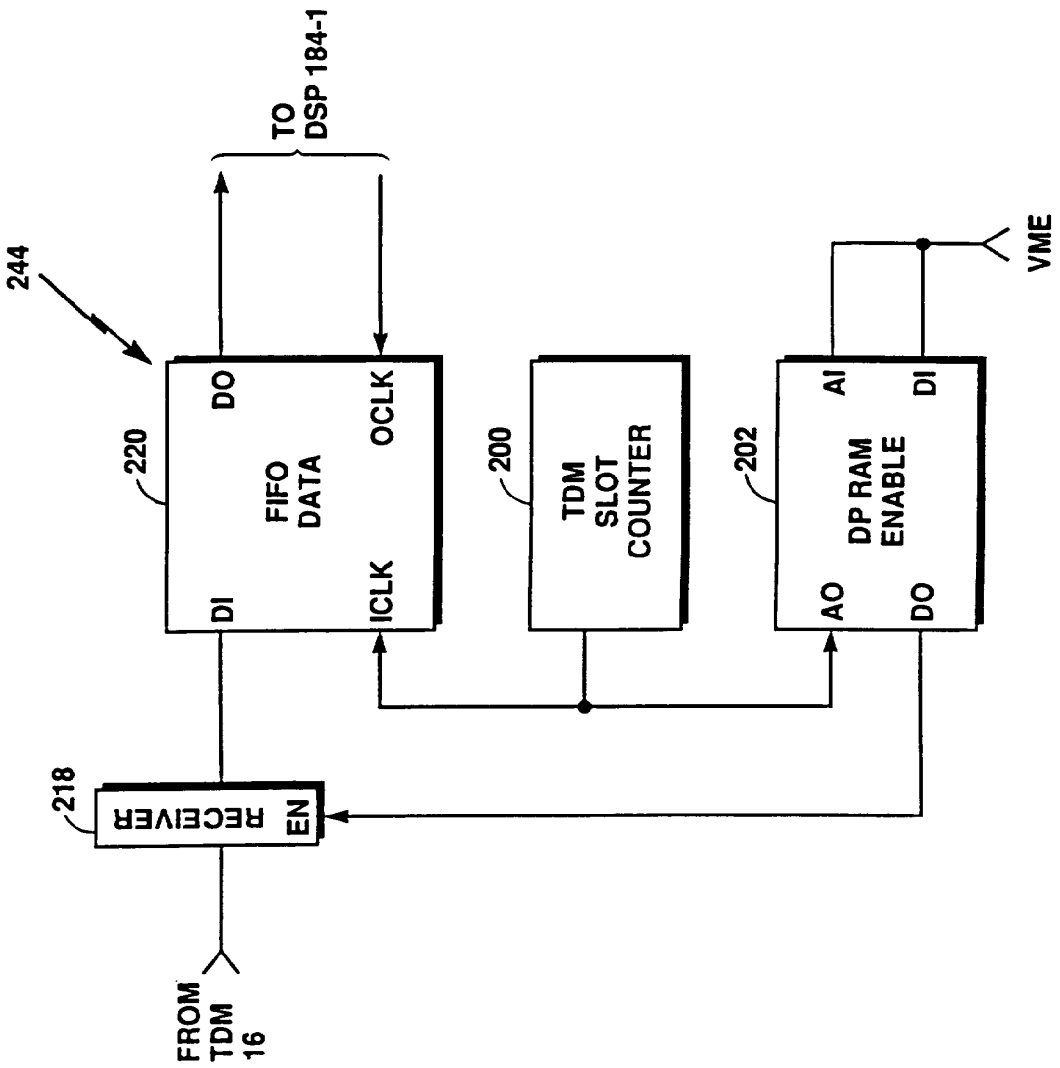
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Fig. 6



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Fig. 7



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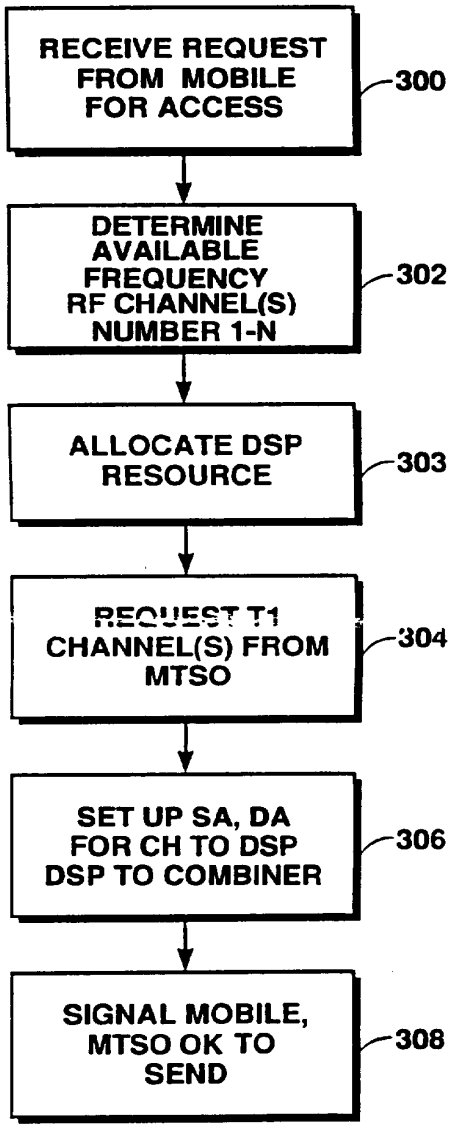


Fig. 8

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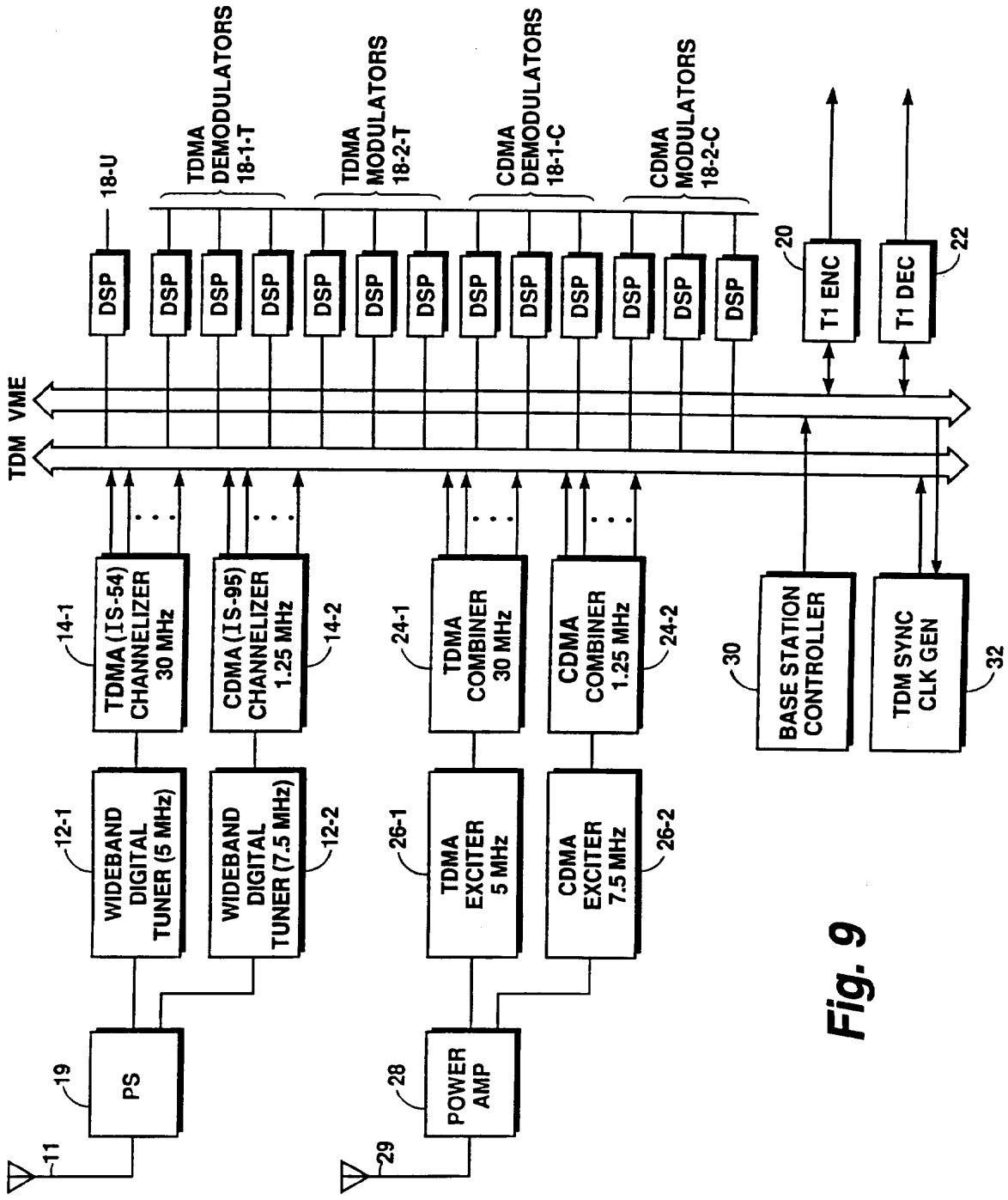


Fig. 9

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INTERNATIONAL SEARCH REPORT

Intern. ..nal Application No
PCT/US 96/02200

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/30 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 590 412 (SIEMENS) 6 April 1994 see claims 1-25; figures 1-4	1-16
X	EP,A,0 439 926 (ATT) 7 August 1991 see page 2, column 1, line 39 - column 2, line 43; figure 3	1-16
X	DE,A,44 23 582 (MOTOROLA) 12 January 1995 see claims 1-8; figures 1-4	1-16
X	EP,A,0 560 388 (NEC CORPORATION) 15 September 1993 see claims 1-5; figures 1-9	1-16
X	EP,A,0 605 182 (NIKI YOSHIRO) 6 July 1994 see claims 1-12	1,6-9,16

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 May 1996	04.07.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Bischof, J-L

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INTERNATIONAL SEARCH REPORT

Intern. ..al Application No
PCT/US 96/02200

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 507 384 (PHILIPS ELECTRONICS UK LIMITED) 7 October 1992 see page 3, line 1 - page 5, line 25; figures 1-7	1-8, 10-12, 14-16
X	EP,A,0 471 246 (MOTOROLA) 19 February 1992 see page 3, column 3, line 8 - column 4, line 26; claims 1-10; figure 1	1-8, 10-12, 14-16

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inten...onal Application No
PCT/US 96/02200

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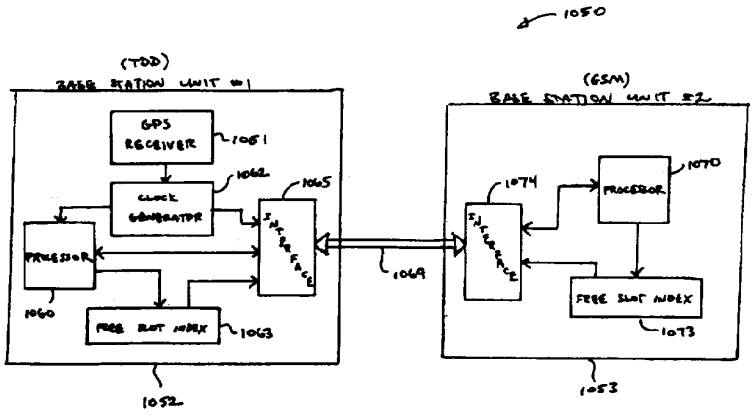
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(54) Title: COEXISTING COMMUNICATION SYSTEMS



(57) Abstract

An integrated communication system supporting multiple TDMA or TDD communication protocols, and includes means for selectively communicating according to either protocol. Each protocol defines time frames and/or time slots of a different duration (901, 911), from which is derived a composite time frame (925) having a predefined timing structure. A first base station unit (104) communicates in a first set of time slots of the composite time frame according to a first TDMA or TDD protocol, and a second base station unit (104) (which may be collocated with the first base station unit) communicates in a second set of time slots of the composite time frame according to a second TDMA or TDD protocol. Coordinating electronics (such as a GPS receiver in one or both base station units) are provided so as to prevent collisions between communications occurring between each base station unit and its respective users. In a particular embodiment, a first protocol is GSM protocol, and a second protocol is a TDD protocol utilizing spread spectrum techniques. The TDD protocol is structured so that each time slot is twice the duration of a GSM time slot, and each time frame is four times the duration of a GSM time frame. The system may comprise a number of "stacked" base stations in a single cell, each operating over a different frequency or using different spreading codes.

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DESCRIPTION

Coexisting Communication Systems

Background of the Invention

Field of the Invention

The present invention pertains to the field of the coexistence of two different communication methods and apparatus, more specifically to the coexistence of a spread spectrum TDMA communication system with a GSM communication system.

Description of the Related Art

A growing demand for flexible, wireless communication has led to the development of a variety of techniques for allocating available communication bandwidth among a steadily increasing number of users of wireless services. One technique for allocating communication bandwidth between a base station and a group of user stations is through the use of time division multiple access (TDMA), wherein transmissions are separated in time to avoid conflicts. In a communication systems utilizing TDMA techniques, a repetitive time frame may be divided into a plurality of smaller time units, or time slots, and communication between base stations and user stations occur in assigned time slots.

Other techniques for allocating communication bandwidth include frequency division multiple access (FDMA), wherein transmissions take place at different frequencies, and code division multiple access (CDMA), wherein transmissions take place using different codes.

Variants of the above techniques include frequency division duplex (FDD) and time division duplex (TDD). As used herein, FDD refers to a technique for establishing full duplex communications having both forward and reverse links separated in frequency, and TDD refers to a technique for establishing full duplex communications

having both forward and reverse links separated in time. Various systems using combinations of FDD, TDD, FDMA, CDMA, and/or TDMA have also been proposed.

A particular FDD/TDMA system in current use is the Global System for Mobile communications ("GSM"). According to GSM standards, communication between a base station and user stations takes place in a time frame which is divided into eight burst periods or time slots. In each of these time slots a different user station can communicate with the base station. No two user stations can communicate with the base station during the same time slot. GSM standards include the use of two distinct frequency bands. The base station transmits over the first frequency band, and the user stations transmit over the second frequency band. The user station transmission lags the base station transmission by several time slots to account for, among other things, propagation delays from the base station to the user station.

The GSM protocol provides for transmission and reception between remote devices and is generally suitable for communication at relatively high data rates. In addition to being a uniform standard in Europe, where it has been allocated a frequency band around the 1.9 GHz region, the GSM protocol has been tested, used and found to be robust, and there is a substantial installed base of devices and systems which utilize the GSM protocol in Europe. While the GSM protocol has not been allocated a specific bandwidth in the United States, it can be used in certain unlicensed bandwidths, and is a standard adopted by some telephone system operators seeking compatibility with user stations configured for GSM in Europe.

Certain other communication systems make use of a technology known as spread-spectrum communication, in which transmitted signals are spread across a frequency band which is wider than the bandwidth of the data being transmitted. In spread spectrum communication, a data signal is typically modulated with a pseudo-random chip

code to generate a transmitted signal spread over a relatively wide bandwidth. The transmitted signal has a low spectral density and appears essentially as noise to those not knowing the chip code. Consequently, spread spectrum communication provides increased security of transmitted information and reduced interference with other sensitive radio equipment being used in the surrounding environment.

Due to the nature of the spread spectrum signal it is typically necessary at the receiver to despread the received spread spectrum signal to recover the original data. In one spread spectrum technique, for example, despreading of the spread spectrum signal is accomplished by correlating the received signal with a reference code matching the pseudo-noise code used in the transmitter to encode the data prior to transmission of the information. After initial correlation is achieved, it is generally necessary to maintain synchronization by tracking the incoming signal so as to keep it aligned with the local reference code. Spread spectrum communication has been implemented in a TDMA environment (see, e.g., U.S. Patent No. 5,455,822 issued Oct. 3, 1995).

A general problem in wireless communication systems is that, because users of any one system may be mobile, they may leave the coverage region of their provider and enter a zone in which the provider does not provide coverage. For example, a user who has purchased a GSM based unit may travel to the United States and find that there is no communication system that will support the GSM based system. Likewise, a user who has purchased a unit that operates in a system configured for spread spectrum communication may travel out of the geographic region serviced by the system provider. While a user may solve this problem by having several different devices (e.g., handsets) for communication with different systems in different localities, switching between handsets may be cumbersome and inconvenient, as well as costly. Moreover,

there is increasing consumer demand to provide lighter handsets of smaller size for easier storage and transportation.

The existence of a multiplicity of different communication systems, each of which may serve different and possibly overlapping geographic regions, has led and will continue to lead to the potential for redundant hardware deployment for base stations and supporting network connections, redundant user hardware, and interference among neighboring wireless providers. At the same time, the number of cellular and wireless users continues to grow, as do the demands for providing more sophisticated wireless data transfer services such as wireless facsimile and other similar services.

It would therefore be advantageous to provide a communication system providing increased user mobility between different communication systems without the need to purchase additional hardware. It would further be advantageous to provide a communication system allowing communication with users according to either of two protocols. It would further be advantageous to provide a means of integrating two communication protocols in an overlapping geographical region, while mitigating interference with users utilizing either of the two communication protocols. It would further by advantageous to provide a means for dynamically allocating communication resources to either of two different communication protocols according to user demand. It would further be advantageous to provide a communication system allowing compatibility within a geographic region of both a GSM protocol and an alternative protocol, thereby increasing the geographic mobility of users of both protocols.

Summary of The Invention

The present invention comprises in certain aspects an integrated communication system supporting multiple

communication protocols. In a preferred embodiment, communication is carried out according to either one of two different TDMA or TDD protocols, and includes means for selectively communicating according to either protocol. In this embodiment, each protocol defines time frames and/or time slots of a different duration, which overlap according to a predefined ratio. The integrated system is synchronized in a manner such that only one user communicates at a time and collisions are thereby avoided. The system may comprise a number of "stacked" base stations in a single cell, each operating over a different frequency or using different spreading codes. The ultimate potential user capacity is therefore a function of the number of available frequencies, time slots, and codes for a given cell.

In another aspect of the present invention, an integrated base station comprises a first base station unit operating according to a first TDMA or TDD protocol, and a second base station unit operating according to a second TDMA or TDD protocol. The first base station unit and second base station unit operate in the same or overlapping geographic region, and are provided with coordinating electronics (such as GPS receiver in one or both base station units) so as to prevent collisions between communications occurring between each base station unit and its respective users. In a particular embodiment, the two base station units are collocated, and share an identical antenna or set of antennas.

According to a preferred embodiment, a first protocol is a GSM protocol, and a second protocol is a TDD protocol utilizing spread spectrum techniques. The TDD protocol is structured so that each time slot is twice the duration of a GSM time slot, and each time frame is four times the duration of a GSM time frame. The two protocols are synchronized by a common synchronization signal. For users of the TDD protocol, spread spectrum communication may be established by a user responding to a general poll

transmitted during an available time slot by the TDD base station unit and by carrying out a handshake transaction. A separate control channel is provided for GSM access.

In another aspect of the invention, a composite time frame is defined with a portion of time slots of the composite time frame allocated to the first protocol and a portion of the time slots allocated to the second protocol. The time slots allocated to each protocol may or may not be contiguous. The composite time frame structure is programmed into the integrated base station so that each base station unit knows in advance the relative position of the time slots allocated to it. Each base station unit independently manages the time slots allocated to it, and independently is responsible for establishing and maintaining communication with user stations using its protocol. In another embodiment of the invention, time slots are allocated on a dynamic basis according to user demand.

Other variations and alternative embodiments are also described herein.

Brief Description of The Drawings

The various objects, features and advantages of the present invention may be better understood by examining the Detailed Description of the Preferred Embodiments found below, together with the appended figures, wherein:

Fig. 1 is a diagram of a pattern of cells in a wireless communication system.

Fig. 2 is a block diagram of a communication system.

Fig. 3 is an illustration of a timing pattern according to existing GSM standards.

Fig. 4 is a block diagram of a transmitter and a receiver in a spread spectrum communication system.

Fig. 5 is a diagram of an arrangement of cells in a wireless communication system showing an exemplary code and frequency reuse pattern.

Fig. 6 is a diagram of a time frame divided into a plurality of time slots.

Fig. 7 is a diagram of an alternative timing structure showing a time frame divided into a plurality of virtual time slots.

Fig. 8 is a diagram illustrating a protocol for establishment of a spread spectrum communication link in a particular communication system.

Fig. 9A is a diagram of a preferred slot structure for a time slot according to a particular TDMA protocol, and Figs. 9B and 9C are diagrams of a base station traffic message structure and a user station traffic message structure, respectively, in the same TDMA protocol.

Figs. 10A-10C are diagrams of preferred polling message formats for use in the TDMA protocol related to Figs. 9A-9C.

Figs. 11A and 11B are diagrams of preferred message header formats for use in the TDMA protocol related to Figs. 9A-9C.

Figs. 12A and 12B are diagrams of a base station information packet and a user station information packet, respectively, for use in the TDMA protocol related to Figs. 9A-9C.

Fig. 13 is a diagram of an integrated base station according to one embodiment of the present invention.

Fig. 14 is a timing diagram of a comparing the timing structure of two different communication protocols.

Fig. 15 is a timing diagram of a composite time frame shown relative to the timing structure of the communication protocols of Fig. 14.

Fig. 16 is a timing diagram of a different composite time frame shown relative to the timing structure of the communication protocols of Fig. 14.

Figs. 17A and 17B are demand migration tables showing, for a composite time frame, possible time slot

allocations for the two communication protocols of Fig. 14.

Fig. 18 is a timing diagram showing waveforms for a slot clock and a frame clock.

Fig. 19 is a frequency channelization plan for a particular TDD communication system, and Fig. 20 is a frequency channelization plan for a GSM communication system.

Figs. 21 and 22 are graphs showing, for a particular embodiment, a frequency channelization relationship for the communication systems having the frequency channelization plans shown in Figs. 19 and 20.

Fig. 23 is a graph showing the frequency usage of a portion of the frequency spectrum during a non-GSM time slot of a composite time frame.

Fig. 24A is a diagram showing a timing relationship between the time frame structure of Fig. 7 utilizing virtual time slots and the GSM time frame structure; Fig. 24B is a diagram of a composite time frame shown relative to the timing structures of Fig. 24A.

Fig. 25 is a diagram of an integrated base station with a dynamic slot allocation capability.

Fig. 26 is a timing diagram showing a "composite" time frame derived from the time frames of two protocols and having conditional time gaps inserted.

Fig. 27 is a diagram of a "composite" time frame comprising a plurality of time slots from two different protocols without regard to the time frame structure of the two protocols.

Detailed Description of The Preferred Embodiments

Figure 1 is a diagram of a pattern of cells in a wireless communication system 101 for communication among a plurality of user stations 102. The wireless communication system 101 of Fig. 1 includes a plurality of cells 103, each with a base station 104, preferably located at or near the center of the cell 103. Each

station (both the base stations 104 and the user stations 102) generally comprises a receiver and a transmitter. In a preferred embodiment, a control station 105 (sometimes referred to herein as a "base station controller"), also comprising a receiver and a transmitter, manages the resources of the system 101.

Figure 2 is a block diagram of a communication system architecture utilized in a preferred embodiment of the present invention. The Fig. 2 communication system comprises a plurality of base stations 104 for communicating with a plurality of user stations 102. The base stations 104 and user stations 102 may operate in a personal communications system (PCS), under rules prescribed by the Federal Communications Commission (FCC).

Each base station 104 is preferably coupled to a base station controller 105 by any of a variety of communication paths 109. The communication paths 109 each comprise one or more communication links 118. Each communication link 118 may include a coaxial cable, a fiber optic cable, a digital radio link, or a telephone line. Each base station controller 105 is preferably connected to one or more communication networks 126, such as a public switched telephone network (PSTN) or personal communication system switching center (PCSC), by one or more communication paths 108, each of which may include a coaxial cable, a fiber optic cable, a digital radio link, or a telephone line.

The Fig. 2 communication system also may include one or more "intelligent" base stations 107 which connect directly to a communication network 126 without interfacing through a base station controller 105. The intelligent base stations 107 bypass the base station controllers 105 for local handoffs and switching of user stations 102, and instead perform these functions directly over the network 126.

In operation each base station 104 formats and sends digital information to its respective base station

controller 105 (or directly to the network 126 in the case of an intelligent base station 107). The base station controllers 105 receive inputs from multiple base stations 104, assist handoffs between base stations 104, and convert and format channel information and signaling information for delivery to the network 126. The base station controllers 105 may also, if desired, manage a local cache VLR database, and may support basic operation, administration and management (OA&M) functions such as billing, monitoring and testing. Each base station controller 105, under control of the network 126, preferably manages local registration and verification of its associated base station 104 and may provide updates to the network 126 regarding the status of the base stations 104.

The network 126 connects to the base station controllers 105 for call delivery and outgoing calls. Intelligent base stations 107 may use a predefined signaling protocol--such as ISDN messaging--for registration, call delivery and handoff over a public telephone switch. The intelligent base station 107 has all the general capabilities of a base station 104, but further may incorporate a BRI card, additional intelligence and local vocoding.

If the network 126 is a GSM network, then base stations 104 preferably connect to the network 126 through a defined "A" interface. The "A" interface may be incorporated in base station controllers 105 and in intelligent base stations 107. Features and functionality of GSM are passed to and from the base stations 104 over the "A" interface in a manner that is transparent to the end user.

The system may also interconnect to cable television distribution networks. The base stations 104 may be miniaturized so that they can be installed inside standard cable TV amplifier boxes. Interfacing may be carried out using analog remote antenna systems and digital transport

mechanisms. For example, T1 and FT1 digital multiplexer outputs from the cable TV network may be used for interfacing, and basic rate (BRI) ISDN links may be used to transport digital channels.

Figure 13 is a diagram of an integrated base station 850 (which can be either a base station 104 or an intelligent base station 107 in Fig. 2) in accordance with one embodiment of the present invention. The integrated base station 850 comprises a first base station unit 852 and a second base station unit 853. In a preferred embodiment, each base station unit 852, 853 is capable of carrying out communication with a plurality of user stations 102 according to multiple communication protocols (e.g., two protocols). In a preferred embodiment, the first base station unit 852 preferably carries out communication with a plurality of user stations 102 using a first protocol, and the second base station unit 853 preferably carries out communication with a plurality of user stations 102 using a second protocol. User stations 102 may be configured for communication using either the first protocol, the second protocol, or both protocols, as further illustrated herein.

In a preferred embodiment, the first protocol is a GSM protocol generally utilizing FDD/TDMA techniques, and the second protocol is a TDMA or TDD protocol having properties allowing it to smoothly integrate with the GSM protocol. A user station 102 desiring to communicate with the integrated base station 850 may utilize either protocol to do so (assuming channel availability). Aspects of two preferred communication protocols are described below, after which appear further details regarding the integration and coexistence of the two preferred protocols.

A first preferred protocol is the GSM protocol. Figure 3 illustrates a timing pattern according to certain existing GSM standards. According to these standards, communication between a base station 104 and user stations

102 is divided into eight burst periods 152. Up to eight different user stations can communicate with a base station, one in each burst period 152.

GSM standards, as noted previously, include the use of two separate frequency bands. The base station 104 transmits to a user station 102 using a frequency channel on a first frequency band F_A, while the user stations 102 transmit using an assigned frequency channel on a second frequency band F_B. After a user station 102 receives a base transmission 155 on the first frequency band F_A during a particular burst period 152, the user station 102 shifts in frequency by a predefined amount (e.g., 40 MHz or 80 MHz) to the second frequency band F_B and transmits a user transmission 156 in response to the base transmission 155 approximately three burst periods 152 later. The three burst period delay is assumed to be large enough to account for propagation time and other delay periods between the base station 104 and the user station 102.

Each GSM burst period 152 is surrounded by guard times 157 to account for uncertain signal propagation delays between the base station 104 and the user station 102. By comparing the actual receive time of the signal from the user station 102 to the expected receive time, the base station 104 may command the user station 102 to advance or retard its transmission timing in order to fall within the proper burst period 152, a feature known as adaptive frame alignment. A specification relating to adaptive frame alignment for the GSM system is TS GSM 05.10.

A second preferred protocol is a TDD/TDMA protocol utilizing aspects of spread-spectrum technology and/or code division multiplexing, as well as frequency division multiplexing as further discussed herein. A spread-spectrum transmitter and receiver are described with respect to Fig. 4, and preferred TDD timing structures are described hereafter with respect to Figs. 6 and 7.

Figure 4 is a block diagram of an exemplary transmitter and receiver in a spread spectrum communication system as may be employed for spreading and despreading signals in a spread spectrum communication system. In Fig. 4, a spread-spectrum transmitter 201 comprises an input port 202 for input data 203, a chip sequence transmitter generator 204, a modulator 205, and a transmitting antenna 206 for transmitting a spread-spectrum signal 207. A spread-spectrum receiver 208 comprises a receiver antenna 209, a chip sequence receiver generator 210, a demodulator 211, and an output port 212 for output data 213. In operation, a single chip sequence 214 is identically generated by both the transmitter generator 204 and the receiver generator 210, and appears essentially random to others not knowing the spreading code upon which it is based. The spread-spectrum signal 207 is despread with demodulator 211 by correlating the received signal with a locally generated version of the chip sequence 214. Exemplary correlators are described in, e.g., U.S. Patent Nos. 5,022,047 and 5,016,255. A preferred method for despreading and correlating spread spectrum signals is described in U.S. Patent Application Serial No. 08/481,613 filed June 7, 1995.

Where spread spectrum communication is used, the control station 105 (see Fig. 1) assigns the base station 104 transmitters and user station 102 transmitters in each cell 103 a spread-spectrum code for modulating radio signal communication in that cell 103. The resulting signal is generally spread across a bandwidth exceeding the bandwidth necessary to transmit the data, hence the term "spread spectrum". Accordingly, radio signals used in that cell 103 are spread across a bandwidth sufficiently wide that both base station 104 receivers and user station 102 receivers in an adjacent cell 103 may distinguish communication which originates in the first cell 103 from communication which originates in the adjacent cell 106.

Figure 5 is a diagram of a preferred cellular environment in which the spread spectrum protocol operates. In Fig. 5, a geographical region 301 is divided into a plurality of cells 103. Associated with each cell 103 is an assigned frequency and an assigned spread spectrum code. Preferably, three different frequencies (or frequency groups) F1, F2 and F3 are assigned in such a manner that no two adjacent cells have the same assigned frequency (or frequency group) F1, F2 or F3, thereby minimizing interference between adjacent cells.

To further reduce the possibility of intercell interference, different near-orthogonal spread spectrum codes C1 through C7 are assigned as shown in a repeating pattern overlapping the frequency reuse pattern. Although seven spread spectrum codes C1 through C7 are shown in Fig. 5, a pattern involving other numbers of spread spectrum codes may be suitable depending upon the particular application.

The use of spread spectrum for carrier modulation permits a very efficient frequency reuse factor of N = 3 for allocating different carrier frequencies F1, F2 and F3 to adjacent cells 103. Interference between cells 103 using the same carrier frequency F1, F2 or F3 is reduced by the propagation loss due to the distance separating the cells 103 (no two cells 103 using the same frequency F1, F2 or F3 are less than two cells 103 in distance away from one another), and also by the spread spectrum processing gain of cells 103 using the same carrier frequencies F1, F2 or F3, obtained by the use of orthogonal or near-orthogonal spreading codes.

Figure 6 is a diagram showing a preferred timing structure for a TDD system. According to the timing structure of Fig. 6, communication over time is broken into a continuous series of time frames 301. A single complete time frame 301 is shown along a timeline 310 in Fig. 6; similar time frames precede and follow time frame 301 in a continuous pattern along the timeline 310.

Time frame 301 is divided into a plurality of time slots 302 numbered consecutively TS1, TS2...TSN, each of which may support duplex communication with a user station 102. Time frame 301 may be thought of as a "polling loop" or a time loop, as depicted in Fig. 6, whereby a base station 104 communicates with user stations 102 sequentially over the time frame 301 in a manner analogous to polling, each user station 102 transmitting and receiving messages in its designated time slot 302. In the Fig. 6 embodiment, each time slot 302 comprises a user segment 305, wherein a user station 102 transmits a user-to-base message to the base station 104, and a base segment 306, wherein the base station 104 transmits a base-to-user message to the user station 102. Communication in time slots 302 may be interleaved, such that user stations 102 transmit in one physical time slot 302 but receive in a different physical time slot 302 (such as described with respect to the Fig. 7 timing structure elsewhere herein).

In an preferred TDD communication system in accordance with Fig. 6, time frames 301 are each 18.46 milliseconds in duration, and each time frame 301 comprises sixteen time slots 302 or, alternatively, eight time slots 302 to support extended range through increased guard times. If sixteen time slots 302 are used, the time slots 302 are preferably each 1153.125 microseconds in duration.

In some embodiments, a user station 102 may communicate in more than one time slot 302 in each time frame 301, so as to support an increased data rate. Similarly, in some embodiments, a user station 102 may periodically skip time frames 301 and communicate in a subset of all time frames 301 (e.g., every other time frame 301, or every fourth time frame 301), so as to support a reduced data rate where a full speed communication link is not necessary. Further information about an exemplary TDMA system supporting variable data

rates may be found in copending U.S. Patent Application Serial No. 08/284,053 filed August 1, 1994.

Figure 7 is a diagram of an alternative preferred timing structure employing virtual time slots, each of which generally comprises a duplex pair of communication links (i.e., one forward link and one reverse link).

In Fig. 7, similar to Fig. 6, communication over time is broken into a continuous series of time frames 601. A single complete time frame 601 is shown along a timeline 610 in Fig. 7; similar time frames precede and follow time frame 601 in a continuous pattern along the timeline 610.

Time frame 601 is divided into a plurality of physical time slots 602 numbered consecutively TS1', TS2'...TSN'. Each physical time slot 602 comprises a user segment 605 wherein a user station 102 transmits a user-to-base message to the base station 104, and a base segment 606 wherein the base station 104 transmits a base-to-user message to a user station 102, which could be a different user station 102 than transmitted to the base station 104 in the same physical time slot 602. Using virtual time slots, communication in physical time slots 602 may be interleaved, such that a user station 102 transmits in one physical time slot 602 but receives in a different physical time slot 602. The user segment 605 and base segment 606 which define the forward link and reverse link transmissions to a given user station 102 (and which are typically located in different physical time slots 602) are referred to as a virtual time slot.

An exemplary virtual time slot 618 is shown in Fig. 7, associated with a particular user station 102 (e.g., user station MS2). The virtual time slot 618 comprises two message segments, one in each of two physical time slots 602a and 602b. Virtual time slot 618 has a user segment 605a in the first physical time slot 602a, and a base segment 606b in the second physical time slot 602b. Between the user segment 605a and the base segment 606b of the virtual time slot 618, the base station 104 transmits

in a base segment 606a of the first physical time slot 602a (e.g., to a second user station 102, such as user station MS1), and another user station 102 (e.g., a third user station 102, such as user station MS3) transmits in a user segment 605b to the base station 104. In this manner, transmissions to and from the base station 104 are interleaved.

Time frame 601 may be thought of as a "polling loop" or a time loop, similar to time frame 301 of the Fig. 6 embodiment, whereby a base station 104 communicates with user stations 102 sequentially over the time frame 601 in a manner analogous to polling, each user station 102 transmitting and receiving messages in its designated virtual time slot 618. The virtual time slots 618 of Fig. 7, however, are not necessarily identical to the physical time slots 602. An advantage of the Fig. 7 timing structure is that it generally provides extended time for the base station 104 to process channel characterization data received from the user station 102.

In an exemplary TDMA communication system, time frames 601 are each 18.46 milliseconds in duration, and each time frame 601 comprises sixteen time slots 602 or, alternatively, eight time slots 602 to support extended range through increased guard times. If sixteen time slots 602 are used, the time slots 602 are preferably each 1153.125 microseconds in duration.

In some embodiments, a user station 102 may communicate in more than one virtual time slot 618 in each time frame 601, so as to support an increased data rate. Similarly, in some embodiments, a user station 102 may periodically skip time frames 601 and communicate in some subset of all time frames 601 (e.g., every other time frame 601, or every fourth time frame 601), so as to support a reduced data rate where a full speed communication link is not necessary.

Communication between a user station 102 and a base station 104 is established in one embodiment by a response

from a user station 102 to a general polling message sent from the base station 104 during an available time slot 302. This process is described in more detail with reference to Fig. 8, which illustrates a protocol for establishment of a spread spectrum communication link in, e.g., the Fig. 6 communication system. A communication link may be established in an analogous manner for the Fig. 7 embodiment.

In the Fig. 8 protocol, messages (base transmissions 306 and user transmissions 305) are generally one of three types: a general poll message 401, a specific poll message 402, or an information message 403. When a message is transmitted by a user station 102, it may be referred to herein as a "response", e.g., a general poll response 404, a specific poll response 405, or an information response 406.

A general poll message 401 is transmitted by the base station 104 in each time slot 302 available for communication. A user station 102 seeking to establish communication monitors transmissions from a base station 104 and ascertains available time slots 302 by receiving general poll messages 401 in those time slots 302.

A user station 102 "acquires" a base station 104 by a sequence of handshaking steps. At a general poll step 407, the base station 104 transmits a general poll message 401 during an unoccupied time slot 302. The user station 102 receives the general poll message 401 and, if it was received without error, transmits a general poll response 404 to the base station 104 in the same time slot 302 of the following time frame 301. The general poll message 401 comprises a field for a base ID 408b, which may be 32 bits long, and which may be recorded by the user station 102. Similarly, the general poll response 404 comprises a field for a user ID 409, which is preferably 72 bits long, and which may be recorded by the base station 104.

Upon receiving a general poll response 404, at a specific poll step 410, the base station 104 transmits a

specific poll message 402, comprising the user ID 409 received by the base station 104 as part of the general poll response 404. The user station 102 receives the specific poll message 402 and, if it was received without error and with the same user ID 409, transmits its specific poll response 405 to the base station 104 in the same time slot 302 of the following time frame 301. The specific poll response 405 comprises the same user ID 409 as the general poll response 404.

In a particular embodiment, the specific poll message 402 may be eliminated as redundant. The user station 102 may therefore follow the general poll response 404 with a specific poll response 405.

Upon receiving a specific poll response 405 comprising a user ID 409 which matches that of the general poll response 404, at a link-established step 411, the base station 104 may transmit a traffic message 403. At this point, the base station 104 and user station 102 have established a communication link 412. The base station 104 may couple a telephone line to the communication channel, and the user station 102 may begin normal operation on a telephone network (e.g., the user station 102 may receive a dial tone, dial a number, make a telephone connection, and perform other telephone operations). The base station 104 and user station 102 may exchange traffic messages 403 and 406, until the communication link 412 is voluntarily terminated, until faulty communication prompts the user station 102 to re-acquire the base station 104, or until handoff of the user station 102 to another base station 104.

Should more than one user station 102 respond to the same general poll message 401, the base station 104 may advertently fail to respond. The lack of response from the base station 104 signals the involved user stations 102 to back off for a calculated time interval before attempting to acquire the same base station 104 using the general poll message 401 and general poll response 404

protocol. The back-off time may be based upon the user ID 409, and therefore each user station 102 will back off for a different length of time to prevent future collisions.

When an incoming telephone call is received at a base station 104, at an incoming-call step 413, the base station 104 transmits a specific poll message 402 with the user ID 409 of the indicated recipient user station 102 (skipping the general poll message 401 and the general poll response 404) on an available time slot 302. Each user station 102 listens regularly for the specific poll message 402, as further described herein, so as to receive the specific poll message 402 within a predetermined time after it is transmitted. When the specific poll message 402 is received, the user station 102 compares the user ID 409 in the message with its own user ID, and if they match, continues with the link-established step 411. The base station 104 may thus establish a communication link 412 with any user station 102 within communication range.

Further details regarding means for establishing communication (particularly spread spectrum communication) in a TDMA system may be found in U.S. Patent No. 5,455,822 and in copending U.S. Patent Application Serial No. 08/284,053 filed August 1, 1994.

In a preferred embodiment, the general poll message 401 comprises a slot pointer (e.g., in slot pointer field 810 shown in and described hereafter with respect to Fig. 11A) which indicates the next time slot 302 (or virtual time slot 618) during which the next general poll message 401 will be transmitted by the base station 104. A user station 102 seeking to establish communication responds to the general poll message 401 not necessarily in the same time slot of the next time frame 301 (or 601), but in the user segment 305 (or 605) of the time slot 302 (or 618) indicated by the slot pointer. Upon receiving a general response message 404 from the user station 102 in the time slot indicated by the slot pointer, the base station 102 responds with a specific poll message 402. Should more

than one user station 102 respond to a general poll message 401, the appearance of a general poll message 401 (rather than a specific poll message 402) in the time slot indicated by the slot pointer will cause each user station 102 involved to back off for a variable period of time depending on the user station ID.

The specific poll message 402 comprises a temporary shorthand identifier (nickname) specific to the user station 102 and known as a correlative ID. The correlative ID appears in future signaling messages (in both directions) until the established link is dropped. In response to the specific poll message 402, the user station 102 responds with a traffic message in a time slot 302 (or 618) assigned by a slot pointer in the header of the specific poll message 402.

Figure 9A is a diagram of a preferred slot structure, and Figs. 9B and 9C are diagrams of a base station traffic message structure and a user station traffic message structure, respectively. In Fig. 9A, a time slot 510 comprises a variable radio delay gap 505, a user station transmit frame 515, a user station turn-around gap 525, a guard time 535, a base station transmit frame 545, and a base station turn-around gap 555. Each user station transmit frame 515 comprises a user preamble 516, a user preamble sounding gap 519, and a user station data frame 521. Similarly, each base station transmit frame 545 comprises a base preamble 547, a base preamble sounding gap 549, and a base transmit data frame 551.

Figure 9B illustrates a preferred message structure for the base transmit data frame 551. The message structure of Fig. 9B comprises a base header field 553, a base D-channel field 557, a base data field 559, and a base cyclical redundancy check (CRC) field 561. In a preferred embodiment, the base header field 553 is 23 bits, the base D-channel field 557 is 8 bits, the base data field 559 is 192 bits, and the base CRC field 561 is 16 bits.

Figure 9C illustrates a preferred message structure for the user station transmit data frame 521. The message structure of Fig. 9C comprises a user header field 523, a user D-channel field 527, a user data field 529, and a user CRC field 531. In a preferred embodiment, the user header field 523 is 17 bits, the user D-channel field 527 is 8 bits, the user data field 529 is 192 bits, and the user CRC field 531 is 16 bits.

In a preferred embodiment, a time slot 301 comprises 3125 chip periods (where each chip period is equal to about 0.369 microseconds); the user transmit frame 515 and the base transmit frame 545 are 519.552 microseconds (1408 chips in duration) and 531.36 microseconds (1440 chips in duration), respectively; the user station turn-around gap 525 is 10.7 microseconds (29 chips in duration); the guard time 535 is 66.4 microseconds (180 chips in duration); and the base station turn-around gap 555 is 25.1 microseconds (68 chips in duration). The effective gap time is 72.3 microseconds, corresponding to a non-interfering base-station-to-base-station range of about 13.5 miles. The bearer channel (i.e., user data field 529) supports a rate of 10,400 bits/second, and the D-channel 527 supports a data rate of 433.33 bits/second.

Figures 10A-10C are diagrams of preferred polling message formats. Figure 10A is a diagram of a general poll message format (such as for general poll message 401 of Fig. 8). The general poll message 701 preferably comprises, in the following sequence, a header field 702, a spare field 703, a zone field 704, a base station controller (BSC) ID field 705, a base ID field 706, a facility field 707, a system type field 708, a service provider field 709, a slot quality field 710, a forward error correction (FEC) field 711, and a frame control word (FCW) field 712. In a preferred embodiment, the header field 702 is 23 bits long, the spare field 703 is 16 bits long, the zone field 704 is 40 bits long, the BSC ID field 705 is 16 bits long, the base ID field 706 is 32 bits

long, the facility field 707 is 32 bits long, the system type field 708 is 8 bits long, the service provider field 709 is 16 bits long, the slot quality field 710 is 8 bits long, the FEC field 711 is 32 bits long, and the frame control word field 712 is 16 bits long, for a total of 239 bits.

The header field 702 identifies the message type and is described more fully with respect to Fig. 11A. The zone field 704 identifies the paging zone of the specific base station 104. A user station 102 may move from one base station 104 service area to another in the same zone without requiring immediate re-registration. The BSC ID field 705 is a sequence uniquely identifying the base station controller 105. The base ID field 706 is a sequence uniquely identifying the base station 104. The facility field 707 describes the services offered by the base station 104 (e.g., ethernet access, aggregate data capability, enhanced voice, etc.). The facility field 707 may include a sub-field indicating which user stations 102 are permitted access to the channel (e.g., 911 calls only, or user stations 102 with specific access codes). The system type field 708 identifies the type of system associated with the base station 104. The service provider field 709 identifies the PCS service provider that operates the base station 104. The slot quality field 710 indicates the relative quality of the time slot in terms of interference. Generally, the lower the number, the better the slot quality. The FEC field 711 is used for forward error correction. The FCW field 712 is used for error detection, and in one embodiment comprises a sequence determined according to following algorithm:

1. Calculate remainder R1 of a seed polynomial SDP modulo-2 divided by a generator polynomial GRP;

2. Calculate product P of x^{16} and content of the message 701 preceding FCW field 710;

3. Calculate remainder R2 of the generator polynomial GNP modulo-2 divided by the product P derived in Step 2;

4. Calculate modulo-2 sum S of remainder R1 and remainder R2; and

5. Calculate the ones-complement of sum S the result of which is transmitted in the FCW field 710.

In a preferred embodiment, the seed polynomial SDP is:

$$x^k(x^{15}+x^{14}+x^{13}+x^{12}+x^{11}+x^{10}+x^9+x^8+x^7+x^6+x^5+x^4+x^3+x^2+x^1+1)$$

and the generator polynomial GRP is:

$$x^{16}+x^{12}+x^5+1$$

Figure 10B is a diagram of a specific poll message format (such as for specific poll message 402 of Fig. 8). The specific poll message 720 preferably comprises, in the following sequence, a header field 721, a correlative ID field 722, a cause field 723, a personal identifier (PID) field 724, an over-the-air (OTA) map type field 725, an OTA map field 726, a spare field 727, a slot quality field 728, a forward error correction field 729, and an FCW field 730. In a preferred embodiment, the header field 721 is 23 bits long, the correlative ID field 722 is 8 bits long, the cause field 723 is 8 bits long, the PID field 724 is 72 bits long, the OTA map type field 725 is 8 bits long, the OTA map field 726 is 32 bits long, the spare field 727 is 32 bits long, the slot quality field 728 is 8 bits long, the FEC field 729 is 32 bits long, and the FCW field 729 is 16 bits long, for a total of 239 bits.

The header field 721, slot quality field 728, FEC field 729, and FCW field 730 are similar to the analogous fields described for Fig. 10A. The correlative ID field 722 is used to temporarily identify one or more channels (i.e., time slots) as being allocated to a specific user station 102. A correlative ID number is assigned for the duration of a call connection and is released for reuse by another user station 102 at the termination of a

connection; the correlative ID number may also be changed during a connection. A specific correlative ID number may be reserved by the base station 104 for broadcast use. The cause field 723 indicates the cause of an error occurring during execution of a previous signaling traffic operation for the particular user station 102. Interpretation of the cause field 723 message may therefore depend upon the type of signal traffic involved. Possible cause messages include, for example, those indicating that the user station 102 is unregistered or will not be accepted for registration, or that the call has not been connected or cannot be completed. The PID field 724 comprises a personal identification number which uniquely identifies the subscriber (e.g., user station 102). The OTA map type field 725 defines the type of map (e.g., superframe, subframe, etc.) that follows in the OTA map field 726. The OTA map field 726 describes the mapping of time slots relative to a particular user station 102. The format of the OTA map field 726 depends on the map type.

Figure 10C is a diagram of a poll response message format (such as for general poll response 404 or specific poll response 405 of Fig. 8). The poll response message 740 preferably comprises, in the following sequence, a header field 741, a first spare field 742, a PID field 743, a service provider field 744, a class field 745, a user capabilities field 746, a second spare field 747, an FEC field 748, and an FCW field 749. In a preferred embodiment, the header field 741 is 17 bits long, the first spare field 742 is 16 bits long, the PID field 743 is 72 bits long, the service provider field 744 is 16 bits long, the class field 745 is 16 bits long, the user capabilities field 746 is 16 bits long, the second spare field 747 is 32 bits long, the FEC field 748 is 32 bits long, and the FCW field 749 is 16 bits long, for a total of 233 bits.

The header field 741 identifies the message type and is more fully described in Fig. 11B. The PID field 743, FEC field 748, and FCW field 746 are similar to the PID field 724, FEC field 729, and FCW field 730, respectively, described with respect to Fig. 10B. The service provider field 744 identifies the PCS service provider that the user station 102 wishes to use. The class field 745 specifies some of the operational parameters being used by the particular user station 102. The class field 745 may comprise a class type sub-field and a class information sub-field. The class type sub-field indicates the user station class type (e.g., GSM or DCS1900 class type, IS-41 class type, etc.). The class information sub-field provides operational information including, for example, revision level, available encryption algorithms, short message capability, ellipsis notation and phase-2 error handling capability, power class, continuous/discontinuous transmission, bandwidth (e.g., 20 MHz or 25 MHz), and nominal power levels. The user capabilities field 746 identifies the features present in the user station 102 (e.g., whether the user station 102 can receive a fax or data connection, whether the user station 102 is capable of ciphering, etc.).

Figures 11A and 11B are diagrams of preferred polling message header formats. Figure 11A is a diagram of a polling message header format for a base polling message (such as general poll message 401 or specific poll message 402 of Fig. 8). The polling message header 801 comprises a base/mobile indicator (B/M) flag 802, an extended protocol (E) flag 803, a packet type field 804, a power adjustment (PWR) field 805, a symmetry field 806, a D-channel suppression (DCS) flag 807, a virtual slot (VS) flag 808, a slot or channel utilization (CU) field 809, a slot pointer field 810, a error check and correct (ARQ) field 811, and a header frame control word (HCF) field 812. In a preferred embodiment, the B/M indicator flag 802, E flag 803, PWR field 805, DCS flag 807, and the VS

flag 808 are each 1 bit long, the packet type field 804 and symmetry field are each 2 bits long, the CU field 809 and ARQ field are each 3 bits long, and the slot pointer field 810 and header HCF field 812 are each 4 bits long, for a total of 23 bits. A twenty-fourth bit of the header 801 is "lost" in establishment of the RF link due to the use of differential phase encoding to transmit six bits of data per symbol code.

The B/M indicator flag 802 indicates whether the originator of the message is a user station 102 or the base station 104. The E flag 803 is used to indicate whether or not an extended protocol is in use. The packet type field 804 specifies which of four packet types is being used, according to Table 8-1A below.

Table 8-1A

Packet Field	Packet Type
00	Normal traffic
01	Specific poll
10	Control (signaling) traffic
11	General poll, or general response

The packet type field 804 also provides an indication of the usage of the D-field 557, according to Table 8-1B below.

Table 8-1B

Packet Field	D-Field Usage
00	D-Channel
01	Correlative ID
10	Correlative ID
11	Reserved

The PWR field 805 is a serialized bit stream from the base station 104 to the user station 102 allowing control of the power level of the user station 102 transmitter.

As each base-to-user message is received at the user station 102, the PWR bit from the last message is analyzed along with the current PWR bit to determine if the power level of the user station 102 transmitter should be raised, lowered or remain unchanged. Power control action therefore requires that at least two consecutive base-to-user messages be received by the user station 102 before any action is taken. The action taken is dictated according to Table 8-2 appearing below.

Table 8-2

Last Bit	Current Bit	Action
0	0	Decrease transmitter power
1	1	Increase transmitter power
0	1	Leave power unchanged
1	0	Leave power unchanged
missing	any	Leave power unchanged
any	missing	Leave power unchanged

The amount of power increase or decrease carried out in response to receiving commands in the PWR field 805 may be a fixed or preset amount--e.g., 1 dB for each time frame 301 (or more frequently if the user station 102 is transmitting in multiple time slots 302 per time frame 301). Using only a single bit for the PWR field 805 saves space in the header 553 of the base-to-user message. Performance is adequate because the quality metrics generally provide sufficient feedback to allow small power adjustment steps over time, but not sufficient feedback to have confidence in making substantial power adjustment steps. However, because only one user station 102 transmits in a given time slot 302 within the general geographic region of a particular base station 104, strict power control of the user stations 102 is not required to avoid intercell interference as it is with CDMA systems not employing time division techniques.

The symmetry field 806 is used by the base station 104 to grant bandwidth to the user station 102. The bandwidth grant applies to the next time slot 302 (or 618) in the channel. The symmetry field 806 contents may be interpreted according to Table 8-3 below.

Table 8-3

Symmetry Bits	Meaning
00	Symmetric bandwidth grant. Each direction has been granted one half of the bandwidth.
01	The maximum bandwidth has been granted to the user station 102, and the minimum bandwidth has been granted to the base station 104.
10	The maximum bandwidth has been granted to the base station 104, and the minimum bandwidth has been granted to the user station 102.
11	Broadcast mode. The entire bandwidth has been granted to the base station 104. There is no user station 102 packet.

The DCS flag 807 indicates the usage of the D-channel for the current message. The DCS flag 807 is set to one value to indicate that the D-channel is disabled to reserve it for use by the application using the bearer channel (B-channel), and is set to another value to indicate that the D-channel is enabled for other usage. The VS flag 808 indicates whether the base station 104 is using a virtual slot mode. If the virtual slot mode is active (e.g., the time slot structure of Fig. 6 is used), then all user station 102 transmissions occur one time slot earlier than if the VS mode is inactive.

The CU field 809 indicates the relative slot utilization for the base station 104. In a preferred embodiment, the CU field contents are defined according to Table 8-4 below.

Table 8-4

CU Field Contents	Utilization
000	No channels available: Find another base station
001	One channel available: 911 calls only
010	Two channels available: 911 calls or handover only
011	Few channels available: Class control is in effect for registrations and originations
100	Nearly full: Access Unrestricted
101	Moderately full: Access Unrestricted
110	Partially full: Access Unrestricted
111	All slots available: Access Unrestricted

Where class control is in effect for registrations and call originations, access leveling and load leveling classes may be identified in the facility field 707 of the general poll message (see Fig. 10A).

The slot pointer field 810 contains an index which identifies the next time slot to be used in the current base/user packet exchange. The user station 102 must transmit in the indicated time slot to continue the exchange. In a particular embodiment, the contents of the slot pointer field 810 may take on any of sixteen different values (e.g., binary 0 to 15), with each value indicating a number of time slots from the present time slot in which the user station 102 is to transmit. For example, a value of zero means that the user station 102 is to transmit in the same slot (in the next frame if at a regular bandwidth rate, or several frames in the future if using a sub-frame rate). A value of one means that the

user station 102 is to transmit in the next time slot of the present time frame. A value of two means that the user station 102 is to transmit in the time slot two places ahead in the present time frame, and so on.

The ARQ field 811 allows the receiving entity (either base station 104 or user station 102) to correct a message error. The ARQ field 811 comprises three subfields of one bit each:

(1) an "ARQ required" sub-field that indicates whether or not ARQ is required for the message sent; (2) an "ACK" sub-field indicating whether or not the sender of the message received correctly the last message sent; and (3) a "message number" sub-field, which indicates the message number (zero or one) of the current message. The ACK sub-field and message number sub-field are preferably always used regardless of whether the ARQ required bit is set.

If ARQ is required (as determined by the value of the ARQ required bit), then the receiving entity performs the following steps:

(1) Compares the message number sub-field of the received message with the message-number sub-field of the previously received message; if they are the same, the new message is ignored.

(2) Checks the ACK sub-field of the received message. If the value is NAK (indicating that the sender of the message did not receive the last message correctly), then the receiving entity resends the old data message; otherwise, it sends a new data message.

(3) Complements the message number sub-field bit each time a new data message is sent.

(4) If a message is received with a FCW error (as explained with respect to Fig. 10A), or did not receive a message at all, then the receiving entity resends the old data message with the ACK sub-field set to NAK.

The header HCF field 812 is used for a cyclic redundancy check calculated over the 12 preceding bits (i.e., the preceding bits of the message header).

Figure 11B is a diagram of a polling message header format for a poll response message (such as general poll response 404 or specific poll response 405 of Fig. 8). The polling response header 820 comprises a base/mobile indicator (B/M) flag 821, an extended protocol (E) flag 822, a packet type field 823, a PWR field 824, a symmetry field 825, a DCS flag 826, a spare field 827, an ARQ field 828, and a header frame control word (HCF) field 829. In a preferred embodiment, the B/M indicator flag 821, E flag 822, and DCS flag 826 are each 1 bit long, the packet type field 823, symmetry field 825, and spare field 827 are each 2 bits long, the ARQ field 828 is 3 bits long, and the HCF field 829 is 4 bits long, for a total of 17 bits. An eighteenth bit is "lost" in the establishment of the RF link due to the use of differential phase encoding to transmit six bits per symbol code.

The B/M indicator flag 821, E flag 822, packet type field 823, PWR field 824, DCS flag 826, ARQ field 828 and HCF field 829 are used for the same purposes as their counterpart fields in the base station header shown in Fig. 11A. The contents of the symmetry field 825 in the user station 102 header may be interpreted according to Table 8-5 below.

Table 8-5

Symmetry Field	Meaning
00	Symmetric bandwidth is requested for the next time slot
01	Maximum bandwidth is requested for the next time slot
10, 11	(Not presently used)

Figure 12A is a diagram of a base station information packet showing in octet format fields generally depicted

in Figs. 9B and 11A. Figure 12B is a diagram of a user station information packet showing in octet format fields generally depicted in Figs. 9C and 11B.

Data may be transmitted between the base station 104 and user stations 102 using an M-ary spread spectrum technique. Suitable M-ary spread spectrum transmission and reception techniques are described in, e.g., U.S. Patent No. 5,022,047 and in U.S. Patent Application Serial No. 08/484,007 filed June 7, 1995. In a preferred embodiment, the base station 104 and user stations 102 each transmit an M-ary direct sequence spread spectrum signal, with M=6, using spread spectrum codes (called "symbol codes") of 32 chips. Thirty-two different symbol codes are used to represent up to thirty-two different data symbols, each comprising five bits of data; phase encoding is also preferably used to allow transmission of a 6th bit of data for each symbol code. Techniques of phase encoding for transmission of an additional bit of information per symbol code are described in, e.g., U.S. Patent Application Serial No. 08/484,007.

Because the base header field 553 is positioned first in the base transmit data frame 551, it loses the first bit from the first transmitted data symbol (which is transmitted using a differential encoding technique). Thus the base header field 553, which comprises four data symbols, is 23 bits in length. The first symbol comprises five data bits, and the latter three symbols each comprises six data bits. Likewise, because the user header field 523 is positioned first in the user transmit data frame 521, it loses the first bit from the first transmitted data symbol. Thus the user header field 523, which comprises three symbols, is 17 bits in length. The first symbol comprises five data bits, and the latter two symbols each comprises six data bits.

User stations 102 in one embodiment may comprise mobile handsets capable of multi-band and/or multi-mode operation. The user stations 102 may be multi-mode in

that they may be capable of both spread spectrum (i.e., wideband) communication and also narrowband communication. The user stations 102 may be multi-band in the sense that they may be set to operate on a plurality of different frequencies, such as frequencies in either the licensed or unlicensed PCS bands. The user stations 102 may operate in one mode (e.g., wideband) over a first frequency band, and another mode (e.g., narrowband) over a second frequency band.

As an example, a user station 102 may be set to operate on a plurality of frequencies between 1850 and 1990 MHZ, with the frequencies separated in discrete steps. Each user station 102 may be equipped with a frequency synthesizer that can be programmed to allow reception and/or transmission on any one of the plurality of frequencies. In a particular embodiment, the programmable frequency steps are in 200 KHz increments (for GSM or narrowband communication) or 1.8 MHZ increments (for spread spectrum communication) within the GSM frequency bands. The user station 102 may also be configured to operate in the isochronous band between 1920 and 1930 MHZ, having a first channel centered at 1920.625 MHZ, and channel spacing of 1.25 MHZ across the remainder of the isochronous band.

Further information regarding dual-mode and dual-band communication is set forth in U.S. Patent Application Serial No. 08/483,514 filed on June 7, 1995.

In one embodiment, channel information is monitored to assist the base station 104 in selecting an antenna for communication with a user station 102. The channel information can also permit the base station 104 to adjust its own output power and that of the user station(s) 102.

Time division duplex permits common antennas to be used for transmit and receive functions at both the base station 104 and the user stations 102, typically without the need for antenna diplexers. Common antennas can be used to transmit and receive because these functions are

separated in time at each of the user stations 102 and base stations 102. The use of common antennas results in simplicity of the base station 104 and user station 102 terminal designs.

A base station 104 preferably includes a plurality of base station antennas providing antenna diversity. The base station 104 includes electronics for selecting the best antenna to be used for communication with each user station 102 during each time slot 302. The base station 104 may receive a user transmission (such as a user-to-base message sent during a user segment 305 of a time slot 302) simultaneously (with possible variations due to reflection or multi-path effects) on each of a plurality of base station antennas. Each base station antenna connects to an individual base station receiver which analyzes the quality of the received user transmission and provides quality metrics to a processor in the base station 104. The base station 104 compares the quality metrics produced by each base station receiver and selects the best quality receiver output signal. In this manner, the most appropriate base station antenna is selected for each user station 102. The metrics from the selected receiver output signal provide a characterization of the communication channel between the base station 104 and the particular user station 102.

When the base station 104 transmits to a particular user station 102, it selects the most appropriate base station antenna for transmission. An antenna and a transmission power level are preferably selected so as to match the characteristics of the transmission channel from the base station 104 to the user station 102. The base station 104 may select as its transmitting antenna the same base station antenna selected to receive the user transmission 305. Because the base station 104 can both receive and transmit on the antenna having the best received signal quality from the user station 102, the user station 102 benefits from antenna diversity even if

it does not have multiple antennas. Because the base station 104 transmits very quickly after receiving the user transmission, there is little time lag, so that the channel characteristics do not change significantly before the base station 104 makes its transmission.

During each subsequent time slot 302 assigned to a particular user station 102 in the polling loop 301, the base station 104 again selects an antenna and power level for a base station transmission (such as a base-to-user message transmitted during a base segment 306 of a time slot 302) based on channel characterization data derived from the most closely preceding user station transmission.

The base station 104 preferably controls its output power on a slot-by-slot basis. To do so, the base station 104 preferably has means to determine the power setting of the user station 102. However; because a single base station 104 can communicate during a polling loop 301 with a large number of user stations 102, each of whose distance from the base station 104 can vary from near zero up to the radius of the cell 103, control of the base station transmitter output power so as to maintain a near-constant received power level at each user station 102 during each time slot 302 may not be practical, largely due to the fact that large changes (e.g., more than 40 dB) in base station transmit output power would be necessary each time slot 302 (e.g., about every 1153 μs). As an alternative to providing power control on a time slot 302 by time slot 302 basis, output power control at the base station 104 can instead be averaged over a longer time interval than each time slot 302.

In response to receiving a user station transmission during the user segment 305 a time slot 302, the base station 104 determines the quality of the received signal including, for example, the received power and the signal-to-noise or interference ratio. During the subsequent base segment 306 in the latter part of the time slot 302, the base station 104 in one embodiment sends a message to

the user station 102 indicating the signal quality received by the base station 104, and commanding the user station 102 to adjust its power if needed. Based on the quality of the received signal, the base station 104 in one embodiment commands the user station 102 to change (increase or decrease) its transmit power by some discrete amount (e.g, in minimum steps of 3 dB) relative to its current setting, until the quality of the user transmissions received by the base station 104 is above an acceptable threshold. A preferred means of power control is described with respect to the PWR field 805 appearing in Fig. 8A.

A preferred power adjustment command from the base station 104 to the user station 102 is encoded according to Table 8-2 appearing earlier herein. Although preferred values are provided in Table 8-2, the number of power control command steps and the differential therebetween may vary depending upon the particular application and the system specifications.

While the above power adjustment and antenna diversity techniques have generally been described with respect to features appearing in the Fig. 6 embodiment, the described techniques are equally applicable to the Fig. 7 embodiment.

Aspects of the invention are directed to facilitating rapid control traffic within the timing structure of the communication system. Handover, establishing communication, or time slot interchange may be carried out in a rapid manner by utilizing multiple time slots spaced less than one time frame apart. In such a manner, the control traffic takes advantage of unused time slots to avoid having to wait an entire time frame for each opportunity to exchange messages between the base station 104 and the user station 102 desiring a transaction. Spare resources are thereby used for the purpose of speeding up control traffic transactions.

In the preferred embodiment wherein the user station 102 transmits prior to the base station 104 in a time slot 302 (or virtual time slot 618), the slot pointer allows the user station 102 to have knowledge of the next available time slot 302. Otherwise, the user station 102 may not necessarily know until a general poll message 401 is received whether or not a particular time slot is available for communication, and then would typically have to wait an entire polling loop before responding to the general poll message 401.

Knowledge of available time slots 302 is also passed to the user station 102 in a specific poll message 402 by use of the OTA map field 726. As noted previously, the OTA map field 726 describes the mapping of time slots relative to a particular user station 102. Thus, for a time frame 301 with sixteen time slots 302, the OTA map field 726 in one embodiment comprises sixteen bits. Each bit may be set to a first value (e.g., "1") to indicate that the time slot 302 associated with that bit is unavailable, and to a second value (e.g., "0") to indicate that the time slot 302 associated with that bit is available for communication. Preferably, the time slot usage is indicated from a standpoint relative to the current time slot 302 of the user station 302--that is, the first bit is associated with the immediately following time slot, the second bit with the next time slot thereafter, the third bit with the next time slot thereafter, and so on. Alternatively, the time slot usage may be indicated from a standpoint with respect to a fixed reference, such as the start of the time frame 301, in which case the user station 302 needs to have available as information the relative starting point of the time frame 301.

Figure 13 is a block diagram of an integrated base station 850 in accordance with one embodiment of the present invention. Integrated base station 850 comprises a first base station unit 852 operating according to a

first TDMA or TDD protocol, and a second base station unit 853 operating according to a second TDMA or TDD protocol. The first base station unit 852 and second base station unit 853 preferably operate in the same or overlapping geographic region. The first base station unit 852 and second base station unit 853, while shown as separate blocks in Fig. 13, may be physically located within the same unit. Alternatively, they may be at separate physical locations but nevertheless nearby one another.

The first base station unit 852 comprises a processor 860, a global positioning satellite (GPS) receiver 861, a clock generator 862, and a free slot index 863. The second base station unit 853 comprises a processor 870 and a free slot index 873. The first base station unit 852 communicates with the second base station unit 853 over communication lines 869. If the first base station unit 852 and second base station unit 853 are collocated, they may share the same antenna or set of antennas (not shown).

In a preferred embodiment, the first base station unit 852 communicates according to the communication protocol generally described with respect to Fig. 6 (or Fig. 7, and including Figs. 8 through 12B; hereinafter collectively referred to as "the Fig. 6 communication protocol", or "the TDD protocol of Fig. 6", or simply "the TDD protocol"), and the second base station unit 853 communicates according to a GSM protocol. In one aspect of the invention, interference between transmissions to and from the first base station unit 852 and the second base station unit 853 are avoided by separating the communications in time according to a predefined timing pattern.

More specifically, communication to and from each of the base station units 852, 853 is carried out according to a timing pattern encompassing one or more time frames of each of the communication protocols. Such a timing pattern is hereinafter generally referred to as a composite time frame, as more fully explained further

herein. Exemplary composite time frames are shown in Figs. 15 and 16.

In each of the composite time frames of Figs. 15 and 16, in general, a portion of the composite time frame is divided into time slots for use with a first protocol, and the remaining portion of the composite time frame is divided into time slots for use with a second protocol. Figure 14 is a diagram comparing time frames of two different protocols, from which the composite time frames of Figs. 15 and 16 are derived. In Fig. 14, a first time frame 901, designated a "Type-1" time frame, is shown. The first time frame 901 comprises a plurality of time slots 902. Also shown in Fig. 14, along a similar time axis, is a second time frame 911, designated a "Type-2" time frame. The second time frame 911 also comprises a plurality of time slots 912. In Fig. 14, the time slots 902 of the first time frame 901 are designated by "TS" followed by two digits (e.g., TS00, TS01, TS02,..., TS15), while the time slots 912 of the second time frame 911 are designated by "TS" followed by a single digit (e.g, TS1, TS2, TS3,..., TS7). It should be noted that the time slots Fig. 14 are numbered starting with "0" or "00", while in the Fig. 6 and 7 drawings the time slots are numbered starting with "1"; no implication by the particular starting reference numeral selected for a particular drawing is intended.

In a preferred embodiment, the first time frame 901 is defined as part of a protocol for TDD communication and, more particularly, the TDD protocol of Fig. 6. In the same preferred embodiment, the second time frame 911 is defined as part of the GSM protocol, as previously described with respect to Fig. 3. In a preferred embodiment, the first time frame 901 has a duration of 18.46 milliseconds, and the second time frame 911 has a duration of 4.615 milliseconds. Accordingly, four of the second time frames 911 in the aggregate have the same duration as a single first time frame 901. In a preferred

embodiment, each of the time slots 902 of the first time frame 901 has a duration of 1153.125 microseconds, and each of the time slots 912 of the second time frame 911 has a duration of 576.92 microseconds. Accordingly, two of the latter time slots 912 in the aggregate have the same duration as a single of the first time slots 902.

In one embodiment of the invention as illustrated in Fig. 15, a composite time frame 925 is defined with a portion of the composite time frame 925 time allocated to the first protocol, and a portion of the composite time frame 925 allocated to the second protocol. In Fig. 15 thus is shown the first time frame 921 (i.e., time frame 901 of Fig. 14) having time slots 922 which are unshaded to indicate their incorporation into the composite time frame 925, and shaded to indicate their exclusion from the composite time frame 925. Similarly is shown in Fig. 15 a set of the second time frames 931 (i.e., time frames 911 of Fig. 14) having time slots 932 which are unshaded to indicate their incorporation into the composite time frame 925, and shaded to indicate their exclusion from the composite time frame 925. The composite time frame 925 therefore comprises a plurality of different length time slots 926, some of which are time slots 926a corresponding to time slots 922 of the first time frame 921, and some of which are time slots 926b corresponding to the time slots 932 of the second time frame 931.

In Fig. 15, the composite time frame 925 comprises four time slots 926a corresponding to the first time frame 921 (i.e., time slots TS00, TS04, TS08, and TS12), and six time slots 926b corresponding to the second time frame 931 (i.e., time slots TS2 through TS7). Because of the timing relationship between the first time frame 921 and the second time frame 931, the first time slots 926a of the composite time frame 925 each appear once, and the second time slots 926b of the composite time frame 925 each appear four times (because the first time frame 921 covers four of the second time frames 931 in relative duration).

Because time division communication according to both the first and second protocols are by their nature periodic, and because the first time frame 921 in this embodiment covers four times the duration of the second time frame 931, the different sized time slots 926a, 926b of the composite time frame 925 will be interspersed according the periodic appearance of specific time slot channels taken from time frames 911 and 931.

The particular composition of the composite time frame 925--i.e., the ratio of the first time slots 926a to the second time slots 926b, and the specific order thereof--can be matched to the specific system needs. Where more users are likely to use the first protocol (associated with the first time frame 921), more of the time slots 926a associated with that protocol may be included in the composite time frame 925. Conversely, where more users are likely to use the second protocol (associated with the second time frame 931), then more of the time slots 926b may be included in the composite time frame 925.

Figure 16 is a diagram of another composite time frame 945 having a different arrangement of time slots 946, each of the time slots 946 corresponding to time slots 922 or 932 of the first time frame 921 and second time frame 931. As with Fig. 15, time slots 922 of the first time frame 921 are unshaded to indicate their incorporation into the composite time frame 945, and shaded to indicate their exclusion from the composite time frame 945; similarly time slots 932 from the set of the second time frames 931 are unshaded to indicate their incorporation into the composite time frame 945, and shaded to indicate their exclusion from the composite time frame 945. The composite time frame 945 therefore comprises a plurality of different length time slots 946, some of which are time slots 946a corresponding to time slots 922 of the first time frame 921, and some of which

are time slots 946b corresponding to the time slots 932 of the second time frame 931.

In Fig. 16, the composite time frame 945 comprises eight time slots 926a corresponding to the first time frame 921 (i.e., time slots TS00, TS01, TS04, TS05, TS08, TS09, TS12 and TS13), and four time slots 926b corresponding to the second time frame 931 (i.e., time slots TS4 through TS7). Because of the timing relationship between the first time frame 921 and the second time frame 931, the first time slots 926a of the composite time frame 945 each appear once, and the second time slots 926b of the composite time frame 945 each appear four times (because the first time frame 921 covers four of the second time frames 931 in relative duration).

Thus, by comparing the different arrangement of time slots 926 and 946 in the composite time frames 925 and 945 from Figs. 15 and 16, respectively, it is apparent that different ratios of time slots may be used according to, for example, differing system requirements. Thus, in Fig. 15, the composite time frame 925 can support up to four users of the first time slots 926a and six users of the second time slots 926b. In Fig. 16, the composite time frame 945 can support up to eight users of the first time slots 946a and four users of the second time slots 926b.

Figure 17A is a demand migration table showing how the ratio of number of supportable users of each protocol changes as the number of allocated time slots changes. The first row 950 of the demand migration table of Fig. 17A corresponds to supportable users of the second protocol (i.e., the GSM protocol), and the second row 951 corresponds to supportable users of the first protocol (i.e., the TDD protocol of Fig. 6). Five different pairing options 954 are provided for in the demand migration table of Fig. 17A, each with a different ratio of supportable GSM protocol users 952 to supportable TDD protocol users 953. As shown in Fig. 17A, under a first pairing option 954, eight GSM protocol users 952 can be

supported with zero TDD protocol users 953 supported in a composite time frame; under a second pairing option 954, six GSM protocol users 952 can be supported with four TDD protocol users 953 supported in a composite time frame; under a third pairing option 954, four GSM protocol users 952 can be supported with eight TDD protocol users 953 supported; and so on. As the number of supportable users of one protocol increases, then the number of supportable users of the other protocol decreases, since the allocation of time slots to one protocol necessarily reduces the number of allocable time slots for the other protocol.

While the embodiments shown in Figs. 15 and 16 have composite time frames 925 and 945 each the same length as the longer of the two time frames 921 and 931 from which they are derived, the present invention is not limited to such an arrangement. In general, the composite time frame should be of a duration sufficient to fit an integral number of both the first and second time frames from which the composite time frame is derived. Thus, for example, a composite time frame may be selected to be, e.g., 60 milliseconds, where the first time frame duration is 12 milliseconds and the second time frame is 20 milliseconds. The 60 millisecond composite time frame duration in such a case conveniently represents the shortest duration fitting an integral number of both a set of the first time frames and a set of the second time frames.

Where there is no such convenient shortest length for a composite time frame (as may commonly occur when the first and second protocols are independently developed for different communication systems by different parties), time gaps may be inserted so that an integral number of each time frame fits within the composite time frame. Figure 26 is a diagram of a composite time frame 1085 illustrating such an arrangement. In Fig. 26, a series of first time frames 1080 having a first time frame duration are shown relative to a series of second time frames 1081

having a second time frame duration. The series of first time frames 1080 are separated by time gaps 1082 of a duration selected so that two of the second time frames 1081 have the same duration as a single first time frame 1080 plus the time gap 1082. The composite time frame 1085 is constructed in the same manner as described with respect to Figs. 15 and 16, except that no channels are available from the series of first time slots 1080 during the time gaps 1082. Thus, in the Fig. 26 embodiment, it is preferable to assign time slots of the second time frame 1081 starting from the end thereof (i.e., the region corresponding to the time gap 1082 inserted between the first time frames 1080), to minimize any wasted space in the composite time frame 1085. The time gaps 1082 therefore appear as "conditional" time gaps 1086 in the composite time frame 1085, because ordinarily the conditional time gaps 1086 will include actual time gaps only when no time slots from the second time frames 1081 are assigned thereto.

Thus, while overcoming some of the problems created by having time frames of unequal length, use of time gaps nevertheless generally results in some inefficiency because a portion of the timeline is wasted, and may also lead to less flexibility because the portion of the composite time frame corresponding to the time gap may be allocated only to one of the two timing protocols.

In a similar, time gaps may be inserted between time slots of either time frame, and conditionally in the composite time frame, to make each time slot of the same duration, or a multiple of the shortest time slot duration. A similar inefficiency problem occurs with time gaps inserted between time slots.

Alternatively, a composite time frame may be constructed such that it comprises a combination of time slots from two different protocols without restriction to the time frame structure which normally defines each set of time slots. Rather, the combination of time frames is

selected according to the system needs, and repeats for each composite time frame. Figure 27 is a diagram of a composite time frame 1090 illustrating such an arrangement. The composite time frame 1090 is made up of time slots 1091 associated with a first communication protocol and time slots 1092 associated with a second communication protocol. While having greater efficiency than the Fig. 26 embodiment in that there are no time gaps leading to potential waste of the time resource, the Fig. 27 embodiment, unless the composite time frame length is equal to an integral number of the time frames of the communication protocols from which the time slots 1091, 1092 are taken, results in a timing structure that is not easily adaptable and can be difficult to integrate into different user environments.

Accordingly, the composite time frame structures shown in Figs. 15 and 16 are preferred (i.e., where there is an integral number of each time frame 921 and 931 in each composite time frame 925 and 945) because of the relative ease of changing the ratio of time slots for the first protocol and the second protocol, according to user demand, without having to change the composite time frame length or make other internal timing adjustments. The demand migration tables of Figs. 17A and 17B illustrate how the ratio of first protocol time slots to second protocol time slots may be modified with relative ease according to specified pairing options, without having to change the composite frame length.

Returning to Fig. 13, the first base station unit 952 communicates over time slots 926 corresponding to one of the time frames 921 or 931 (e.g., time slots 926a corresponding to the first time frame 921), and the second base station unit 953 communicates over time slots 926 corresponding to the other of the time frames 921 or 931 (e.g., time slots 926b corresponding to the second time frame 931). Thus, each base station unit 852, 853 communicates with user stations 102 according to the

protocol assigned to the particular base station unit 852, 853.

In a preferred embodiment, the composite time frame structure is programmed into the integrated base station 850 so that each base station unit 852, 853 knows in advance the relative position of the time slots allocated to it. Each base station unit 852, 853 independently manages the time slots allocated to it, and independently is responsible for establishing and maintaining communication with user stations 102 using the protocol assigned to it.

In more detail, each base station unit 852, 853 is provided with means for determining which time slots of the composite time frame are available, or have been preassigned to it, for communication. The first base station unit 852 has a free slot index 863 which may comprise, for example, a static or dynamic memory. If the free slot index 863 comprises a dynamic memory, then it may be downloaded remotely by a base station controller 105 (see Fig. 2) so as to allow dynamic reprogramming of the time slot allocation to the base station units 852, 853. The free slot index 863 stores a map of time slots allocated to the base station unit 852. Thus, if composite time frame 925 of Fig. 15 is implemented in the Fig. 13 integrated base station 850, then the free slot index 863 would comprise a map having sixteen locations, each location corresponding to one of the time slots 922, with the locations corresponding to time slots TS00, TS04, TS08, and TS12 being set to indicate their assignment to the first base station unit 852.

According to the above example, when the first base station unit 852 communicates, it uses only time slots TS00, TS04, TS08 and TS12. When a channel is set up, the first base station unit 852 uses only one of the time slots from the allocated set of time slots (TS00, TS04, TS08 and TS12). In this particular embodiment, a general polling message is transmitted by the base station unit

852 to indicate the availability of a free time slot for users of the first protocol. Accordingly, a general poll message is only sent over time slots TS00, TS04, TS08 or TS12, and only when the particular time slot is free. The other time slots 922 are not used by the first base station unit 852, unless they are later assigned to it.

Likewise, the second base station unit 853 has a free slot index 873 similar to the free slot index 863 of the first base station unit 852. However, the free slot index 873 for the second base station unit 853 stores a map of time slots allocated to the second base station unit 853. Thus, if the composite time frame 925 of Fig. 15 is implemented in the Fig. 13 integrated base station 850, then the free slot index 873 would comprise a map having eight locations (or alternatively thirty-two locations, one for each position in the composite time frame), each corresponding to one of the time slots 932 for the second time frame 931, with the locations in the free slot index 973 for time slots TS2 through TS7 being set to indicate their assignment to the second base station unit 853.

According to the above example, when the second base station unit 853 communicates, it uses only one of the time slots from the allocated set of time slots (i.e., TS2 through TS7). In this particular embodiment, the second protocol is a GSM protocol, which utilizes a separate control channel for initiating communication. Thus, when the base station unit 853 receives a request to establish a new communication channel with a user station 102, it selects a free time slots only from time slots TS2 through TS7, but not TS0 or TS1, which have not been assigned to it. The second base station 853 makes this determination by examining the contents of the free slot index 873 prior to making a channel assignment.

The first base station unit 852 maintains synchronization with the second base station unit 853 by use of communication lines 869. To facilitate synchronization on a system-wide basis, the first base station unit

852 is, as previously noted, preferably configured with a GPS receiver 861, which receives timing information transmitted by satellite as may be accomplished by means well known in the art.

The GPS receiver 861 provides timing information to a clock generator 862, which generates a slot clock signal 869a and a frame clock signal 869b. Figure 18 is a timing diagram showing a slot clock waveform 965 for the slot clock signal 869a and a frame clock waveform 966 for the frame clock signal 869b. The slot clock waveform 965 is preferably a fifty percent duty cycle square wave clock waveform (as shown in Fig. 18) that allows demarcation of the time slots TS0, TS1, TS2,... of the first (GSM) protocol and also of the time slots TS00, TS01, TS02,... of the second (TDD) protocol (since, in this particular embodiment, the time slots of the first protocol are of half the duration of those of the second protocol). The frame clock waveform 966 comprises a frame marker 967 at the start of each composite time frame. Using either of the composite time frames 925 or 945 of Figs. 15 or 16, the frame marker 967 would also indicate the start of each TDD time frame 921.

By use of the slot clock signal 869a and the frame clock signal 869b, the integrated base station 850 maintains internal synchronization among the two base station units 852, 853. Each base station unit 852, 853 thereby knows the timing of each of the time slots, and knows when each composite time frame 925 or 945 starts and ends. While the GPS receiver 861 in the Fig. 13 embodiment is shown as a component of the first base station unit 852, it may also reside in the second base station unit 853, or each base station unit 852, 853 may have its own GPS receiver. Alternatively, the two base station units 852, 853 may share the same GPS receiver 861, but each have its own internal clock generation electronics, so long as the start of the composite time frame is synchronized. Alternatively, the GPS receiver

861 may be located further upstream--e.g., at a base station controller 105 (see Fig. 2)--which transmits to the integrated base station 850 timing information regarding the start of the composite time frame, and other timing information as necessary.

In a preferred embodiment, transmissions according to the second (TDD) protocol from the first base station unit 852 are wideband, and are made using spread spectrum technology. Because the first (GSM) protocol is narrowband, transmissions made according to the TDD protocol will usually cover multiple frequency channels of the GSM protocol.

Figures 19 and 20 are graphs illustrating frequency channelization plans for a TDD communication system and a GSM communication system, respectively, utilizing the timing structures shown in Fig. 14. In Fig. 19 is shown a frequency bandwidth 970 of predetermined width (e.g., 15 MHz in the Fig. 19 embodiment). The frequency bandwidth 970 is apportioned among individual system components and thereby provides for separation of communications by frequency division multiplexing. In the Fig. 19 embodiment, the frequency bandwidth 970 is apportioned among a plurality of system components each using approximately 1.8 MHz of bandwidth, partially overlapping so as to permit fourteen separate TDD frequency bands 972 within the frequency bandwidth 970. Each TDD frequency band 972 can support a TDD base station 104 and its constituent user stations 102. Frequencies in a geographic region are preferably reused according to the reuse pattern shown in Fig. 5 and described previously herein. Frequency guard bands 973 and 974 are preferably provided at the edges of the frequency bandwidth 970 to minimize interference with users of adjacent frequency bands.

In a preferred embodiment, transmitters operating in the TDD system of Fig. 6 transmit a wideband signal using spread spectrum technology, with a chipping rate of about

2.7 MHz (0.369 milliseconds per chip) and in accordance with techniques described in U.S. Patent Application Serial No. 08/423,225 filed on April 17, 1995.

Figure 20 shows a frequency channelization plan for a GSM communication system. The Fig. 20 frequency channelization plan includes a user frequency band 976 of, e.g., 15 MHZ, over which GSM user stations 102 transmit to a base station 104, and a base frequency band 977 over which a base station 104 transmits to user stations 102. Within the user frequency band 976, a plurality of frequency channels 978 are defined, each allocated a 200 KHz bandwidth (although GSM standards provide for a 271 KHz null-to-null transmission bandwidth). Thus, up to seventy-five frequency channels (not considering frequency guard bands) may be contained within the user frequency band 976. Similarly, as GSM is an FDD system, the base frequency band is divided into frequency channels 979 of 200 KHz each. The user frequency band 976 is separated by a predefined frequency separation F_S from the base frequency band 977; the predefined frequency separation F_S is typically 40 MHZ in Europe, but may be 80 MHZ or of any other suitable size in the United States and elsewhere. Preferably, each user frequency channel 978 is paired with a corresponding base frequency channel 979 separated by the predefined frequency separation F_S, so that each user frequency channel 978 is thus separated by the same frequency distance from its corresponding base frequency channel 979.

While seventy-five frequency channel pairings (not considering frequency guard bands) may therefore be defined within the GSM frequency channelization plan shown in Fig. 20, the GSM system is preferably deployed using a three-cell frequency reuse pattern similar to the frequency reuse pattern shown in Fig. 5 (i.e., ignoring the code reuse pattern shown in Fig. 5). Thus, only a third of the frequency channels 978, 979 are assigned to a given base station 104. Typically, a base station 104

will be assigned frequency channels 978, 979 which are evenly spaced over the frequency bands 976, 977; that is, the base station 104 will be assigned every third frequency channel 978, 979 from the lowest frequency channel pairing assigned to that base station 104, each frequency channel at the GSM base station unit 853 therefore being separated by 600 KHz from the neighboring frequency channels.

Figures 21 and 22 are graphs showing, for a particular embodiment, a frequency channelization relationship for the communication systems having the frequency channelization plans shown in Figs. 19 and 20. Figure 21 shows a relationship between the approximately 1.8 MHZ bandwidth 981 assigned to a given TDD base station 104 and a plurality of frequency channels 982--in this case, nine frequency channels 982. A first set of frequency channels 983 is associated with a first set of frequencies (Group A) in the GSM three-cell frequency reuse pattern; a second set of frequency channels 984 is associated with a second set of frequencies (Group B) in the GSM three-cell frequency reuse pattern; and a third set of frequency channels 985 is associated with a third set of frequencies (Group C) in the GSM three-cell frequency reuse pattern. The Group A, Group B, and Group C frequency channels are distinguished in Fig. 21 according to the shading of each, as identified by the legend appearing in Fig. 21.

In a preferred embodiment, the TDD base station unit 852 transmits in place of the GSM base station unit 853 with which it is integrated (see Fig. 13 integrated base station 850). Accordingly, the TDD base station unit 852 transmits "in place of" the GSM frequency channels with which it overlaps. For example, if the TDD base station unit 852 is integrated with a GSM base station unit 853 assigned to Group A frequencies, then, during a TDD time slot within a composite time frame (such as composite time frame 925 or 945), the frequency channel usage will appear

as shown in Fig. 23. Thus, the frequency usage for an integrated base station 850 alternates, according to the time slot arrangement within a composite time frame 925 or 945, between three narrowband GSM frequency channels 982 and a single wideband TDD frequency channel 981.

Also as shown in Fig. 21, the bandwidth 981 for the TDD base station varies slightly depending on the roll-off factor or "α" associated with the TDD channel modulation spectrum. For an α of 0.32, the TDD transmitter transmits over a bandwidth 981a as shown in Fig. 21; for an α of 0.18, the TDD transmitter transmits over a slightly narrower bandwidth 981b as shown in Fig. 21. Generally, the lower the value of α, the narrower the bandwidth of the transmission and the more efficient it is; however, the more difficult it is to implement.

The frequency channelization plan of Fig. 22 illustrates the coexistence of a plurality of integrated base stations 850 in a preferred embodiment of the present invention. In Fig. 22 is shown a lower frequency band 990 and an upper frequency band 991. The lower frequency band 990 corresponds to the user frequency band 976 of Fig. 20, and the upper frequency band 991 corresponds to the base frequency band 977 of Fig. 20. A plurality of TDD frequency bands (i.e., channels) 995, 997 are defined in the lower frequency band 990 and the upper frequency band 991, respectively. Similarly, a plurality of GSM frequency channels 994, 996 are defined in the lower frequency band 990 and the upper frequency band 991, respectively. Each TDD frequency band 995 or 997 overlaps a plurality of GSM frequency channels 994 or 996 in a manner similar to that shown in and described with respect to Figs. 21 and 23.

Because the GSM system is an FDD/TDMA system, with user stations 102 lagging behind the base station 104 in duplex communication by three time slots, the timing structure to support GSM communication with a given user station 102 is duplicated on two different frequency

bands, according to the GSM frequency channel pairing for the particular user station 102. The TDD protocol of Fig. 6, however, only requires a single frequency band to support duplex communication with a given user station 102. In order to most efficiently allocate system resources, therefore, the same composite time frame structure that is deployed in one frequency band 990, 991 should also be deployed in the corresponding location in the other frequency band 990, 991. More particularly, the a composite time frame defined for operating in the upper frequency band 991 (i.e., the GSM base frequency band 977) preferably has a counterpart composite time frame defined for operating in the lower frequency band 990 (i.e., the GSM user frequency band 976), but offset and lagging by three GSM time slots.

Thus, for example, for a composite time frame 925 such as depicted in Fig. 15 supporting four TDD users and six GSM users and defined for operation in the upper frequency band 991, a counterpart composite time frame 925 supporting four additional TDD users is defined for operation in the lower frequency band 990, but lagging by three GSM time slots 932. Because the GSM system uses frequency division duplexing, the counterpart GSM time slots in the lower frequency band 990 are already used to support the same GSM users receiving base-to-user communications over the upper frequency band channels; the counterpart TDD time slots would, if not assigned to another composite time frame in the manner described, may otherwise go unused and therefore be wasted. Thus, when both the upper and lower frequency bands 991, 990 are considered, two composite time frames (one on the upper frequency band 991 and one on the lower frequency band 990) may support, for example, a total of eight TDD users and six GSM users (assuming the composite time frame 925 of Fig. 15).

In a preferred embodiment, two composite time frames are serviced by the same integrated base station 850. In

this embodiment, the TDD base station unit 852 services a composite time frame in the lower frequency band 990, and another composite time frame in the upper frequency band 991. The composite time frames are preferably separated by the same frequency separation as GSM user and base transmissions (i.e., usually 40 MHZ or 80 MHZ). A user station 102 operating in the TDD protocol may, if interfering, by assigned a different TDD time slot (by performing a time slot interchange), or may be assigned a TDD time slot in the other frequency band 990, 991 being serviced by the same TDD base station unit 852 (by performing a frequency interchange, optionally coupled with a time slot interchange). Accordingly, the TDD base station unit 852 has a variety of options when interference becomes a problem for a given user station 102.

The integrated base station 850 of Fig. 13 is preferably capable of being configured according to any of a plurality of slot allocation options, such as any one of the five slot allocation options shown in Fig. 17A or 17B. Where only one frequency band is considered, the options of Fig. 17A are preferably employed. As shown in Fig. 17A, the more GSM users supported, the fewer TDD users are supportable, and vice versa. Each integrated base station 850 may be configured with a set of switches whereby one of the five options of Fig. 17A is manually selectable. Alternatively, each integrated base station 850 may be configured with a software table (e.g., in ROM), whereby one of the five options of Fig. 17A is selectable by software via a system control program or the base station controller 105, for example.

Where both the upper and lower frequency bands 991, 990 are considered, the options of Fig. 17B are preferably employed. In the embodiment described with respect to Figs. 21 and 23, four TDD user channels are supportable for each three GSM user channels. Thus, for example, if all the time slots of the composite time frame pair (i.e.,

one upper band composite time frame and one lower band composite time frame) are allocated to GSM users, then twenty-four GSM users may be supported. If, on the other hand, all the time slots of the composite time frame pair are allocated to TDD users, then thirty-two TDD users may be supported (sixteen on each of the upper and lower frequency bands 991, 990). Figure 17B shows several other slot allocation pairing options between these two extremes. As explained with respect to Fig. 17A, an integrated base station 850 in this embodiment is preferably provided with manual switches or a software table to enable selection from among the slot allocation pairings.

While in the TDD system each user station 102 "seizes" an available time slot by responding to a general polling message, in the GSM system a user station 102 initiates communication over a predefined control channel (known as the BCCH channel). The BCCH channel is generally selected as a specific GSM time slot on a particular base channel frequency 979 (or possibly multiple such channels). A user station 102 determines the location of the BCCH channel by scanning frequencies and time slots until the BCCH channel is recognized. The user station 102 can thereafter find out information about neighboring base stations 104, including the time/frequency channels of their respective BCCH channels, from system information transmitted over the BCCH channel to which it is currently listening.

The GSM base station unit 853 generally transmits over the BCCH channel with maximum power so that it can be heard by user stations 102 as far away as possible, and so that user stations 102 seeking to initiate communication or handoff can evaluate the relative signal power of the closest base stations 104. However, because the GSM base station unit 853 transmits with maximum power over the BCCH channel, a possibility for interference with a collocated TDD base station unit 852 exists. In

particular, the BCCH channel may interfere in the high frequency band 991 with reception by the TDD base station unit 852; moreover, the interference may "spill over" into nearby frequencies due to the strength of the BCCH channel transmission. Accordingly, as the BCCH channel is predefined in frequency and time, the TDD base station unit 852 is preferably configured with electronics for interference cancellation which suppress at the TDD base station receiver the BCCH channel transmissions when they occur.

Figures 24A and 24B are diagrams showing another embodiment of a composite time frame wherein virtual time slots (as shown in Fig. 7) are used in the TDD timing protocol. Figure 24A is a diagram showing a timing relationship between the time frame structure of Fig. 7 utilizing virtual time slots and the GSM time frame structure. In Fig. 24A, a TDD time frame 1002 (similar to time frame 601 in Fig. 7) comprises a plurality of virtual time slots 1003. The virtual time slots 1003 are designated by "VS" followed by "M" for a user station time segment and "B" for a base station time segment, and then followed by a virtual slot numerical identifier. Thus, for example, "VS-M3" denotes a virtual time slot segment in which a user station transmits in virtual slot no. 3. A total of sixteen virtual time slots 1003 appear in the time frame 1002 of Fig. 24A. Also shown in Fig. 24A are a series of GSM time frames 1012, each having eight GSM time slots 1013. In a preferred embodiment, each segment 1004 (whether a base segment or a user segment) of a virtual time slot 1003 has the same duration as a GSM time slot 1013.

Figure 24B is a diagram of a composite time frame 1022 shown relative to the timing structures of Fig. 24A, and constructed according to the same principles as the composite time frames 925 and 945 shown in Figs. 15 and 16. The main distinction is that each virtual time slot 1003 corresponds to two non-contiguous time segments 1023

of the composite time frame 1022. The composite time frame 1022 is thereby made up of a plurality of time segments 1023, which time segments 1023 are used to define GSM time slots 1023b (with one time segment 1023 per GSM time slot 1023b) and TDD virtual time slots 1023a (with two time segments 1023 per TDD virtual time slot 1023a).

In another embodiment of the invention, time slots are allocated on a dynamic basis according to user demand. Figure 25 is a block diagram of an integrated base station 1050 having a dynamic slot allocation capability. In the Fig. 25 embodiment, the integrated base station 1050 comprises a first base station unit 1052 and a second base station unit 1053. The GPS receiver 1061, clock generator 1062, processor 1060, and free slot index 1063 function in a similar manner to their analogous counterparts in the first base station unit 852 of Fig. 13; likewise, the processor 1070 and free slot index 1073 also function in a similar manner to their analogous counterparts in the second base station unit 853 of Fig. 13.

In the Fig. 25 embodiment, each base station unit 1052, 1053 further comprises an interface 1065 and 1074, respectively, which are linked by a set of control signal lines 1069. The interface 1065 in the first base station unit 1052 is connected to the clock generator 1062, the processor 1060, and the free slot index 1063. The interface 1074 in the second base station unit 1053 is connected to the processor 1070 and the free slot index 1073. Through the interfaces 1065, 1074, and the control signal lines 1069 connecting them, the processors 1060 and 1070 may communicate with one another, may inquire as to the status of the free slot index 1063, 1073, and, in the case of the second base station unit 1073, may obtain timing and marker information from the clock generator 1062.

In this embodiment, each base station unit 1052, 1053 is initially preassigned a default time slot assignment according to a composite time frame in a similar manner to the Fig. 13 embodiment. However, the Fig. 25 integrated

base station 1050 can dynamically change the time slot allocation according to user demand. In this embodiment, the free slot index 1063, 1073 of each base station unit 1052, 1053 stores information not only identifying which time slots have been assigned to the base station unit 1052 or 1053, but also which of the assigned time slots are in use (and, conversely, which time slots are therefore available). The free slot index 1063 or 1073 may be occasionally examined by the other base station unit to obtain the usage status of the other base station unit's time slots.

When a base station unit's allocated time slots become full or are approaching such a state, it may request additional time slot resources from the other base station unit 1052, 1053. This request is made over the control signal lines 1069, and may be referred to as time slot transfer request.

For example, if the second base station unit 1053 is becoming or has become full, then it sends a time slot transfer request message across the control signal lines 1069 by interface 1074. The message is received at interface 1065, which informs the processor 1060 of the request. The processor 1060 examines its free slot index 1063 to determine whether or not free time slots are available, and may further consider impending communication demands for the users it supports. If the processor 1060 determines that it can give up time slots without a significant effect on its users, it then assigns one or more of its time slots to the other base station unit 1053. It does this by first changing its free slot index 1063 to indicate that the time slots are now allocated to the other base station unit 1053, and then sends a response message over the control signal lines 1069 to the second base station unit 1053 informing it that the request for additional time slots has been granted, and also informing it of the particular time slot(s) transferred.

Upon receiving the responsive message, the second base station unit 1053 updates its free slot index 1073 to indicate the new time slots available to it. The second base station unit 1053 thereafter uses these time slots as though they were originally assigned to it. If the first base station unit 1052 later requests a time slot transfer from the second base station unit 1053, then the second base station unit 1053 will normally favor transferring the same time slots back to the first user station unit 1052. The second base station 1053 may perform a time slot interchange among its own users to effectuate such a time slot transfer back to the first base station unit 1052.

Accordingly, time slots allocated dynamically between the two base station units 1052, 1053 of the integrated base station 1050, thereby allowing usage of two different communication protocols according to user demand. Each base station unit 1052, 1053 independently manages its own time slot resources, but may transfer time slots to the other base station unit 1052, 1053 upon request. If one communication protocol is favored over the other, the system may also provide a prioritization scheme whereby a request for transfer of time slots to one of the two base station units 1052, 1053 takes precedence.

Each interface 1065, 1074 may comprise an independent microprocessor or micro-controller for facilitating transfer of control information and slot allocation requests and responses.

In addition to the embodiments thus far described, various other modifications and variations are contemplated within the scope of the present invention.

Thus, for example, although preferred embodiments have been described herein using two protocols--i.e., the GSM protocol and the TDD protocol of Fig. 6--the principles of the present invention may be expanded to encompass more than two protocols coexisting by use of the same timesharing techniques previously described. For

example, each protocol may be preassigned specific time slots within a composite time frame, and each of a plurality of base station units (preferably one for each protocol) uses the time slots preassigned to its protocol. Each of the base station units in such an embodiment is preferably connected with synchronizing information including a system clock and a composite time frame marker.

Additionally, other protocols than those specifically described making use of time separation to avoid collisions among users may also be used. For example, a timesharing system having a composite time frame as previously described may operate with a first protocol such as that of Fig. 6, and a second protocol such as the Digital European Cordless Telecommunications (DECT) system protocol. The DECT protocol is an existing and well known protocol using time division multiplexing developed in and, at present, primarily deployed in Europe.

While the present invention has been set forth in the form of its preferred embodiments, many variations and modifications are possible which remain within the scope and spirit of the invention. Such variations or modifications will become clear to one of ordinary skill in the art after inspection of the specification and drawings herein. Moreover, such variations and modifications are considered to be within the purview of any appended claims.

Claims

1. A communication system comprising:

a first protocol for time division multiple access communication, said first protocol including a first plurality of time slots;

a second protocol for time division multiple access communication, said second protocol including a second plurality of time slots; and

means for selectively communicating according to either said first protocol or said second protocol.

2. The communication system of claim 1 wherein each time slot of said first plurality of time slots has a duration equal to an integral number of time slots of said second plurality of time slots.

3. The communication system of claim 1 wherein said first protocol is a time division duplex protocol, and wherein said second protocol is a frequency division duplex protocol.

4. The communication system of claim 1 wherein said second protocol is a GSM protocol.

5. The communication system of claim 1 wherein said first plurality of time slots and said second plurality of time slots collectively comprise a composite time frame.

6. The communication system of claim 1 further comprising an integrated base station, said integrated base station comprising a first base station unit configured to operate according to said first protocol and a second base station unit configured to operate according to said second protocol.

7. The communication system of claim 6 further comprising a synchronizing signal between said first base station unit and said second base station unit.

8. The communication system of claim 6 wherein said integrated base station comprises a GPS receiver.

9. A communication system comprising:

a first base station unit, said first base station unit operating according to a first protocol for time division multiple access communication in a first cellular region;

a second base station unit, said second base unit operating according to a second protocol for time division multiple access communication in a second cellular region at least partially overlapping with said first cellular region; and

a synchronization signal connected from said first base station unit to said second base station unit, whereby first communications between said first base station unit and user stations using said first protocol are coordinated with second communications between said second base station unit and user stations using said second protocol so as to prevent collisions between said first communications and said second communications.

10. The communication system of claim 9 wherein said first base station unit and said second base station unit are collocated.

11. The communication system of claim 9 wherein said first base station unit and said second base station unit share at least one common antenna.

12. The communication system of claim 9 further comprising a GPS receiver connected to a clock generator,

said clock generator outputting said synchronization signal.

13. The communication system of claim 9 wherein said first protocol is a time division duplex protocol, and said second protocol is a frequency division duplex protocol.

14. The communication system of claim 13 wherein said second protocol is a GSM protocol.

15. The communication system of claim 13 wherein said second base station unit transmits over a first frequency band and receives over a second frequency band, and wherein said first base station unit transmits and receives over a third frequency band at least partially overlapping said first or second frequency band.

16. The communication system of claim 9 wherein said first base station unit and said second base station unit communicate over the same frequency band.

17. A method for communication comprising the steps of:

defining a plurality of first time frames, each comprising a first group of time slots,

defining a plurality of second time frames, each comprising a second group of time slots, wherein said first group of time slots and said second group of time slots overlap temporally; and

selectively communicating at a given time over only one time slot from said first group of time slots and said second group of time slots.

18. The method of claim 17 wherein said step of selectively communicating at a given time over only one time slot from said first group of time slots and said

second group of time slots comprises the steps of communicating in time division duplex in a first time slot from said first group of time slots, and communicating in frequency division duplex in a second time slot from said second group of time slots.

19. The method of claim 18 wherein said step of communicating in time division duplex comprises the step of transmitting a first message in a spread spectrum format, and wherein said step of communicating in frequency division duplex comprises the step of transmitting a second message in a GSM format.

20. A communication system comprising

a first base station unit operating according to a first protocol, whereby communication between a first plurality of user stations and said first base station unit is carried out in time slots and using frequency division duplexing, said first base station unit transmitting over a first frequency band and receiving over a second frequency band;

a second base station unit operating according to a second protocol, whereby communication between a second plurality of user stations and said second base station unit is carried out using time division duplexing, said first base station unit transmitting and receiving over at least one of said first frequency band and said second frequency band; and

a synchronizing signal between said first base station unit and said second base station unit.

21. The communication system of claim 20 wherein said first base station unit transmits and receives messages in a GSM format.

22. The communication system of claim 20 wherein said second base station unit transmits and receives messages in a spread spectrum format.

23. The communication system of claim 20 further comprising a GPS receiver.

24. In a communication system, a timing structure for communication comprising:

a series of composite time frames;

in each of said composite time frames, a plurality of first time slots, each of a first predefined duration; and

in each of said composite time frames, a plurality of second time slots, each of a second predefined duration.

25. The timing structure of claim 24 wherein the relative positioning of said first time slots and said second time slots is the same in each of said composite time frames.

26. The timing structure of claim 24 wherein said first time slots are associated with a first communication protocol and said second time slots are associated with a second communication protocol.

27. The timing structure of claim 26 wherein said first communication protocol is a time division duplex protocol, and said second protocol is a frequency division duplex protocol.

28. The timing structure of claim 27 wherein said second communication protocol is a GSM protocol.

29. The timing structure of claim 25 wherein said first predefined duration is twice said second predefined duration.

30. A method for communicating comprising the steps of:

transmitting, over a first frequency band, a first base-to-user message from a first base station unit to a first user station;

receiving said first base-to-user message at said first user station;

transmitting, over a second frequency band at least partially overlapping said first frequency band, a first user-to-base message from a second base station unit to a second base station unit;

receiving said first user-to-base message at said second base station unit;

transmitting, over said second frequency band, a second base-to-user message from said second base station unit to said second user station;

receiving said second base-to-user message at said second user station;

transmitting, over a third frequency band separate and distinct from said first frequency band, a second user-to-base message from said first base station to said first base station unit; and

receiving said second user-to-base message at said second base station unit.

31. The method of claim 30 wherein said first user-to-base message and said second base-to-user message are transmitted as spread spectrum messages, and said first base-to-user message and said second user-to-base message are transmitted as narrowband messages.

32. The method of claim 30 wherein said first base station unit and said second base station unit are collocated.

33. The method of claim 30 wherein said first base-to-user message and said second user-to-base message are transmitted according to a GSM protocol.

34. The method of claim 30 wherein said first frequency band is entirely contained within said second frequency band.

35. In a communication system, a timing structure for communication comprising:

a composite time frame having a duration of 18.46 milliseconds;

a plurality of first time slots in said composite time frame, each of said first time slots supporting a half-duplex GSM communication link, with a corresponding second half-duplex GSM communication link located on a different frequency band; and

a plurality of second time slots in said composite time frame, each of said second time slots having twice the duration of one of said first time slots, and each of said second time slots supporting two half-duplex time division communication links.

36. The timing structure of claim 35 wherein said two half-duplex time division communication links collectively form a full duplex time division communication link.

37. The timing structure of claim 35 wherein each of said first time slots has a duration of about 576.92 microseconds, and each of said second time slots has a duration of about 1153.125 microseconds.

AMENDED CLAIMS

[received by the International Bureau on 24 March 1997 (24.03.97); original claims 1, 6, 24 and 30 amended; remaining claims unchanged (4 pages)]

1. A communication system comprising:

a plurality of cells;

a first transceiver geographically located in a first of said plurality of cells comprising;

a first protocol for time division multiple access communication, said first protocol including a first plurality of time slots;

a second transceiver geographically located in said first cell comprising;

a second protocol for time division multiple access communication, said second protocol including a second plurality of time slots; and

means for selectively communicating according to either said first protocol or said second protocol within said first cell.

2. The communication system of claim 1 wherein each time slot of said first plurality of time slots has a duration equal to an integral number of time slots of said second plurality of time slots.

3. The communication system of claim 1 wherein said first protocol is a time division duplex protocol, and wherein said second protocol is a frequency division duplex protocol.

4. The communication system of claim 1 wherein said second protocol is a GSM protocol.

5. The communication system of claim 1 wherein said first plurality of time slots and said second plurality of time slots collectively comprise a composite time frame.

6. A communication system comprising:

a first protocol for time division multiple access communication, said first

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protocol including a first plurality of time slots;

a second protocol for time division multiple access communication, said second protocol including a second plurality of time slots;

an integrated base station, said integrated base station comprising a first base station unit configured to operated according to said first protocol and a second base station unit configured to operate according to said second protocol; and

means for selectively communicating according to either said first protocol or said second protocol.

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23. The communication system of claim 20 further comprising a GPS receiver.

24. In a time division multiple access wireless communication system including a base station and user stations communicating via a first and second protocol, a timing structure for communication comprising:

a series of composite time frames;

in each of said composite time frame, a plurality of first time slots for communication according to said first protocol, each of a predefined duration; and

in each of said composite time frames, a plurality of second time slots, each of a second predefined duration.

25. The timing structure of claim 24 wherein the relative positioning of said first time slots and said second time slots is the same in each of said composite time frames.

26. The timing structure of claim 24 wherein said first time slots are associated with a first communication protocol and said second time slots are associated with a second communication protocol.

27. The timing structure of claim 26 wherein said first communication protocol is a time division duplex protocol, and said second protocol is a frequency division duplex protocol.

28. The timing structure of claim 27 wherein said second communication protocol is a GSM protocol.

29. The timing structure of claim 25 wherein said first predefined duration is twice said second predefined duration.

30. A method for communicating comprising the steps of:

transmitting, over a first frequency band, a first base-to-user message from a

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first base station unit to a first user station;

receiving said first base-to-user message at said first user station;

transmitting, over a second frequency band at least partially overlapping said first frequency band, a first user-to-base message from a second user station to a second base station unit, said first base station unit and second base station unit being located within a same cell;

receiving said first user-to-base message at said second base station unit;

transmitting, over said second frequency band, a second base-to-user message from said second base station unit to said second user station;

receiving said second base-to-user message at said second user station;

transmitting, over a third frequency band separate and distinct from said first frequency band, a second user-to-base message from said first user station to said first base station unit; and

receiving said second user-to-base message at said first base station.

31. The method of claim 30 wherein said first user-to-base message and said second base-to-user message are transmitted as spread spectrum messages, and said first base-to-user message and said second user-to-base message are transmitted as narrowband messages.

32. The method of claim 30 wherein said first base station unit and said second base station unit are collocated.

33. The method of claim 30 wherein said first base-to-user message and said second user-to-base message are transmitted according to a GSM protocol.

34. The method of claim 30 wherein said first frequency band is entirely contained within said second frequency band.

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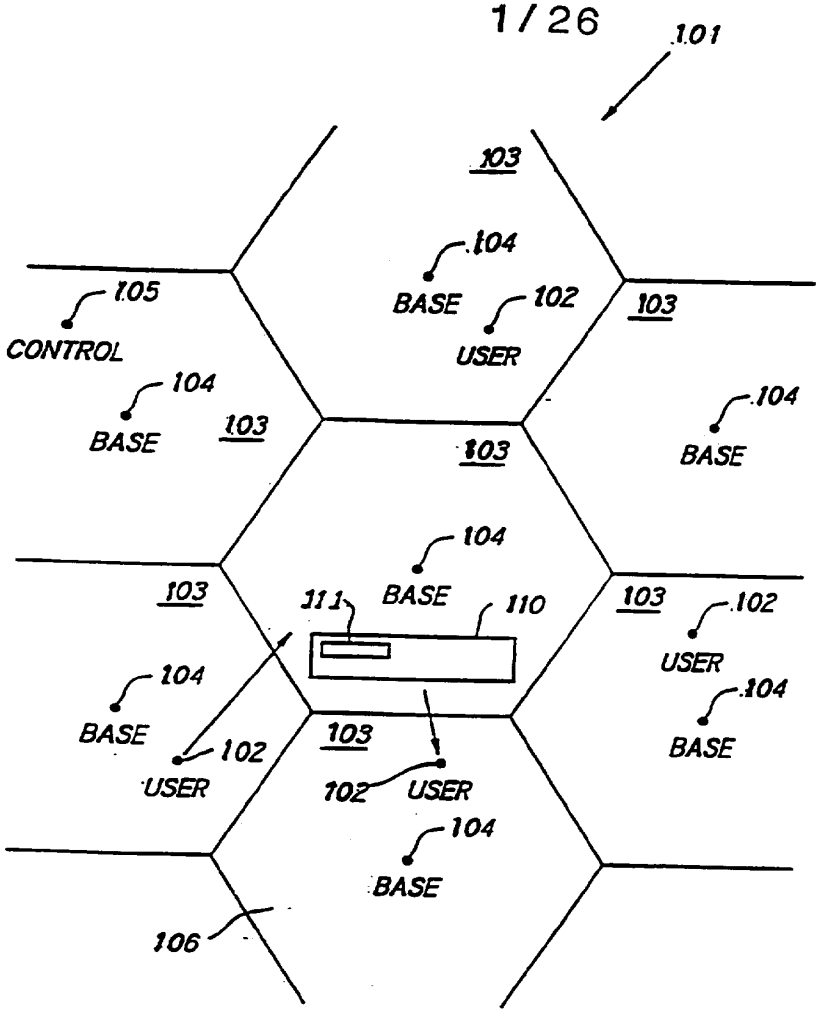

101
103
104
BASE
102
USER
105
CONTROL
104
BASE
103
103
104
BASE
103
104
BASE
111
110
103
102
USER
104
BASE
103
102
USER
102
USER
104
BASE
106

FIG 1

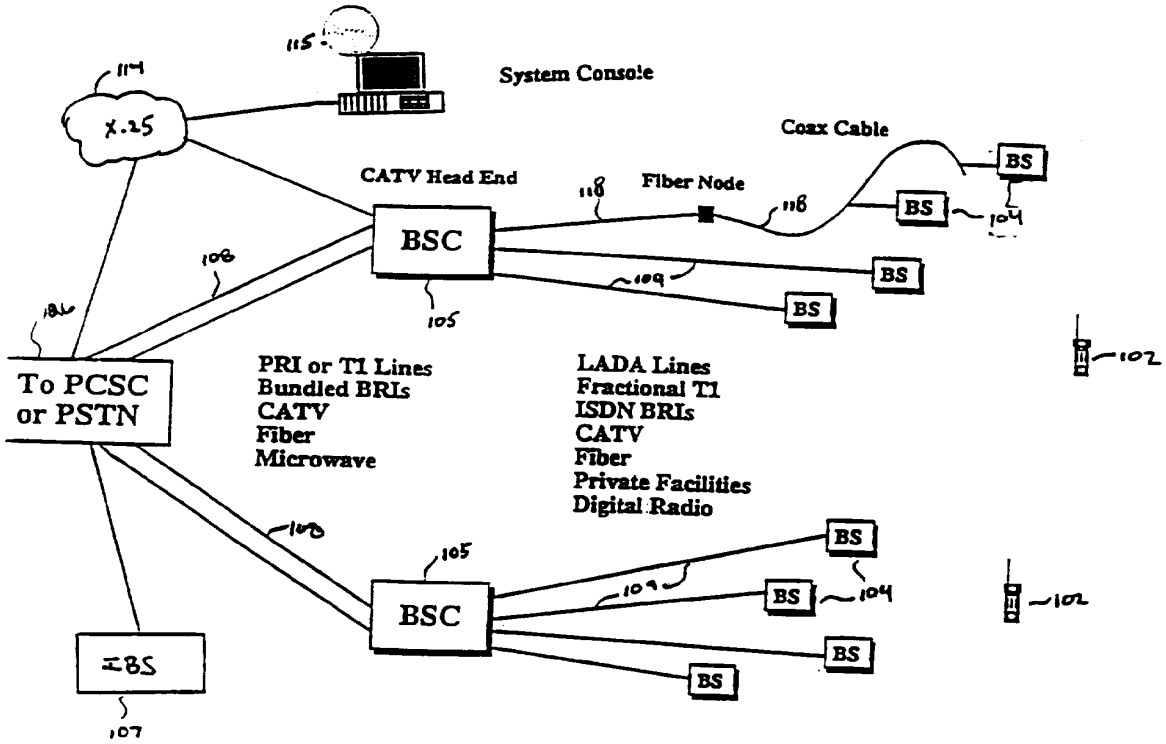
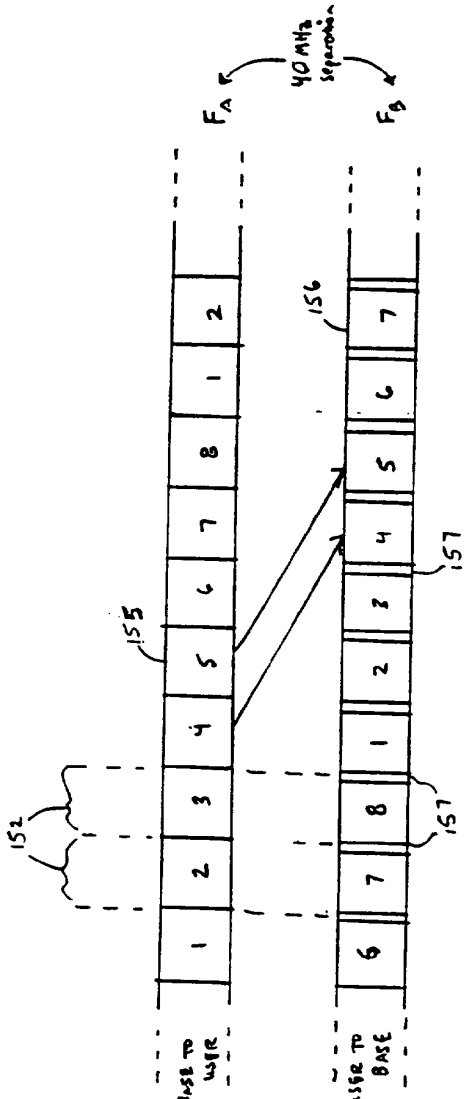

System Console
X.25
Coax Cable
CATV Head End
Fiber Node
BSC
BS
To PCSC
or PSTN
PRI or T1 Lines
Bundled BRIs
CATV
Fiber
Microwave
LADA Lines
Fractional T1
ISDN BRIs
CATV
Fiber
Private Facilities
Digital Radio
MSC
105
106
107
108
109
114
115
116
118
102
104

FIGURE 2



GSM PROTOCOL

FIGURE 3

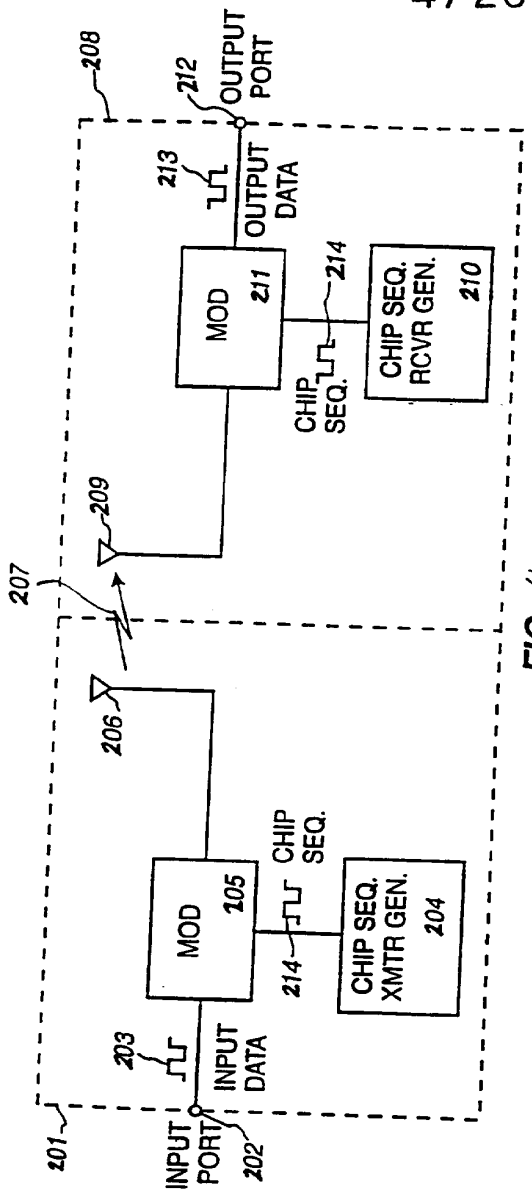
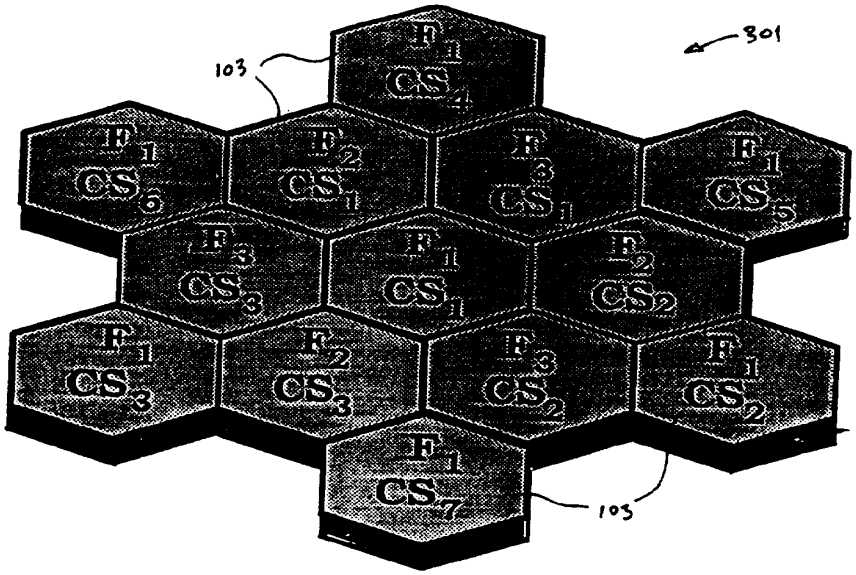

208
212
OUTPUT PORT
213
OUTPUT DATA
MOD 211
214
CHIP SEQ. RCVR GEN. 210
CHIP SEQ.
209
207
206
CHIP SEQ.
MOD 105
214
CHIP SEQ. XMTR GEN. 204
203
INPUT DATA
INPUT PORT 202
101

FIG. 4



N=3 Frequency Reuse Using CDMA

FIGURE 5

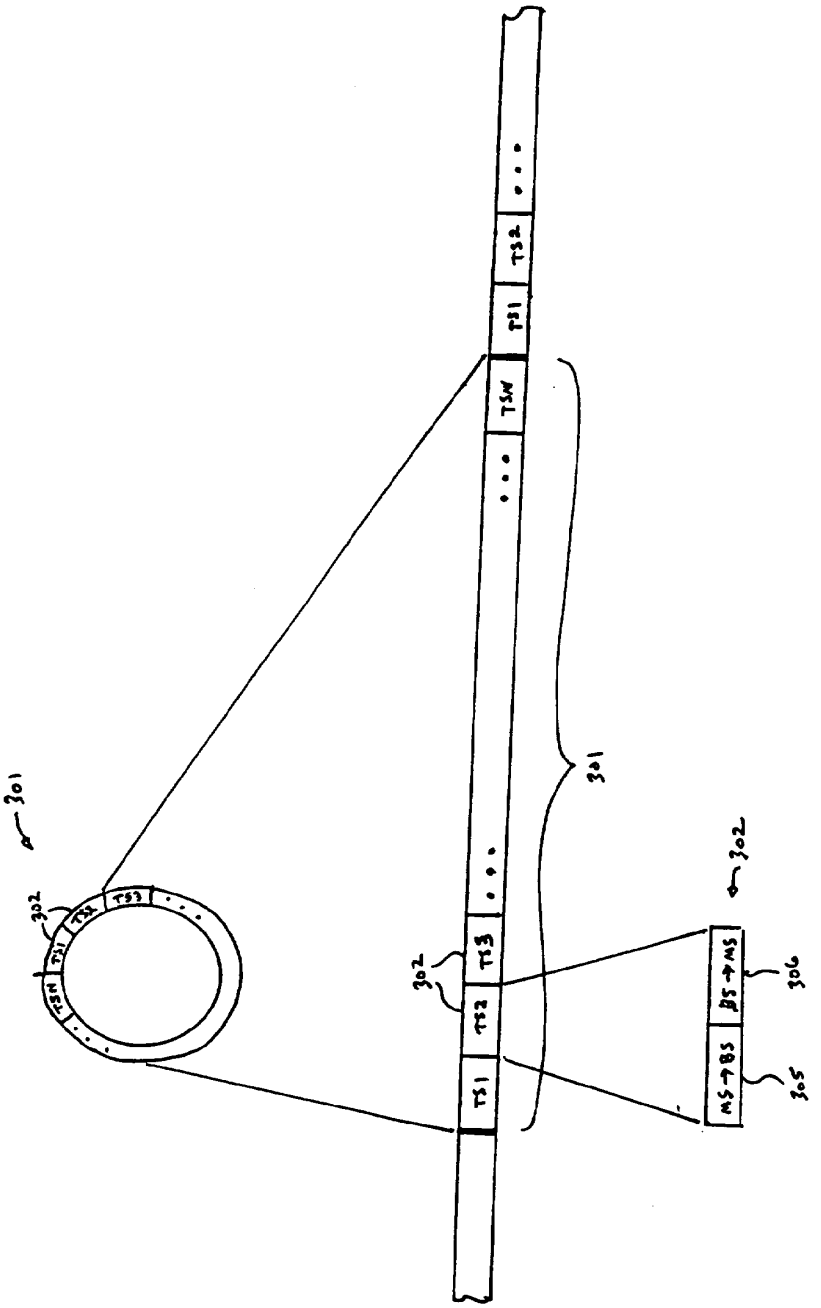

301
302
TS3
TS2
TS1
TSN
TS3
TS2
TS1
301
302
302
BS→MS
MS→BS
306
305

FIGURE 6

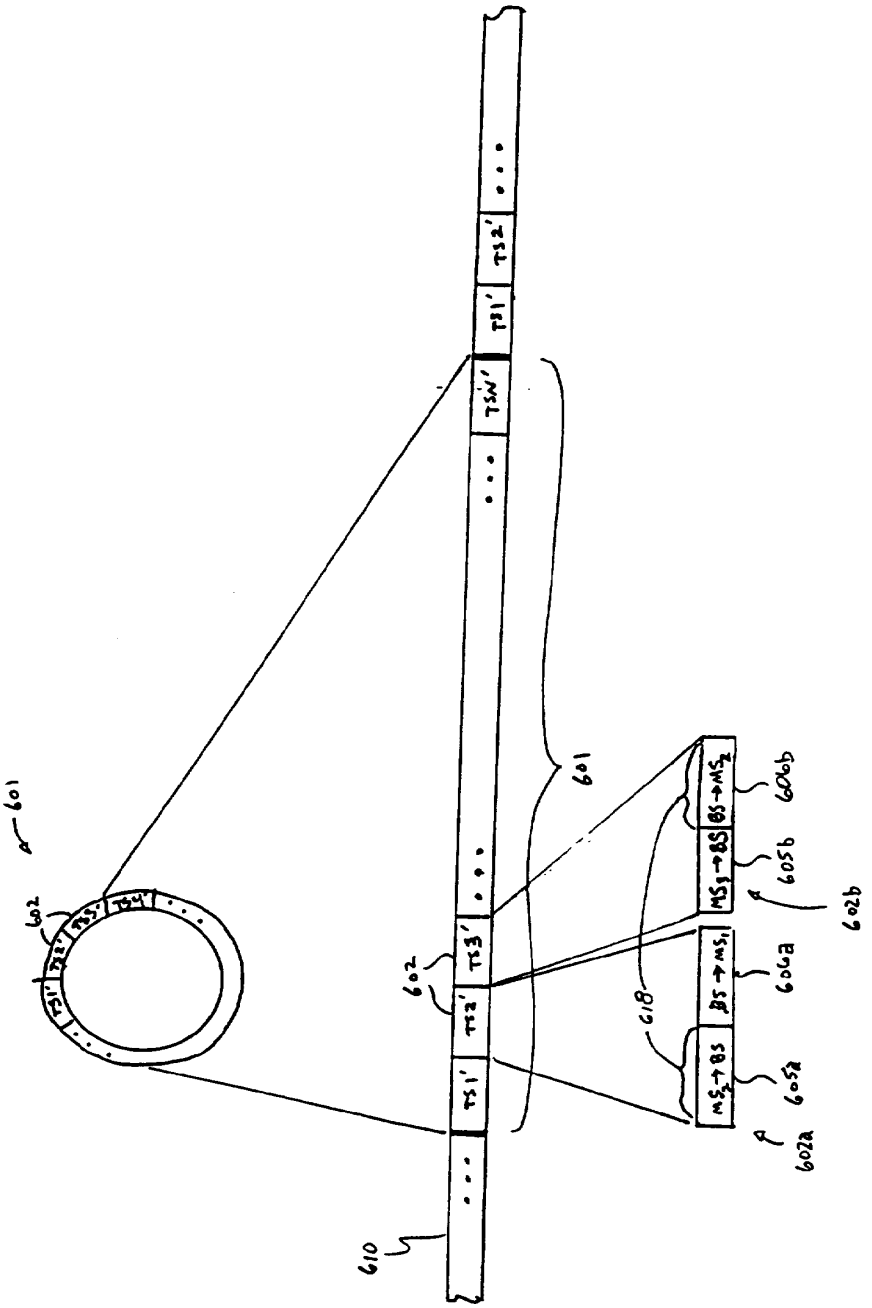


FIGURE 7
(VIRTUAL TIME SLOTS)

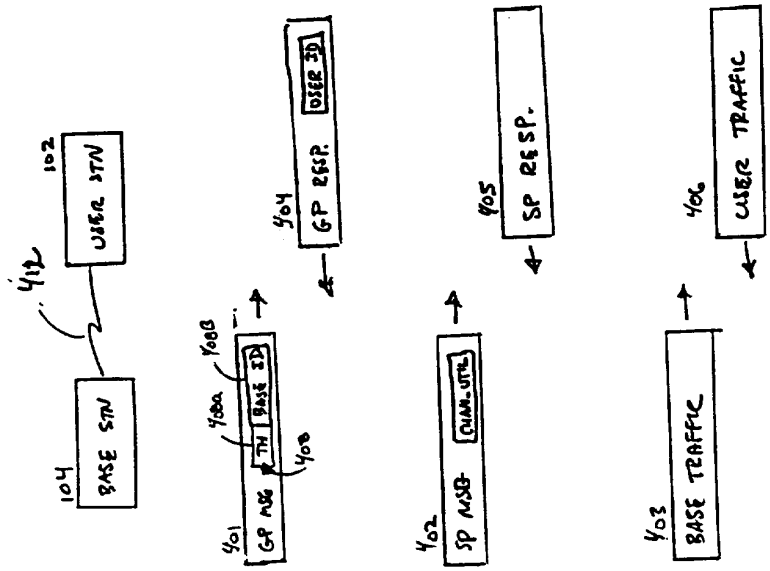
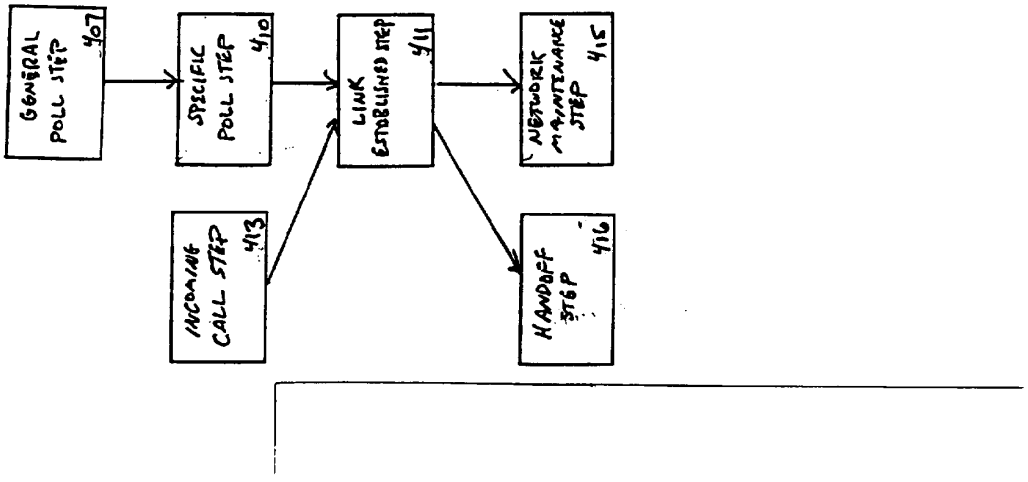

102
USER STN
412
104
BASE STN
401
GP ASG
TN
BASE ID
408a
408b
408
404
GP RESP.
USER ID
405
SP RESP.
402
SP ASG
CHAN. UTIL.
403
BASE TRAFFIC
406
USER TRAFFIC

FIGURE 8


GENERAL POLL STEP 407
SPECIFIC POLL STEP 410
LINK ESTABLISHED STEP 411
NETWORK MAINTENANCE STEP 415
INCOMING CALL STEP 413
HANDOFF STEP 416

SLOT STRUCTURE

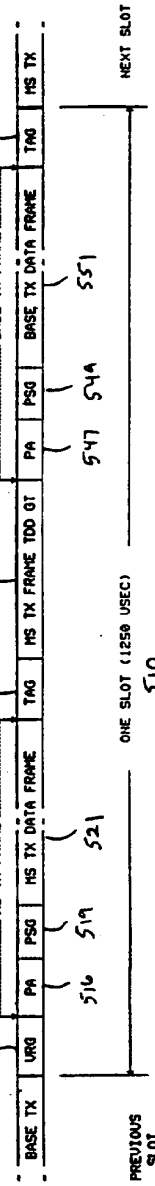


FIGURE 9A

BASE TRANSMIT DATA FRAME STRUCTURE

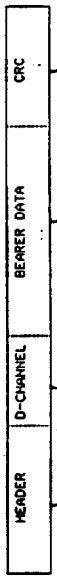


FIGURE 9B

MS TRANSMIT DATA FRAME STRUCTURE

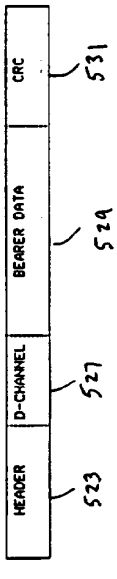


FIGURE 9C

NOTES:

1. MS - MOBILE STATION (HANDSET)
2. TAG - TURN-AROUND GAP
3. TDD - TIME DIVISION DUPLEX
4. GT - GUARD TIME
5. PA - PREAMBLE
6. PSG - PREAMBLE SOUNDING GAP
7. CHIP PERIOD
8. SYMBOL PERIOD
9. VRG - VARIABLE RADIO DELAY GAP

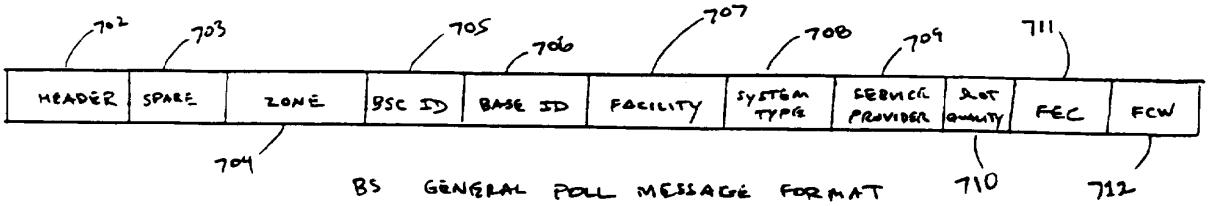


FIG. 10A

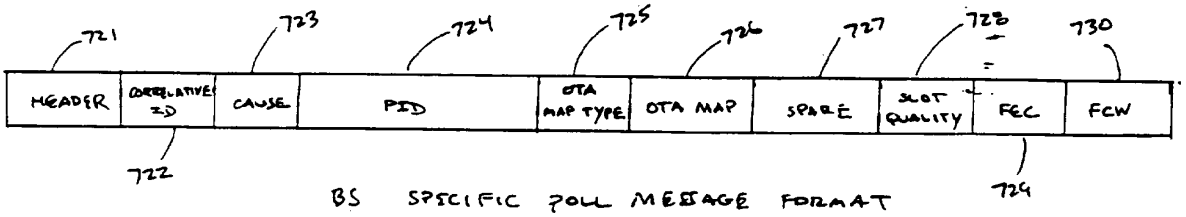


FIG. 10B

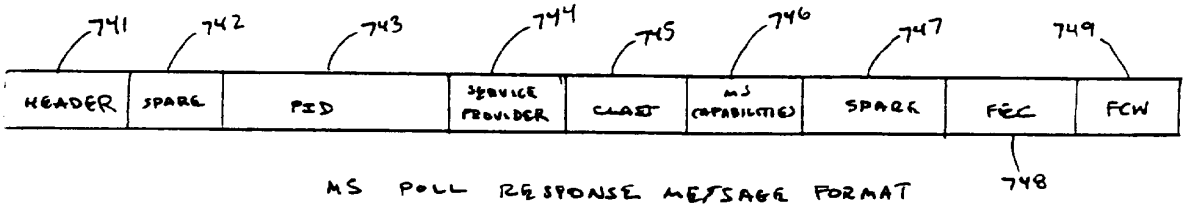
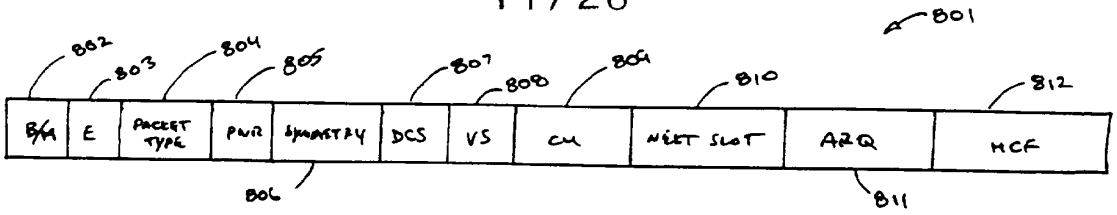
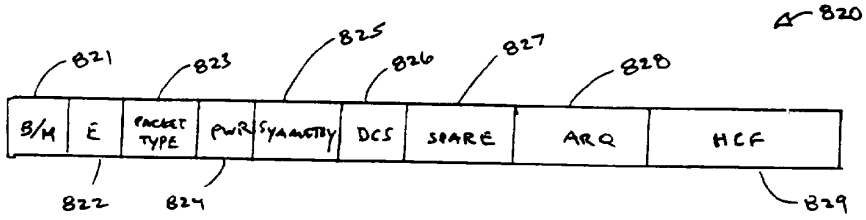


FIG. 10C



BS POLLING FRAME HEADER

FIG. 11A



MS POLLING FRAME HEADER

FIG. 11B

BS Packet

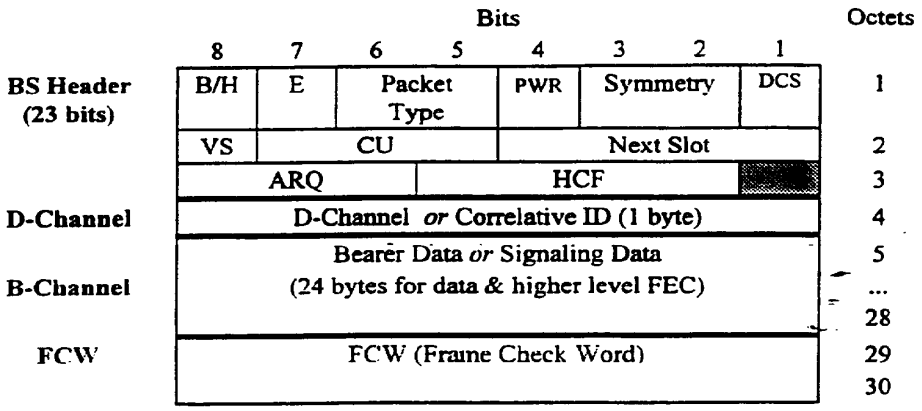


FIGURE 12A

MS Packet

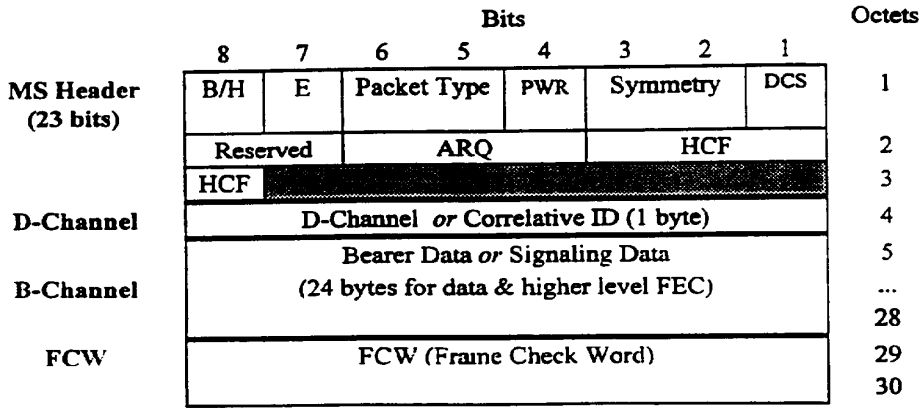


FIGURE 12B

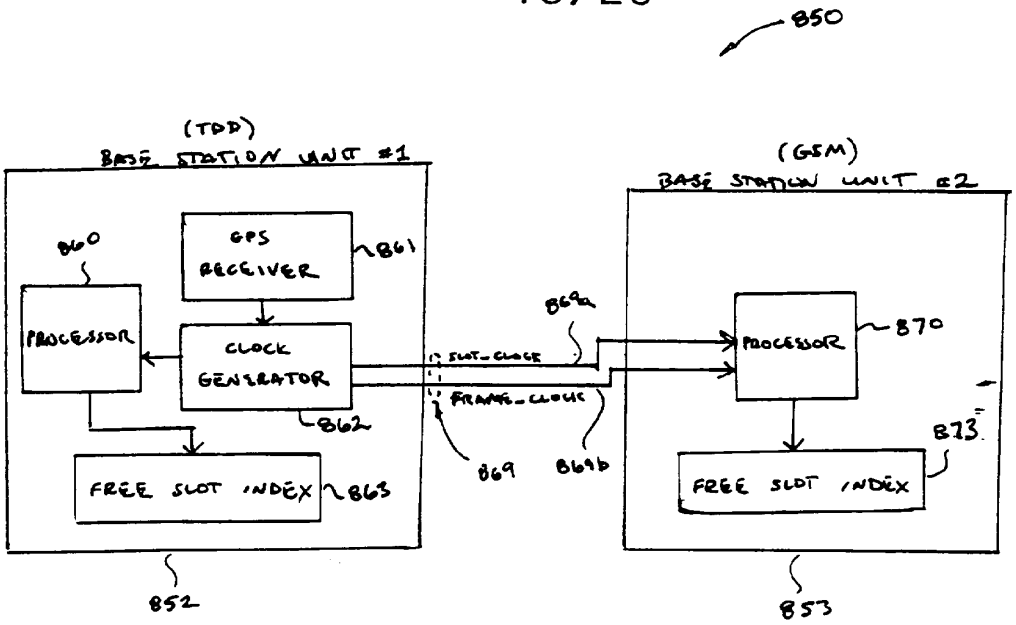

850
(TDD)
BASE STATION UNIT #1
(GSM)
BASE STATION UNIT #2
860
GPS RECEIVER
861
PROCESSOR
CLOCK GENERATOR
862
FREE SLOT INDEX
863
SLOT_CLOCK
FRAME_CLOCK
869a
869
869b
PROCESSOR
870
873
FREE SLOT INDEX
852
853

FIGURE 13

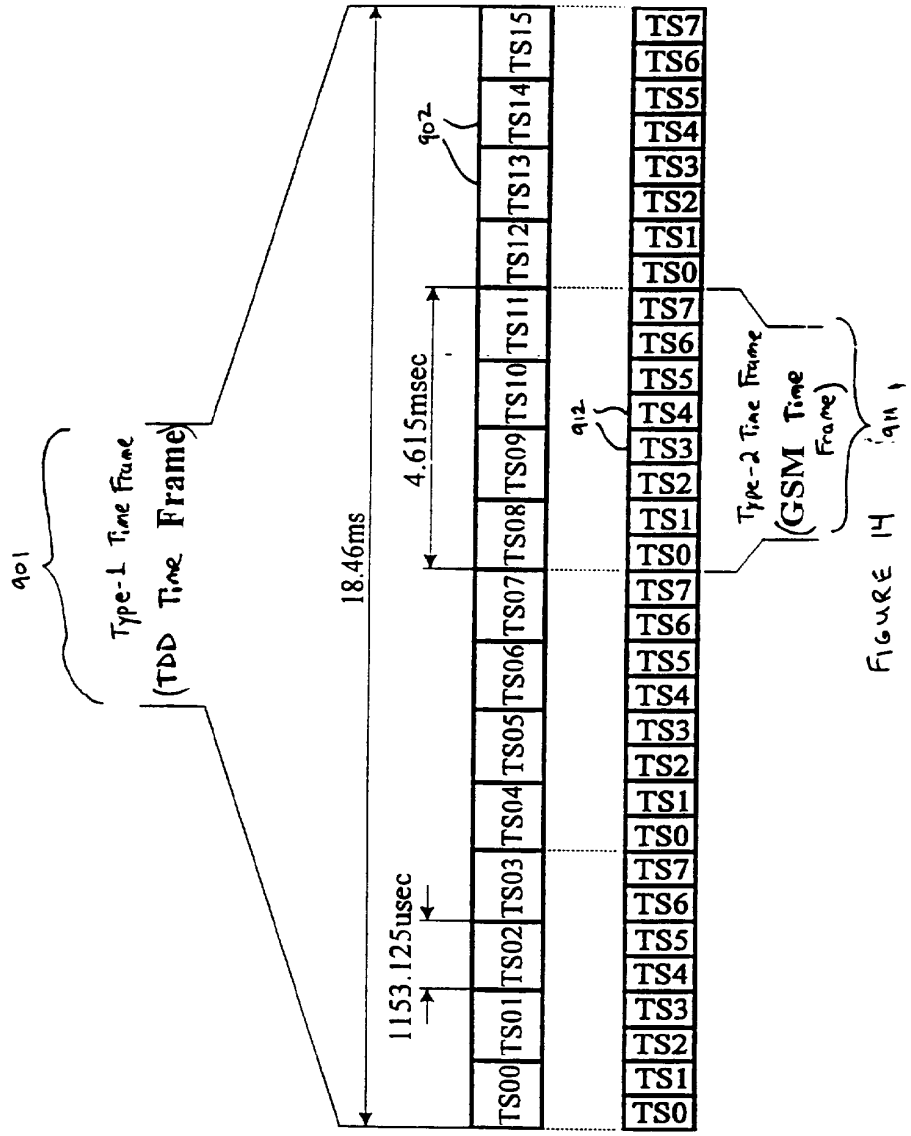

901
Type-1 Time Frame
(TDD Time Frame)
18.46ms
4.615msec
1153.125usec
902
912
Type-2 Time Frame
(GSM Time Frame)
911
TS15
TS14
TS13
TS12
TS11
TS10
TS09
TS08
TS07
TS06
TS05
TS04
TS03
TS02
TS01
TS00
TS7
TS6
TS5
TS4
TS3
TS2
TS1
TS0

FIGURE 14

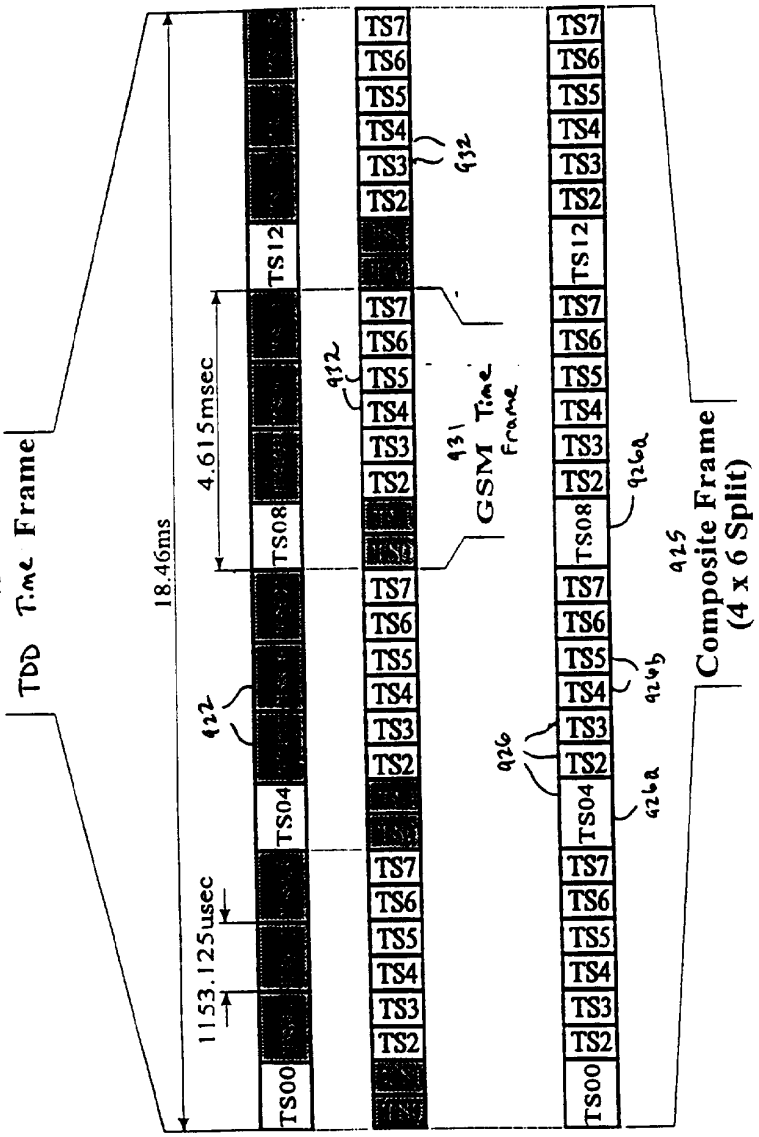

421
TDD Time Frame
18.46ms
4.615msec
1153.125usec
TS12
TS08
TS04
TS00
422
432
431
GSM Time Frame
426a
426b
426
425
Composite Frame
(4 x 6 Split)
TS7
TS6
TS5
TS4
TS3
TS2

FIGURE 15

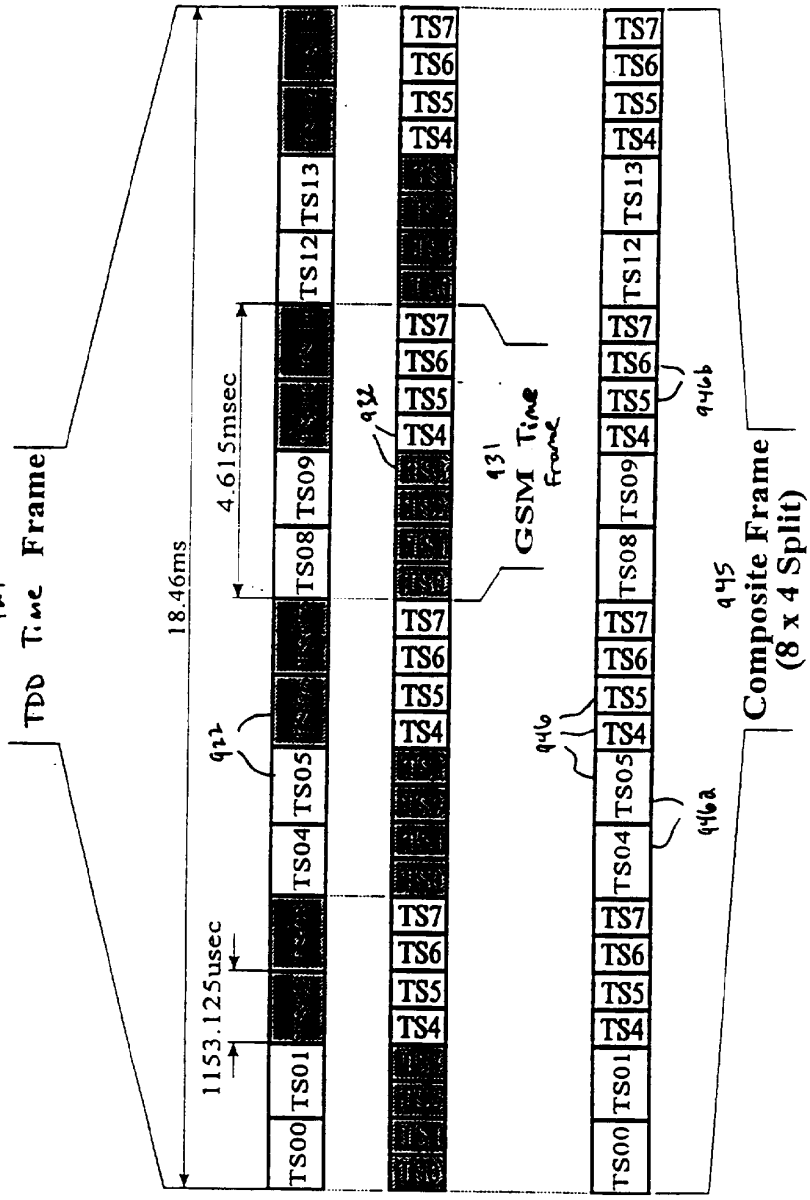

921
TDD Time Frame
18.46ms
4.615msec
1153.125usec
TS00
TS01
TS04
TS05
TS08
TS09
TS12
TS13
922
932
931
GSM Time Frame
946
946a
946b
945
Composite Frame
(8 x 4 Split)

Figure 16

Demand Migration Tables

(Including BCCH channel)

Table 1: Slot allocation

Option:	*1*	*2*	*3*	*4*	*5*
GSM	8	6	4	2	0
TDD	0	4	8	12	16

950, 951, 952, 953, 954

FIGURE 17A

Table 2: Per 1.875MHz (x2) *

Option:	*1*	*2*	*3*	*4*	*5*
GSM	24	18	12	6	0
TDD	0	8	16	24	32

955, 956, 957, 958, 959

* 3 GSM RF channels / TDD RF channel pair

FIGURE 17B

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
01089

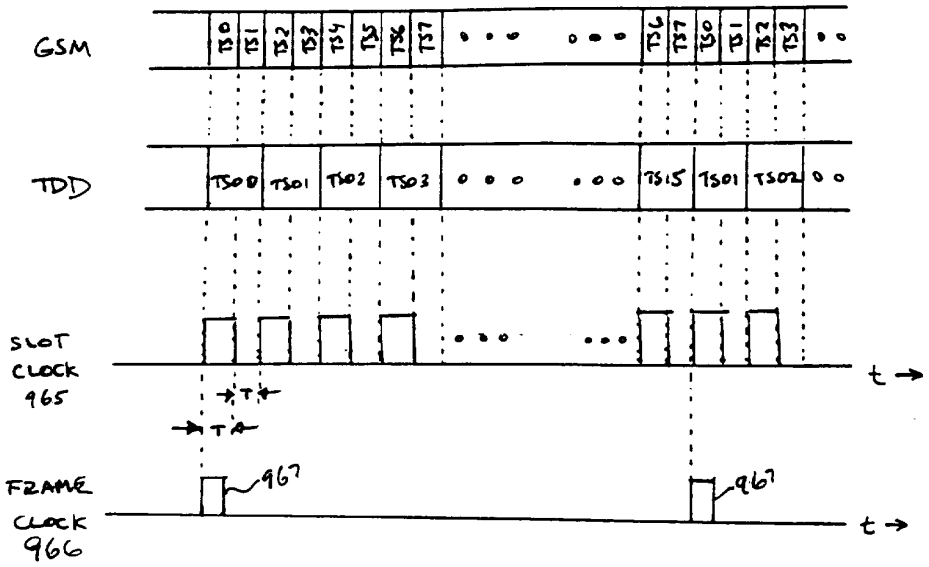

GSM
TS0
TS1
TS2
TS3
TS4
TS5
TS6
TS7
TS6
TS7
TS0
TS1
TS2
TS3
TDD
TS00
TS01
TS02
TS03
TS15
TS01
TS02
SLOT CLOCK 965
t
TA
FRAME CLOCK 966
967
967
t

FIGURE 18

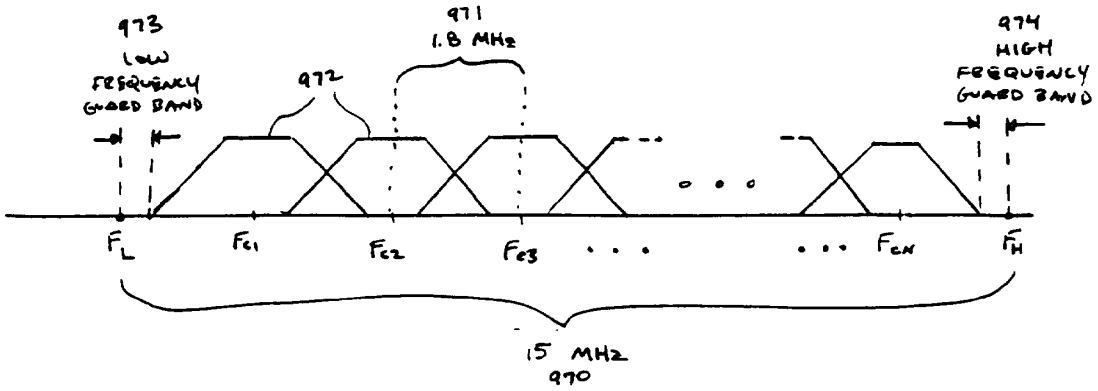


FIGURE 19

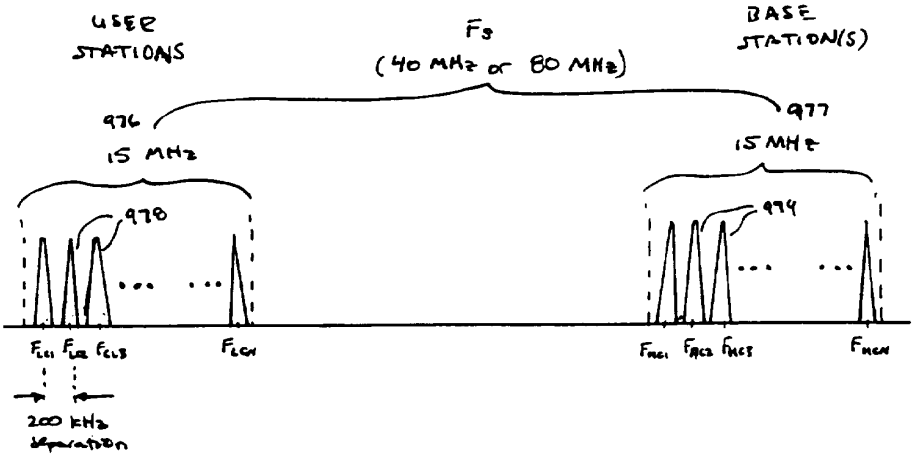


FIGURE 20

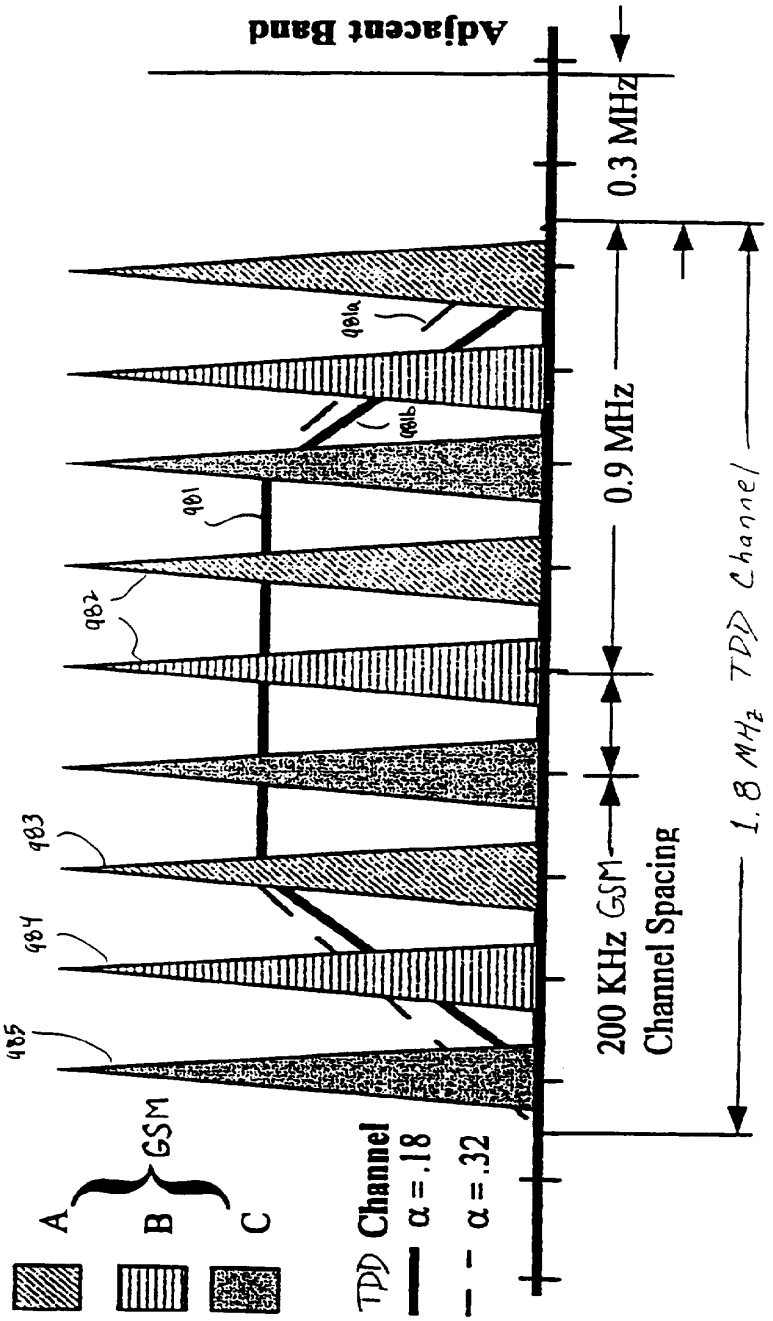

Adjacent Band
0.3 MHz
0.9 MHz
1.8 MHz TDD Channel
200 KHz GSM Channel Spacing
401a
401b
401
402
403
404
405
A
B
C
GSM
TDD Channel
α = .18
α = .32

FIGURE 21

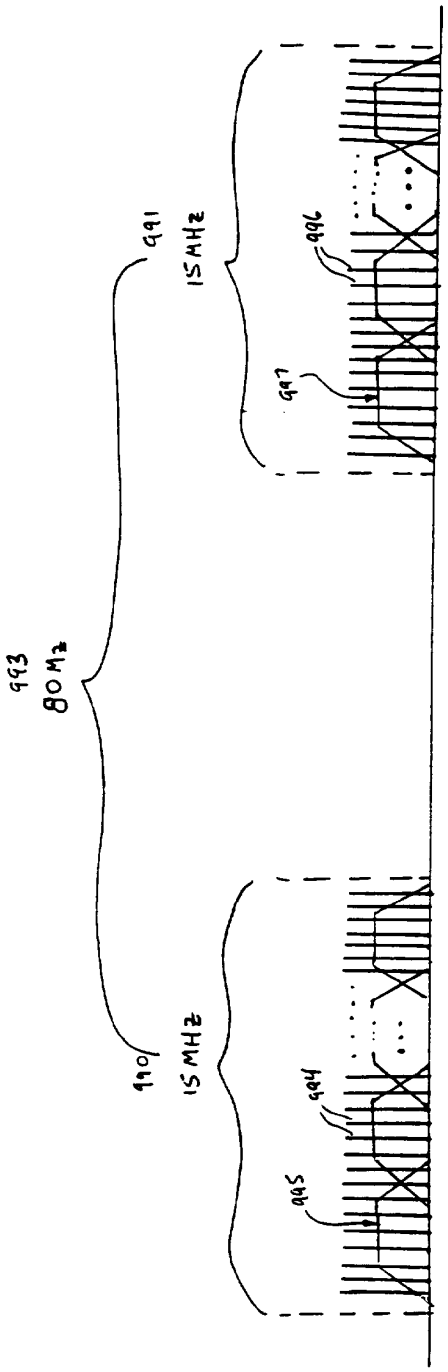


FIGURE 22

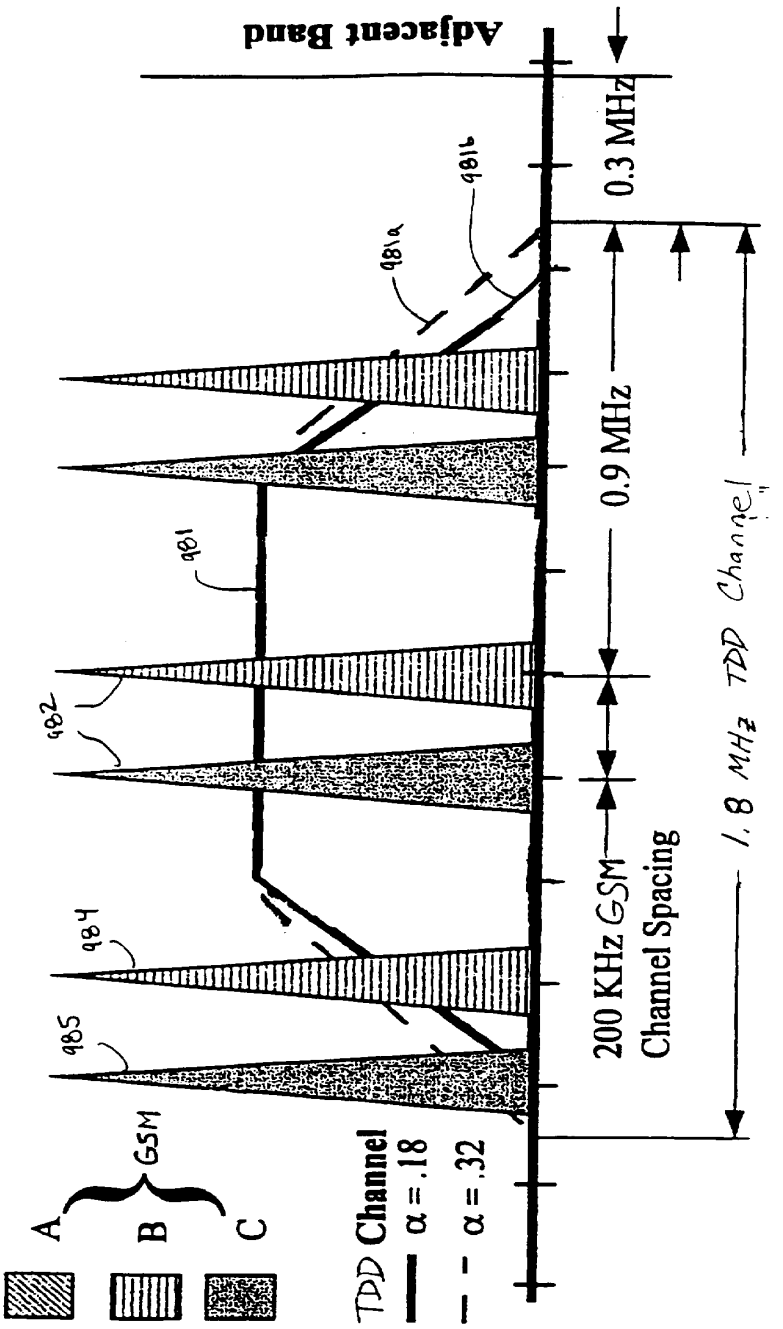

Adjacent Band
0.3 MHz
0.9 MHz
1.8 MHz TDD Channel
200 KHz GSM Channel Spacing
481a
481b
481
482
484
485
A
B
C
GSM
TDD Channel
α = .18
α = .32

FIGURE 23

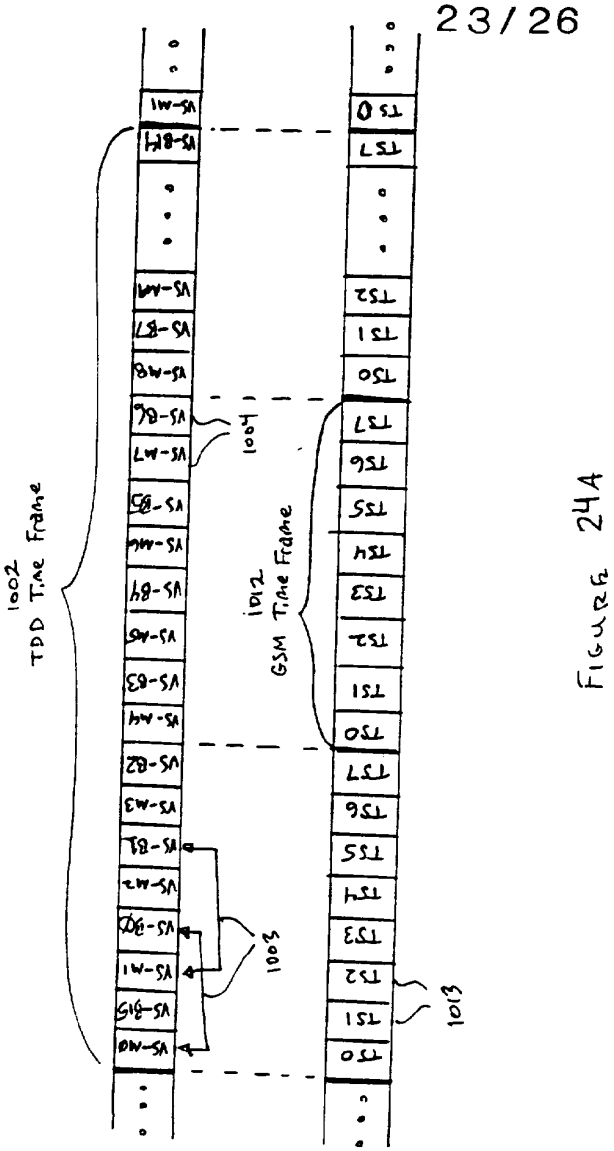


FIGURE 24A

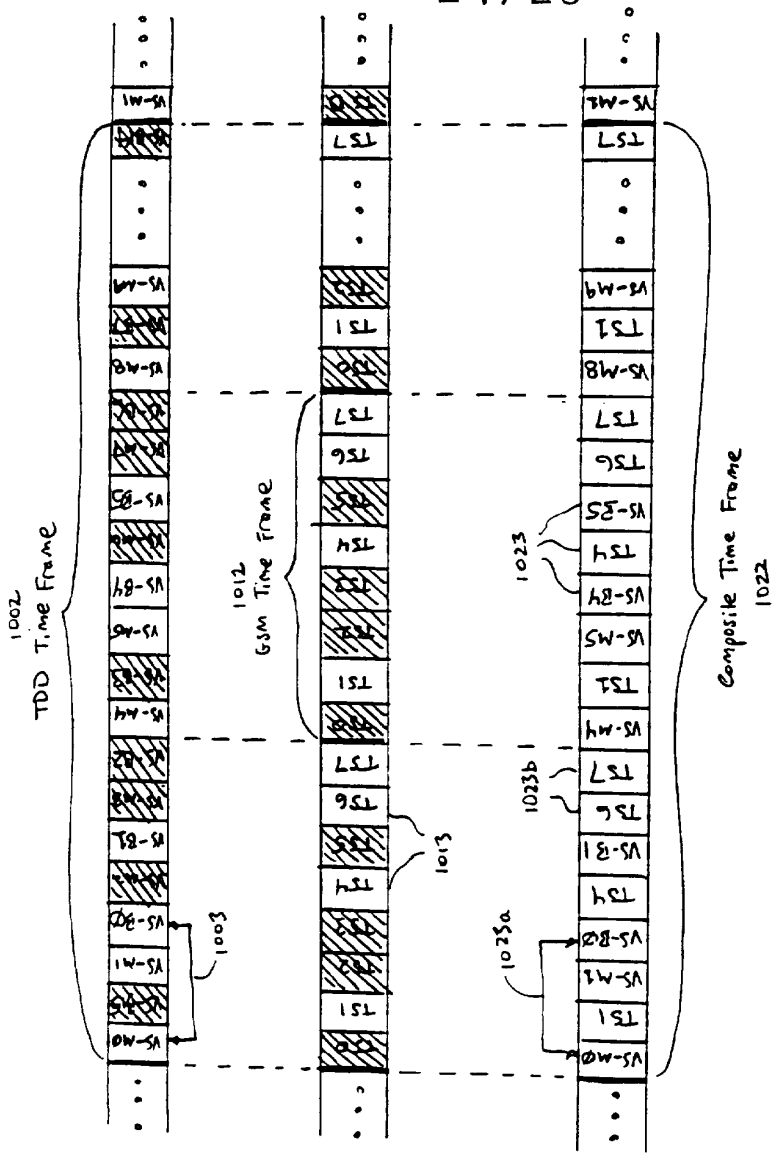

1002
TDD Time Frame
1012
GSM Time Frame
1022
Composite Time Frame
1003
1013
1023
1023b
1025a

FIGURE 24B

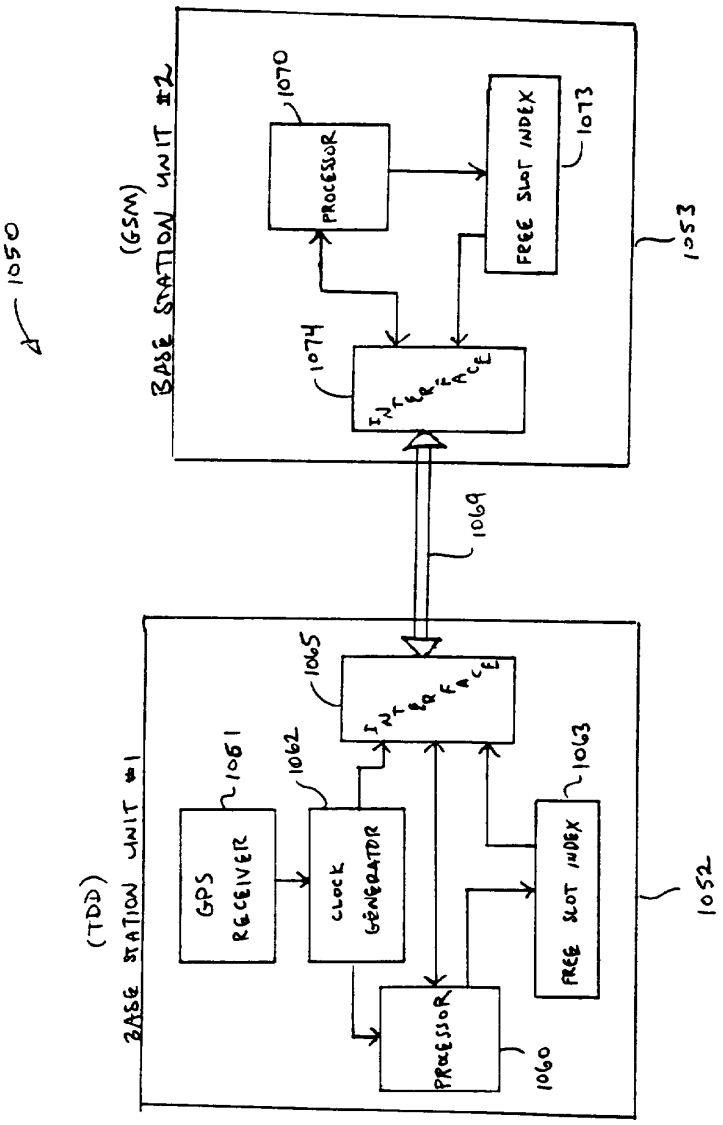

1050
(GSM)
BASE STATION UNIT #2
1070
PROCESSOR
1073
FREE SLOT INDEX
1053
1074
INTERFACE
1069
1065
INTERFACE
(TDD)
BASE STATION UNIT #1
1061
GPS RECEIVER
1062
CLOCK GENERATOR
1063
FREE SLOT INDEX
PROCESSOR
1060
1052

FIGURE 25

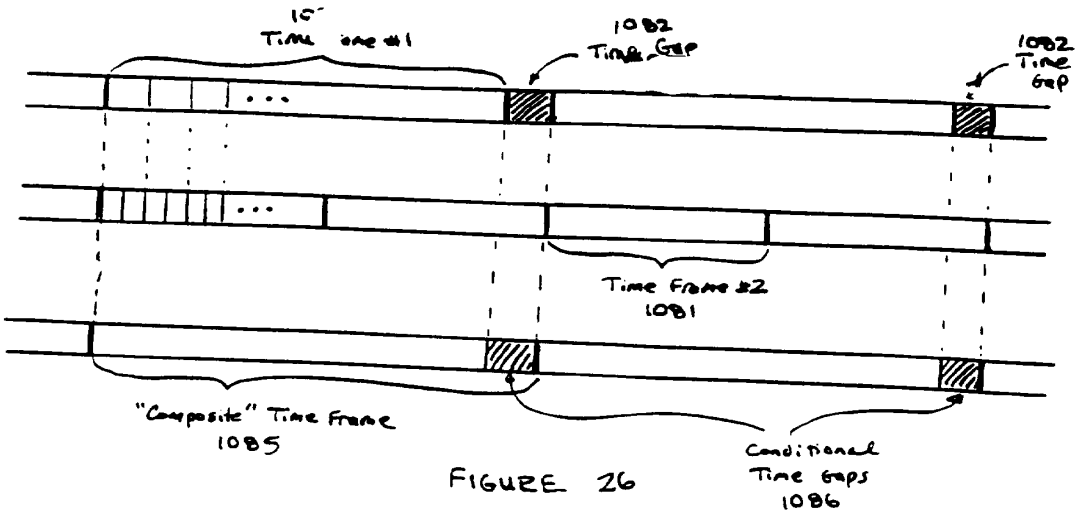


FIGURE 26

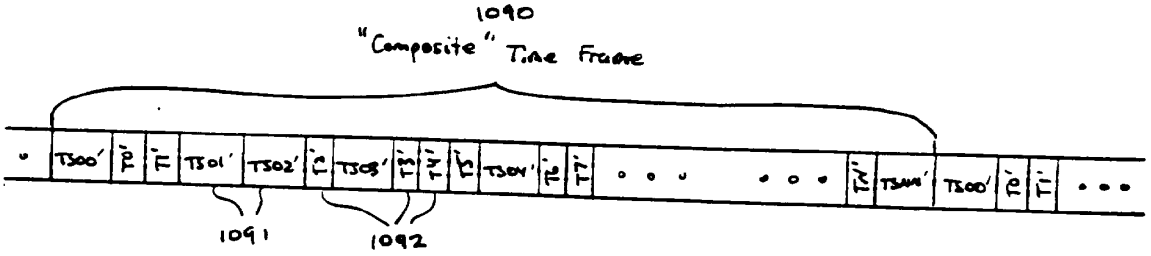


FIGURE 27

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/16068

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04J 3/16; H04L 5/14; H04B 1/56
US CL :370/ 95.3, 24, 29
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/95.1, 95.3, 24, 29

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P ---- Y,P	US,A, 5,475,677 (ARNOLD ET AL) 12 December 1995, lines 12-57,col.7; lines 22-62,col.8; figs.4,5.	1-3 ---- 4,5,26-28
Y --- X	US, A, 5,282,202 (BERNSTEIN ET AL) 25 January 1994, fig.8. fig. 8.	4,5,26-28 ---------- 24,25,29
A	US, A, 5,349,635 (SCOTT) 20 September 1994, see entire reference.	1-37

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search 16 DECEMBER 1996	Date of mailing of the international search report 22 JAN 1997
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(30) Priority Data:
08/607,588 27 February 1996 (27.02.96) US

(71) Applicant: AIRNET COMMUNICATIONS CORPORATION [US/US]; 100 Rialto Place, S300, Melbourne, FL 32901 (US).

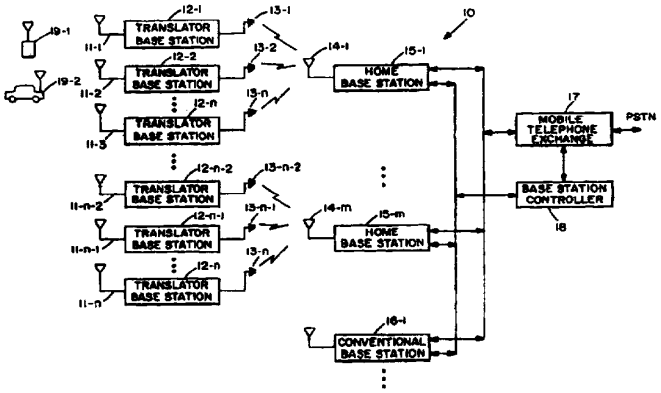
(72) Inventors: CARNEY, Ronald, R.; 916 Flower Street, N.W., Palm Bay, FL 32907 (US). POOR, Victor, D.; 1208 East River Drive, No. 302, Melbourne, FL 32901 (US).

(74) Agents: THIBODEAU, David, J., Jr. et al.; Hamilton, Brook, Smith & Reynolds, P.C., Two Militia Drive, Lexington, MA 02173 (US).

(81) Designated States: AU, CA, JP, KR, MX, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: CELLULAR SYSTEM PLAN USING IN BAND-TRANSLATORS



(57) Abstract

A wireless system architecture whereby high efficiency broadband transceiver systems can be deployed at an initial build out stage of the system in a cost-efficient manner. A home base station location is identified within each cluster of cells and rather than deploy a complete suite of base station equipment at each of the cells in the cluster, inexpensive translator units are located in the outlying cells serviced by the home base station in which low traffic density is expected. The translators are connected to directional antennas arranged to point back to the home base station site. The translators are deployed in such a way which meshes with the eventually intended frequency reuse for the entire cluster of cells. The translator to base station radio links operate in-band, that is, within the frequencies assigned to the service provider. For example, the available frequency bands are divided into at least two sub-bands, where a first sub-band is assigned for use as a home base station to translator base station communication link and a second sub-band is assigned for use by the mobile station to translator communication link. If desired, a third sub-band can then be used for deployment of base transceiver systems in the conventional fashion where the base station equipment located at the center of a cell site communicates only with mobile stations located within that cell.

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CELLULAR SYSTEM PLAN USING IN BAND-TRANSLATORS

FIELD OF THE INVENTION

This invention relates generally to wireless communication systems and in particular to a system architecture that makes use of in band-translators deployed in peripheral cells of a cell cluster.

BACKGROUND OF THE INVENTION

The ever increasing need for wireless communication services such as Cellular Mobile Telephone (CMT), Digital Cellular Network (DCN), Personal Communication Services (PCS) and the like, typically requires the operators of such systems to serve an ever increasing number of users in a given service area. As a result, certain types of base station equipment including high capacity broadband transceiver systems (BTS) have been developed which are intended to service a relatively large number of active mobile stations in each cell. Such broadband transceiver system equipment can typically service, for example, ninety-six simultaneously active mobile stations in a single four-foot tall rack of electronic equipment. This base station equipment typically costs less than $2000 to $4000 per channel to deploy, and so the cost per channel serviced is relationally low.

When coupled with efficient frequency reuse schemes, such as that described in a co-pending U.S. patent application Serial No. 08/331,455 entitled "A Method For Obtaining Times One Frequency Reuse in Communication Systems" filed by John R. Doner on October 31, 1994 and

assigned to AirNet Communications Corporation who is the assignee of this application, maximum efficiency in densely populated urban environments is obtained. According to that arrangement the cells are each split into six radial sectors and frequencies are assigned to the sectors in such a manner as to provide the ability to reuse each available frequency in every third cell. Although this frequency reuse scheme is highly efficient, it requires at least two complete sets of multi-channel transceiver equipment such as in the form of a broadband transceiver system (BTS) to be located in each cell.

However, when a wireless system first comes on line, demand for use in most of the cells is relatively low, and it is typically not possible to justify the cost of deploying complex multichannel broadband transceiver system equipment based only upon the initial number of subscribers. Because only a few cells at high expected traffic demand locations (such as at a freeway intersection) will justify the expense to build-out with high capacity broadband transceiver system equipment, the service provider is faced with a dilemma. He can build-out the system with less expensive narrowband equipment initially, to provide some level of coverage, and then upgrade to the more efficient equipment as the number of subscribers rapidly increases in the service area. However, the initial investment in narrowband equipment is then lost. Alternatively, a larger up front investment can be made to initially deploy high capacity equipment, so that once demand increases, the users of the system can be accommodated without receiving busy signals and the like. But this has the disadvantage of carrying the money cost of a larger up front investment.

Some have proposed various techniques for extending the service area of a given cell. For example, U.S. Patent 4,727,490 issued to Kawano et al. and assigned to

Mitsubishi Denki Kabushiki Kaisha, discloses a mobile telephone system in which a number of repeater stations are installed at the boundary points of hexagonally shaped cells. The repeaters define a small or minor array which is, in effect, superimposed on a major array of conventional base stations installed at the center of the cells. With this arrangement, any signals received in so-called minor service areas by the repeaters are relayed to the nearest base station.

Another technique was disclosed in U.S. Patent 5,152,002 issued to Leslie et al., and assigned to Orion Industries, Inc., wherein the coverage of a cell is extended by including a number of so-called "boosters" arranged in a serial chain. As a mobile station moves along an elongated area of coverage, it is automatically picked up by an approaching booster and dropped by a receding booster. These boosters, or translators, use highly directive antennas to communicate with one another and thus ultimately via the serial chain with the controlling central site. The boosters may either be used in the mode where the boosted signal is transmitted at the same frequency as it is received or in a mode where the incoming signal is retransmitted at a different translated frequency.

Unfortunately, each of these techniques have their difficulties. With the first method, which uses an array of repeaters co-located with the primary cell sites, the implementation of diversity receivers becomes a problem. Specifically, certain types of cellular communication systems, particularly those that use digital forms of modulation, are susceptible to multi-path fading and other distortion. It is imperative in such systems to deploy diversity antennas at each cell site. This repeater array scheme makes implementation of diversity antennas extremely difficult, since each repeater simply forwards its received

signal to the base station, and diversity information as represented by the phase of the signal received at the repeater, is thus lost.

The second scheme works fine in a situation where the boosters are intended to be laid in a straight line along a highway, a tunnel, a narrow depression in the terrain such as a ravine or adjacent a riverbed. However, there is no teaching of how to efficiently deploy the boosters in a two-dimensional grid, or to share the available translated frequencies as must be done if the advantages of cell site extension are to be obtained throughout an entire service region, such as a large city.

DESCRIPTION OF THE INVENTION

Objects of the Invention

It is an object of this invention to provide a cellular system architecture whereby high efficiency broadband transceiver systems can be deployed at an initial build-out stage of the system in a cost-efficient manner.

Another object is to provide a migration strategy for a wireless system which not only is inexpensive to build-out initially but also provides for efficient deployment of high-capacity systems in later years of system build-out.

A further object is to provide a wireless system in which hardware deployment costs are strictly driven by user demand throughout the stages of system deployment.

Another object is to provide such a system in which the initial low cost build-out footprint of cells is the same as in a completely built out system, to avoid the need for reconfiguring cells and associated antenna sites.

Yet another object is to minimize the backhaul costs and the need for associated secondary transmit licenses.

A still further object is to permit the implementation of conventional diversity receiving schemes.

SUMMARY OF THE INVENTION

Briefly, the invention is an architecture for a wireless communication system in which the cells are grouped into clusters and the available frequency spectrum is divided into frequency reuse groups. A home cell location is identified within each cluster and a base station located at or near the home cell site serves the multiple cells in the reuse cluster.

Rather than deploy a complete suite of base station equipment at each of the cells in the cluster, translator units are located in the outlying cells serviced by the home base station in which low traffic density is expected. The translators are connected to directional antennas arranged to point back to the home base station site. The translators are deployed in such a way which meshes with the eventually intended frequency reuse for the entire cluster of cells.

The translator to base station radio links operate in-band, that is, within the frequencies assigned to the service provider. For example, the service provider is a Personal Communication Services (PCS) provider in the United States having the use of a pair of 15 MHz bands (one for down links and one for up links). Each of the available frequency bands are divided into at least two sub-bands. A first sub-band is assigned for use as a home base station to translator base station communication link. A second sub band is assigned for use by the mobile station to translator communication link. If desired, a third sub-band can then be used for deployment of base transceiver systems in the conventional fashion where the base station equipment located at the center of a cell site communicates only with mobile stations located within that cell.

Because the cost of modifying mobile station equipment is prohibitive, the mobile stations communicate with the translator base stations in the conventional

fashion, that is, the down link channel frequencies (from base station to mobile station) are selected from the lower band of frequencies, and the uplink channel frequencies (from mobile station to base station) are selected from the upper band of frequencies. However, the links between the home base station and the translator base stations are inverted, in the sense that the lower band of frequencies is used for the uplink from translator to base station, and the upper band of frequencies is used for the down link from the home base station to the translator base station.

In one variation, the home base station may make use of omni-directional receiving equipment and in such case the home base station is located in the center of the cell cluster. In another implementation, the home base station may make use of sectorized antennas and the cell reuse group is assigned frequencies as in a fully sectorized arrangement.

Efficient frequency reuse may be effectively planned for at even the initial system build-out stages. For example, an "N=12" reuse pattern may be used which permits the deployment of twelve (12) cells around a central cell site in an approximately equidistant fashion. The home cell site then uses omni-directional antennas to communicate with the translators. The N=12 pattern may then be repeated throughout the service area by inverting the orientation of the alternating columns of cell groups. In this manner, compatibility with an reuse pattern which may be upgraded to higher reuse densities on a cell by cell basis is maintained.

In another arrangement, the N=12 pattern is simply repeated across the service area and the center cell is sectorized at initial system build-out.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention and its novel advantages and features, reference should be made to the accompanying drawings in which:

Fig. 1 is a block diagram of the components of a wireless communication system that makes use of in-band translator base stations, home base stations, conventional base stations, and mobile stations according to the invention;

Fig. 2 is a diagram of a frequency assignment plan which is implemented according to the invention showing the ranges of radio channels typically assigned to the home base station, translator base station, mobile station and conventional base station;

Fig. 3 is a illustration of the typical arrangement of the home base station, mobile station and translator base station illustrating how communication links are deployed in an up link direction from the mobile station through the translator to the home base station, and in a down link direction from the home base station through the translator to the mobile station;

Fig. 4 is a circuit diagram of the components of the translator as implemented to provide diversity reception in both the mobile station to translator base station link as well as in the translator to home base station link;

Fig. 5 is one possible layout of home base station and translators implemented according to the invention in cell clusters where traffic densities are low, using a frequency reuse factor of twelve;

Fig. 6 illustrates how the layout of Fig. 5 can be repeated through out a service area such as throughout a metropolitan trading area (MTA); and

Fig. 7 is an alternative arrangement of home base station and translators overlaid on a frequency reuse pattern which makes use of a sectorized home base station.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 is a block diagram of the components of a wireless communication system such as a Personal Communication System (PCS) or similar cellular system in which translator base stations are deployed in peripheral cells of a cell cluster to concentrate radio signal traffic to and from a home base station. In-band radio frequency channel assignments are made to the translator base stations, home base stations, and mobile stations in a particular fashion that will be described shortly.

The system 10 includes translator omni-directional antennas 11-1, 11-2, 11-3, ..., 11-n-2, 11-n-1, 11-n (collectively, the omni-directional antennas 11), translator base stations (translators) 12-1, 12-2, ..., 12-n, translator directional antennas 13-1, 13-2, ..., 13-n, home base station antennas 14-1, ..., 14-m, home base stations 15-1, ... 15-m, one or more conventional base stations 16-1, a mobile telephone exchange 17, one or more base station controllers 18, and mobile stations 19-1, 19-2.

The system 10 provides voice and or data communication between the mobile stations 19 and the Public Switch Telephone Network (PSTN) by sending signals over radio channels. In the particular embodiment of the invention being described, the radio signaling protocol, or "air interface" may, for example, be the PCS-1900 standard promulgated by the Telecommunications Industry Association (TIA) in the United States [which is identical in relevant aspects to the Global System for Mobile Communication (GSM) standard promulgated in Europe and elsewhere by the European Telecommunication Standards Institute (ETSI)].

The translator base stations 12-1, 12-2, ..., 12-i are each located in what would normally be considered approximately the center of a cell site among a group or cluster of cells. The translators 12 receive radio signals

from the mobile stations 19 and forward them to the associated home base station 15-1. Likewise, radio signals originating at the home base station 15-1 are forwarded by the translators 12 to the mobile stations 19.

The translator "base stations" 12, each associated with a respective cell, do not perform demodulation and modulation functions within each cell as would a conventional base station. Rather, they serve to frequency-translate signals received from the mobile stations 19 located in its respective cell, and then direct such signals on a different frequency to the home base station 15-1 associated with the particular translator base station 12-1. The translators 12 also perform the inverse function to translate signals received from the home base station to direct them to the mobile stations 19. The specific manner of translation will be discussed below in connection with Fig. 2 and 4.

The home base stations 15-1, ..., 15-m and conventional base station 16-1 are responsible for demodulating radio signals and connecting them to the Public Switched Telephone Network (PSTN) through the mobile exchange 17. The base stations 15-1, ..., 15-m and conventional base station 16-1 also modulate signals received from the PSTN through the mobile exchange 17 to format them for transmission over the air through the translators 12. The conventional base station 16-1 is typically located substantially in the center of a particular cell of the system 10. In a manner that will be described shortly the home base stations 15-1, ..., 15-m may or may not be located in the center of a particular cell.

In contrast, the conventional base station 16-1 operates as in the prior art to directly service the mobile units 19 located in or traveling through its associated cell.

The base station controller 18, of which there may be more than one, has a number of functions. The primary function is to manage the logical connections made between mobile stations 19 and the PSTN. In order to do so, the base station controller 18 assigns transmit and receive radio carrier frequencies to each individual mobile station 19, translators 12, home base stations 15, and conventional base station 16. Typically, there may be five to twenty base stations 15 and/or 16 serviced by a single base station controller 18.

The present invention is in the specific manner in which the base station controller 18 assign radio carrier frequencies for use by the mobile stations 19, translators 12, home base stations 15, and conventional base station 16. The frequency assignments are made to the home base stations 15 and conventional base stations 16 so that they do not interfere with one another.

Specifically, in the up link direction, that is for signals transmitted from mobile station 19 to the home base station 15-1, a signal originating at a mobile station 19 is first received at an omni-directional antenna 11-2 at an exemplary translator 12-2. The translator 12-2 then converts the radio carrier frequency of the signal received from the mobile station 19 to a different carrier frequency. The carrier frequency conversion is in-band that is, as will be described shortly in connection with Fig. 2, the translation is wholly within the frequency bandwidth allocated to the service provider for wireless service. The translated signal is then sent out on an antenna 13-2 such as a Yagi antenna which provides a highly directional link back to the associated home base station 15-1. The translated signal is then received on by the antenna 14-1 associated with the home base station 15-1 and processed in the conventional manner.

Processing in the down link direction from the home base station 15-1 to the mobile station 19 is analogous. In particular, the signal from the PSTN is modulated by the home base station 15-1 and then transmitted on the antenna 14-1. The directional antenna 13-2 provides a highly directional radio link between the home base station 14-1 and the translator 12-2. The translator base station 12-2 then receives the down link signal, which is then translated to a frequency normally assigned for the use by the mobile station 19. This translated signal is then output on the omni-directional antenna 11-2 and then ultimately received by the mobile station 19.

Fig. 2 shows the in-band frequency assignments made to the home base station 15, the translator base station 12, the mobile station 19 and the conventional base station 16 as required to practice this invention. The vertical axis in the diagram represents frequency. The four columns of boxes represent frequency allocations for the home base station plan 25, the translator base station plan 22, the mobile station plan 29, and the conventional base station plan 26. The left side of the diagram illustrates a representation of the frequency allocations typically made available to a wireless service provider, including a lower band of frequencies 20 and an upper band of frequencies 21. For a PCS provider in the United States, 15 MHz of spectrum is allocated in each of the upper and lower bands 20 and 21. The lower 15 MHz of spectrum, a contiguous block of spectrum in a range from 1850 to 1910 MHz, is typically used for uplinks, or mobile station to base station transmissions, and the upper 15 MHz block of frequency spectrum, located 80 MHz away, in the 1930 to 1990 MHz range, is typically used for down links. A conventional base station 16-1 is thus assigned to transmit on the upper band of frequencies 21 and to receive on the lower band of frequencies 20.

In accordance with the invention each of the up link and down link bands 20 and 21 are divided into a number of sub-bands. In the illustrated embodiment there are three frequency sub-bands, 20-1, 20-2, 20-3 each representing 5 MHz of the up link band. Similarly, the down link band 21 is divided into three sub-bands 21-1, 21-2, and 21-3, each also containing 5 MHz of spectrum.

As shown in the right hand side of Fig. 2, the two lowest sub-bands 20-1 and 21-1 are assigned for use by the conventional base station 16-1 in the conventional manner. Thus, the lowest band 20-1 is reserved for use as a direct uplink between the mobile stations 19 and the conventional base stations 16-1. Similarly, the lowest sub-band 21-1 of the down link band 21 is reserved for the direct links between the conventional base station 16-1 and the mobile station 19.

Frequency assignments are made to the home base station 15 such that the up link from the translators 12 to the home base station 15 makes use of the upper sub-bands 21-3 of the upper band 21. The down link between home base station 15 and translators 12 similarly uses the upper most sub-band 20-3.

The middle sub-band 21-2 of the upper spectrum portion 21 is used as the down link from the translators 12 to the mobile stations 19 and the middle sub-band 20-2 of the lower spectrum 20 is used as the up link from the mobile station 19 to the translators 12.

The cross hatched lines in the home base station frequency assignment plan 25, that is, the lower and middle sub-bands 20-1, 20-2, 21-1, and 21-2 are not in use by the home base station 15. The cross hatched lines in the translator base station plan 22 also indicate that the lowest sub-bands 20-1 and 21-1 are not used by the translators 12.

It can now be understood from Fig. 2 how frequencies are assigned to mobile stations 19, home base stations 15 and translators 12 according to the invention. In particular, in the uplink direction, a mobile station 19 is assigned a particular transmit channel within the range of sub-band 20-2. The signal is then received from the mobile station 19 by the translator base station 12. The translator base station 12 then translates the received signal by 85 MHz to a corresponding channel in the upper sub-band 21-3. The signal is then transmitted to the home base station 15.

In the downlink direction, from the home base station 15 to the mobile station 19, a channel is first selected in the upper sub-band 20-3 for transmitting to the translator 12. The signal received by the translator 12 is then translated by 75 MHz, to a frequency in the middle sub-band 21-2, for transmission to the mobile station 19.

As a result, the mobile stations 19 and conventional basestations 16-1 thus always continue to transmit and receive in frequency bands as they would in a conventional wireless system. Only the frequency plan 25 for the home base station 15 is "inverted" in the sense that it transmits in a band of frequencies 20 which is normally reserved for receiving in a conventional base station 16-1, and in that it receives signals in a band 21 which is normally reserved for base station transmitting.

Division of the available spectrum into three sub-groups makes it possible for conventional base stations 16 to be mixed with the translator base stations to provide for maximum flexibility in building up the system 10.

Fig. 3 is a diagram illustrating the manner in which signals are transmitted from the mobile station 19 through the translator base station 12 and ultimately to the associated home base station 15 in a down link direction, that is from the home base station 15 to the mobile station

19. For a given voice channel, the home base station 15 receives signals from the translator 12 on a carrier frequency, F1, and transmits on a carrier frequency F1 minus B MHz, where B is the sub-band size (5 MHz in this example) and S is the separation between lower and upper bands (80 MHz in this example). The mobile station 19 then receives that signal on carrier frequency (F1-B) and transmits on a translated frequency (F1-S-B).

As illustrated, the translator base station 12 has two bi-directional signaling links, one link 31 for communication with the home base station 15, and one link 32 for communication with the mobile station 19. Link 31 permits the translator 12 to receive and transmit with respect to the home base station 15 on frequencies (F1-S) and F1 respectively. This transmission is carried out with directional antennas 13 as previously mentioned.

The link 32 between the translator 12 and the mobile station 19 is such that the translator 12 transmits signals to the mobile station 19 on a frequency (F1-B) and receives signals from the mobile station on a frequency (F1-S-B). Another exemplary translator base station 12-3 serviced by the home base station 15-1 will use another set of frequencies similarly selected from the same band.

Fig. 4 is a detailed block diagram of components of an exemplary translator base station 12. The translator 12 shifts the carrier frequency of the signals received from one link to the appropriate transmit frequency for the other link. The illustrated translator implements frequency diversity for each of the links.

Translator 12-1 thus may be implemented using a pair of omni-directional antennas 11-1-A, 11-1-B for the mobile station link 32 and a pair of directional antennas 13-1-A and 13-1-B for the home base station link 31. A first signal processing chain shifts the carrier frequency of signals received from the mobile unit on the omni-

directional antennas 11-1, and consists of a duplexer 58, a pair of mixers 40A, and 40B, a synthesizer 41, a pair of intermediate frequency (IF) filters 42A, and 42B, a comparator 43, a switch 44, an output mixer 45, an output synthesizer 46, a power amplifier 47 and a duplexer 48. The input mixers 40A and 40B, synthesizer 41, and IF filters 42A, 42B implement a conventional heterodyne receiver. A portion of the signal generated by the IF filters 42A and 42B is fed to the comparator 43 to provide a logic signal 49 indicating which of the two signal paths, that is either the signal path originating from antenna 11-1-A or the signal path originating from the antenna 11-1-B (as received through the duplexer 58) is being received with greater signal power. This logic signal 49 then operates the switch 44 to either select the output of the IF filter 42A or IF filter, 42B to be output to the mixer 45 and output power amplifier 47. The power amplifier 47 then forward the signal for transmission through the duplexer 48 to the directional antenna 13-1-A.

Similarly, signals received from the home base station on the pair of diversity antennas 13-1-A, and 13-1-B, are fed to the mixers 50A, and 50B, synthesizer 51 and IF filters 52A, and 52B. Again a pair of heterodyne receivers is implemented to produce two IF signals representative of the signals received by each of the antennas 13-1-A and 13-1-B. The comparator 53 and switch 54 then feed to the mixer 55. The signal is then finally fed through the power amplifier 57 and duplexer 58 and out to the omni-directional antenna 11-1-B.

Because no signal uses a radio frequency which is in use in the same cell for more than one type of link, the translator 12 may thus be used to take advantage of diversity reception for both the home base to translator link 31 and the mobile to translator link 32. This is unlike prior art systems that use repeaters where diversity

information is either not preserved or requires multiple signal paths to be preserved.

Fig. 5 shows the preferred layout of a cluster 62 of cells using one possible arrangement of the home base station 15-1 and its associated translator base stations 12. The particular cluster 62 illustrated contains twelve cells 60-1, 60-2, 60-3,...60-12 located as close as possible to a central point. It should be understood however, that other frequency reuse factors greater or lesser than 12 can be accommodated using the invention. Although the cells 60 are shown as six sectored cells it should also be understood that at the initial build-out of the system 10, the cells 60 would not typically be sectorized until such time as the traffic demand in the cell so dictates. The illustrated "N=12" arrangement is shown sectorized to indicate that the system may have the individual cells 62 cut over to a sectorized arrangement to support highly efficient reuse schemes such as N=3.

Each of the cells 60 has a unique group frequency assigned to it. For the example being described, 1/12th of the frequencies are available in each cell; given the 5 MHz sub-bands previously described and assuming PCS 1900 which use 200 kHz channels, two channels are available in each cell (each PCS 1900 radio channel carries up to 8 voice channels).

In the initial build-out phase of the system 10 a translator base station 12-1 is located in the center of the cell 60-1 and likewise a translator base station 12-2, ..., 12-12 is located in each of the eleven other cells 60-2, ..., 60-12. A home base station 15-1 is located in the center of the entire twelve cell cluster 62 which may not coincide with the center of one of the cells 60, as shown. In the illustrated cell arrangement, the home base station is located in a vertex of the three innermost cells 60-10, 60-11, 60-12 and not exactly at a cell center.

Considering cell 60-1, the arrow 64-1 indicates the direction in which the directional antennas 13-1 associated with the translator 12-1 are oriented to point back to the home base station 15-1. Although not shown in Fig. 5, each of the other cells 60-2, ..., 60-12 each have a directional antenna pointing back to the home base station 15-1. As a result, any mobile station 19 traveling through any of the cells 60-1 ,..., 60-12 in cluster 62 is processed by the home base station 15-1.

The N=12 pattern shown in Fig. 5 is asymmetric in a sense that the area of the cluster is not the same in an upper half as it is in a lower half. As shown in Fig. 6, however, the asymmetric N=12 pattern can be repeated through a given service area by alternating the orientation of cluster columns. Thus in a middle cluster column 65, the cells may be oriented such that the "Y" formed by the three inner cells is upside down. The adjacent cluster columns of these groups, such as columns 66 and 67, may be oriented such that the "Y" is rightside up.

Fig. 7 shows an alternate arrangement for the positioning of home base stations 15-1 and translator base stations 12-1, ..., 12-12. In this arrangement, the N=12 pattern is first laid out in any convenient arrangement, rather than the particular configuration in Fig. 5. One of the cells, such as cell 70, is then chosen as the location of the home base station 15-1. This particular cell 70, even at initial system build-out, is split into six sectors and assigned alternating frequency groups among the six sectors, (B1, B3, B1, B3, B1, B3). The translator base stations 12 are deployed in the eleven cells adjacent the center cell 20, and are serviced by the associated sector 71 equipment. For example, translators 12-1,...12-12 are deployed in the cells 71-1, ..., 71-11, approximately in the center of each of the cells 71-1,...71-11. As the mobile station traffic increases in a particular cell, it

may be individually cut over to become a sectional cell in an N=3 pattern.

It is now understood how a wireless communication system may be configured to permit deploying high efficiency broadband transceiver system equipment by using in-band translators laid out in a conventional system footprint. The advantages of the invention may be used to provide to an effective system coverage area without the need for building out more high capacity broadband base transceiver systems than is absolutely necessary. Furthermore, there is no difficulty with implementing directional or diversity antennas so that multi path distortion effects and other problems may be adequately addressed. Backhaul costs also are minimized by taking advantage of the frequency allocations already made to the service provider.

CLAIMS

What is claimed is:

1. A wireless communication system consisting of a plurality of cells, the plurality of cells being located substantially adjacent one another, and the cellular communication system operating over a specified frequency range, the cellular communication system making use of a frequency allocation plan that arranges the cells into clusters, with each of the cells in a cluster being assigned for use a subset of an entire band of available carrier frequencies in the specified frequency range, the system comprising:

home base station means including a broadband transceiver system for receiving and transmitting multiple radio signals on multiple carrier frequencies, including means for demodulating said received radio signals and for coupling demodulated signals to a switching means, and means for modulating signals received from the switching means and coupling them for radio transmission on the multiple carrier frequencies;

a plurality of mobile stations located in a service area covered by the cluster of cells, each mobile station transmitting and receiving a radio signal; and

a plurality of translator base station means located in a like plurality of cells in the cluster, each translator base station means including means for receiving a first radio signal from a mobile station located in the cell and translating a carrier frequency of said first received radio signal to another carrier frequency within the specified radio frequency range to produce a first translated signal and then transmitting said first translated signal to the home base station means, and also

including means for receiving a second radio signal from said home base station means and translating a carrier frequency of said second received radio signal another carrier frequency within the specified radio frequency range, to produce a second translated signal, and then transmitting said second translated signal to said mobile station, such that the carrier frequencies of said first and second translated signals are assigned from different ones of a plurality of groups of the carrier frequencies in the available band of carrier frequencies.

2. A system as in claim 1 wherein the available band of carrier frequencies is divided into an up link portion, for base station to mobile station radio transmission links, and a down link portion, for mobile station to base station radio transmissionlinks, and each of the avialable bands of carrier frequencies are divided into three sub-bands including a lower, middle, and upper sub-band.

3. A system as in claim 2 wherein the carrier frequency of the first radio signal is within the translated signal is selected from the upper sub-band of the down link portion.

4. A system as in claim 3 wherein the a carrier frequency of the first radio signal is within the middle sub-band of the uplink portion.

5. A system as in claim 2 wherein the carrier frequency of the second translated signal is selected from the middle sub-band of the downlink portion.

6. A system as in claim 5 wherein the carrier frequency of the second radio signal is within the upper sub-band of the uplink portion.

7. A system as in claim 1 wherein the translator means include directional antennas arranged to point back to a site of the home base station means.

8. A system as in claim 1 wherein the home base station means includes sectorized antenna equpment and the home base station means is located in the center of one of the cells in the cluster.

9. A system as in claim 1 wherein the home base station means includes omni-directional antenna equipment, and the home base station is located in the center of the cell cluster.

10. A system as in claim 9 wherein each cluster contains twelve cells positioned as close as possible about the home base station means, and a pattern of cells formed thereby is repeated throughout a service area by inverting the orientation of alternating cloumns of clusters

11. A system as in claim 1 wherein the translator base station means includes diversity receiving means for receiving both the first and second radio signals.

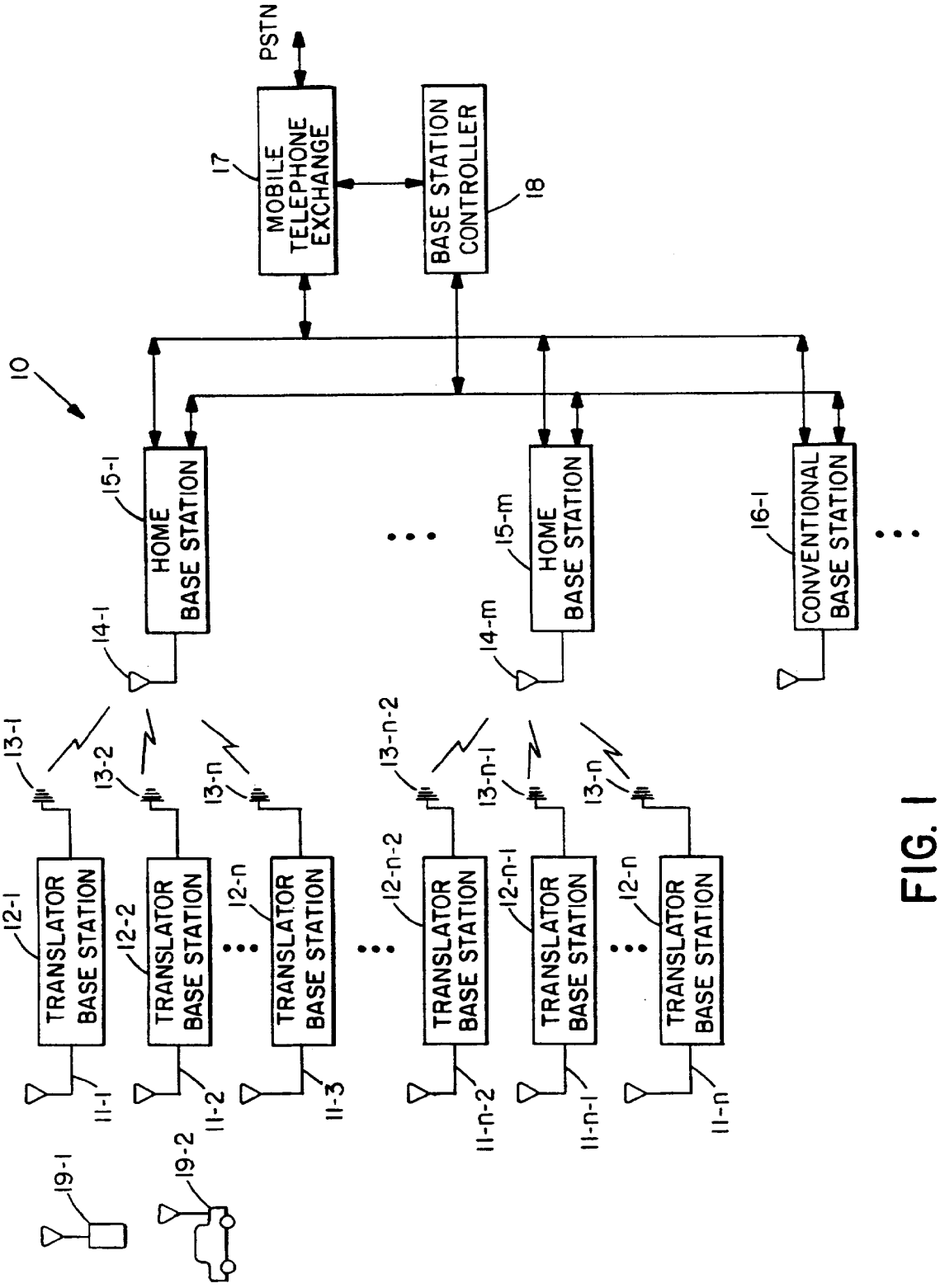


FIG. 1

EX-1002
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01123

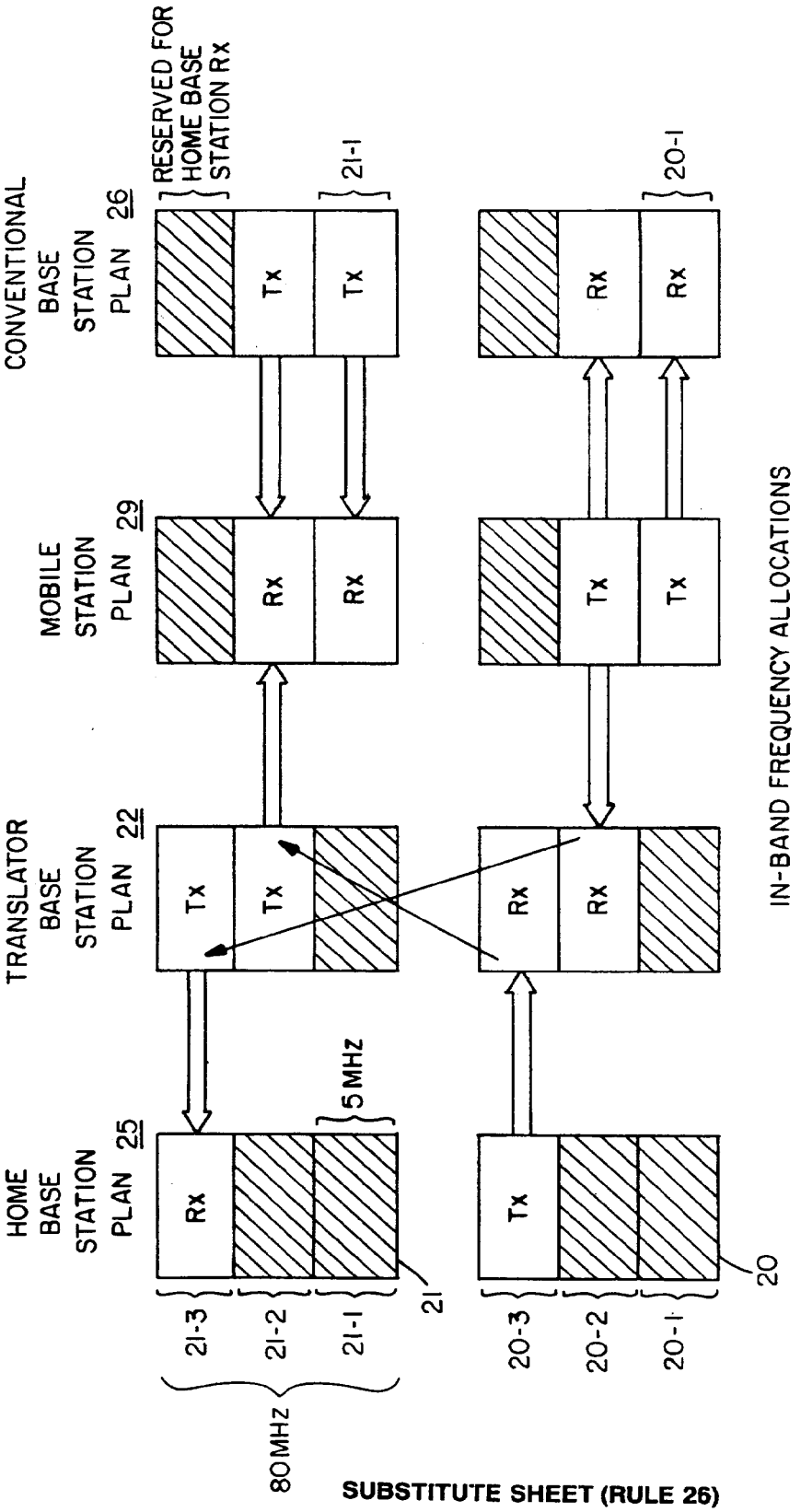


FIG. 2

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01124

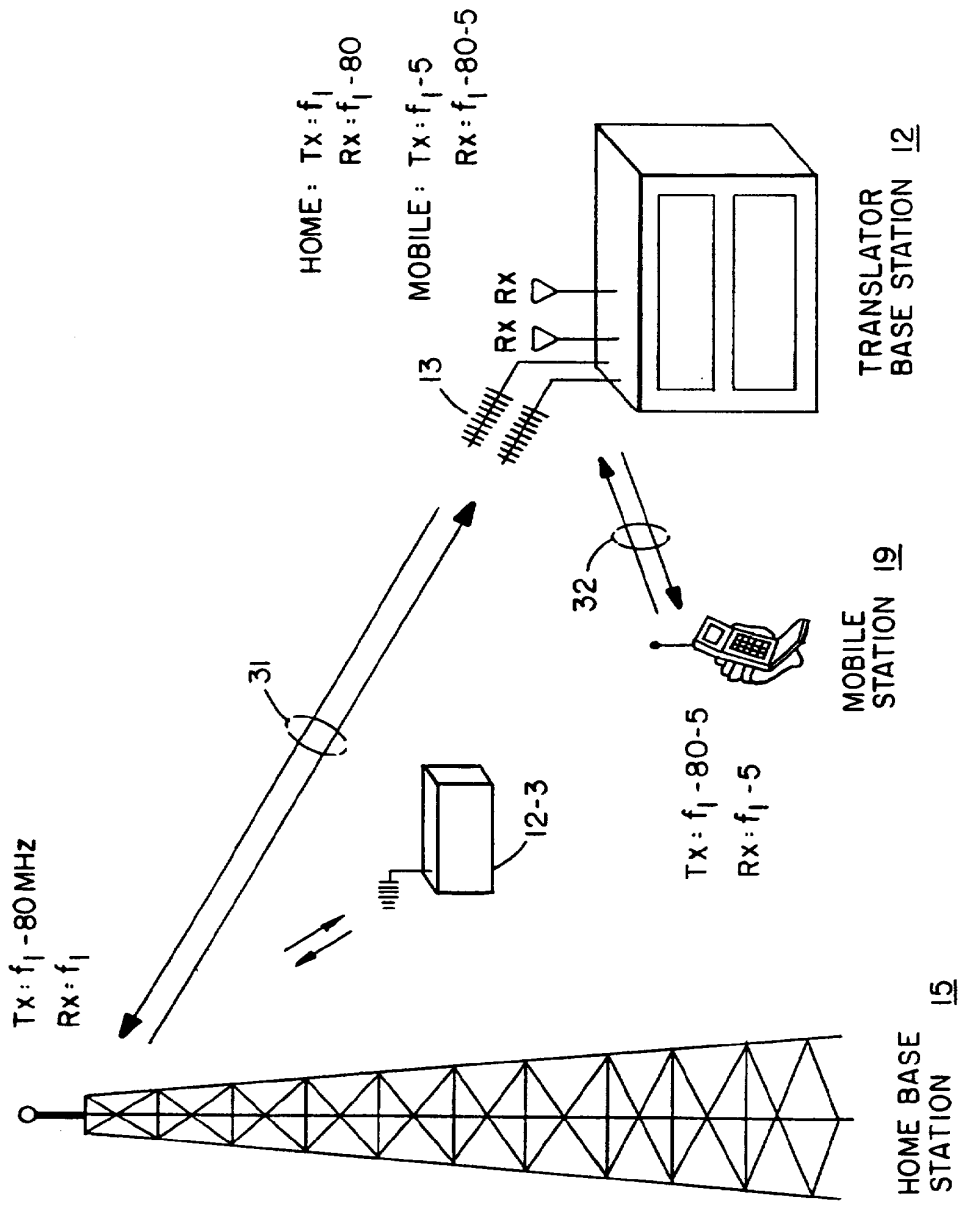


FIG. 3

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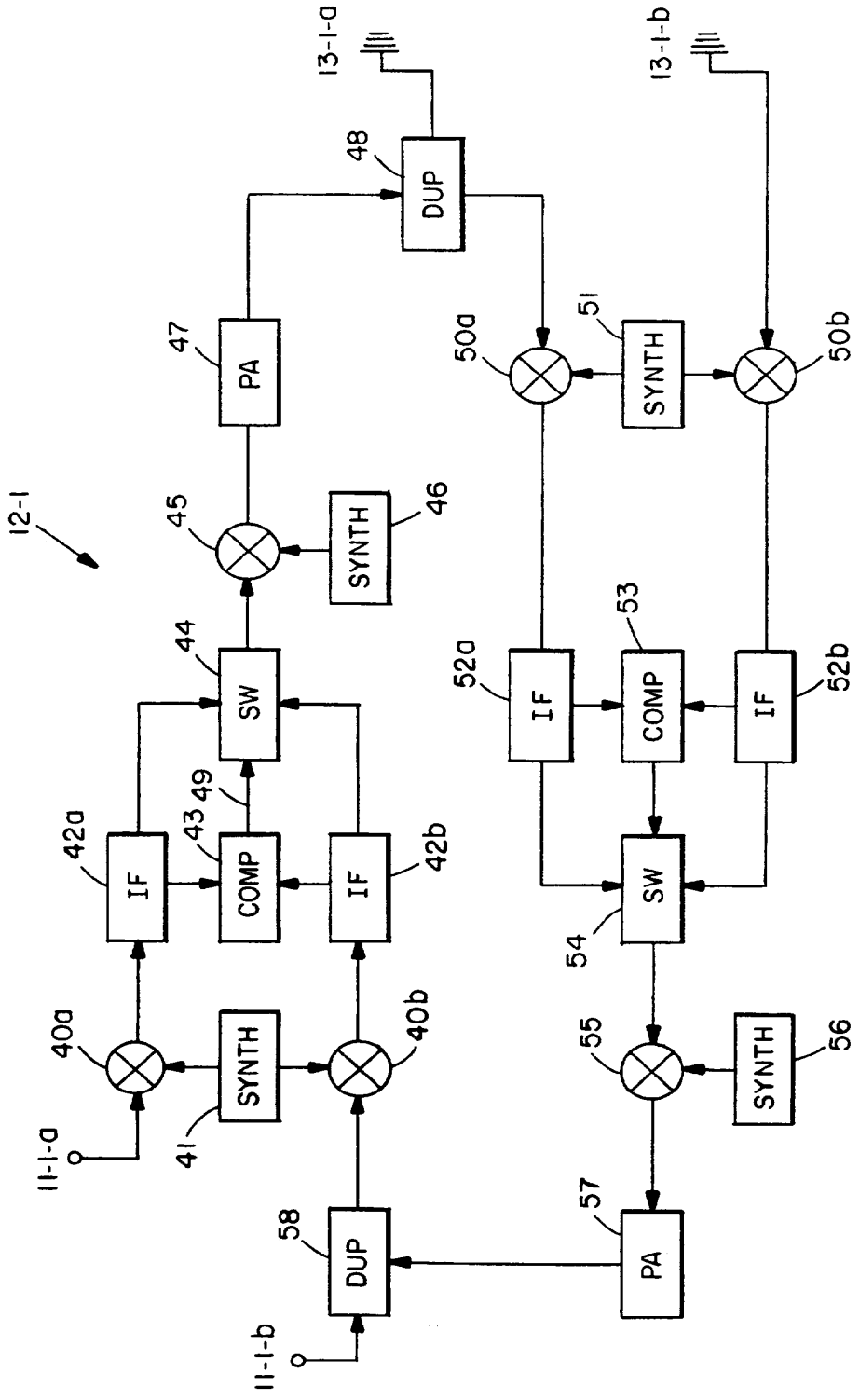


FIG. 4

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01126

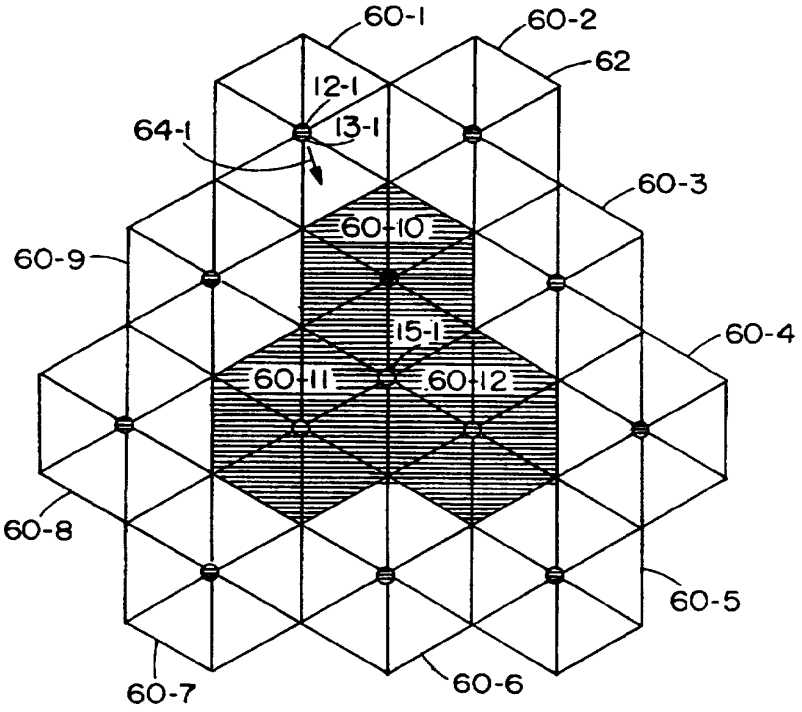


FIG. 5

EX-1002
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01127

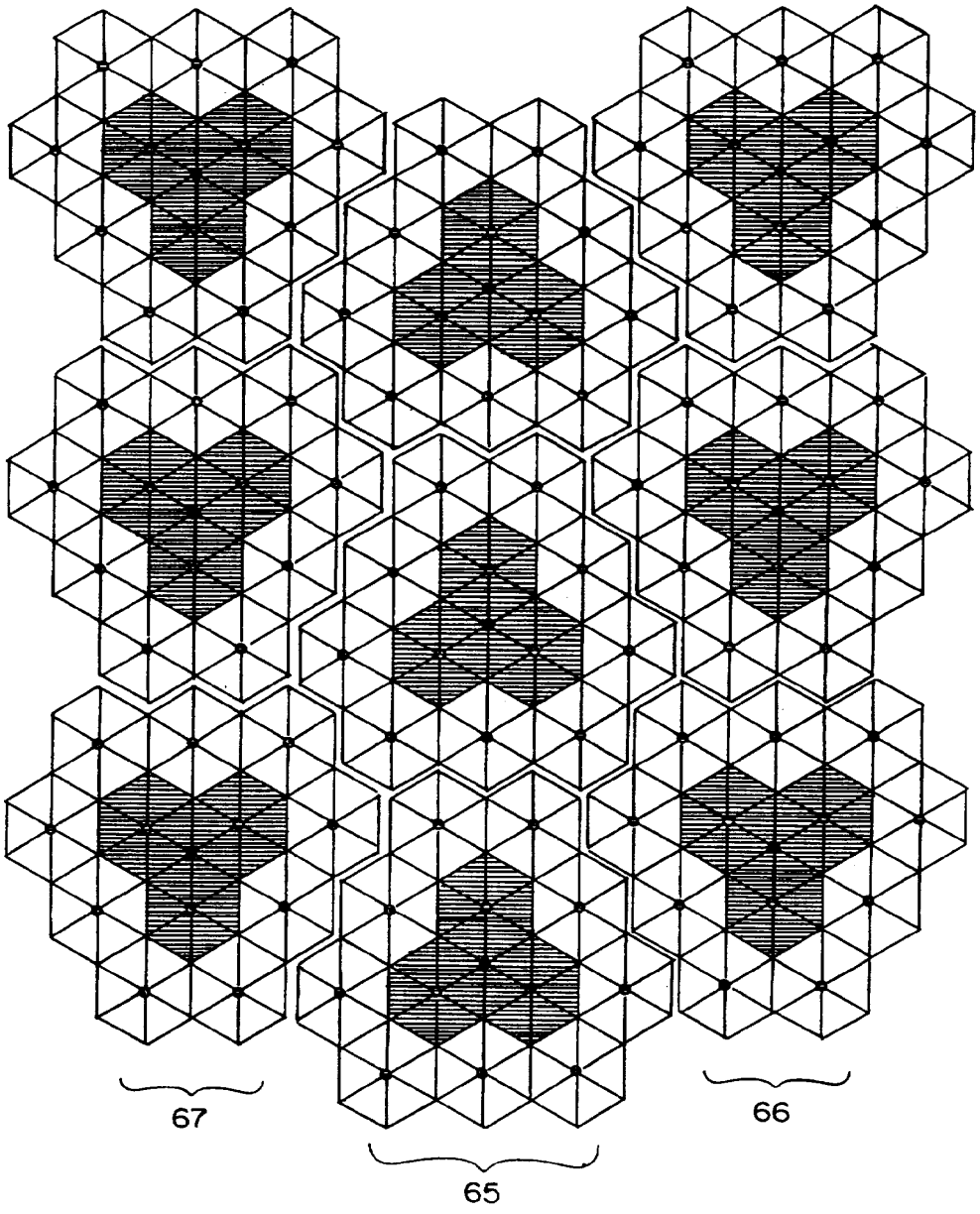


FIG. 6

EX-1002
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01128

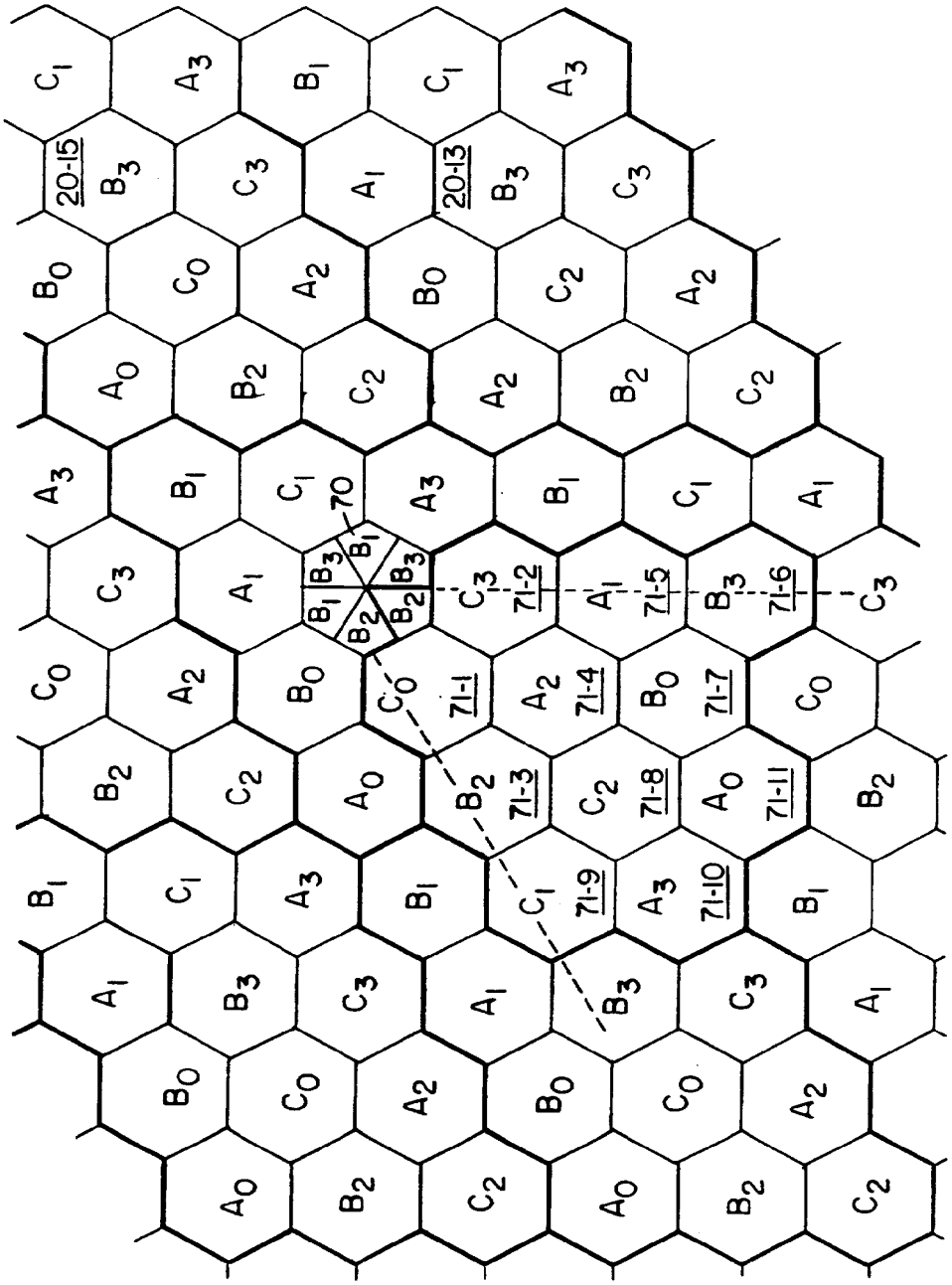


FIG. 7

EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
01129

INTERNATIONAL SEARCH REPORT

International / cation No
PCT/US 97/03026

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 93 20664 A (MOTOROLA INC) 14 October 1993	1,7-9
A	see page 4, line 31 - page 5, line 9 see page 6, line 1 - line 36 see page 7, line 14 - page 8, line 27 see page 8, line 36 - page 9, line 5 see page 9, line 25 - line 36 see page 10, line 5 - page 11, line 9 ---	2-6,10
Y	EP 0 617 524 A (MATRA COMMUNICATION) 28 September 1994 see column 2, line 20 - line 44 see column 2, line 54 - column 3, line 27 see column 3, line 34 - column 5, line 38 --- -/--	1,7,9

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
21 July 1997	31. 07. 97

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EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
01130

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/03026

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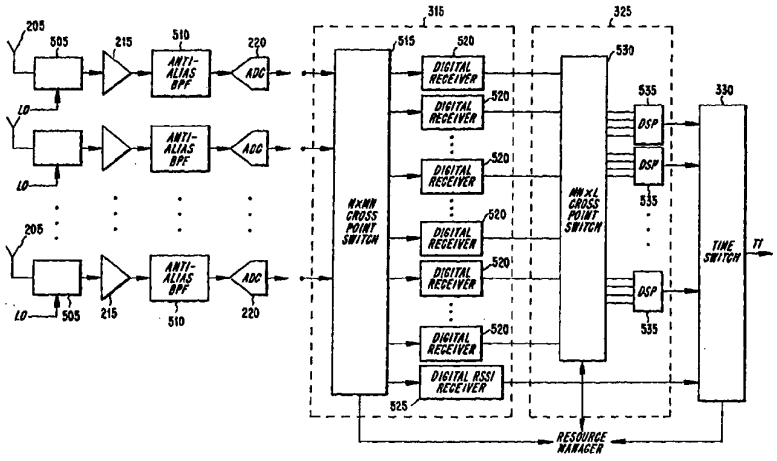
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(57) Abstract

A wideband digital architecture for use in radio communications systems. In an exemplary embodiment, a central hub station is coupled by high speed digital data transports to multiple distributed radio transceivers. The radio transceivers are designed to perform relatively little signal processing, while the central hub is designed to perform computationally intensive signal processing tasks. By exchanging wideband data between the radio transceivers and the hub, by centralizing key system resources at the hub, and by adaptively allocating the system resources in accordance with actual system usage, the radio architecture of the present invention maximizes overall system capacity, flexibility, and resource usage efficiency while minimizing overall system cost.

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A FLEXIBLE WIDEBAND ARCHITECTURE FOR USE IN RADIO COMMUNICATIONS SYSTEMS

BACKGROUND

The present invention relates to radio communications and, more particularly, to a distributed wideband architecture for use in radio communications systems.

Today, indoor cellular systems, as well as many small-cell, or pico-cell, outdoor systems, use relatively unintelligent, centralized base stations in conjunction with distributed analog transceivers to transmit and receive communication signals to and from local mobile users operating within the systems. Communication signals are allocated to, and modulated on, frequency division multiplexed (FDM) carriers, or channels, within an overall frequency bandwidth designated for use by the systems. Channel selection and allocation is typically performed using relatively costly, narrowband analog filters located within the analog transceivers or within the base station. The analog filters are tuned to a pre-selected and fixed frequency bandwidth and are capable of supporting only a single air-interface standard. Thus, current systems are inflexible in terms of protocol and, for a given number of transceivers, are limited with respect to the overall number of users which can be simultaneously accommodated in an overall geographic coverage area.

The inflexible nature of current system design also yields fixed user capacity within each single-transceiver coverage area and makes extremely inefficient use of transceiver hardware. As a result, available FDM channels may lie dormant even as potential users are denied access to the system. Empirical data suggest that usage efficiency in these systems is typically less than 30%. Such inefficiency often requires that a large number of analog transceivers be used to obtain only modest system capacity and sometimes leads to overly complex and overly costly base station design. Also, due to the fixed-protocol nature of current systems, system designers must practice careful pre-installation frequency planning and coordination with respect to existing, comparatively powerful, outdoor systems. This can result in high installation and operations costs and may further limit the capacity of the

installed system. Thus, there is a real need for an improved radio system architecture.

SUMMARY

The present invention fulfills the above-described and other needs by providing an improved wideband digital architecture which significantly increases overall hardware usage efficiency as compared to conventional systems. The present invention centralizes, shares, and re-uses key system resources, incorporates programmable frequency bandwidths, and adaptively supports a variety of air-interface standards in order to maximize system capacity and flexibility and to minimize the need for careful frequency planning and coordination with respect to existing systems. For example, by monitoring call traffic conditions at multiple distributed radio transceivers, a radio system constructed in accordance with the teachings of the present invention can adaptively allocate what would otherwise be idle system resources to heavy traffic areas on an as needed basis. Additionally, by measuring prevailing signal strengths on available frequency channels, such a radio system can automatically develop a frequency allocation plan which does not conflict with surrounding systems.

In brief, the present invention teaches a digital radio system architecture based on an intelligent wideband radio base station, or hub, controlling streamlined, distributed radio transceivers, or radio heads. The scaled-down radio heads are linked to the central hub station through high speed digital data transports and are designed to perform relatively little signal processing (e.g., multi-carrier RF power amplification, frequency upconversion and downconversion, wideband low-noise amplification, digital-to-analog and analog-to-digital conversion, etc.). The central hub, on the other hand, is designed to perform more computationally intensive signal processing tasks (e.g., signal modulation and demodulation, channel selection and allocation, channel coding and decoding, air-frame synchronization, etc.). By centralizing and adaptively allocating system resources in accordance with actual system usage, the present invention teaches an extremely flexible architecture which combines high system capacity with low overall system cost.

The radio heads are designed to be very small, unobtrusive units which are readily installed, for example, in the ceilings and corners of office buildings, manufacturing facilities, shopping malls, sports arenas, etc. Because the radio heads need perform only minimal signal processing tasks, their cost and overall power consumption is significantly lower as compared to the analog radio transceivers of conventional systems. Additionally, the hub station of the present invention cost effectively consolidates, or pools, many of the required signal processing resources at a single central location. As described below, a resource manager within the hub station can be programmed to dynamically allocate system resources among the radio heads, as necessary, based on changing call traffic conditions. Thus, system usage efficiency is dramatically improved, and tremendous savings in terms of system cost, size, and complexity are possible. These and other features and advantages of the present invention are explained hereinafter with reference to the illustrative examples shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of an exemplary radio communications system constructed in accordance with the teachings of the present invention.

Figure 2 is a block diagram of an exemplary radio transceiver, or radio head, which may be used, for example, in implementing the system of Figure 1.

Figure 3 is a block diagram of an exemplary central hub station which may be used in conjunction with the radio transceiver of Figure 2 to implement the radio communications system of Figure 1.

Figure 4 is a conceptualization of a translation, between frequency division multiplexed (FDM) information signals and corresponding time division multiplexed (TDM) signals, which may be performed, for example, using components located within the embodiments of Figures 1-3.

Figure 5 depicts a first exemplary embodiment of an adaptive signal channelizer which may be used, for example, in the hub station of Figure 3.

Figure 6 is a block diagram of a digital receiver which may be used, for example, in constructing the exemplary channelizer of Figure 5.

Figure 7 depicts a second exemplary embodiment of an adaptive signal channelizer which may be used, for example, in the hub station of Figure 3.

Figure 8 is a block diagram of an exemplary discrete Fourier transform (DFT) circuit used, for example, in constructing the exemplary channelizer of Figure 7.

DETAILED DESCRIPTION

Figure 1 depicts a radio system architecture constructed in accordance with the teachings of the present invention. As shown, a central hub station 120 is coupled, through multiple high speed data transports 130, to a number of distributed radio head transceivers 110. The hub station 120 is also coupled, through an industry standard T1 TDM channel, to a mobile switching center (MSC) 100. The MSC is used to connect the local radio system comprising the hub 120 and the radio heads 110 to other communication networks (e.g., the public switched telephone network). Thus, mobile users within the coverage area of the radio heads 110 can communicate with other local users in the same coverage area or with remote users in other networks. The hub station 120 and the radio heads 110 might be used, for example, to provide mobile telephone and pager service within an office building or manufacturing plant.

The radio heads 110 transmit and receive information signals to and from local user mobile stations on multiple FDM carriers lying within a specified frequency band. For example, the U.S. industry standard IS-136 (AMPS/D-AMPS) cellular frequency plan includes 416 30kHz FDM channels spanning a 12.5MHz FDM band. Therefore, calls to and from local users are allocated, during system operation, to specific FDM channels. Also, because the MSC communication link typically utilizes a TDM scheme, information signals are translated back and forth between the FDM and TDM formats.

As described above, analogous conventional systems utilize inflexible, analog-type radio transceivers tuned to specific FDM channels. Each such analog transceiver can accommodate only a fixed number of users on a fixed number of FDM channels. Therefore, as system usage fluctuates over time, local users near one transceiver may be denied system access even as available FDM channels,

dedicated for use by other transceivers, lie dormant. A common example of usage fluctuation occurs when workers in an office building gather in one confined area, such as a cafeteria or auditorium. In a conventional system, a transceiver located in the common gathering place may be completely idle most of the time, but may not be able to accommodate the periodic spikes in user demand. By way of contrast, the present invention teaches a system which utilizes modern digital technology to adaptively allocate frequency channels across the multiple radio heads 110 of Figure 1. By pooling critical resources at the hub station 120 of Figure 1, the system of the present invention is not only highly flexible, but also extremely efficient, and therefore, cost effective.

Figure 2 depicts an exemplary radio head 110 which can be used to implement the system of Figure 1. As shown, an RF antenna 205 is connected to a duplexer 230 which is in turn connected to a receive, or uplink, signal processing path and a transmit, or downlink, signal processing path. In the uplink signal processing path, the duplexer 230 is coupled to a low-noise amplifier (LNA) 225 which is in turn coupled to an uplink heterodyne mixer 210. The uplink mixer 210 is connected to an amplifier 215 which is in turn connected to an analog-to-digital converter (ADC) 220. The ADC 220 feeds a parallel-to-serial data converter 250 which in turn feeds an input of a high speed data transport 130 connected to the hub station (not shown). In the downlink signal processing path, an output of the high speed data transport 130 is coupled to a serial-to-parallel data converter 255 which is in turn coupled to a digital-to-analog converter (DAC) 245. The DAC 245 feeds a downlink heterodyne mixer 240 which feeds a multi-carrier power amplifier (MCPA) 235. An output of the MCPA 235 is connected to an input of the duplexer 230.

During uplink operation, a wideband signal (i.e., a signal including all FDM channels within the overall reserved frequency band) is received at the radio head antenna 205 and amplified at the LNA 225 and the amplifier 215 to a signal level which is appropriate for input to the ADC 220. The uplink mixer 210 is used to downconvert the wideband signal to an intermediate frequency (IF) level. The ADC 220 digitizes the wideband signal and provides the resulting digital samples, through the parallel-to-serial converter 250, to the high speed data transport 130 for transfer

to the hub station. During downlink operation, the radio head 110 receives wideband digital carrier samples from the hub station via the high speed data transport 130. The wideband samples are fed through the serial-to-parallel converter 255 and converted to a wideband analog signal at the DAC 245. The wideband, multi-carrier signal is upconverted to an RF frequency level at the downlink mixer 240, amplified at the MCPA 235, and ultimately broadcast at the radio head antenna 205. Note that the duplexer 230 isolates the uplink signal processing path from the antenna 205 during downlink operations and vice versa.

Figure 3 depicts an exemplary hub station 120 which may be used, for example, in conjunction with radio heads constructed in accordance with Figure 2 to implement the radio system of Figure 1. As shown, a series of high speed data transports 130, each connected to a radio head (not shown), are coupled through a connecting block 310 to an uplink channel selector 315 and a downlink channel selector 320. The uplink channel selector 315 is connected to a multi-channel demodulator 325 which is in turn connected to an uplink time switch 330. The uplink time switch 330 is connected to an MSC (not shown). A downlink time switch 345, also connected to the MSC, is coupled to a multi-channel modulator 340 which is in turn coupled to the downlink channel selector 320. A resource manager 335 is connected to the uplink and downlink channel selectors 315, 320, as well as the multi-channel demodulator 325, the multi-channel modulator 340, and the uplink and downlink time switches 330, 345.

During uplink operation, digital wideband FDM signals are received at the hub 120 from the radio heads 110 via the high speed data transports 130, and information signals (e.g., voice signals) are delivered from the hub 120 to the MSC via a standard T1 TDM communication channel. Individual carriers within the wideband signals received from the radio heads 110 are adaptively selected, demodulated, and arranged in TDM format within an uplink channelizer 350 which includes the uplink channel selector 315, the multi-channel demodulator 325, and the uplink time switch 330. As is described in more detail below, precisely which hardware components within the uplink channelizer 350 operate on precisely which individual carriers from precisely which radio heads at any given time is controlled by the resource manager 335.

Conversely, during downlink operation, information signals are received at the hub 120 from the MSC via a standard T1 TDM channel, and digital wideband FDM signals are delivered from the hub 120 to the radio heads 110 via the high speed data transports 130. The information signals received at the hub 120 from the MSC are modulated on digital FDM carriers and selectively delivered to the radio heads 110 by a downlink channelizer 355 made up of the downlink channel selector 320, the multi-channel modulator 340, and the downlink time switch 345. Again, precisely which hardware components within the downlink channelizer 355 operate on precisely which radio head carriers at any given time is controlled by the resource manager 335.

Because the resource manager 335 can monitor system activity and then adaptively and selectively route information signals to and from any and all of the wideband radio heads 110 as appropriate, the radio system of Figure 3 can easily handle the above described problems associated with continually changing call traffic conditions. Additionally, because the channel allocation, modulation, demodulation, and format conversion functions are collected at the central hub station 120, maximum resource utilization and efficiency can be achieved.

It is important to note here that the components of Figure 3 are conceptual in nature and are intended primarily to aid understanding of the teachings of the present invention. Practical implementation of the various aspects of Figure 3 may be accomplished using hardware components that may not correspond one-to-one with the broad functional blocks of Figure 3. For example, the connecting block 310 situated between the data transports 130 and the uplink and downlink channel selectors 315, 320 is included in Figure 3 merely to indicate that any information signal received from, or directed to, the MSC can be directed to, or received from, any one of the radio heads 110. As is made clear below, the precise type of connection between the data transports 130 and the uplink and downlink channel selectors 315, 320 will depend upon which of several possible uplink and downlink channelizer embodiments is being implemented. Additionally, though the uplink channelizer 350 of Figure 3 is shown to include three distinct functional blocks, namely the uplink channel selector 315, the multi-channel demodulator 325, and the uplink time switch 330, actual implementation of the uplink channelizer 350 may

result in a blending of functionality across discrete hardware components. The same may be said of the downlink channelizer 355 which is shown in Figure 3 to include the downlink time switch 345, the multi-channel modulator 340, and the downlink channel selector 320.

The resource manager 335 may be implemented as a stand-alone component, using for example a designated programmable micro-controller, or it may instead be implemented in software running on a processor which is used to otherwise control hub station functionality. Many standard processors available today are well suited for carrying out the tasks associated with the resource manager 335. As is described in more detail below, the resource manager 335 monitors signal levels and interference measurements received from receive signal strength indicators (RSSIs) within the uplink channelizer 350, as well as call traffic messages received from the MSC 100, to assign calls to appropriate channels (i.e., frequency carriers and time slots) within the system and to control non-blocking switches within the uplink and downlink channelizers 350,355 to dynamically allocate signal processing resources as capacity requirements evolve.

Implementation of the high speed data transports 130 of Figure 3 will depend upon, among other things, the physical separation between the radio heads 110 and the hub station 120. Because wideband digital signals are transferred, data rates in the uplink direction may be as high as 550 mega-bits per second (Mbps), while downlink data rates may be as high as 640Mbps for current cellular bandwidths. However, several media exist today which can accommodate such high speed data transfer rates. For example, Fiber Channel and Fiber Distributed Data Interface (FDDI) protocols are available at these rates, as are Asynchronous Transfer Mode (ATM) and Synchronous Optical Network / Synchronous Data Hierarchy (SONET/SDH) protocols. While fiber should most likely be used for distances greater than 100 meters, Gigabit Ethernet is often suitable for shorter distances.

As described below, both the uplink channelizer 350 and the downlink channelizer 355 can be implemented effectively in several different ways. No matter the exact implementation, however, the high-level functionality of the channelizers is as shown in Figure 4. With respect to the uplink channelizer 350, Figure 4 indicates that, among multiple wideband FDM signals arriving at the hub

station from multiple radio heads, individual information signals are selected, demodulated, and ultimately delivered to an MSC in time-domain format. Conversely, with respect to the downlink channelizer 355, Figure 4 indicates that individual information signals, arriving at the hub station from an MSC in time-domain format, are modulated and selectively dispersed to the multiple radio heads in wideband FDM format. Those skilled in the art will appreciate that individual FDM carriers within the system may contain a single information signal (e.g., in an AMPS mode) or multiple information signals assigned to interleaved carrier time slots (e.g., in a D-AMPS mode).

Next described are two possible configurations for the uplink channelizer 350. Though only two embodiments are described in detail, those skilled in the art will appreciate that other equivalent configurations are contemplated herein. Additionally, although the embodiments are described specifically with respect to the uplink channelizer 350, analogous embodiments for the downlink channelizer 355 are also contemplated.

Figure 5 depicts an uplink channelizer implemented using a bank of digital receivers 520. As shown, multiple radio heads (each depicted as a combination of the radio head uplink components described with respect to Figure 2) are connected via high speed data transports (not shown) to an uplink channel selector 315 which is in turn connected to a multi-channel demodulator 325. The multi-channel demodulator 325 is coupled to an uplink time switch 330 which is in turn coupled via a T1 communication link to an MSC (not shown). Within the uplink channel selector 315, a primary cross-point switch 515 is connected to a bank of digital receivers 520 and to a digital RSSI unit 525. Additionally, within the multi-channel demodulator 325, a secondary cross-point switch 530 is connected to a bank of digital signal processors 535. The primary cross-point switch 515, the secondary cross-point switch 530, and the uplink time switch 330 are coupled to a resource manager (not shown). Also, although no connection is explicitly shown, it will be understood that the resource manager has access to information output by the RSSI unit 525.

In operation, N digital wideband FDM signals, received from N distributed radio heads, are selectively coupled through the Nx(M*N) primary cross-point

switch 515 to M*N digital receivers (N and M integers). The primary cross-point switch 515, under control of the resource manager, enables a wideband FDM signal received from any radio head to be coupled to any one, or more, of the N*M digital receivers 520. Note that M represents the nominal, or average, number of digital receivers 520 available per radio head. Advantageously, because the radio heads and the digital receivers 520 are not fixedly coupled, the number of digital receivers 520 can be changed as capacity requirements evolve. In practice, the number M of digital receivers 520 used per radio head is bounded by the number of channels available in the system (e.g., 416 in an IS-136 system). Each digital receiver 520 accepts a time-sampled wideband FDM input and produces a single-carrier output.

An exemplary digital receiver 520 is depicted in Figure 6. As shown, a digital wideband FDM input is mixed, at mixers 610, with the output of an NCO 620 which is set to downconvert a particular channel within the FDM spectrum to baseband. In-phase (I) and quadrature (Q) components of the down-converted signal, arising at the outputs of the mixers 610 and representing one FDM channel from one radio head, are input to a high-decimation FIR filter 630. The FIR filter 630 removes unwanted images generated during the mixing process and reduces the sample rate from the relatively high wideband FDM rate to one that is more appropriate for the single baseband carrier. The down-sampled I and Q components which are output by the FIR filter 630 can be time multiplexed to form a single sample stream using a parallel-to-serial converter (not shown). Digital receivers 520 such as that shown in Figure 6 are low cost, widely available, and can be adaptively programmed to select and process any single channel within the FDM spectrum.

As shown in Figure 5, the M*N outputs from the M*N digital receivers 520 are input to the (M*N)xL secondary cross-point switch 530. The secondary cross-point switch 530, under the control of the resource manager, selectively couples the digital receiver outputs to L digital signal processors (DSPs) 535 (L an integer). The DSPs 535 demodulate the single-carrier signals received from the digital receivers 520 and may perform additional signal processing (e.g., channel coding). Demodulated outputs from the DSPs 535 (i.e., time-domain information signals such as voice signals) are input to the uplink time switch 330 where they are TDM formatted for delivery to the MSC.

Again, because the DSPs 535 are not fixedly coupled to the digital receivers 520, the number L of DSPs 535 can be readily changed depending upon system capacity requirements. Also, note that up to four digital receiver outputs may be input to one DSP 535 for purposes of diversity processing. In other words, a signal emitted by one local mobile station can be received at multiple radio heads, and the redundant signals can be combined, for example in a weighted summing operation, to provide an optimized signal. The number of diversity branches (i.e., the number of outputs of the (M*N)xL cross-point switch 530 directed to a single DSP 535) can be adjusted dynamically in accordance with changing traffic demands to achieve "soft" trade-offs between system performance and system capacity.

The embodiment of Figure 5 allows the hub station to provide flexible capacity per geographic coverage area. Using the primary and secondary cross-point switches 515, 530, the resource manager can dynamically assign the M*N digital receivers 520 and the L DSPs 535 to any of the N geographic coverage areas as traffic densities in those areas change over time. The resource manager can monitor system activity, for example, via the RSSI receiver 525. As known, the RSSI receiver 525 can measure signal level, signal activity, and signal quality. Channels are measured to determine whether a signal is present, and, if so, to assess the strength of the signal and to determine whether the signal is analog or digital, voice or control, valid in the indoor system or originating from an outdoor system, etc. Channels at each radio head can be monitored in cyclic fashion, and the resource manager can process the resulting data to create and maintain a channel status matrix which the resource manager can then use to assign channels when calls are set up.

Because the digital receivers 520 in the embodiment of Figure 5 are so efficiently utilized, fewer receivers need be employed for given capacity and coverage area requirements as compared to conventional systems. Also, because the digital receivers 520 are easily programmable, the embodiment of Figure 5 is readily configured to operate in compliance with virtually any air-interface standard (e.g., GSM, DECT, AMPS, D-AMPS, etc.). Therefore, a combination of the embodiments of Figures 3 and 5 represents, in many ways, a "universal" hub station. The architecture of Figure 5 is particularly attractive when a relatively

small number of carriers are to be processed (as discussed below, the embodiment of Figure 7 is, perhaps, more efficient for large numbers of system users).

Again, though the embodiment of Figure 5 has been described with respect to an uplink channelizer, those skilled in the art will appreciate that an analogous embodiment can be constructed to implement a downlink channelizer. Also, those skilled in the art will appreciate that the present invention encompasses many variations on the embodiment of Figure 5. For example, it may be desirable in certain contexts to give up some flexibility, in exchange for reduced cost and complexity, by constructing a system similar to the embodiment of Figure 5, wherein either one or both of the cross-point switches 515, 530 are excluded. Such a system would still provide significant advantages over presently available analog systems.

Figure 7 depicts another embodiment of an uplink channelizer in which the required signal processing is accomplished using a bank of DFT-type multi-channel demultiplexers 705. As shown, multiple radio heads (each depicted as a combination of the radio head uplink components described with respect to Figure 2) are connected via high speed data transports (not shown) to an uplink channel selector 315 which is in turn connected to a multi-channel demodulator 325. The multi-channel demodulator 325 is coupled to an uplink time switch 330 which is in turn coupled via a T1 communication link to an MSC (not shown).

Within the uplink channel selector 315, there are N signal processing circuits, each circuit corresponding to one of the N radio heads (N an integer). Each circuit includes a DFT demultiplexer 705, an MxM cross-point switch 710 (M an integer), a time multiplexer (MUX) 715, and an RSSI processor 720. Each DFT demultiplexer 705 produces M outputs which are input to the corresponding MxM cross-point switch 710. A subset of the M outputs from each MxM cross-point switch 710 are input to the corresponding time MUX 715 and the remaining outputs from each MxM cross-point switch 710 are input to the corresponding RSSI processor 720.

Within the multi-channel demodulator 325, N outputs produced by the N signal processing circuits are input to an NxL cross-point switch 730, and L outputs from the NxL cross-point switch 730 are input to L DSPs 535. Outputs from the

DSPs 535 are input to the uplink time switch 330. As shown, the MxM cross-point switches 710, the NxL cross-point switch 730, and the uplink time switch 330 are connected to a resource manager (not shown). Though, for convenience, only one MxM cross-point switch 710 is shown connected to the resource manager, it will be appreciated that all of the MxM cross-point switches 710 are connected to the resource manager. Also, though the connections are not explicitly shown, it will be understood that the resource manager controls the time MUXes 715 and monitors the RSSIs 720.

In operation, each wideband, multi-carrier FDM signal received from a radio head is translated, as described below, by a DFT demultiplexer 705 to yield the individual channel signals which are received at the radio head. Since each wideband signal contains M carriers (e.g., 416 for typical cellular applications), each DFT demultiplexer 705 produces M individual channel signals. Active radio head channels will contain, for example, one or more local user voice signals, and inactive channels may contain noise or signals picked up from other surrounding systems. The MxM cross point switches 710, under control of the resource manager, then separate the active and non-active channels. Active channels are input directly to the time MUXes 715, and inactive channels are coupled through the RSSI processors 720 to the time MUXes 715. The time MUXes 715 then format the time-domain signals, either as a single TDM signal or as parallel streams of time data, for input to the multi-channel demodulator 325. Signal processing performed at the multi-channel demodulator 325 is similar to that described with respect to the multi-channel demodulator of the embodiment of Figure 5. Note that, although only one input is shown for each DSP 535, several inputs may actually be coupled to each DSP 535, as is described with respect to Figure 5, for purposes of diversity processing.

DFT demultiplexers such as those shown in Figure 7 are described, for example, in M. Bellanger and J. Daguet, "TDM-FDM Transmultiplexer: Digital Polyphase and FFT", *IEEE Transactions on Communications*, September 1974, which is incorporated herein by reference. In brief, a DFT-based demultiplexer translates a wideband FDM signal using a standard DFT algorithm (or a DCT algorithm for purely real signals) to produce corresponding individual channel

signals. However, because direct computation of DFTs is numerically intensive and inefficient, DFT demultiplexers are typically implemented in practice using a fast Fourier transform (FFT) algorithm in combination with a polyphase weighting network. Therefore, the DFT blocks 705 of Figure 7 may be implemented as shown in Figure 8.

In Figure 8, a wideband digital FDM signal is input to a switch 830 which alternately connects the FDM signal to multiple weighting blocks 840. Outputs from the weighting blocks are input to an FFT block 820. In operation, the wideband samples input to the switch 830 are multiplied, at the weighting blocks 840, by appropriate weighting coefficients $H_n(z)$ which correspond to taps of a polyphase filter. The resulting weighted samples are processed, as is well known in the art, through an FFT algorithm at the FFT block 820 to produce the desired individual-channel samples. Of course, Figure 8 is a schematic representation only, and the switching and computational functions are carried out in practice using appropriate DSP hardware.

As with the embodiment of Figure 5, the embodiment of Figure 7 enables the hub station to provide flexible capacity per geographic coverage area. Using the cross-point switches 710, 730, the resource manager can dynamically access any channel from any geographic coverage area and adaptively utilize the DSPs 535 as traffic densities change with time. The resource manager can monitor system activity, for example, by monitoring output of the RSSI processors 720 and the DSPs 535 as is described above with respect to Figure 5.

The embodiment of Figure 7 is extremely cost efficient in contexts where there are often large numbers of active channels. However, the cost and availability of high speed, wideband FFT processors may make the embodiment of Figure 5 the preferred choice in contexts involving lower system capacity. Though the embodiment of Figure 7 has been described with respect to an uplink channelizer, those skilled in the art will appreciate that an analogous embodiment can be constructed to implement a downlink channelizer using IDFT-type multi-channel multiplexers. Also, those skilled in the art will appreciate that the present invention encompasses many variations on the embodiment of Figure 7. For example, it may be advantageous in certain contexts, from a cost standpoint, to construct a system

similar to the embodiment of Figure 7, but excluding the cross-point switch 730. Additionally, note in Figure 7 that there are gaps in the connections between the uplink channelizer 315 and the multi-channel demodulator 325. These gaps indicate that the DFT signal processing circuits can be physically located either at the hub station or at the individual radio heads, as appropriate.

In sum, the present invention teaches a highly flexible and efficient wideband radio architecture. Those skilled in the art will appreciate that the present invention is not limited to the specific exemplary embodiments which have been described herein for purposes of illustration. The scope of the invention, therefore, is defined by the claims which are appended hereto, rather than the foregoing description, and all equivalents which are consistent with the meaning of the claims are intended to be embraced therein.

CLAIMS:

1. A radio communications system, comprising:

a plurality of distributed radio transceivers, wherein each of said transceivers includes a wideband radio transmitter for transmitting multiple information signals on multiple frequency channels to multiple system users, and wherein each of said transceivers includes a wideband radio receiver for receiving multiple information signals on multiple frequency channels from the multiple system users;

a plurality of high speed data transports, each one of said data transports connected to a corresponding one of said transceivers, for carrying wideband signals containing multiple information signals; and

a hub station, connected to each one of said data transports and exchanging wideband signals with each of one said transceivers, wherein said hub station includes a) a downlink channelizer for coupling information signals received from a mobile switching center to said data transports, b) an uplink channelizer for coupling information signals received at said data transports to the mobile switching center, and c) a resource manager for monitoring system activity and for controlling said downlink channelizer and said uplink channelizer to adaptively allocate and utilize channelizer resources in selecting and processing information signals.

2. The system of claim 1, wherein said system provides radio-communication support for a pico-cell in a cellular radio communications system.

3. The system of claim 1, wherein said system provides radio-communication support for an indoor cell in a cellular radio communications system.

4. The system of claim 1, wherein at least one of said high speed data transports is implemented using a fiber optic link.

5. The system of claim 1, wherein at least one of said high speed data transports is implemented using an ethernet link.

6. A radio transceiver, comprising:

a wideband radio transmitter for simultaneously transmitting multiple information signals on multiple frequency channels to multiple mobile stations in a radio communications system;

a wideband radio receiver for simultaneously receiving multiple information signals on multiple frequency channels from the multiple mobile stations in the system; and

a high speed data transport interface for exchanging, through a high speed data transport, wideband signals containing multiple information signals with a hub station in the radio communications system.

7. The radio transceiver of claim 6, further comprising an uplink channelizer for converting wideband frequency-division multiplexed signals received at the transceiver to time-division multiplexed signals which are delivered to the hub station.

8. The radio transceiver of claim 6, further comprising a downlink channelizer for converting time-division multiplexed signals received from the hub station to wideband frequency-division multiplexed signals which are transmitted to the mobile stations.

9. A hub station, comprising:

a plurality of high speed data transport interfaces for receiving a plurality of wideband uplink signals, each wideband uplink signal containing multiple uplink information signals, from a plurality of distributed radio transceivers and for transmitting a plurality of wideband downlink signals, each wideband downlink signal containing multiple downlink information signals, to the plurality of distributed radio transceivers;

a communication interface for transmitting a formatted uplink signal containing multiple uplink information signals to a mobile switching center and for receiving a formatted downlink signal containing multiple downlink information signals from the mobile switching center;

an uplink channelizer disposed between said high speed data transport interfaces and said communication interface for processing uplink information signals received from the distributed radio transceivers and for arranging selected uplink information signals to form a formatted uplink signal which is delivered to the mobile switching center;

a downlink channelizer disposed between said communication interface and said high speed data transport interfaces for processing downlink information signals received from the mobile switching center and for arranging selected downlink information signals to form a plurality of wideband downlink signals which are delivered to the distributed radio transceivers; and

a resource manager coupled to said uplink and downlink channelizers for monitoring system activity and for controlling said uplink and downlink channelizers to adaptively allocate and utilize channelizer components in selecting, processing, and arranging the uplink and downlink information signals.

10. The hub station of claim 9, wherein the uplink channelizer comprises:

an uplink channel selector for accepting the wideband uplink signals received at said high speed data transport interfaces and for selectively generating, under control of said resource manager, a plurality of single-channel uplink signals, each single-channel uplink signal corresponding to a selected channel within one of the wideband uplink signals;

a multi-channel demodulator coupled to said uplink channel selector for receiving the single-channel uplink signals and for selectively processing the single-channel uplink signals, under control of said resource manager, to produce a plurality of demodulated uplink signals; and

an uplink time switch coupled to said multi-channel demodulator for arranging the demodulated uplink signals, under control of said resource manager, to form a formatted uplink signal which is delivered to the mobile switching center.

11. The hub station of claim 10, wherein said uplink channel selector includes at least one receive signal strength indicator generating output which is used

by said resource manager to monitor activity on channels within the wideband uplink signals received from the distributed radio transceivers.

12. The hub station of claim 10, wherein said uplink channel selector comprises:

a plurality of digital receivers, each of said digital receivers accepting a wideband uplink signal and downconverting a selected channel within the wideband uplink signal to produce a single-channel uplink signal which is delivered to said multi-channel demodulator; and

a cross-point switch coupled to said resource manager for selectively directing wideband uplink signals received from the distributed radio transceivers to inputs of said digital receivers.

13. The hub station of claim 10, wherein said uplink channel selector comprises a plurality of processing circuits, each of said processing circuits including a discrete Fourier transform demultiplexer and a cross-point switch which is coupled to said resource manager, wherein each of said processing circuits receives a wideband uplink signal from a distributed radio transceiver and produces, under control of said resource manager, a plurality of single-channel uplink signals which are delivered to said multi-channel demodulator.

14. The hub station of claim 13, wherein each of said processing circuits further comprises a multiplexer for arranging the plurality of single-channel uplink signals generated by the processing circuit to form a time-division multiplexed signal which is delivered to said multi-channel demodulator.

15. The hub station of claim 10, wherein said multi-channel demodulator comprises:

a plurality of digital signal processors, each of said processors processing at least one of the single-channel uplink signals generated by said uplink channel selector to produce a demodulated uplink signal; and

a cross-point switch coupled to said resource manager for selectively directing the single-channel uplink signals received from said uplink channel selector to inputs of said digital signal processors.

16. The hub station of claim 15, wherein each of said processors processes more than one of the single-channel uplink signals generated by said uplink channel selector to provide channel diversity.

17. The hub station of claim 9, wherein the downlink channelizer comprises:

a downlink time switch for accepting a formatted downlink signal from the mobile switching center and for parsing the formatted downlink signal, under control of said resource manager, to produce a plurality of unmodulated downlink signals;

a multi-channel modulator coupled to said downlink time switch for receiving the unmodulated downlink signals and for selectively processing the unmodulated downlink signals, under control of said resource manager, to create a plurality of single-channel downlink signals; and

a downlink channel selector coupled to said multi-channel modulator for accepting the single-channel downlink signals and for selectively generating, under control of said resource manager, a plurality of wideband downlink signals which are delivered to the distributed radio transceivers.

18. The hub station of claim 17, wherein said downlink channel selector comprises a bank of digital upconverters, each of said upconverters upconverting a single-channel downlink signal to a selected channel within a wideband downlink signal which is delivered to a distributed radio transceiver.

19. The hub station of claim 17, wherein said downlink channel selector comprises a bank of inverse discrete Fourier transform multiplexers, each of said multiplexers translating a plurality of single-channel downlink signals to form a wideband downlink signal which is delivered to a distributed radio transceiver.

20. A method for conducting radio communications in a system including a centralized hub station and a plurality of distributed radio transceivers, comprising the steps of:

using a plurality of high speed data transports to pass wideband signals, each wideband signal containing a plurality of information signals, between the hub station and the distributed radio transceivers;

continually measuring system activity; and

dynamically allocating, based on said step of measuring, hub station resources in processing and directing the information signals.

FIG. 1

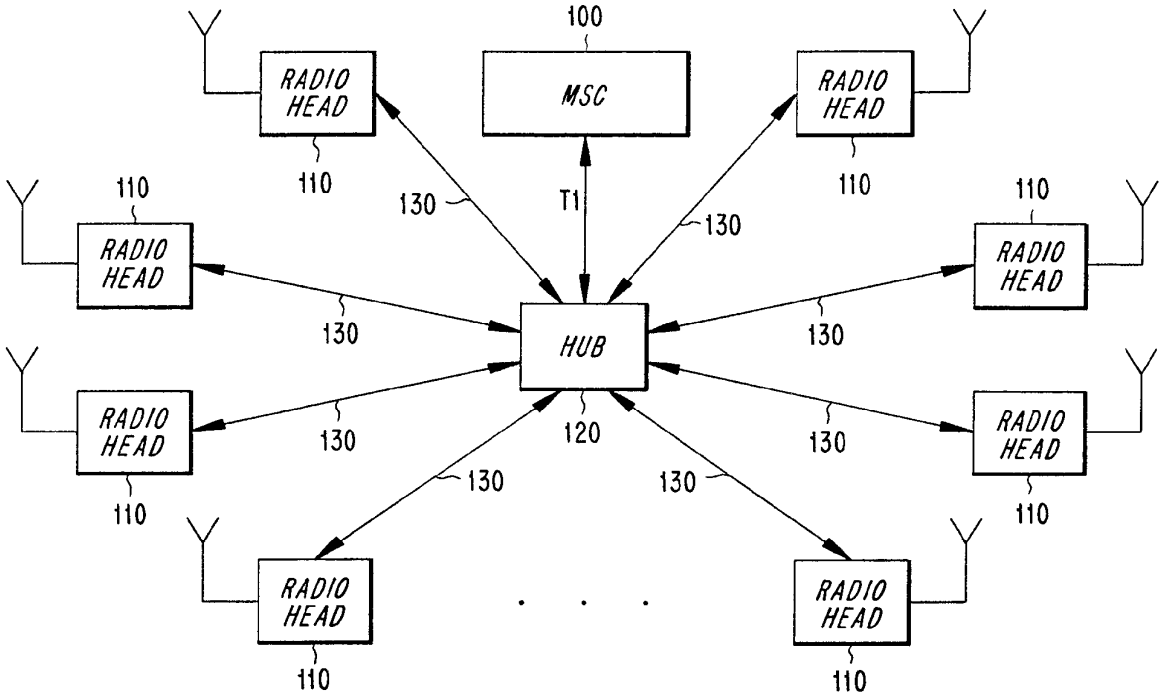

100
MSC
RADIO HEAD
110
T1
130
HUB
120

FIG. 2

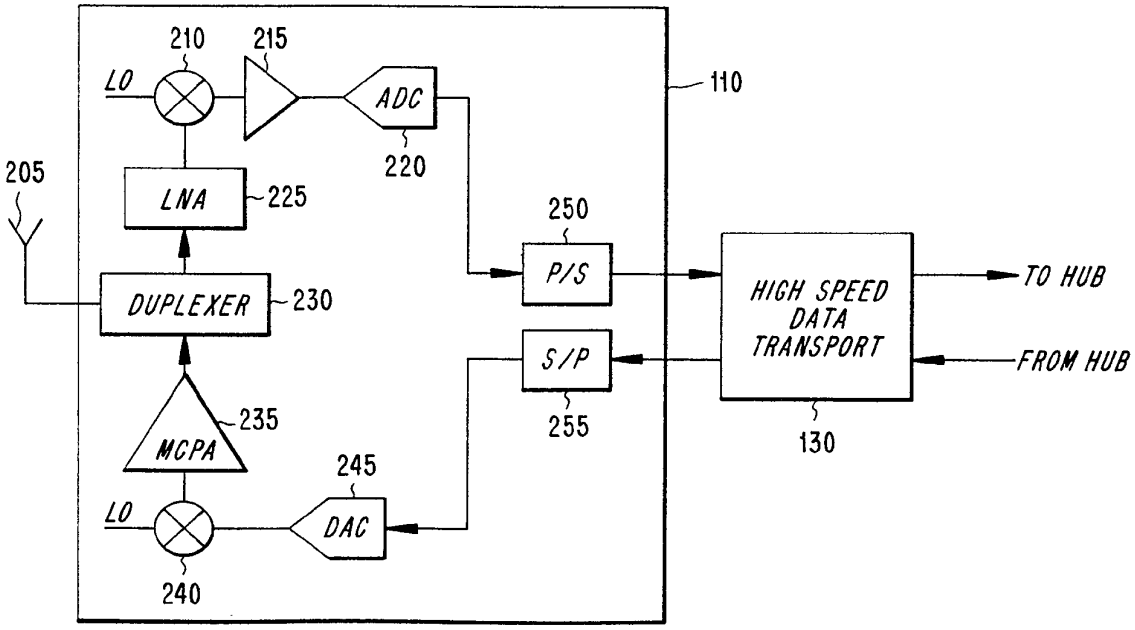
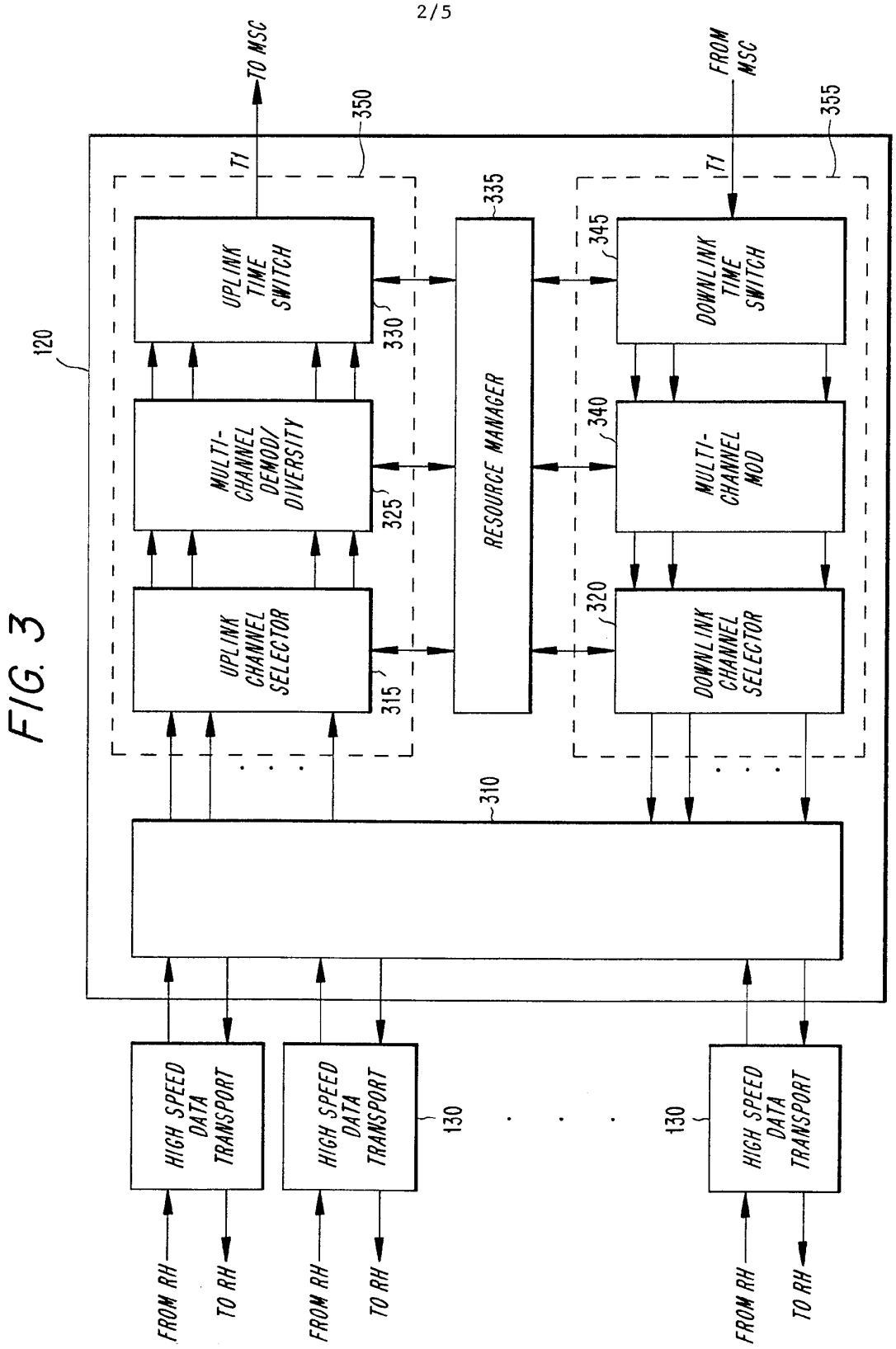

110
210
215
LO
ADC
220
205
LNA
225
250
P/S
DUPLEXER
230
HIGH SPEED DATA TRANSPORT
TO HUB
FROM HUB
S/P
255
MCPA
235
245
LO
DAC
240
130

FIG. 3


120
TO MSC
FROM MSC
350
355
T1
T1
UPLINK TIME SWITCH
DOWNLINK TIME SWITCH
330
335
345
MULTI-CHANNEL DEMOD/ DIVERSITY
RESOURCE MANAGER
MULTI-CHANNEL MOD
325
340
UPLINK CHANNEL SELECTOR
DOWNLINK CHANNEL SELECTOR
315
320
310
HIGH SPEED DATA TRANSPORT
HIGH SPEED DATA TRANSPORT
HIGH SPEED DATA TRANSPORT
130
130
FROM RH
TO RH
FROM RH
TO RH
FROM RH
TO RH

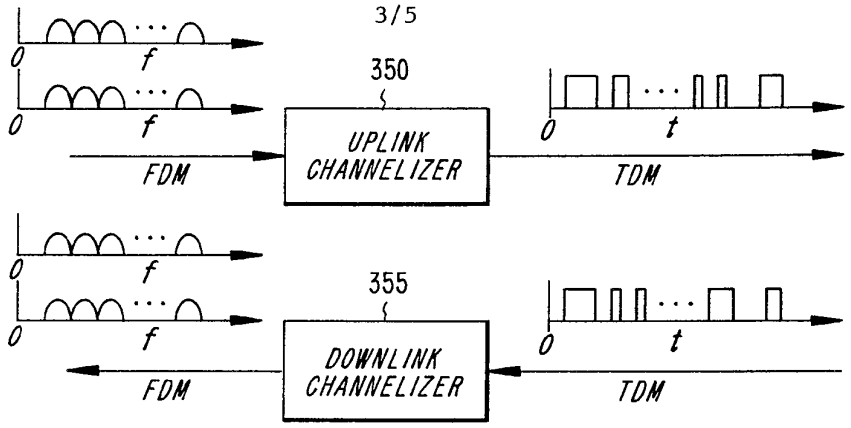


FIG. 4

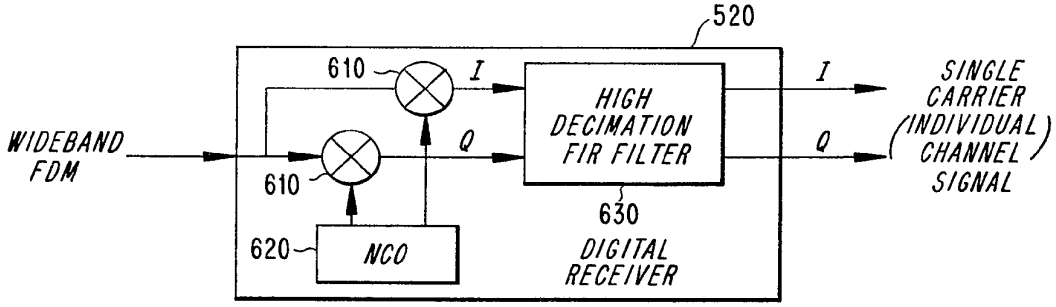


FIG. 6

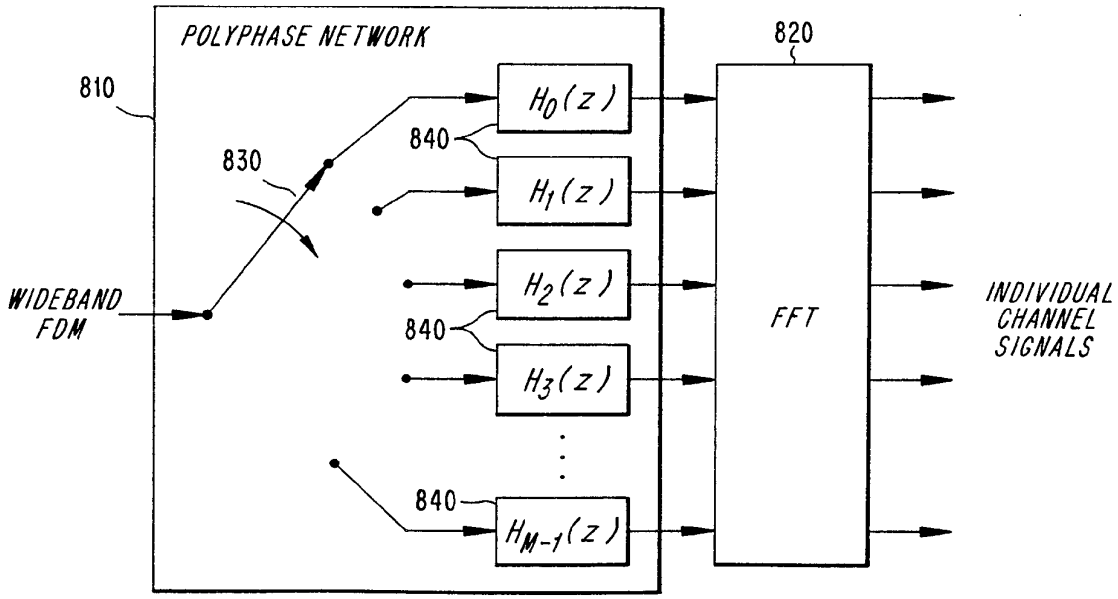


FIG. 8

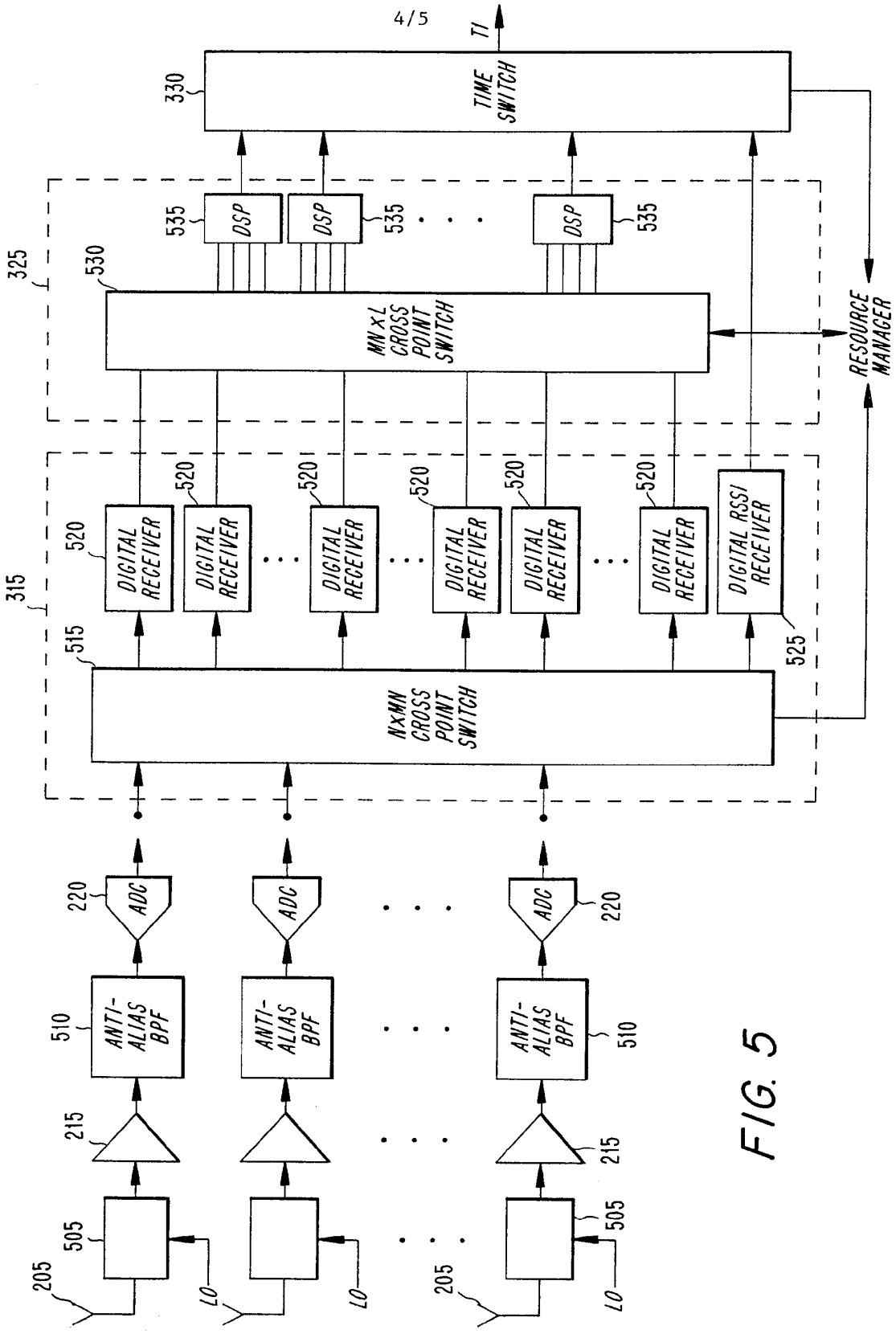

T1
TIME SWITCH
330
DSP
535
MN x L CROSS POINT SWITCH
530
325
RESOURCE MANAGER
DIGITAL RECEIVER
DIGITAL RSSI RECEIVER
520
525
315
NxMN CROSS POINT SWITCH
515
ADC
220
ANTI-ALIAS BPF
510
215
505
205
LO

FIG. 5

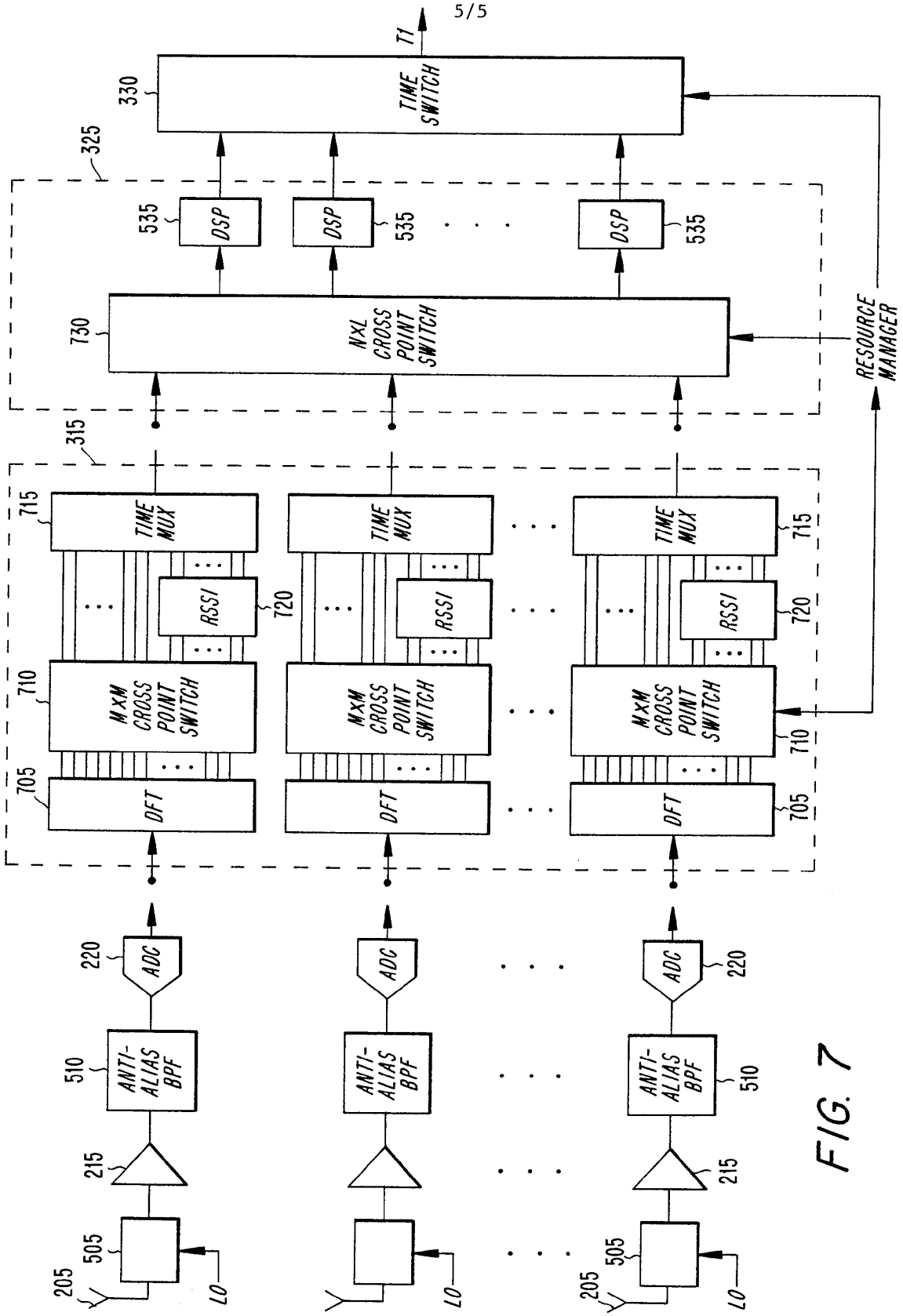

T1
TIME SWITCH
330
325
DSP
535
NXL CROSS POINT SWITCH
730
RESOURCE MANAGER
315
TIME MUX
715
RSSI
720
MXM CROSS POINT SWITCH
710
DFT
705
ADC
220
ANTI-ALIAS BPF
510
215
505
LO
205

FIG. 7

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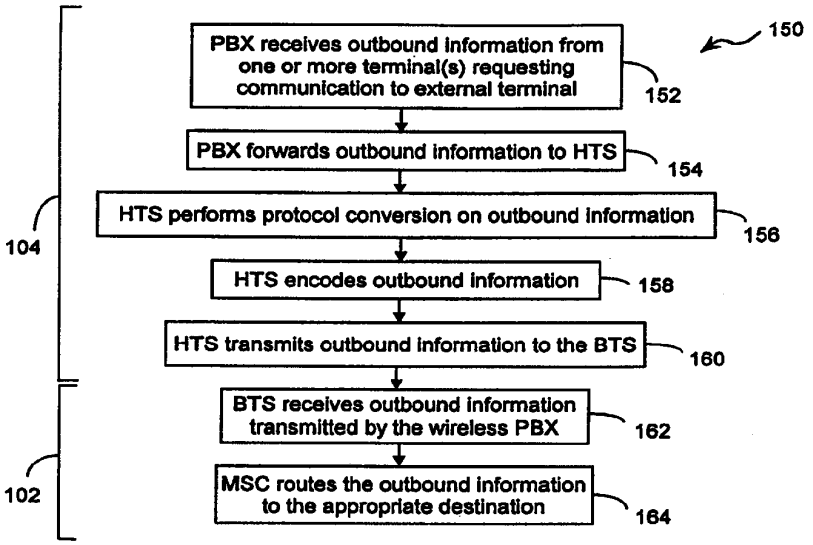
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(57) Abstract

A base transceiver station (40) includes a first transceiver configured to communicate with a first mobile station on a first frequency band (SA), and a second transceiver configured to communicate with a second mobile station on a second frequency band (SB). These bands can be, for example, 900 Mhz and 1800 Mhz frequency bands. The base transceiver station (40) includes a processor configured to instruct the first transceiver to receive inbound information from the first mobile station and to transmit outbound information to the first mobile station and to instruct the second transceiver to receive inbound information from the second mobile station and to transmit outbound information to the second mobile station. A trunk module is coupled to the processor and configured to communicate the first information and the second information with a base station controller (20). The base station controller (20) is coupled to the base transceiver station (40) and configured to communicate the inbound information and outbound information with the base transceiver station (40). In one embodiment, a time division multiplexing technique is used to communicate the inbound information and outbound information between the base transceiver station (40) and base station controller (20). Advantages of the invention include the ability to incorporate multiple transceivers communicating over multiple frequency bands in a single base transceiver station (40). This allows easier placement of the various transceivers in a single location and improves cellular service to mobile stations.



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WIRELESS CO-TENANT BASE STATION

REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Ser. No. 09/049,606, pending, which is a continuation of U.S. Ser. No. 08/434,598, now U.S. Pat. No. 5,734,979, incorporated herein by reference; and U.S. Ser. No. 08/927,353, pending, which is a continuation-in-part of U.S. Ser. No. 08/435,709, now U.S. Pat. No. 5,734,699, incorporated herein by reference.

This application claims priority to U.S. Prov. No. 60/071,584 filed on January 15, 1998.

FIELD

The present invention relates to a wireless co-tenant base station. In particular, the base station is capable of providing multiple radios to communicate with different mobile stations on different frequency bands or protocols.

BACKGROUND

Existing cellular base stations are configured to communicate with one type of mobile station. The radios that are incorporated in to the base stations are designed to communicate with one type of mobile station. For example, one type of radio is configured to communicate with a 900 MHz frequency band mobile station and another type of radio is configured to communicate with an 1800 Mhz frequency band mobile station. If a cellular service provider wants to serve both types of mobile stations, the service provider would need to install a 900 Mhz base station and an 1800 Mhz base station.

Therefore, a limitation of existing cellular base stations is that they are not equipped to provide service to multiple types of mobile stations.

What is needed is a cellular base station that can provide service to multiple types of mobile stations.

SUMMARY

The invention overcomes the identified problems and provides a base station that can serve multiple types of mobile stations. A base transceiver station (BTS) according to an exemplary embodiment includes a first transceiver configured to communicate with a first mobile station on a first frequency band, and a second transceiver configured to communicate with a second mobile station on a second frequency band. These bands can be, for example, 900 MHz and 1800 MHz frequency bands. The BTS includes a processor configured to instruct the first transceiver to receive inbound information from the first mobile station and to transmit outbound information to the first mobile station and to instruct the second transceiver to receive inbound information from the second mobile station and to transmit outbound information to the second mobile station. A trunk module is coupled to the processor and configured to communicate the first information and the second information with a base station controller (BSC). The BSC is coupled to the BTS and configured to communicate the inbound information and outbound information with the BTS. In one embodiment, a time division multiplexing technique is used to communicate the inbound information and outbound information between the BTS and BSC.

In another embodiment, the first information includes first voice/data information and first control information and the second information includes second voice/data information and second control information. The control information is associated with an Abis communication protocol between the BTS and BSC and is multiplexed over a single Abis link between the BTS and BSC.

Another embodiment of the base transceiver station includes a third transceiver configured to communicate with a third mobile station over a third frequency band. This band can be, for example, a 1900 MHz frequency band. The processor is configured to instruct the third transceiver to receive inbound

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information from the third mobile station and to transmit outbound information to the third mobile station. The trunk module is configured to communicate the third information with the BSC. The time division multiplexing technique is used to communicate the third inbound information and third outbound information between the BTS and BSC.

Advantages of the invention include the ability to incorporate multiple transceivers in a BTS for communicating on multiple frequency bands. This allows easier placement of the various transceivers in a single location and improves cellular service to mobile stations.

BRIEF DESCRIPTION OF THE FIGURES

Additional advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings, in which:

Figure 1 depicts a cellular network according to the prior art;

Figures 2A-B depict a geographically sectorized base transceiver station according to the prior art;

Figure 3 depicts a frequency band sectorized base transceiver station according to an embodiment of the invention;

Figure 4 depicts a base transceiver station and base station controller according to an embodiment of the invention;

Figure 5 depicts the control traffic between a base transceiver station and a base station controller according to embodiments of the invention;

Figure 6 depicts a base transceiver station and base station controller according to an alternate embodiment of the invention; and

Figures 7A-B depict a base transceiver station and base station controller according to an alternate embodiment of the invention.

DETAILED DESCRIPTION

Exemplary embodiments are described with reference to specific configurations. Those skilled in the art will appreciate that various changes and modifications can be made to the exemplary embodiments while remaining within the scope of the claims. For example, the exemplary embodiments are described

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with reference to the Global Systems for Mobile Communications (GSM) protocol. However, any communication protocol and a wide range of frequencies can be used in the invention.

A. The Cellular Network

Figures 1 and 2A-B depict a conventional cellular network 10. A group of base transceiver stations (BTS) 12a-c are positioned in predetermined locations to provide cellular service to a mobile station (MS) 14 over a given area of cells 16a-c. Each BTS 12a-c contain the same protocol and frequency band of transceiver radios to communicate with the same type of MS 14. In a conventional network, for example, the communication between the BTS 12a and MS 14 is in a single frequency band such as a 900 Mhz frequency band. The communication between the BTS 12a and MS 14 includes both voice/data information and control information. The BTS 12a-c are coupled via cables to a base station controller (BSC) 20.

The communication between the BTS 12a-c and BSC 20 includes both voice/data information and control information including a traffic channel, in one embodiment, at 16 or 64 kbit/s carrying speech or data of one radio traffic channel, and a signaling channel at 16 or 64 kbit/s carrying signaling/control information. In GSM the protocol of the signaling/control information is called an Abis link protocol that serves to associate the correct control information with the correct MS 14. This control link is broken down into three logical links for each terminal equipment including a radio signaling link (RSL) used for supporting traffic management procedures, an operations and maintenance link (OML) used for supporting network management procedures, and a layer 2 management link (L2ML) used for transferring layer 2 management messages to a transceiver (TRX) or to the base station control functions (BCF).

The Abis link protocol provides this information to support the radio resource management in the BTS. The basic communications between the BTS and BSC are based on the known cell structures and the transition of MS 14 from one cell to another. Additional complexities of radio resource management are introduced with sectorized cells, where additional radios are positioned in the BTS to

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cover specific geographical sectors. In this configuration, the BCF and Abis link must distinguish between radios in the same BTS but having different geographic coverage.

Figures 2A-B depict conventional geographically sectorized cells. This requires additional transceivers in each BTS, but also increases the service capacity. These cells are designed using multiple transceivers and antennas to communicate with specific geographical sectors within a given cell. Figure 2A, for example, is a two-sector BTS and cell where sector 16a1 provides service to MS in angles 1-180 and sector 16a2 provides service to MS in angles 181-360. This configuration requires at least two transceivers, each one servicing one of the sectors. Figure 2B, for example, is a three-sector BTS and cell where sector 16a1 provides service to MS in angles 1-120, sector 16a2 provides service to MS in angles 121-240 and sector 16a3 provides service to MS in angles 241-360. This configuration requires at least three transceivers, each one servicing one of the sectors.

The initialization of the conventional network is also important. The BTS 12a receives instructions from the BSC 20 to instruct the BTS 12a how to set up the base station control functions (BCF). These functions include instructions for each transceiver including what frequency sequence to use, which sector to service and how to service each MS that initiates a call with an off hook signal. Moreover the BCF is responsible for the Abis protocol link that serves to communicate the voice/data and control information between the BTS and BSC.

Figure 3 depicts a frequency band sectorization according to an embodiment of the invention. Instead of the geographical sectors of Figures 2A-B, the invention employs frequency band sectors in a cell 18a. The frequency sectors employ the same geographical space as one another, but operate on different frequency bands. In this embodiment, sector 18a1 represents a 900 Mhz frequency band and sector 18a2 represents an 1800 Mhz frequency band. When a 900 Mhz frequency band MS is in the cell, the MS communicates with the BTS 40 over the 900 Mhz frequency band. When an 1800 Mhz frequency band MS is in the cell, the MS communicates with the BTS 40 over the 1800 Mhz frequency band. The internal structure of the BTS 40 according to an embodiment of the invention is now described.

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B. BTS

Figure 4 depicts the internal structure of the BTS 40 according to an embodiment of the invention. A chassis 40 includes a first transceiver (TRXA) 42 configured to communicate on the 900 Mhz frequency band. A second transceiver (TRXB) 44 is configured to communicate on the 1800 Mhz frequency band. These transceivers serve as the basis to communicate over the radio frequency (RF) link with any MS in the cell 18a. In other embodiments, additional transceivers are included within the chassis 40 such as extra 900 Mhz or 1800 Mhz transceivers, and one or more 1900 Mhz transceivers or other transceivers.

Conventional radio frequency communication is used between the BTS and MS. An aspect of the invention is that the MS does not notice any difference between the inventive base station and the conventional base stations depicted in Figure 1. The BTS, however, recognizes each type of MS and communicates with that type of MS in order to service the call. From the perspective of the BTS, outbound information is transmitted to the MS and inbound information is received from the MS. The inbound information includes conventional inbound voice/data information and inbound control information. The control information includes frame numbers and counts. The outbound information includes conventional outbound voice/data information and outbound control information.

A central processing unit (CPU) 46 is coupled to the transceivers 42 and 44 and is configured to process the inbound information and outbound information associated with the MS in the cell 18a. The CPU further provides all the instructions to the transceivers in order to initialize the transceivers. The CPU performs what are called the base station control functions (BCF).

A trunk module 48 is coupled to the transceivers 42, 44 and the CPU 46 and is configured to communicate the inbound information and the outbound information with the BSC 20. The BSC has a trunk module 52 that is configured to communicate inbound information and outbound information with the BTS 40. The BSC has a central processor unit (CPU) 54 that is coupled to the trunk module 52, and to a second trunk module 56 and configured to communicate with the mobile services switching center (MSC) 26, illustrated in Fig. 3. The BSC CPU 54 communicates voice/data information and control information with the BTS CPU 46

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over the Abis protocol link between the BSC and BTS. The Abis link provides the radio resource instructions necessary for initialization and ongoing voice/data information and control information transfer.

In conventional cellular systems, the Abis link is capable of carrying the instructions to instruct the BTS to configure itself with the geographical sectors 16a-c illustrated in Figures 2A-B. In the invention, the Abis link is capable of carrying the instructions to instruct the BTS to configure itself with the frequency band sectors 18a-b illustrated in Figure 3. The frequency band sectors, however, are more difficult to initialize because the conventional radio resource management controls are not designed to accommodate this type of arrangement. Therefore, the invention provides an initialization that creates a BCF that can control the transceivers in order to effectively communicate with a plurality of mobile stations on different frequency bands. The initialization procedure provides the configuration parameters that determines the transmission frequency, for example, whether the TRX uses 900 MHz or 1800 MHz frequency bands. In addition to the RF channel, the configuration parameters also specify the power level. In a time domain multiplexed embodiment, the initialization commands further specify which time slots each TRX will use. In GSM, each RF frequency consists of eight TDM time slots. These time slots are also referred to as channels.

Figure 5 depicts various configurations for the BSC/BTS Abis protocol link. In one example, a single TRX BTS 62 includes a single TRX and a BCF to control the TRX. In another example, a three TRX BTS 64 includes three TRXs and a BCF to control the TRXs. In yet another example, a multiple TRX BTS 66 includes a plurality of TRXs each controlled by the BSC 20 over a separate Abis link. In any of these BTS configurations 62, 64, 66, the BSC provides control information to the BCF in the BTS. In the invention, the BCF controls the TRXs for frequency band sectorization. The wireless co-tenant base station of the present invention can be employed with any of these physical configurations.

In an embodiment which uses a single Abis link for more than one TRX, as shown with BTS 64 in Figure 5, time domain multiplexing can be used to couple the TRX signals to the Abis link. Each Abis interface has 30 time slots. In one embodiment, each TRX only uses two time slots. For example, in GSM there are

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eight RF time slots. Each RF time slot uses only 16K of the Abis, however, each time slot on the Abis interface has a 64K capacity. Therefore, each TRX only uses a portion of the 64K Abis interface capacity. If additional TRXs are desired to be added, one the 64K Abis interface capacity is exceeded, additional Abis links are established to meet the capacity requirements.

In the BTS 64 embodiment, each TRX includes a FIFO memory. The BCF controls the TRX's by writing commands to the TRX's FIFO memory. The BCF sends the commands to the TRX's over a system bus.

Additional embodiments of a base transceiver station and base station controller are shown in Figures 6 and 7A-B. Figure 6 shows that additional trunks can be employed between the BTS and the BSC in order to handle each of the TRXs respectively. Figures 7A-B show that the communication between the BTS and BSC can be performed using a time division multiple access (TDMA) technique where each TRX is allocated a time slot and the BCF places respective control/data information in each respective time slot and transfers the TDMA word to the BSC.

C. Conclusion

Advantages of the invention include the ability to incorporate multiple transceivers communicating over multiple frequency bands in a single BTS. This allows easier placement of the various transceivers in a single location and improves cellular service to mobile stations.

Having disclosed exemplary embodiments and the best mode, modifications and variations may be made to the disclosed embodiments while remaining within the scope of the invention as defined by the following claims.

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CLAIMS

What is claimed is:

1. A base transceiver station (BTS) for communicating with a first mobile station on a first frequency band and a second mobile station on a second frequency band, comprising:

a first transceiver configured to communicate, in a geographic cell, first information with said first mobile station over said first frequency band;

a second transceiver configured to communicate, in the geographic cell, second information with said second mobile station over said second frequency band;

a processor coupled to said first transceiver and said second transceiver and configured to perform base station control functions including to instruct said first transceiver to communicate with said first mobile station and to instruct said second transceiver to communicate with said second mobile station; and

a trunk module coupled to said processor and configured to communicate said first information and said second information with a base station controller (BSC).

2. The BTS of claim 1, wherein:

said first information includes first voice/data information and first control information;

said second information includes second voice/data information and second control information;

said processor is configured to multiplex said first information and said second information via said trunk module with said BSC.

3. The BTS of claim 2, wherein:

said first control information includes first Abis information;

said second control information includes second Abis information; and

said processor is configured to multiplex said first Abis information and said second Abis information via said trunk module with said BSC.

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4. The BTS of claim 1 for further communicating with a third mobile station on a third frequency band and further comprising:

a third transceiver configured to communicate with said third mobile station over said third frequency band; and

said processor is coupled to said third transceiver and configured to instruct said third transceiver to communicate with said third mobile station.

5. The BTS of claim 4, wherein:

said first information includes first voice/data information and first control information;

said second information includes second voice/data information and second control information;

said third information includes third voice/data information and third control information; and

said processor is configured to multiplex said first information, said second information and said third information via said trunk module with said BSC

6. The BTS of claim 5, wherein:

said first control information includes first Abis information;

said second control information includes second Abis information;

said third control information includes third Abis information; and

said processor is configured to multiplex said first Abis information, said second Abis information and said third Abis information via said trunk module with said BSC.

7. A base station controller (BSC) for communicating with a base transceiver station (BTS) having a plurality of communication frequency bands, comprising:

a trunk module configured to communicate, in a geographic cell, first information associated with a first frequency band of said plurality of frequency bands and to communicate, in the geographic cell, second information associated with a second frequency band of said plurality of frequency bands.

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8. The BSC of claim 7, further comprising:

a processor configured to associate said first information with a first mobile station in a first frequency band and said second information with a second mobile station in a second frequency band.

9. A trunk module for use with a multi-band cellular communication network, comprising:

an Abis link configured to multiplex first control information representing communication over a first frequency band and second control information representing communication over a second frequency band.

10. A method of communicating with a first mobile station on a first frequency band and a second mobile station on a second frequency band, comprising the steps of:

communicating, in a geographic cell, first information with said first mobile station over said first frequency band;

communicating, in the geographic cell, second information with said second mobile station over said second frequency band;

performing base station control functions including instructing a first transceiver to communicate with said first mobile station and instructing a second transceiver to communicate with said second mobile station; and

communicating said first information and said second information with a base station controller (BSC).

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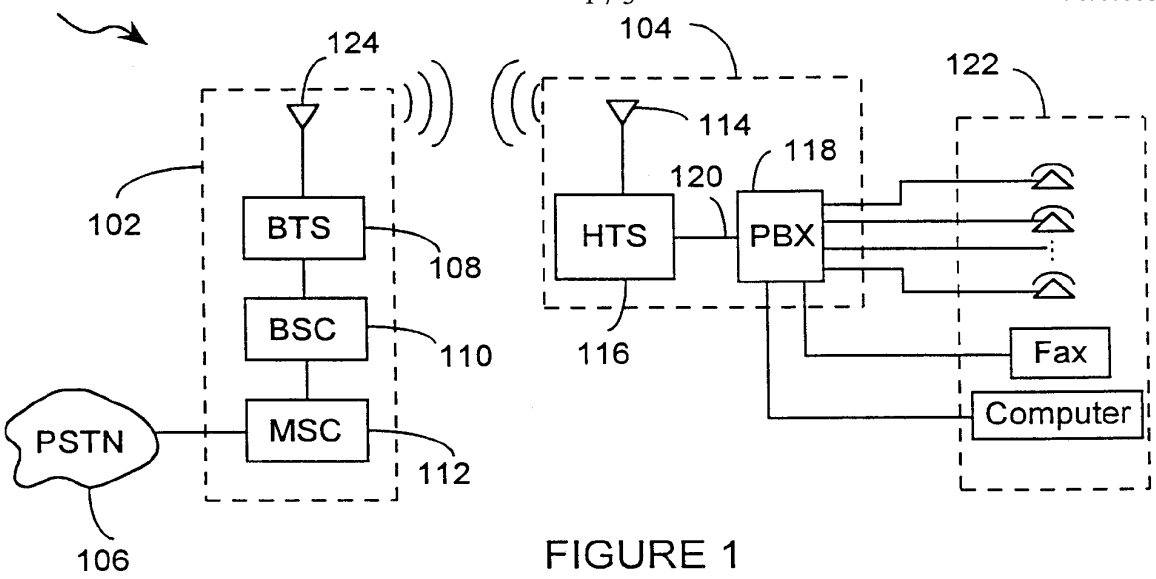


FIGURE 1

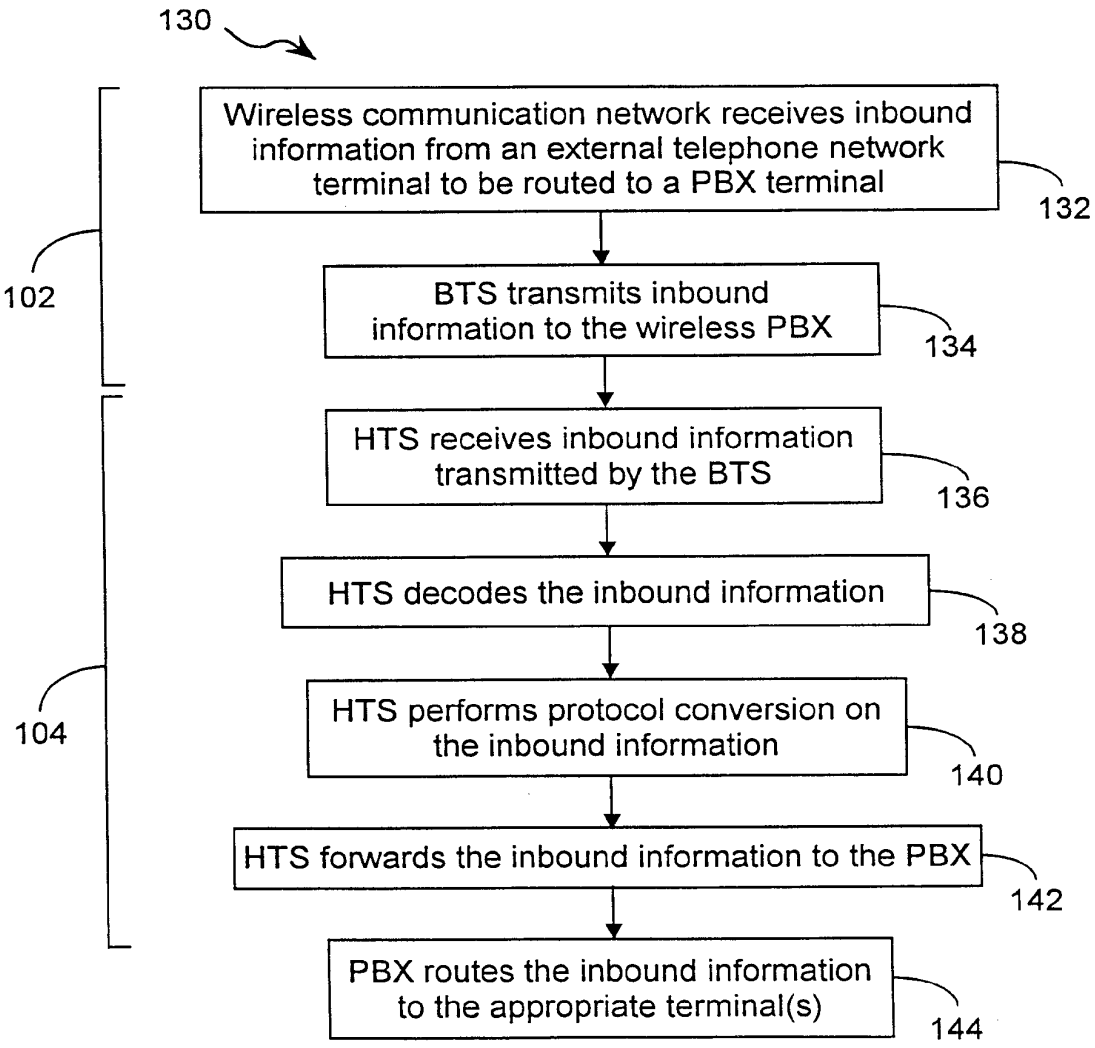


FIGURE 2

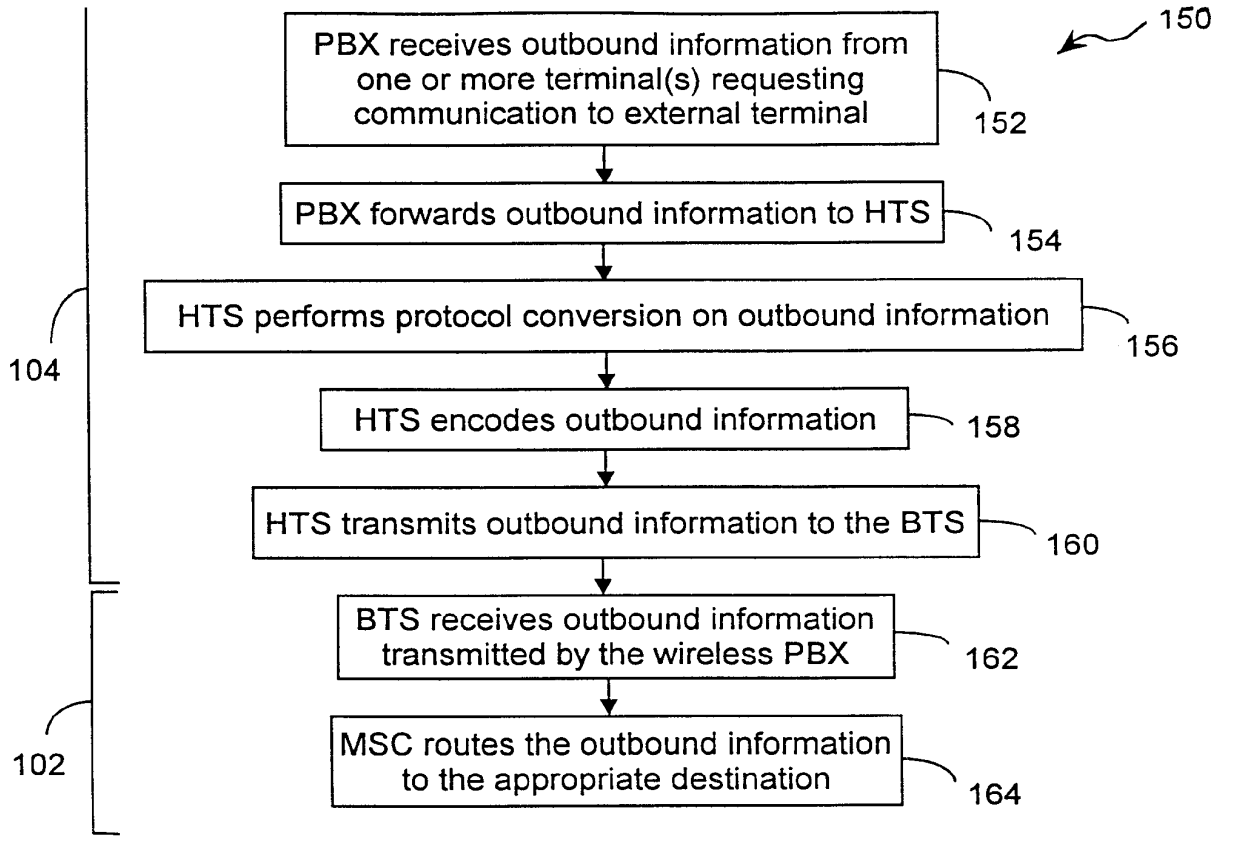


FIGURE 3

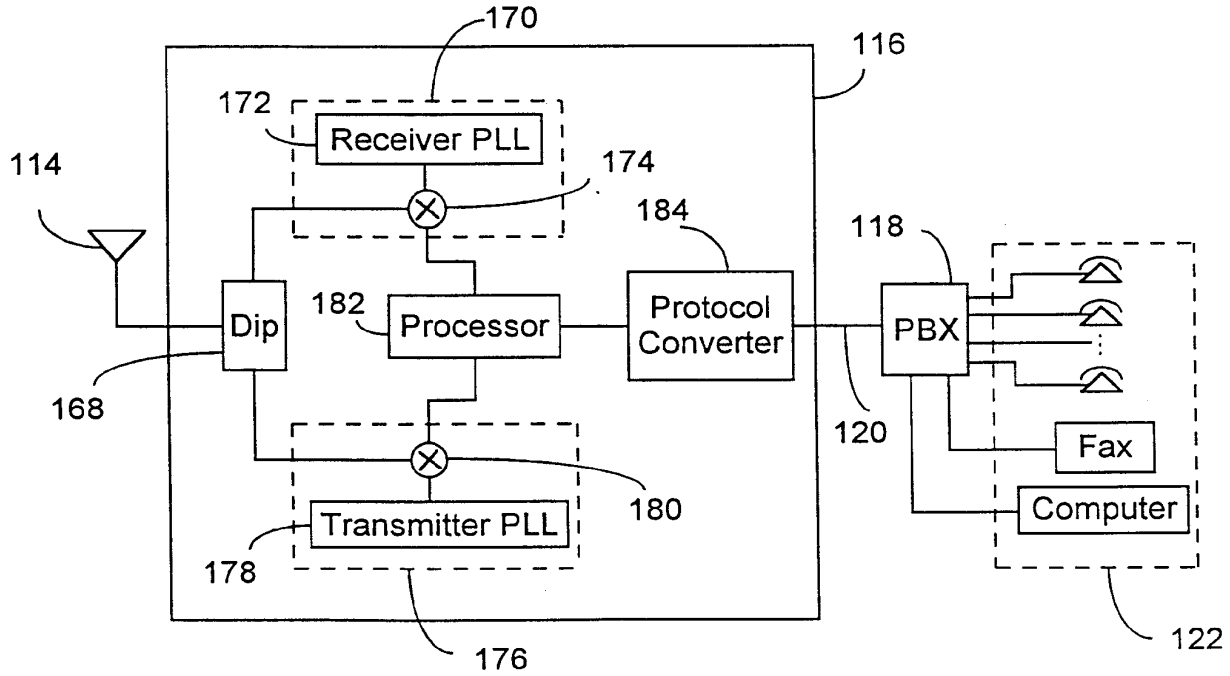


FIGURE 4

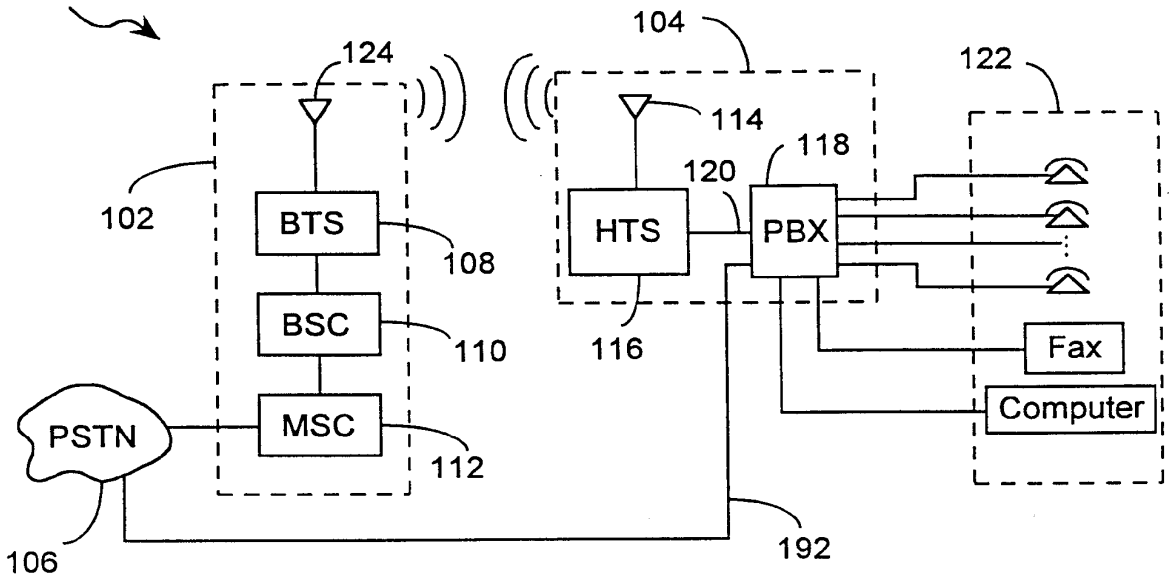


FIGURE 5

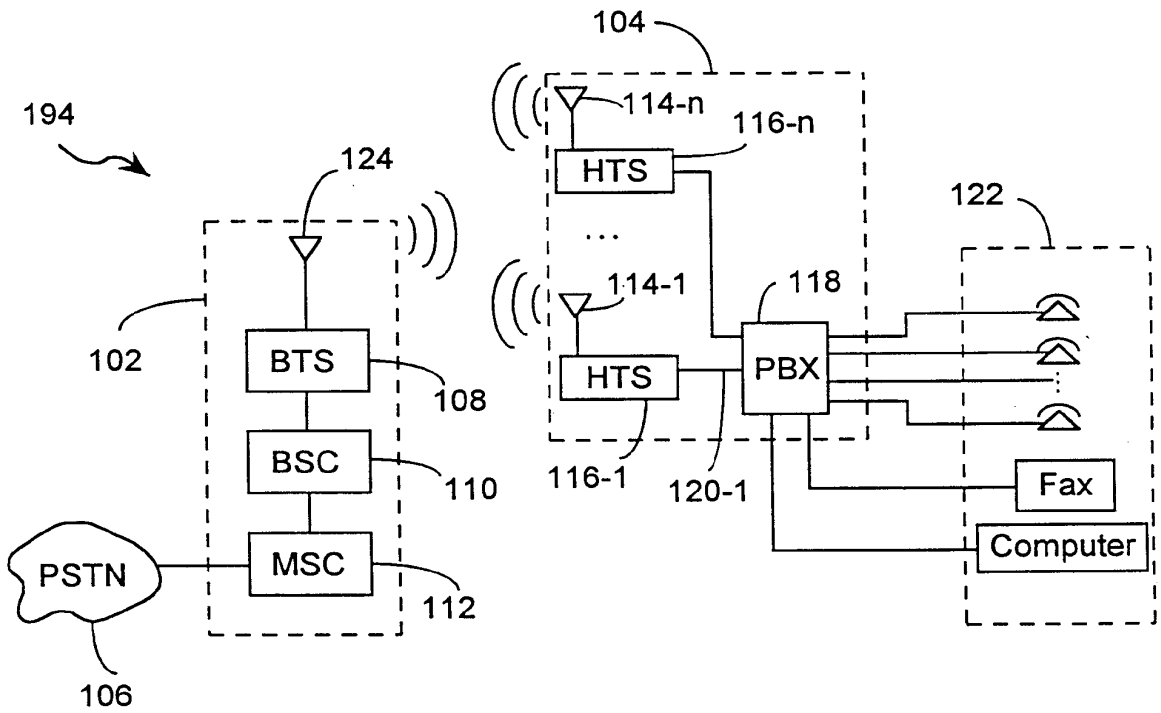


FIGURE 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/00844

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :H04B 1/38; H04M 1/00
US CL :455/426, 552, 560, 561
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/426, 552, 560, 561, 422, 454, 553

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,457,734 A (ERYAMAN ET AL) 10 October 1995, column 1 line 13 to column 2 line 46, column 3 line 7 to column 5 line 62.	1-10
A, P	US 5,822,693 A (HARRISON) 13 October 1998, columns 2-6.	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 24 FEBRUARY 1999	Date of mailing of the international search report 07 APR 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer NGUYEN VO James R. Matthews Telephone No. (703) 308-6728

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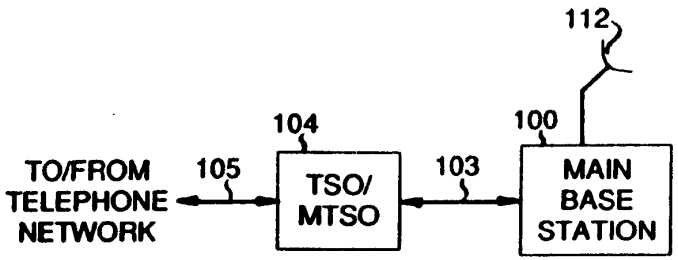
(54) **Method and apparatus for providing wireless communications between remote locations.**

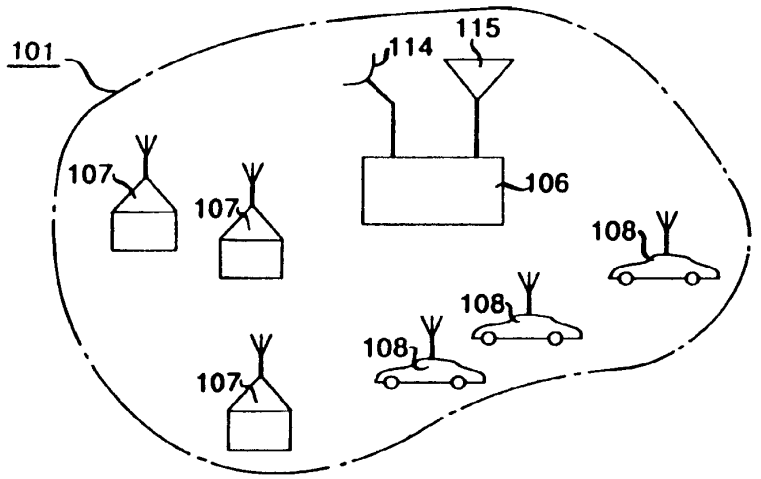
(57) A wireless telecommunication system includes a microwave link between a main base station (100) and a remote reception and radiation site (106) capable of communicating with a plurality of telephone subscriber stations (107, 108). At the main base station (100), radio frequency signals intended for the telephone subscriber stations are modulated on a microwave frequency carrier signal prior their transmission, via a microwave antenna (112), to the remote site. At the remote site (106), the frequencies of the microwave signals, received at a microwave antenna (114), are reduced prior to modulating such frequency-reduced signals on a radio frequency carrier signal and radiating, via a radio frequency antenna (115), the modulated radio signals out of the site. All radio signals received at the remote site from telephone subscriber stations are modulated on a microwave carrier signal prior to their transmission, via a microwave antenna (114), to the main base station (100). At the main base station (100), the frequencies of the incoming microwave signals are reduced prior to modulating such frequency-reduced signals on a radio frequency carrier signal and coupling the modulated radio signals to a receiver.

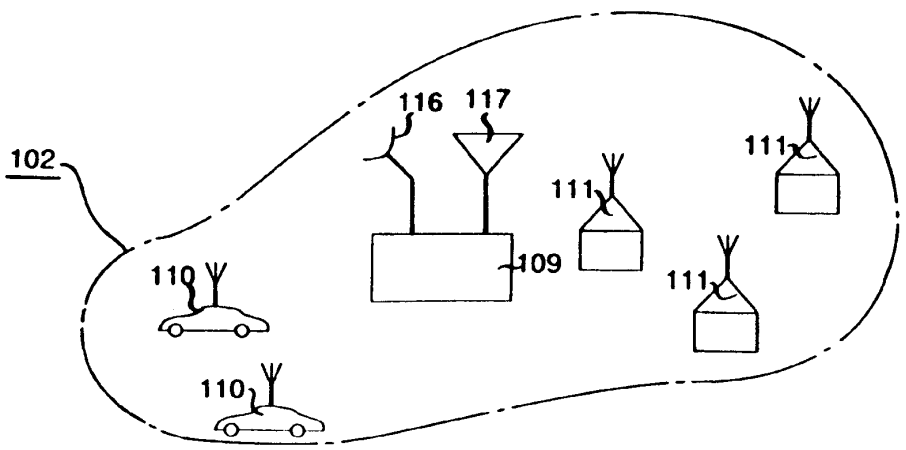
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FIG. 1







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Technical Field

The present invention generally relates to wireless communications systems and, more particularly, to techniques for providing wireless telecommunications between a main base station and a remote location which includes, for example, a mobile radio reception and radiation cellular site.

Background of the Invention

In high capacity cellular mobile radiotelephone systems, a plurality of base stations, also referred to as cell sites, are arranged so that each cell site covers a respective geographical area called a cell. Typically, each such cell site contains a radio transmitter-receiver and is directly wired to a mobile telephone switching office (MTSO) which in turn is part of a regional or nationwide network of telephone switching offices. One example of such cell site is the AT&T Series I cell sites (Model 1 and Model 2 architecture) used in the family of AUTOPLEX® cellular telecommunications systems which are commercially available from the American Telephone and Telegraph Company of New York, N.Y. Because of increased demands for more radio channels resulting from a growing cellular customers base, cellular telephone service providers often desire to expand their networks to service an increasing number of subscriber stations within a geographical location.

Various solutions to meet the foregoing need have suggested placing cell site antennas geographically very close to the potential locations of mobile or portable subscriber stations and carrying signals between the cell site and its remote antennas over either coaxial transmission lines or an optical fiber cable network interconnecting the cell site and its antennas. One such microcellular communication system includes optical fiber connections between a cellular base station and a plurality of radio frequency antennas. Such optical fiber links operate satisfactorily for their intended purposes for which they were originally designed. However, due to rapid growth of cellular customer demands combined with the requirements of quickly, reliably and cost-effectively providing cellular service to customers either on a permanent basis or on a temporary one, such as for example in case of emergencies, there exists a need for a more flexible, lower-cost and more easily and quickly expandable communication system than now exists with commercially available equipments.

Summary of the Invention

The foregoing need is met in an embodiment of the invention wherein a method for providing wireless communications between a main base station of a type capable of being connected to a telephone network and at least one remote reception and radiation site of a type capable of communicating with a plurality of telephone subscriber stations over predetermined radio frequencies comprises the steps of reducing the frequency of radio signals which are intended for the telephone subscriber stations to a lower frequency range, amplifying the frequency-reduced signals, modulating the amplified signals on a microwave frequency carrier signal, amplifying the microwave frequency modulated signals, and coupling the amplified microwave signals to a microwave antenna for transmission to the remote reception and radiation site.

In accordance with another embodiment, a method for receiving wireless communications signals at the main base station from the remote reception and radiation site comprises the steps of receiving at the microwave antenna of the main base station incoming microwave signals, amplifying the received microwave signals, reducing the frequency of the amplified signals to a substantially lower frequency range which includes the subscriber stations predetermined radio frequencies, amplifying the frequency-reduced signals, modulating the amplified frequency-reduced signals on a radio frequency carrier signal to generate radio frequency signals, and coupling the generated radio frequency signals to a receiver within the main base station.

In accordance with a further embodiment, a method for transmitting from the reception and radiation site a plurality of radio telecommunications signals having predetermined radio frequencies and intended for a plurality of telephone subscriber stations comprises the steps of receiving at the site incoming microwave signals, reducing the frequencies of the received microwave signals to substantially lower frequencies thereby generating intermediate signals, modulating the intermediate signals on a carrier signal having a frequency selected from the predetermined radio frequencies, and coupling the modulated radio signals to a radio frequency antenna.

In accordance with a still further embodiment, a method for processing at the reception and radiation site a plurality of radio telecommunications signals having predetermined radio frequencies comprises the steps of receiving at the site incoming radio signals, reducing the frequencies of the received radio signals to lower frequencies to generate intermediate signals, modulating the intermediate signals on a microwave frequency carrier signal, and coupling the modulated microwave signals to a microwave frequency antenna.

In one illustrative embodiment of the invention, transmitting apparatus at the main base station comprise a frequency downconverter for reducing the frequency of cellular radio signals intended for a mobile subscriber sation, and a modulator for modulating the

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frequency-reduced signals on a microwave carrier for transmission to a remote mobile radio reception and

communication link 103, to a telephone switching office 104, for example, a mobile telephone switching

tional block diagram form, only certain portions of the main base station 100 useful in the understanding of one embodiment of the invention. The main base station 100 comprises a transmitter portion and a receiver portion. Communication signals between the MTSO 104 and the various telephone subscriber stations 107, 108, 110 and 111, shown in FIG. 1, are derived from, as well as detected at radio channel units within the main base station 100 of which one such radio channel unit 200 is illustratively shown. In the transmitter portion of the main base station 100, radio signals to be transmitted to distant telephone subscriber stations are present on output lead 201 of radio channel unit 200. In the receiver portion of the main base station 100, radio signals received from distant telephone subscriber stations are present on input lead 212 of radio channel unit 200. Typically, the transmission radio signals present on lead 201 have frequencies that differ from those of reception radio signals present on lead 212. In connection with cellular mobile telephone communications, a typical transmission radio frequency for outgoing signals on lead 201 is of the order of 870 MHz, while a typical reception radio frequency for incoming signals on lead 212 is of the order of 825 MHz. In accordance with one aspect of the invention, the frequency of the outgoing signals present on lead 201 is reduced by a frequency downconverter 202 to a frequency range of the order of the frequency band of the remote site, e.g., 106, to which such outgoing signals are intended. For purpose of illustration only, in connection with the foregoing example, the 870 MHz frequency of the outgoing radio signals may be reduced by the downconverter 202 to about 2 MHz. Next, in such case, the 2 MHz frequency-reduced signals are amplified via amplifier 203 and applied to a modulator 204 adapted to modulate the frequency-reduced signals on a microwave frequency carrier signal. The frequency of the latter may be selected from any of the normally used microwave frequency bands, e.g., the 18 GHz band. The output signals of the modulator 204 are preferably coupled to a microwave amplifier 205 prior to coupling to the microwave antenna 112 via a microwave duplexer 206. Given desired frequency ranges and bands, the downconverter 202, the amplifiers 203 and 205, the modulator 204 and the duplexer 206 can be selected from any commercially available circuits meeting desired frequency and amplification parameters.

As shown in FIG. 2, the receiver portion of the main base station 100 includes a microwave amplifier 207 coupled to the duplexer 206 and adapted to amplify incoming microwave signals received at the antenna 112. In accordance with another aspect of the invention, a frequency downconverter circuit 208 has an input coupled to the output of amplifier 207 so that the frequency of the incoming microwave signals received at the antenna 112 is substantially reduced to a frequency range of the order of the frequency band of a remote site, e.g., 106 or 109, from which the incoming microwave signals originate. Referring to the above-mentioned example, the output signals of the downconverter 208 may have a frequency of the order of 2 MHz. Such substantially reduced frequency signals are next amplified via amplifier 209 and applied to a modulator 210 adapted to modulate them on a radio frequency carrier signal. It may be desirable to connect a second amplifier circuit (not shown) to the output of the modulator 210 if the amplitudes of the modulated radio frequency signals, as generated by the modulator 210 and present on the lead 212, are of insufficient magnitudes for further processing by the radio channel unit 200.

Although the embodiment of FIG. 2 was described with reference to a single microwave antenna 112 and an associated duplexer 206, separate transmission and reception microwave antennas can readily be substituted for the antenna 112 thus eliminating the need for duplexer 206.

Referring now to FIG. 3, there is shown, in functional block diagram form, various circuit elements included in the remote reception and radiation site 106. As mentioned in connection with the description of the arrangement shown in FIG. 1, the microwave antenna 114 is adapted to receive and transmit microwave signals, respectively, from and to the main base station. A duplexer circuit 301, such as for example a microwave circulator of commercially available type, is connected to the antenna 114 so that the site 106 comprises two portions, namely a microwave receive/radio transmit portion 302, and a radio receive/microwave transmit portion 303 both coupled to the antenna 114. In accordance with an illustrative embodiment, the portion 302 includes a frequency downconverter 304, having an input terminal coupled to one output of the duplexer 301, for substantially reducing the frequency of the microwave signals received at the antenna 114 and generating intermediate signals, present on downconverter output lead 305. These intermediate signals are connected to a modulator circuit 306 for modulating them on a carrier radio signal having a predetermined frequency selected from the frequency band used for radio transmission of signals intended for the subscriber telephone stations served by the site 106. An amplifier circuit 307, preferably a linear amplifier, and a duplexer 308 are connected between the output of the modulator circuit 306 and the radio antenna 115. Shown in FIG. 3, are two filter circuits 309 and 310 that may be optimally inserted in the circuit of the portion 302 depending upon the frequency bands desired, respectively, for the intermediate signals and for the modulated radio signals.

As shown in FIG. 3, the other portion of the reception and radiation site 106, i.e., the radio receive/microwave transmit portion 303, includes a

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frequency downconverter 311 for reducing the frequency of radio signals received at the radio antenna 115, and for generating second intermediate signals on lead 312. A modulator circuit 313 is coupled to the downconverter 311 for modulating the intermediate signals present on lead 312 on a microwave frequency carrier signal. The modulated signals are coupled to the microwave antenna 114 via an amplifier 314 and the duplexer 301. Also shown in FIG. 3, are filter circuits 315, 316 and 317 that may be optionally inserted in the circuit of portion 303 depending upon the respective frequency bands desired at various points along this circuit.

The above embodiment of FIG. 3 was described with reference to a single antenna 114 and an associated duplexer 301 for implementing both the reception and transmission of microwave signals. Also, a single radio antenna 115, in association with a duplexer 308, is shown to implement both the transmission and reception of radio signal. Clearly, a transmit antenna and a receive antenna can readily be substituted for each of the antennas 114 and 115 thus rendering unnecessary their associated duplexers 301 and 308.

Although the present invention has been described in connection with particular embodiments thereof, additional embodiments, modifications and applications which will be apparent to those skilled in the art are included within the spirit and scope of the invention.

Claims

1. A method for providing wireless communications between a main base station (100) of a type capable of being connected to a telephone network (104) and at least one remote reception and radiation site (106) of a type capable of communicating with a plurality of telephone subscriber stations (107,108) over predetermined radio frequencies, CHARACTERISED BY reducing the frequency of radio signals which are intended for the telephone subscriber stations to a lower frequency range, amplifying the frequency-reduced signals, modulating the amplified signals on a microwave frequency carrier signal, amplifying the microwave frequency modulated signals, and coupling the amplified microwave signals to a microwave antenna (112) for transmission to the remote reception and radiation site.

2. A method as claimed in claim 1 wherein the frequency reducing step comprises the step of reducing the frequency of the radio signals to a frequency range of the order of the frequency band of the remote reception and radiation site.

3. A method for receiving wireless communications signals at a main base station (100) of a type capable of being connected to a telephone network (104) from at least one remote reception and radiation site (106) of a type capable of communicating with a plurality of telephone subscriber stations (107,108) over predetermined radio frequencies, CHARACTERISED BY receiving at a microwave antenna (112) of the main base station incoming microwave signals, amplifying the received microwave signals, reducing the frequency of the amplified signals to a substantially lower frequency range which comprises the subscriber stations predetermined radio frequencies, amplifying the frequency-reduced signals, modulating the amplified frequency-reduced signals on a radio frequency carrier signal to generate radio frequency signals, and coupling the generated radio frequency signals to receiving means (200) within the main base station.

4. A method for transmitting from a reception and radiation site (106) a plurality of radio telecommunications signals having predetermined radio frequencies and intended for a plurality of telephone subscriber stations (107,108), CHARACTERISED BY receiving at the site incoming microwave signals, reducing the frequencies of the received microwave signals to substantially lower frequencies thereby generating intermediate signals, modulating the intermediate signals on a carrier signal having a frequency selected from the predetermined radio frequencies, and coupling the modulated radio signals to a radio frequency antenna (115).

5. A method as claimed in claim 4 wherein the frequency reducing step comprises the step of generating the intermediate signals having frequencies in a frequency range of the order of the frequency band of the telephone subscriber stations.

6. A method for processing at a reception and radiation site (106) a plurality of radio telecommunications signals having predetermined radio frequencies, comprising the steps of receiving at the site incoming radio signals, reducing the frequencies of the received radio signals to lower frequencies to generate intermediate signals, modulating the intermediate signals on a microwave frequency carrier signal, and coupling the modulated microwave signals to a microwave frequency antenna (114).

7. Apparatus for providing wireless communications between a main base station (100) of a type capable of being connected to a telephone network

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(104) and at least one remote reception and radiation site (106) of a type capable of communicating with a plurality of telephone subscriber stations (107,108) CHARACTERISED IN THAT the apparatus comprises means (202) for reducing the frequency of radio signals intended for the telephone subscriber stations to a lower frequency range, means (203) for amplifying the frequency-reduced signals, means (204) for modulating the amplified signals on a microwave frequency carrier signal, means (205) for amplifying the microwave frequency modulated signals, and means (206) for coupling the amplified microwave signal to a microwave antenna (112) for transmission to the remote reception and radiation site.

8. Apparatus as claimed in claim 7 wherein the lower frequency range is of the order of the frequency band of the remote reception and radiation site.

9. Apparatus for receiving wireless communications at a main base station (100) of a type capable of being connected to a telephone network (104) from at least one remote reception and radiation site (106) of a type capable of communicating with a plurality of telephone subscriber stations (107,108), CHARACTERISED IN THAT the apparatus comprises means (112) for receiving at the main base station incoming microwave signals, means (207) for amplifying the received microwave signals, means (208) for reducing the frequency of the amplified signals to a substantially lower frequency range, means (209) for amplifying the frequency-reduced signals, and means (210) for modulating the amplified frequency-reduced signals on a radio frequency carrier signal thereby generating radio frequency signals.

10. Apparatus as claimed in claim 9 wherein the substantially lower frequency range is of the order of the frequency band of the telephone subscriber stations.

11. A reception and radiation site (106) CHARACTERISED BY a first antenna (115) for transmitting radio signals having frequencies in a first range of frequencies, a second antenna (114) for receiving microwave signals having frequencies in a second range of frequencies that are substantially higher than the frequencies in the first range of frequencies, means (304) coupled to the second antenna for substantially reducing the frequencies of the received microwave signals thereby generating intermediate signals, means (306) coupled to the frequency reducing means for modifying the intermediate signals on a radio frequency carrier signal, and means (308) for coupling the modulated radio signals to the first antenna.

12. A reception and radiation site (106) CHARACTERISED BY a first antenna (115) for receiving radio signals having frequencies in a first range of frequencies, a second antenna (114) for transmitting microwave signals having frequencies in a second range of frequencies that are substantially higher than the frequencies in the first range of frequencies, means (311) coupled to the first antenna for reducing the frequencies of the received radio signals thereby generating intermediate signals, means (313) coupled to the frequency reducing means for modulating the intermediate signals on a microwave frequency carrier signal, and means (301) for coupling the modulated microwave signals to the second antenna.

13. A mobile radio reception and radiation cellular site (106) CHARACTERISED BY a first antenna (115) for transmitting mobile radio signals having frequencies in a first range of frequencies, a second antenna (114) for receiving microwave signals having frequencies in a second range of frequencies that are substantially higher than the frequencies in the first range of frequencies, means (304) coupled to the second antenna for substantially reducing the frequencies of the received microwave signals thereby generating intermediate signals, means (306) coupled to the frequency reducing means for modulating the intermediate signals on a radio frequency carrier signal, and means (308) for coupling the modulated radio signals to the first antenna.

14. A mobile radio reception and radiation cellular site (106) CHARACTERISED BY a first antenna (115) for receiving mobile radio signals having frequencies in a first range of frequencies, a second antenna (114) for transmitting microwave signals having frequencies in a second range of frequencies that are substantially higher that the frequencies in the first range of frequencies, means (311) coupled to the first antenna for reducing the frequencies of the received mobile radio signals thereby generating intermediate signals, means (313) coupled to the frequency reducing means for modulating the intermediate signals on a microwave frequency carrier signal, and means (301) for coupling the modulated microwave signals to the second antenna.

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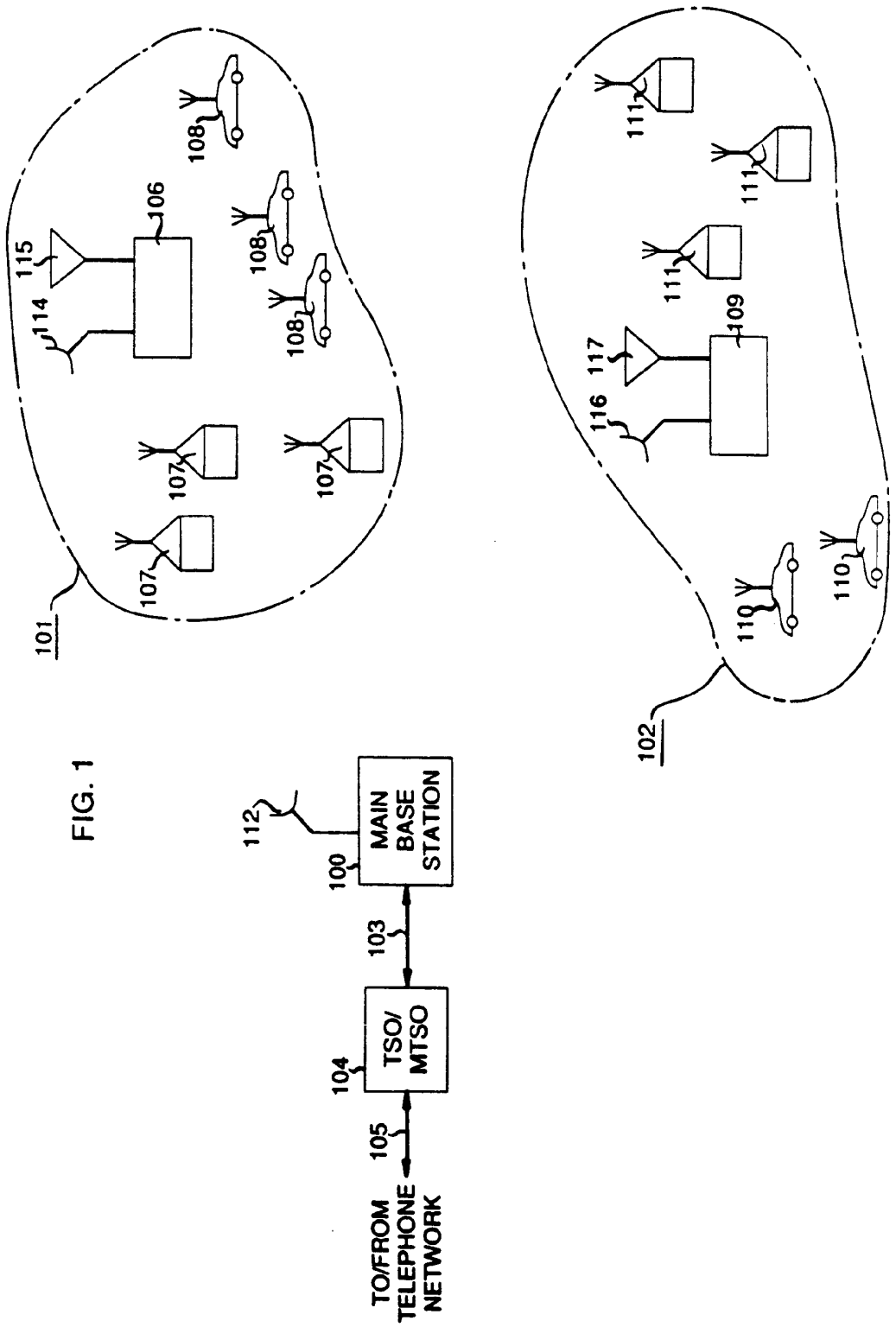
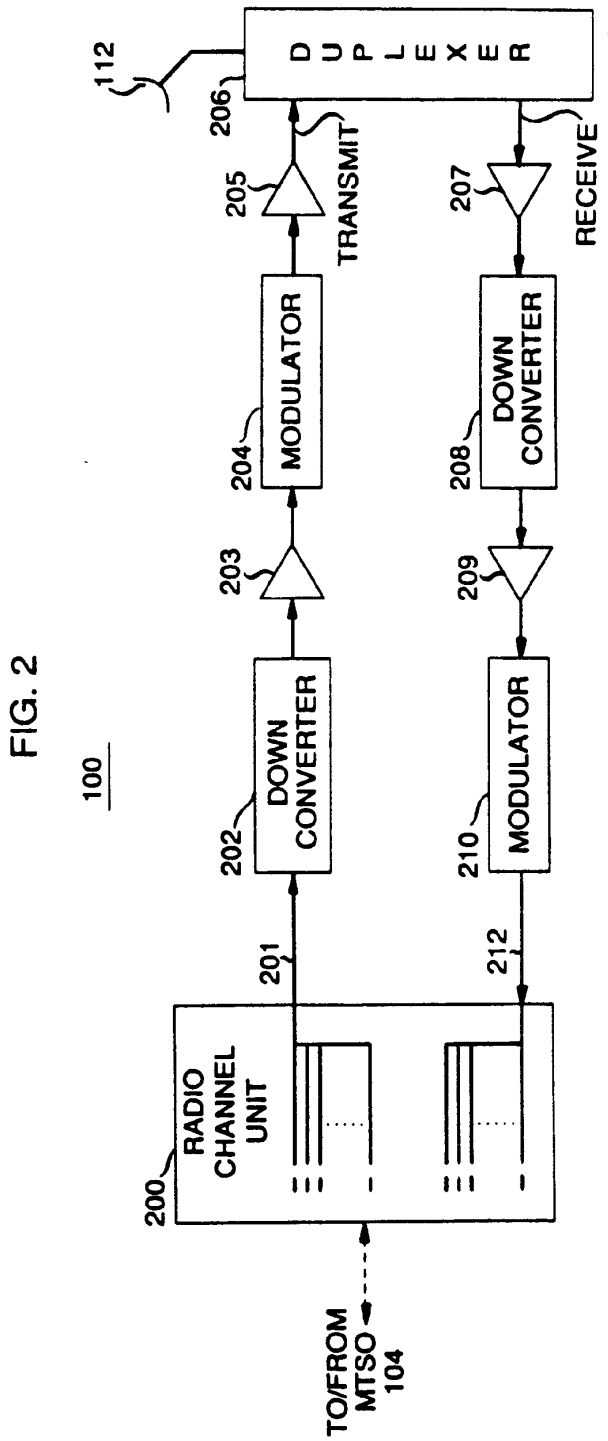


FIG. 1

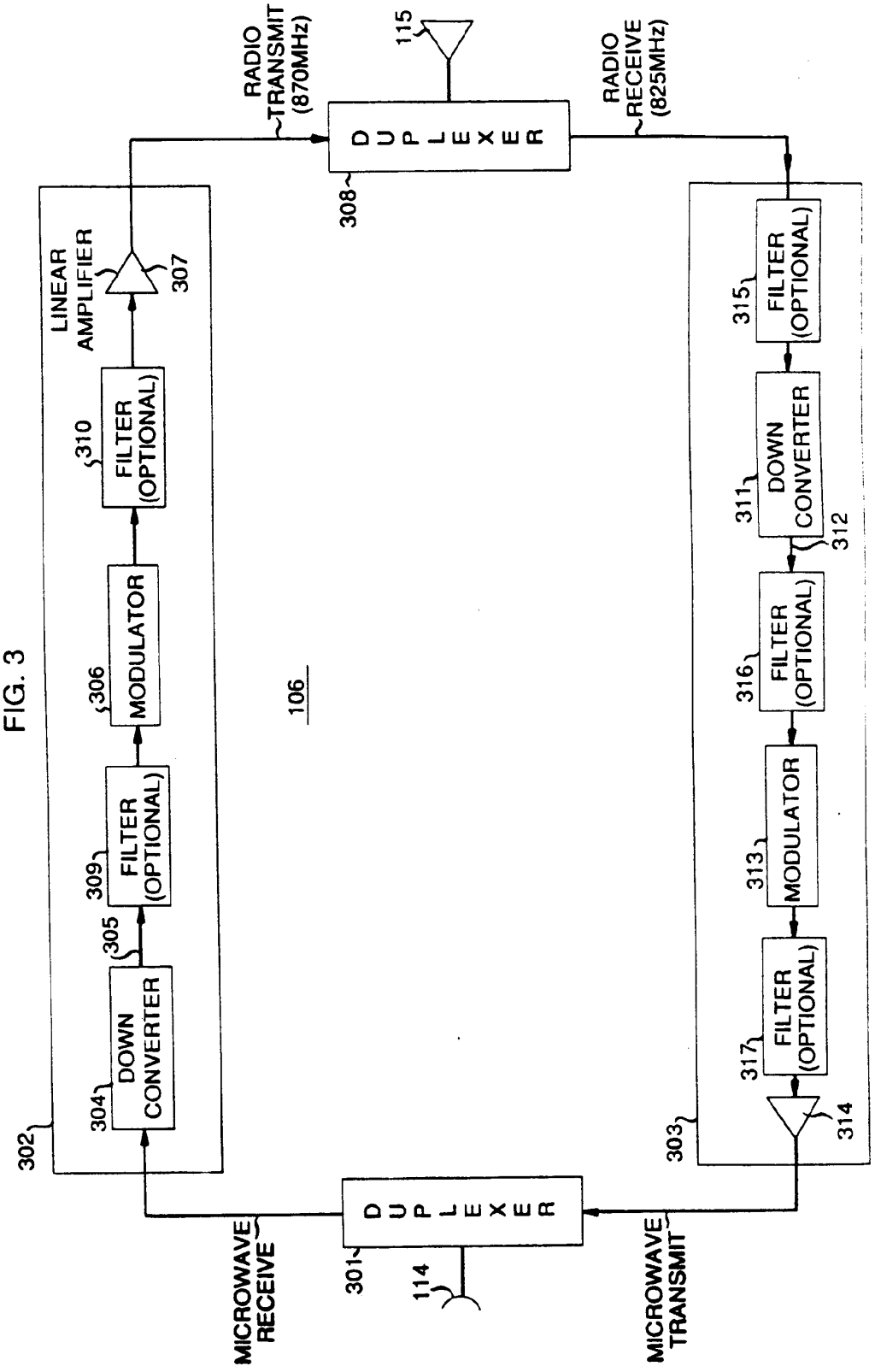
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FIG. 2



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FIG. 3



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Electronic Acknowledgement Receipt

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Application Number:	11627255
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Confirmation Number:	1589
Title of Invention:	DISTRIBUTED REMOTE BASE STATION SYSTEM
First Named Inventor/Applicant Name:	Robert J. Koziy
Customer Number:	34206
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Application Type:	Utility under 35 USC 111(a)

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	11627255
	Filing Date	2007-01-25
	First Named Inventor	Koziy
	Art Unit	
	Examiner Name	
	Attorney Docket Number	100.829US01

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	First Named Inventor	Koziy
	Art Unit	
	Examiner Name	
	Attorney Docket Number	100.829US01

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	First Named Inventor	Koziy
	Art Unit	
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	Attorney Docket Number	100.829US01

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	Filing Date	2007-01-25
	First Named Inventor	Koziy
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	Attorney Docket Number	100.829US01

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	11627255
	Filing Date	2007-01-25
	First Named Inventor	Koziy
	Art Unit	
	Examiner Name	
	Attorney Docket Number	100.829US01

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/David N. Fogg/	Date (YYYY-MM-DD)	2008-06-11
Name/Print	Fogg, David N.	Registration Number	35138

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PTO/SB/06 (12-04)
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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 11/627,255

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))							300
SEARCH FEE (37 CFR 1.16(k), (l), or (m))							500
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))							200
TOTAL CLAIMS (37 CFR 1.16(i))	27 minus 20 =	7	X$ 25		OR	X$50	350
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4 minus 3 =	* 1	X$100			X$200	200
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			180			360	
1			TOTAL	0		TOTAL	1550

APPLICATION AS AMENDED – PART II

4/18/07

AMENDMENT A	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDI-TIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDI-TIONAL FEE ($)
Total (37 CFR 1.16(i))	* 27	Minus	** 27	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	* 4	Minus	*** 4	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					180		OR	360	
					TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

AMENDMENT B	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDI-TIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDI-TIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
11/627,255	01/25/2007	2611	1680	100.829US01	27	4

CONFIRMATION NO. 1589

UPDATED FILING RECEIPT

34206
FOGG & POWERS LLC
10 SOUTH FIFTH STREET
SUITE 1000
MINNEAPOLIS, MN55402

Date Mailed: 04/27/2007

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please mail to the Commissioner for Patents P.O. Box 1450 Alexandria Va 22313-1450. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).**

Applicant(s)

Robert J. Koziy, Burnsville, MN;
Harold A. Roberts, Eden Prairie, MN;
Todd Schieffert, Edina, MN;

Assignment For Published Patent Application

ADC Telecommunications, Inc., Eden Prairie, MN

Power of Attorney: The patent practitioners associated with Customer Number 34206

Domestic Priority data as claimed by applicant

Foreign Applications

If Required, Foreign Filing License Granted: 02/20/2007

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US11/627,255**

Projected Publication Date: 07/31/2008

Non-Publication Request: No

Early Publication Request: No

Title

DISTRIBUTED REMOTE BASE STATION SYSTEM

Preliminary Class

375

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

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Applicant(s)	Robert J. Koziy et al.	**PRELIMINARY AMENDMENT**
Serial No.	11/627,255	
Filing Date	1/25/2007	
Group Art Unit	Not Assigned	
Examiner Name	Not Assigned	
Confirmation No.	1589	
Examiner Name	Unknown	
Attorney Docket No.	100.829US01	
Title: DEVICE MOUNT WITH STABILIZING FUNCTION		

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Before taking up the above-identified patent application for examination, please amend the claims as follows.

Amendments to the Claims are reflected in the listing of claims that begins on page 2 of this paper.

Remarks begin on page 7 of this paper.

Amendments to the Claims:

This listing of claims will replace all prior versions and listings of claims in the application:

Listing of claims:

1. (Original) A distributed base station system for high speed data transmission comprising:

a plurality of remote antennas, each antenna being coupled to a router;

wherein the plurality of remote antennas are coupled to each other and are arranged into a network.

2. (Original) The distributed base station system of claim 1, wherein the plurality of remote antennas are arranged in a tree configuration.

3. (Original) The distributed base station system of claim 1, wherein the plurality of remote antennas are arranged in a ring configuration.

4. (Original) The distributed base station system of claim 1, wherein at least one of the plurality of remote antennas is coupled to a remote base station.

5. (Original) The distributed base station system of claim 1, wherein each of the plurality of remote antennas is coupled to a remote base station.

6. (Original) The distributed base station system of claim 1, wherein the system transports data using a protocol that is compliant with IEEE 802.16.

7. (Original) The distributed base station system of claim 1, further comprising:

a fiber optic transport mechanism between two of the plurality of remote antennas.

8. (Original) The distributed base station system of claim 1, further comprising:

a millimeter wave transceiver configured to transport data between two of the plurality of remote antennas.

9. (Original) A method of transmitting a wireless communication signal comprising:

receiving a RF signal at a first remote wireless communication station;

routing the RF signal to a second remote wireless communication station; and

transmitting the RF signal from an antenna at the second remote wireless communication station.

10. (Original) The method of claim 9, further comprising:

sending the RF signal from a local base station to the first remote wireless communication station.

11. (Original) The method of claim 9, wherein receiving the RF signal receives the RF signal via an antenna at the first remote wireless communication station.

12. (Original) The method of claim 11, further comprising:

processing the RF signal by a base station at the second remote wireless communication station to form a second RF signal; and

routing the second RF signal to a third remote wireless base station.

13. (Original) The method of claim 12, further comprising:

transmitting the second RF signal from an antenna of the third remote wireless base station.

14. (Original) The method of claim 9, further comprising:

splitting the RF signal and sending a duplicate RF signal to a third remote wireless communication station; and

transmitting the duplicate RF signal from an antenna at the third remote wireless communication station.

15. (Original) The method of claim 9, further comprising:
sending the RF signal from a host unit to the first wireless communication station.

16. (Original) The method of claim 9, wherein transmitting further comprises:
transmitting the RF signal to a mobile device.

17. (Original) The method of claim 9, further comprising:
processing the RF signal by a base station at the first remote wireless communication station to form a second RF signal; and
transmitting the second RF signal from an antenna at the first remote wireless communication station.

18. (Original) The method of claim 9, wherein the RF signal is transported using a protocol that is compliant with IEEE 802.16.

19. (Original) The method of claim 9, wherein routing the RF signal further comprises:
routing the RF signal through a third wireless communication station and then to the second remote wireless communication station.

20. (Original) A method of transmitting a wireless communication signal comprising:
receiving a RF signal at an antenna of a first remote wireless communication station;
processing the RF signal by a base station at the first remote wireless communication station;
routing the processed RF signal through a network of remote wireless communication stations to a second remote wireless communication station; and

transmitting a processed RF signal from the antenna of the first remote wireless communication station.

21. (Original) The method of claim 20, wherein the RF signal is transported using a protocol that is compliant with IEEE 802.16.

22. (Original) The method of claim 20, wherein transmitting further comprises:
transmitting the processed RF signal to a mobile device.

23. (Original) The method of claim 20, wherein receiving the RF signal receives the RF signal via an antenna at the first remote wireless communication station.

24. (Original) The method of claim 20, further comprising:
sending the RF signal from a local base station to the first remote wireless communication station.

25~~24~~. (Currently Amended) A remote wireless communication station for transmitting high speed wireless data comprising:
a remote unit;
a router coupled to the remote unit; and
an antenna coupled to the remote unit.

26~~25~~. (Currently Amended) The remote wireless communication station of claim 25~~24~~, wherein the remote unit is configured to transmit data using a protocol compliant with IEEE 802.16.

27~~26~~. (Currently Amended) The remote wireless communication station of claim 25~~24~~, further comprising:
a baseband unit; and

wherein the remote unit is coupled to the baseband unit and is configured as a base station.

CONCLUSION

The claims as originally presented contained an error in numbering. As a result, original claims 24-26 have been renumbered to 25-27 in order to correct the typographical errors and do not represent any new matter. Claims 1-27 are currently pending in this application.

If the Examiner has any questions or concerns regarding this application, please contact the undersigned at 612-332-4720.

Respectfully submitted,

Date: April 18, 2007

/David N. Fogg/
David N. Fogg
Reg. No. 35138

Attorneys for Applicant
Fogg & Powers LLC
P.O. Box 581339
Minneapolis, MN 55458-1339
T – (612) 332-4720
F – (612) 332-4731

Electronic Patent Application Fee Transmittal

Application Number:	11627255
Filing Date:	25-Jan-2007
Title of Invention:	DISTRIBUTED REMOTE BASE STATION SYSTEM
First Named Inventor/Applicant Name:	Robert Koziy
Filer:	David Fogg/Lisa Gentry
Attorney Docket Number:	100.829US01
Filed as Large Entity	

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	300	300
Utility Search Fee	1111	1	500	500
Utility Examination Fee	1311	1	200	200
Pages:				
Claims:				
Claims in excess of 20	1202	7	50	350
Independent claims in excess of 3	1201	1	200	200
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Late filing fee for oath or declaration	1051	1	130	130
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1680**

Electronic Acknowledgement Receipt

EFS ID:	1692446
Application Number:	11627255
International Application Number:	
Confirmation Number:	1589
Title of Invention:	DISTRIBUTED REMOTE BASE STATION SYSTEM
First Named Inventor/Applicant Name:	Robert Koziy
Customer Number:	34206
Filer:	David Fogg/Lisa Gentry
Filer Authorized By:	David Fogg
Attorney Docket Number:	100.829US01
Receipt Date:	18-APR-2007
Filing Date:	25-JAN-2007
Time Stamp:	11:40:09
Application Type:	Utility

Payment information:

Submitted with Payment	yes
Payment was successfully received in RAM	$1680
RAM confirmation Number	1582
Deposit Account	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)

1	Miscellaneous Incoming Letter	00093073.pdf	62114	no	1
Warnings:					
Information:					
2	Oath or Declaration filed	00093031.pdf	92971	no	2
Warnings:					
Information:					
3		00093076.pdf	79623	yes	7

Multipart Description/PDF files in .zip description

Document Description	Start	End
Preliminary Amendment	1	1
Claims	2	6
Applicant Arguments/Remarks Made in an Amendment	7	7

Warnings:					
Information:					
4	Fee Worksheet (PTO-06)	fee-info.pdf	8731	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	243439	

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Applicants	Robert J. Koziy	COMMUNICATION RE: MISSING PARTS
Serial No.	11/627,255	
Filing Date	1/25/2007	
Group Art Unit	Unknown	
Confirmation No.	1589	
Examiner Name	Unknown	
Attorney Docket No.	100.829US01	
Title: A DISTRIBUTED REMOTE BASE STATION SYSTEM		

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450

In response to the Notice to File Missing Parts of Provisional Application mailed February 21, 2007, Applicant submits herewith the signed Declaration and Power of Attorney of the inventors. Payment of the filing fees totaling $1680 ($300 for the filing fee, $350 for 7 additional claims over 20, $200 for one additional independent claim, $500 for the search fee, and $200 for the examination fee, including the Missing Parts $130 surcharge) is being made by credit card.

It is believed that no further fees are due in connection with this communication. However, the Office is authorized to charge any additional fees or credit any overpayments to Deposit Account No. 502432.

If the Examiner has any questions or concerns regarding this application, please contact the undersigned at 612-332-4720.

Respectfully submitted,

Date: April 18, 2007

/David N. Fogg/
David N. Fogg
Reg. No. 35138

Attorneys for Applicant
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United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

	Declaration Submitted with Initial Filing	Or	X	Declaration Submitted After Initial Filing (surcharge 37 CFR 1.16(e) required)	Atty. Docket No. 100.829US01
					First Named Inventor: Robert J. Koziy

As below named inventor(s), we declare that:
Our citizenship(s) are as stated below next to our name(s). We believe that we are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **A DISTRIBUTED REMOTE BASE STATION SYSTEM.**

This declaration is directed to Application Number 11/627,255, filed on 1/25/2007, as amended on _____.

We hereby state that we have reviewed and understand the contents of the above-identified application, including the claims as amended and by any amendment specifically referred to above.

We acknowledge the duty to disclose information that is material to patentability as defined in 37 C.F.R. 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

We claim foreign priority benefits under 35 U.S.C. § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached

As named inventor(s), we appoint the registered practitioners associated with Fogg & Powers, LLC

at Customer Number(s) **34206**

to prosecute this application and to transact all business in the United States Patent and Trademark Office connected herewith, with full right of substitution.

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We declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further |that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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APPLICATION NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
11/627,255	01/25/2007	Robert Koziy	100.829US01

CONFIRMATION NO. 1589

34206
FOGG & POWERS LLC
10 SOUTH FIFTH STREET
SUITE 1000
MINNEAPOLIS, MN 55402

FORMALITIES LETTER

Date Mailed: 02/21/2007

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  Applicant must submit $ **300** *to complete the basic filing fee for a non-small entity. If appropriate, applicant may make a written assertion of entitlement to small entity status and pay the small entity filing fee (37 CFR 1.27).*
- The oath or declaration is missing. *A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.*
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Additional claim fees of **$550** as a non-small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- To avoid abandonment, a surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $130 for a non-small entity, must be submitted with the missing items identified in this letter.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$1680** for a non-small entity

- **$300** Statutory basic filing fee.
- **$130** Surcharge.

- The application search fee has not been paid. Applicant must submit **$500** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit **$200** to complete the examination fee for a non-small entity.

- Total additional claim fee(s) for this application is **$550**

  - **$200** for **1** independent claims over 3.
  - **$350** for **7** total claims over 20.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	DRAWINGS	TOT CLAIMS	IND CLAIMS
11/627,255	01/25/2007	2611	0.00	100.829US01	9	27	4

CONFIRMATION NO. 1589

FILING RECEIPT

34206
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Date Mailed: 02/21/2007

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please mail to the Commissioner for Patents P.O. Box 1450 Alexandria Va 22313-1450. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).**

Applicant(s)

Robert Koziy, Burnsville, MN;
Harold Roberts, Eden Prairie, MN;
Todd Schieffert, Edina, MN;

Assignment For Published Patent Application

ADC Telecommunications, Inc., Eden Prairie, MN

Power of Attorney: None

Domestic Priority data as claimed by applicant

Foreign Applications

If Required, Foreign Filing License Granted: 02/20/2007

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US11/627,255**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No

Title

DISTRIBUTED REMOTE BASE STATION SYSTEM

Preliminary Class

375

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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A DISTRIBUTED REMOTE BASE STATION SYSTEM

RELATED APPLICATIONS

[0001] This application is related to the following commonly assigned applications filed on even date herewith, each of which is hereby incorporated herein by reference:

[0002] U.S. Patent Application Serial No. __/___,___ (Attorney Docket No. 100.828US01), entitled "MODULAR WIRELESS COMMUNICATIONS PLATFORM" (the '828 Application).

BACKGROUND

[0003] Traditional wireless communication systems may have distributed antennas to expand the range of a centralized base station. Any signals received by the distributed antennas must be sent back to the centralized base station for processing regardless of where the ultimate destination of the signal is located. This causes unneeded transmission of signals and results in increased latencies for users of the system. Additionally, each remote antenna is required to share capacity with every other antenna connected to the centralized base station. This causes unacceptable disruption of services for some users of the system.

[0004] For the reasons stated above, and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for a distributed antenna system that effectively and efficiently processes wireless communication signals.

SUMMARY

[0005] The above-mentioned problems of current systems are addressed by embodiments of the present invention and will be understood by reading and studying the following specification. The following summary is made by way of example and not by way of limitation. It is merely provided to aid the reader in understanding some of the aspects of

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the invention. In one embodiment, a distributed base station system for high speed data transmission is disclosed. The system includes a plurality of remote antennas, each antenna being coupled to a router. The plurality of remote antennas is coupled to each other and is arranged into a network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The present invention can be more easily understood and further advantages and uses thereof more readily apparent, when considered in view of the detailed description and the following figures in which:

[0007] Figure 1 is an illustration of one embodiment of a system using a universal wireless communications platform;

[0008] Figure 2 illustrates a schematic view of one embodiment of a host unit for use in the system of Figure 1;

[0009] Figure 3 illustrates a schematic view of one embodiment of a remote unit for use in the system of Figure 1;

[0010] Figure 4 illustrates a schematic view of one embodiment of a DART module for using in either the host unit of Figure 2 or the remote unit of Figure 3;

[0011] Figure 5 illustrates a schematic view of one embodiment of a SeRF communicator for use in either the host unit of Figure 2 or the remote unit of Figure 3;

[0012] Figure 6 illustrates another configuration of the system of Figure 1;

[0013] Figure 7 illustrates yet another configuration of the system of Figure 1;

[0014] Figure 8 illustrates one embodiment of a distributed base station system; and

[0015] Figure 9 illustrates another embodiment of a distributed base station system.

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[0016] In accordance with common practice, the various described features are not drawn to scale but are drawn to emphasize specific features relevant to the present invention. Reference characters denote like elements throughout Figures and text.

DETAILED DESCRIPTION

[0017] In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific illustrative embodiments in which the device may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

[0018] The present apparatus is a modular wireless platform that enables a system facilitator to easily and inexpensively adapt their wireless system for use with different data transport mechanisms, frequency bands, communication technologies, and intelligence distribution. This modular platform is made up of a reconfigurable host unit and a reconfigurable remote unit designed for use in a system with a central node and a plurality of distributed antennas. The host unit is located near the central node and facilitates transmission/reception of information to/from the remote units which are located remotely with an accompanying antenna. The remote units function to transmit/receive transmissions from the host unit and transmit/receive wireless signals over accompanying antenna to mobile costumers.

[0019] Host unit and remote unit have a modular design and defined interfaces that allow components to be removed and installed to adapt to the needs of the service providers. Both host and remote unit are designed around a serial radio frequency (SeRF) communicator and have a defined interface where different varieties of digital to analog radio frequency transceiver (DART) modules can be connected and disconnected. There are many different DART modules, and each DART module is designed for a particular

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technology and frequency band. Thus, technology and frequency band adjustments can be made by simply replacing the DART module in the host unit or remote unit. Additionally, host unit and remote unit are designed to allow different transport mechanisms between the host unit and remote unit. For example, the same host unit and remote unit that use fiber optic for inter-unit transmission can be adapted to use E Band wireless transmission instead of or concurrently with the fiber optic. Finally, wireless processing functionality can be placed all on a base station near the central node, or the functionality can be distributed throughout each of the remote units. The flexibility to modify the functionality of each remote unit allows the wireless platform to support centralized base stations and distributed base stations, either separately or concurrently.

[0020] Figure 1 is a block diagram of one embodiment of a system 100 using a modular wireless communications platform. System 100 is a field configurable distributed antenna system (DAS) that provides bidirectional transport of a fixed portion of RF spectrum from an Internet Protocol (IP) gateway 101 to a remote antenna 108. Along with IP gateway 101 and remote antenna 108, system 100 includes a base station 103, a host unit 102, a transport mechanism 104, and a remote unit 106. Host unit 102, a modular host transceiver and remote unit 106, a modular remote radio head, work together to transmit and receive data to/from remote antennas. In this embodiment, host unit 102 provides the interface between a base station 101 a signal transport mechanism 104. Remote unit 106 provides the interface between transport mechanism 104 and a remote antenna 108. In this embodiment, signal transport mechanism 104 is an optical fiber, and host unit 102 sends optical signals through the optical fiber to remote unit 106.

[0021] In the transmission direction of transport, base station 103 performs baseband processing on IP data from IP gateway and places the IP data onto a channel. In one embodiment base station 103 is an IEEE 802.16 compliant base station. Optionally, base station 103 may also meet the requirements of WiMax, WiBro, or a similar consortium. In another embodiment, base station 103 is an 800MHz or 1900MHz base station. In yet another embodiment, the system is a cellular/PCS system and base station 103 communicates with a base station controller. In still another embodiment, base station 103 communicates with a voice/PSTN gateway. Base station 103 also creates the

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protocol and modulation type for the channel. Base station 103 then converts the IP packetized data into an analog RF signal for transmission over antenna 108. Base station 103 sends the RF signal to host unit 102. Host unit 102 converts the RF signal for long distance high speed transmission over transport mechanism 104. Host unit 102 sends the signal over transport mechanism 104, and the signal is received by remote unit 106. Remote unit 106 converts the received signal back into an RF signal and transmits the signal over antenna 108 to consumer mobile devices.

[0022] Figure 2 illustrates a schematic diagram of one embodiment of a host unit 102 for use in a modular wireless communications platform. Host unit 102 has a serial radio frequency (SeRF) communicator 202 that is coupled to a digital to analog radio frequency transceiver (DART) interface 204. DART interface 204 has a plurality of DART connectors each of which is configured to receive a pluggable DART module 208. Further, DART connectors are configured to connect DART module 208 to SeRF communicator 202. DART interface 204 is a common interface that is configured to allow communication between SeRF communicator 202 and different varieties of DART modules 208. Additionally, DART interface 204 allows multiple DART modules 208, 210, 212 to connect to a single SeRF communicator 202. In this embodiment, DART interface 204 is a passive host backplane to which SeRF communicator 202 also connects. In this embodiment, DART interface 204 has eight DART connectors for a DART module 208. In another embodiment, instead of being a host backplane, DART interface 204 is integrated with SeRF communicator 202.

[0023] DART modules 208, 210, 212 provide bi-directional conversion to/from analog RF signals from/to digital sampled RF. In one direction of communication, DART module 208 receives an incoming analog RF signal from base station 103 and converts the analog signal to a digital signal for use by SeRF communicator 202. In the other direction DART modules 208, 210, 212 receive digital sampled RF data from SeRF communicator 202 and convert the data to analog RF for use by base station 103.

[0024] Each DART module 208, 210, 212 has a common communication interface for communication with SeRF communicator 202, and a RF processing portion that is exclusive to one frequency band and communication technology. Each DART module

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208, 210, 212, therefore, converts to/from one analog RF to the digital signal used by SeRF communicator. For example, DART module 208 is designed to transmit 850 MHz cellular transmissions. As another example, DART module 210 transmits 1900 MHz PCS signals. Some of the other options for DART modules 208, 210, 212 include Nextel 800 band, Nextel 900 band, PCS full band, PCS half band, BRS, WiMax, and the European GSM 900, DCS 1800, and UMTS 2100. By allowing different varieties of DART modules 208, 210, 212 to be plugged into DART interface 206, host unit 102 is configurable to any of the above frequency bands and technologies as well as any new technologies or frequency bands that are developed. Host unit 102, once installed, is field configurable to transmit a variety desired by insertion of a different DART module. Additionally, since SeRF communicator 202 is configured to communicate with multiple different DART modules 208, 210, 212, a single host unit 102 can transmit/receive multiple frequency bands or technologies.

[0025] SeRF communicator 202 provides bi-directional conversion to/from a SeRF stream from/to a high speed optical serial data stream. In one direction, SeRF communicator 202 receives incoming SeRF streams from DART modules 208, 210, 212 and sends a serial optical data stream over transport mechanism 104 to remote unit 106. In the other direction, SeRF communicator 202 receives an optical serial data stream from a remote unit 106 and provides SeRF streams to DART modules 208, 210, 212. In one embodiment, the SeRF stream between DART module 208 and SeRF communicator is a parallel stream. In another embodiment, SeRF stream is a serial data stream.

[0026] SeRF communicator 202 also allows multiple DART modules 208, 210, 212 to operate in parallel. SeRF communicator 202 actively multiplexes the signals from each DART module 208, 210, 212 such that they are sent simultaneously over a single transport mechanism 104. To accomplish this, SeRF communicator 202 re-clocks each DART module 208, 210, 212 to ensure synchronization.

[0027] In one embodiment, an optical multiplex module 214 is optically coupled to SeRF communicator 202. Optical multiplex module 214 performs multiplexing/de-multiplexing of an optical serial data stream to/from SeRF communicator 202 over

transport mechanism 104. In this embodiment, optical multiplex module 214 performs wavelength division multiplexing.

[0028] In another embodiment, transport mechanism 104 is a wireless millimeter wave signal transceiver (e.g. E Band/70GHz radio). In this embodiment, host unit 102 sends optical signals to the millimeter wave transceiver which converts the optical signals into millimeter waves and transmits the millimeter waves to a similar millimeter wave transceiver connected to remote unit 106. In yet another embodiment, transport mechanism 104 is a microwave radio transceiver. In still another embodiment, transport mechanism 104 is a T1 connection for transmission of IP data.

[0029] Figure 3 is a schematic diagram of one embodiment of a remote unit 106 for use in a modular wireless communications platform. Remote unit 106 has a SeRF communicator 302, a SeRF interface 304, at least one DART interface 306. In this embodiment, DART modules 308, 309, 311, power amplified 310, duplexer/linear amplifier 312, and optical multiplex module 314 are all installed in remote unit 106 which is connected to antenna 108.

[0030] SeRF communicator 302 is designed and performs similar to SeRF communicator 202 of host unit 102. Likewise, DART modules 308, 309, 311 have the same features and design options as DART modules 208, 210, 212 of host unit 102. There is a slight difference from host unit 102, however, in the manner in which SeRF communicator 302 and DART modules 308, 309, 311 are connected. In this embodiment of remote unit 106, SeRF communicator 302 has a SeRF interface 304 which is used to link SeRF communicator to SeRF cables 305. SeRF cables 305 are used to allow DART modules 308, 309, 311 to be physically spaced from SeRF communicator 302 and from other DART modules. SeRF cables 305 connect to DART interface 306. DART modules 308 connected to DART interface 306 and communicate with SeRF communicator 302 through DART interface 306 over SeRF cables 305 and through SeRF interface 304. In another embodiment, SeRF interface 304, and SeRF cables 305 are eliminated and DART interface 306 is integrated into SeRF communicator 302.

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[0031] DART modules 308 perform similar to DART module 208, except the ultimate destination/origination of the signals to/from DART modules 308 is antenna 108 and not base station 101 as in host unit 102. Optical multiplex module 314 also performs similarly to optical multiplex module 214 of host unit 102.

[0032] In the transmission direction, once a signal is converted to analog RF by DART module 308, the signal is sent through RF interface 322 (explained below) to power amplifier 310. Power amplifier 310 amplifies the RF signal received from DART module 308 for output through duplexer/linear amplifier 312 to antenna 108. Similar to DART modules 308, 309, 311, power amplifier 310 is designed for a certain frequency band and technology. Power amplifier 310 is, therefore, removable and is plugged into a power amplifier connector on remote unit 106 which is configured to receive power amplifier 310. Power amplifier connector is configured to couple power amplifier to duplexer/linear amplifier 312 and to DART module 308. Power amplifier 310 also has an alarm and control line that is connected to DART interface 306 for communication to SeRF communicator 302.

[0033] Once the signal is amplified by power amplifier 310, duplexer/linear amplifier 312 provides duplexing of the signal which is necessary to connect transmit and receive signals to a common antenna. Duplexer/linear amplifier 312 also provides low noise amplification of received signals and rms power detection of incident and reflected RF power in transmission signal. Similar to DART modules 308, 309, 311 and power amplifier 310, duplexer/linear amplifier 312 is frequency band and technology specific, and is removable. Duplexer/linear amplifier 312 plugs into a connector in remote unit 106 configured to receive duplexer/linear amplifier 312. Furthermore, the connector is configured to couple duplexer/linear amplifier 312 to power amplifier 310 and to antenna 108. Duplexer/linear amplifier 312 also has a control and alarm line that is connected to DART interface 320 for communication to SeRF communicator 302. In this embodiment, the frequency band and technology allow use of a single power amplifier 310 and duplexer/linear amplifier 318 by both DART module 308 and DART module 309. In this embodiment, a RF interface 322 is placed between power amplifier 310, duplexer/linear amplifier 312 and DART modules 308, 309. RF interface 322 provides

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RF splitting/combining of the RF transmit and receive signals necessary to allow connection of two DART modules 308, 309 to a single power amplifier 310 and duplexer/linear amplifier 312.

[0034] Figure 4 shows a schematic view of one embodiment of a DART module 400 for use in either host unit 102 or remote unit 106. There are multiple embodiments of DART module 400 as described above, however, the common elements are described hereafter. DART module 400 has an edge connector 402 for connection to a DART interface. DART module 400 has two main signal paths; a transmission path 404 and a reception path 406. For signals received from a SeRF communicator, DART module 400 forms parallel digital RF data from the incoming SeRF stream, if needed, at FPGA 403. In this embodiment, FPGA 403 is a logic device that is programmed to convert serial digital data into RF sampled data and programmed to convert RF sampled data into serial digital data. DART module 400 then converts the digital signal to analog with digital to analog converter (DAC) 408. Transmission path 404 continues as DART module 400 filters, amplifies and up-converts the analog signal for RF transmission with an assortment of filters 410, amplifiers 412, an oscillator 414, and an attenuator 416. The transmission path exits DART module 400 at an SMA connector 420. The signals travel in the opposite direction down reception path 406, where they are converted from analog to digital and sent to a SeRF communicator. First signals are received at SMA connector 420. DART module 400 then amplifies, down-converts, filters the incoming RF signal with a plurality of filters 410, amplifiers 412, oscillators 414, and attenuators 416. DART module 400 then digitizes the signal with analog to digital converter 422. FPGA 403 then forms a SeRF stream and provides the SeRF stream as parallel digital RF sampled data to a SeRF communicator.

[0035] Figure 5 illustrates a schematic view of one embodiment of a SeRF communicator 500 for use in either host unit 102 or remote unit 106. Serial radio frequency communicator 500 has a plurality of optical input/outputs 502, a clock 504, a field programmable gate array (FPGA) 506, a plurality of DART links 508, and a processor 510. In this embodiment, SeRF communicator 500 has eight (8) optical input/outputs 502. Optical input/outputs 502 connect to optical fiber which is used as a transport

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mechanism, or optical fiber that links SeRF communicator 500 to an optical multiplexer or a millimeter waver or microwave transceiver. Optical input/outputs 502 receiver high speed serial data transmission from another SeRF communicator. In addition, optical input/outputs 502 receive Open Base Station Architecture (OBSAI) protocol data from a baseband unit. In one embodiment, to aid in the ability of optical input/outputs 502 to receive multiple data formats, the signals received from optical input/outputs 502 are transmitted at the same frequency which is set to match the OBSAI protocol. Also, OBSAI data is stripped at the data link layer with a 8B/10B encoder to provide a good ones and zeros balance and remove approximately 20 percent of the OBSAID overhead. Finally, 16-bit filler words are used to provide a 24/25^{ths} transport ratio and match a 2.94 GBps transport speed to enable transport of OBSAI or SeRF data. The OBSAI protocol data is explained in more detail below with reference to Figure 6. Optical input/outputs 206, also conform to the optical small form-factor pluggable multi-source agreement. Alternatively, any frequency of signal or shape of connector could be used as is known in the art. SeRF communicator 500 has eight (8) optical input/outputs and DART links 508 for 8 separate DART modules which transmit RF sampled data to/from DART modules.

[0036] In one embodiment, DART links 508 and corresponding connectors on a DART interface carry 6 slots of digitized RF payload for reading and writing DART FPGA registers from SeRF FGPA 506. Each slot consists of 16 bits: 15 bits of digitized RF and 1 overhead bit used to transfer FPGA register data. The slots are framed in groups of 6 16-bit words, with each slot repeating at the sampling rate of 15.36M samples per second. A "superframe" of 32 frames encapsulates the data payload and provides synchronization. Thus, in this embodiment DART links 508 are16-bit parallel data streams. In another embodiment, DART links 508 are serial. FPGA 506 has eight SERDES to serializer and deserializers each data stream. Thus, there is one SERDES for each DART link 508 and optical input/output 502.

[0037] In one direction, SeRF communicator 500 receives incoming SeRF streams over DART links 508 from DART modules, assembles data frames, and sends an outgoing optical serial data stream through optical input/outputs 502. In the other direction, SeRF communicator 500 receives an optical serial data stream from another SeRF

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communicator at optical input/outputs 502. SeRF communicator 500 then disassembles the frames of the serial data stream, and provides SeRF streams over DART links 508 to DART modules. SeRF communicator 500 also performs splitting and summing for digital simulcast, and provides a user interface for alarm, status, or configuration management. SeRF communicator 500 also provides bi-directional conversion to/from OBSAI protocol data received at optical input/outputs 502 from/to RF sampled data for DART modules. Additionally, SeRF communicator 500 has at least one RJ-45 connector 216 for receiving IP packets. In one embodiment, RJ-45 connector 216 supports Gigabit Ethernet.

[0038] Along with being configurable to communicate on different frequency band/sub-bands and with different technologies, host unit 102 and remote unit 106 are configurable to perform more or less of the wireless processing of the RF signal. Host unit 102 and remote unit 106 are configurable into three different functional configurations. The first configuration is illustrated in Figure 1 and has host unit 101 and remote unit 106 functioning as a range extender for base station 101. In this configuration, backhaul data is transmitted between host unit 102 and remote unit 106. The second configuration is illustrated in Figure 6, and has fronthaul data transmitted between host unit 102 and remote unit 106. In this configuration remote unit 106 performs the functionality of a base station. The third configuration is illustrated in Figure 7 and has 'midhaul' data transmission between host unit 102 and remote unit 106. In this embodiment, 'midhaul' data refers to OBSAI protocol data or similar partially processed wireless signals. Each of the three configurations will now be explained in further detail.

[0039] Referring back to Figure 1, system 100 shows one configuration for connection of host unit 102 and remote unit 106 in which remote unit 106 functions as a range extender. In this option, base station 103 contains all necessary components to convert IP packets received from an Internet gateway into an analog bit stream for transmission over antenna 108. Except for needed amplification, the signal is ready for transmission over antenna 108 once sent by base station 103. Host device 102 and remote device 106 do not perform any further processing on the data except what is required to send and receive the data over long range transmission. Host unit 102 contains the components as

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illustrated in Figure 2 and receives the analog signal from base station 103 at the DART module matching the analog signal frequency band and technology. Host unit 102 converts the signal and transmits the data over transport mechanism 104. Remote unit 106 contains the components as shown in Figure 3. Remote unit 106 receives the signal from transport mechanism 104 and sends the data to the DART module matching the frequency band and technology. The signal is then converted and transmitted over antenna 108 to mobile users.

[0040] Figure 6 shows another configuration of a system 100 where base station functionality is performed at remote unit 106. This configuration provides increased capacity to a network of antennas by allowing each remote unit 106 to function as a base station. In this embodiment of system 100, IP data is not processed by a base station before sending to remote unit 106. Instead IP data is received at host unit 102 directly from IP gateway 101. IP data is received at an RJ-45 connector on SeRF communicator 202 of host unit 102. In this configuration, therefore, the signal does not travel through DART module 208, 210, 212 of host unit 102. The IP data is converted to a serial optical stream and transmitted over transport mechanism 104 to remote unit 106. Remote unit 106 receives the IP data at SeRF communicator 302.

[0041] Remote Unit 106, in this embodiment, has a baseband unit 602 which is connected to a slot of DART interface 306. In this configuration, baseband unit 602 is in fact a remote WiMax base station which replaces the functionality of base station 103 in the first configuration. SeRF communicator 302 converts the packetized optical data received into 25-75 Mbps data and sends the data over to baseband unit 602. Baseband unit 602 performs baseband processing to put the IP data onto a channel. Baseband unit 602 also creates the protocol and modulation type for the channel. Baseband unit 602 then converts the data to match the OBSAI protocol. This OBSAI data is sent back into an optical input/output 502 of SeRF communicator 302. SeRF communicator 302 uses software to convert the OBSAI protocol data into digital RF sampled data and sends the digital RF data to DART module 308 for transmission over antenna 108. In another embodiment, baseband unit 602 converts IP data to/from common public radio interface (CPRI). Alternatively, any digital baseband protocol, including standard and proprietary

protocols, or any software defined radio interface could be used by baseband unit 602 and SeRF communicator 302.

[0042] Figure 7 illustrates yet another configuration of a system 100 in which remote unit 106 performs the functionality of a base station, and the baseband processing is performed prior to transmission by host unit 102. In this embodiment, IP data is received at a baseband unit 702 which converts the IP data into data conforming to the OBSAI protocol. Alternatively, any of the protocols listed with respect to Figure 6 could be used. The OBSAI protocol data is sent to host unit 102 and OBSAI protocol data is transmitted over transport mechanism 104. In another embodiment, the OBSAI conversion is done in SeRF 202 of host unit 102 before the serial data is transmitted to remote unit 106. Here again, DART module 208 is not used at host unit 102, since the data has not been converted to RF yet. The OBSAI protocol data is received by remote device 106 at SeRF communicator 302. SeRF communicator 302 converts the OBSAI protocol data into digital RF sampled data and interfaces with DART 308. DART 308 converts the data to analog RF and the signal is sent over antenna 108.

[0043] Since host unit 102 and remote unit 106 have multiple input/outputs and can have multiple types of DART modules connected to each, host unit 102 and remote unit 106 are configured to multiplex different functional configurations through different input/outputs simultaneously. Thus, in one embodiment, a first input/output of host unit 102 and remote unit 106 function as a range extender for a base station. A second input/output of host unit 102 and remote unit 106 function to transmit 'midhaul' data. At the same time a third input/output of host unit 102 and remote unit 106 functions to transmit fronthaul data and remote unit 106 performs baseband processing upon the data.

[0044] The modular design of modular wireless communications protocol allows many different combinations of transport mechanisms, frequency bands, communication technologies, and processing functionality to operate simultaneously on the same host unit and remote unit.

[0045] Placing a base station at a remote wireless communication stations such as described with the configuration of Figure 6 allows service providers to set up a

distributed base station system. Figure 8 illustrates one embodiment of a distributed base station system 800. System 800 has a central node 801 having an IP gateway and a plurality of remote wireless communication stations 802, 804, 806, 808, 810, 812. Each remote station 802, 804, 806, 808, 810, 812 includes a remote unit 814, 816, 818, 820, 822, 824, an antenna 826, and a router 828. In this embodiment, remote unit 818 and remote unit 820 are configured into a WiMax compatible base station. In another embodiment, all remote units 814, 816, 818, 820, 822, 824 are configured into PCS cellular base stations. Alternatively, any number of remote units 814, 816, 818, 820, 822, 824 could be configured into a base station for any of the technology or frequency bands described with respect to system 100. Each remote station 802, 804, 806, 808, 810, 812 functions similarly, except that they will vary based on the configuration of their respective remote unit 814, 816, 818, 820, 822, 824.

[0046] Distributed base station system 800 has many advantages over traditional centralized base station systems. For example, remote stations 806, 806 which are equipped with a base station do not need to transmit signals back to central node 801 for base station processing. Instead, when an RF signal is received via antenna 826 at remote station 806, for example, remote station 806 processes the RF signal with remote unit 818, which is configured as a base station. Processing the RF signal forms a second RF signal which is then routed toward the destination of the RF signal. In this embodiment, the RF signal received at remote unit 806 is from a first mobile device which is in communication with a second mobile device which is the destination of the second RF signal. In another embodiment, the RF signal is received from a fixed internet user and the destination of the second RF signal is on the internet via IP gateway at central node 801. In this embodiment, the second mobile device is within transmission range of remote station 812. Thus, after processing by remote unit 818 at remote station 806, routers 828 at remote stations 806, 810, 812 route the second RF signal through remote station 810 to remote station 812. Thus, distributed base station system 800 simplifies and speeds up the processing of wireless signals.

[0047] In addition, there are many other advantages of a distributed base station system. For example, since each remote station 802, 804, 806, 808, 810, 812 includes a router, a

best path is found to the from the origination remote station to the destination remote station. This decreases the latency of communication transmission, and also reduces unnecessary network traffic. In addition, in one embodiment where each remote station 802, 804, 806, 808, 810, 812 is equipped with a base station, each remote station 802, 804, 806, 808, 810, 812 obtains dedicated capacity to the system. Dedicated capacity refers the allocation of an unvarying amount of bandwidth to each remote station 802, 804, 806, 808, 810, 812. For example, in one embodiment, each remote station 802, 804, 806, 808, 810, 812 is allocated 25 Mbps of bandwidth. This is not possible in previous systems, because each remote station shares the capacity of a single central base station.

[0048] In one embodiment, remote stations 802, 804, 806, 808, 810, 812 are set up in a ring configuration as shown in Figure 8. The ring structure is advantageous, because a ring configuration allows multiple paths to be found to each remote station 802, 804, 806, 808, 810, 812. Thus, there are more options for a best path to be found to each remote device 802, 804, 806, 808, 810, 812, and congested areas are more easily avoided. In another embodiment, shown in Figure 9, remote stations 902, 904, 906, 908, 910, 912 are arranged into tree configurations. Tree configurations are advantageous, because they reduce the complexity of the network and the amount of communication links that must be established. Tree configurations, however, still provide reduced latencies by allowing signals to be routed through the local hubs (e.g. remote station 902 and 908) and not requiring transmission to central hub 901.

[0049] In yet another embodiment, a plurality of remote stations is set up in a daisy chain configuration. Alternatively, any combination of ring, tree, or daisy chain configurations could be used to network a plurality of remote stations.

[0050] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

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CLAIMS

What is claimed is:

1. A distributed base station system for high speed data transmission comprising:

a plurality of remote antennas, each antenna being coupled to a router;

wherein the plurality of remote antennas are coupled to each other and are arranged into a network.

2. The distributed base station system of claim 1, wherein the plurality of remote antennas are arranged in a tree configuration.

3. The distributed base station system of claim 1, wherein the plurality of remote antennas are arranged in a ring configuration.

4. The distributed base station system of claim 1, wherein at least one of the plurality of remote antennas is coupled to a remote base station.

5. The distributed base station system of claim 1, wherein each of the plurality of remote antennas is coupled to a remote base station.

6. The distributed base station system of claim 1, wherein the system transports data using a protocol that is compliant with IEEE 802.16.

7. The distributed base station system of claim 1, further comprising:

a fiber optic transport mechanism between two of the plurality of remote antennas.

8. The distributed base station system of claim 1, further comprising:

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a millimeter wave transceiver configured to transport data between two of the plurality of remote antennas.

9. A method of transmitting a wireless communication signal comprising:

receiving a RF signal at a first remote wireless communication station;

routing the RF signal to a second remote wireless communication station; and

transmitting the RF signal from an antenna at the second remote wireless communication station.

10. The method of claim 9, further comprising:

sending the RF signal from a local base station to the first remote wireless communication station.

11. The method of claim 9, wherein receiving the RF signal receives the RF signal via an antenna at the first remote wireless communication station.

12. The method of claim 11, further comprising:

processing the RF signal by a base station at the second remote wireless communication station to form a second RF signal; and

routing the second RF signal to a third remote wireless base station.

13. The method of claim 12, further comprising:

transmitting the second RF signal from an antenna of the third remote wireless base station.

14. The method of claim 9, further comprising:

splitting the RF signal and sending a duplicate RF signal to a third remote wireless communication station; and

transmitting the duplicate RF signal from an antenna at the third remote wireless communication station.

15. The method of claim 9, further comprising:

sending the RF signal from a host unit to the first wireless communication station.

16. The method of claim 9, wherein transmitting further comprises:

transmitting the RF signal to a mobile device.

17. The method of claim 9, further comprising:

processing the RF signal by a base station at the first remote wireless communication station to form a second RF signal; and

transmitting the second RF signal from an antenna at the first remote wireless communication station.

18. The method of claim 9, wherein the RF signal is transported using a protocol that is compliant with IEEE 802.16.

19. The method of claim 9, wherein routing the RF signal further comprises:

routing the RF signal through a third wireless communication station and then to the second remote wireless communication station.

20. A method of transmitting a wireless communication signal comprising:

receiving a RF signal at an antenna of a first remote wireless communication station;

processing the RF signal by a base station at the first remote wireless communication station;

routing the processed RF signal through a network of remote wireless communication stations to a second remote wireless communication station; and

transmitting a processed RF signal from the antenna of the first remote wireless communication station.

21. The method of claim 20, wherein the RF signal is transported using a protocol that is compliant with IEEE 802.16.

22. The method of claim 20, wherein transmitting further comprises:
transmitting the processed RF signal to a mobile device.

23. The method of claim 20, wherein receiving the RF signal receives the RF signal via an antenna at the first remote wireless communication station.

24. The method of claim 20, further comprising:
sending the RF signal from a local base station to the first remote wireless communication station.

24. A remote wireless communication station for transmitting high speed wireless data comprising:
a remote unit;
a router coupled to the remote unit; and
an antenna coupled to the remote unit.

25. The remote wireless communication station of claim 24, wherein the remote unit is configured to transmit data using a protocol compliant with IEEE 802.16.

26. The remote wireless communication station of claim 24, further comprising:
a baseband unit; and
wherein the remote unit is coupled to the baseband unit and is configured as a base station.

ABSTRACT

A distributed base station system for high speed data transmission is disclosed. The system includes a plurality of remote antennas, each antenna being coupled to a router. The plurality of remote antennas is coupled to each other and is arranged into a network.

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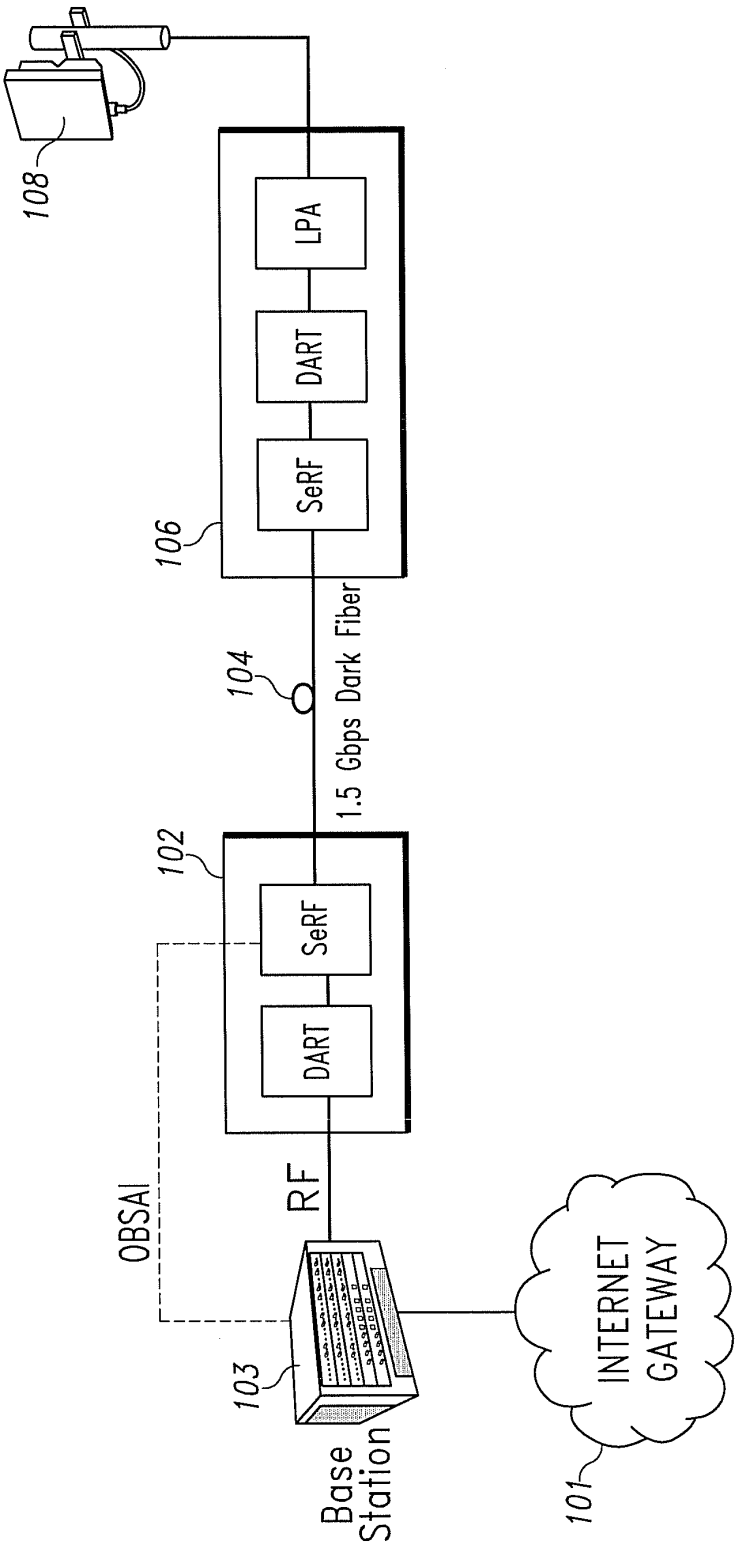

108
LPA
DART
SeRF
106
104
1.5 Gbps Dark Fiber
102
SeRF
DART
RF
OBSAI
103
Base Station
INTERNET GATEWAY
101

Fig. 1

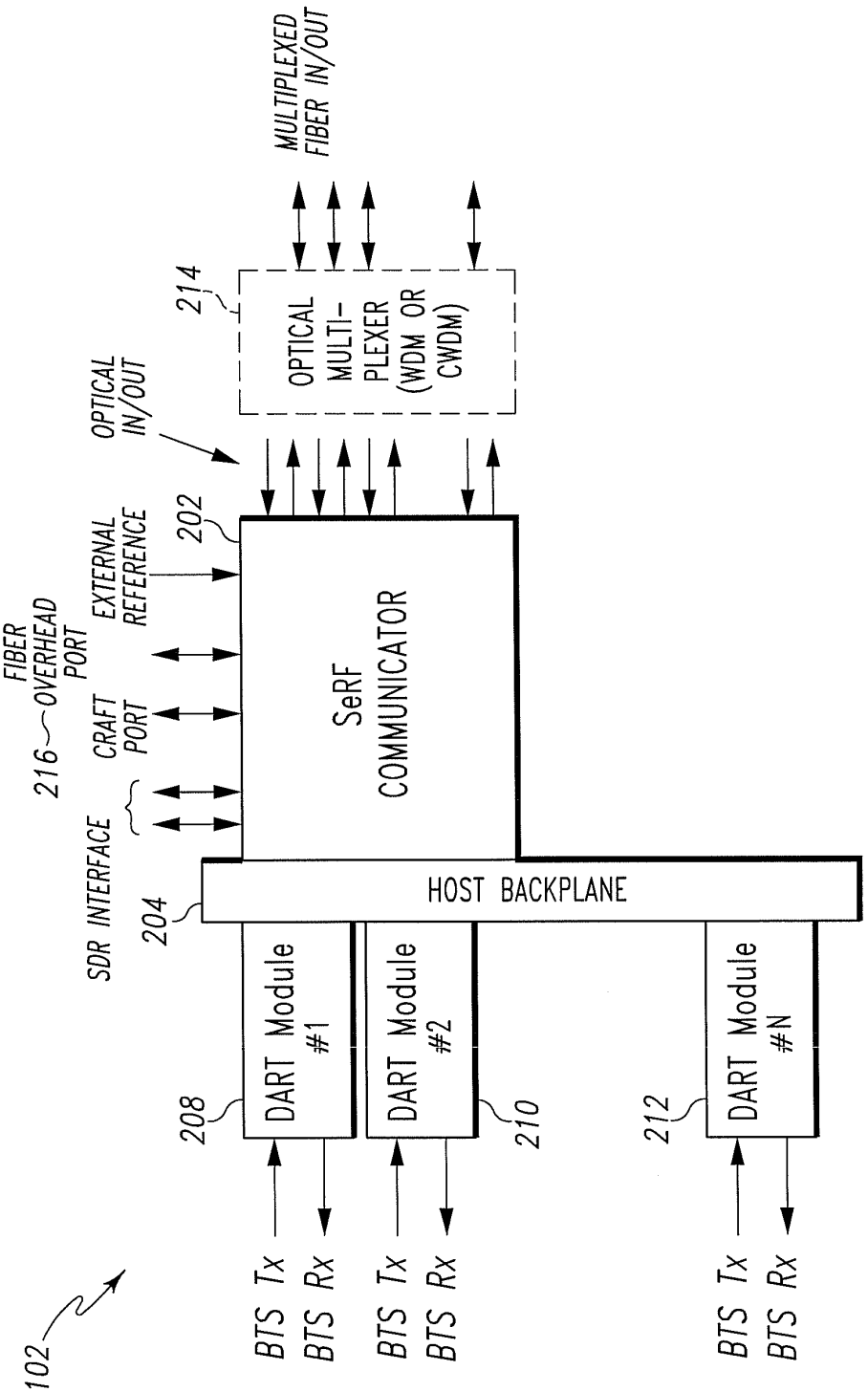

MULTIPLEXED FIBER IN/OUT
214
OPTICAL MULTI-PLEXER (WDM OR CWDM)
OPTICAL IN/OUT
202
EXTERNAL REFERENCE
FIBER OVERHEAD PORT
216
CRAFT PORT
SDR INTERFACE
204
SeRF COMMUNICATOR
HOST BACKPLANE
DART Module #1
DART Module #2
DART Module #N
208
210
212
BTS Tx
BTS Rx
BTS Tx
BTS Rx
BTS Tx
BTS Rx
102
HOST MODULARITY

Fig. 2

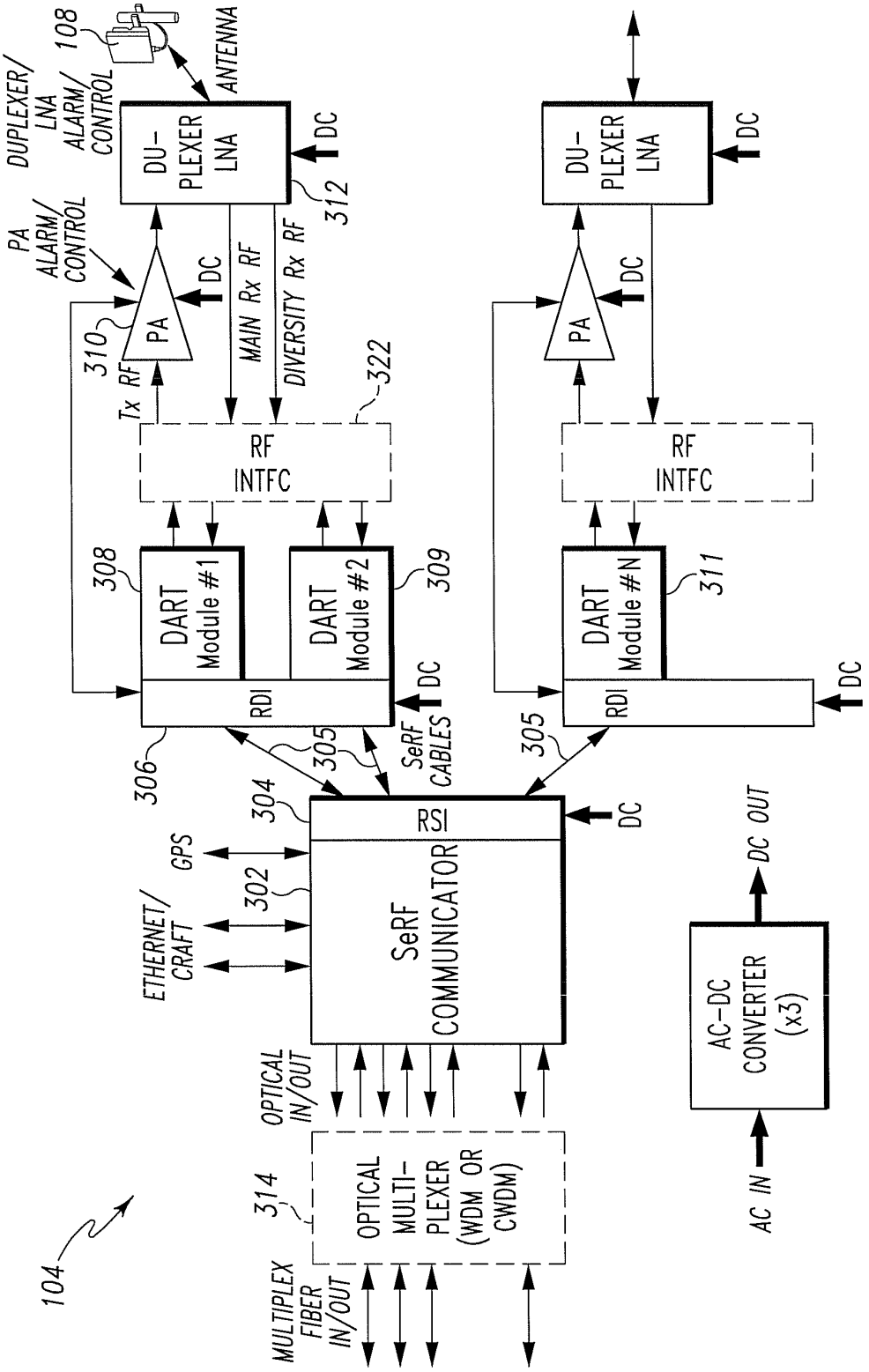

104
108
ANTENNA
DUPLEXER/ LNA ALARM/ CONTROL
DU- PLEXER LNA
DC
312
PA ALARM/ CONTROL
PA
310
Tx RF
MAIN Rx RF
DIVERSITY Rx RF
322
RF INTFC
DART Module #1
DART Module #2
DART Module #N
308
309
311
RDI
306
305
SeRF CABLES
304
RS
SeRF COMMUNICATOR
GPS
ETHERNET/ CRAFT
302
OPTICAL IN/OUT
314
OPTICAL MULTI- PLEXER (WDM OR CWDM)
MULTIPLEX FIBER IN/OUT
AC-DC CONVERTER (x3)
AC IN
DC OUT
REMOTE MODULARITY

Fig. 3

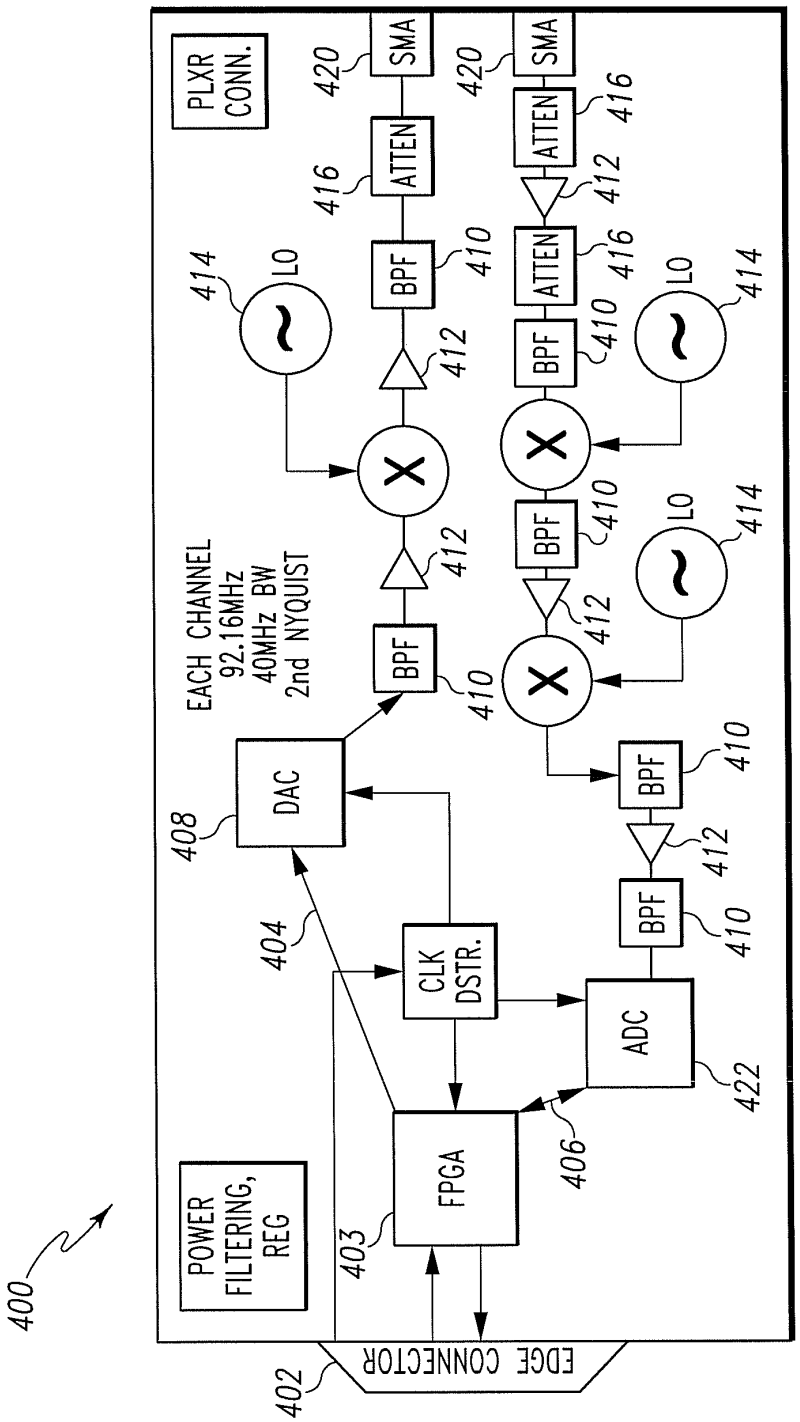

400
402
EDGE CONNECTOR
403
POWER FILTERING, REG
FPGA
406
CLK DSTR.
404
DAC
408
ADC
422
EACH CHANNEL
92.16MHz
40MHz BW
2nd NYQUIST
PLXR CONN.
BPF
410
ATTEN
412
LO
414
SMA
416
420
DART MODULE FUNCTIONALITY

Fig. 4

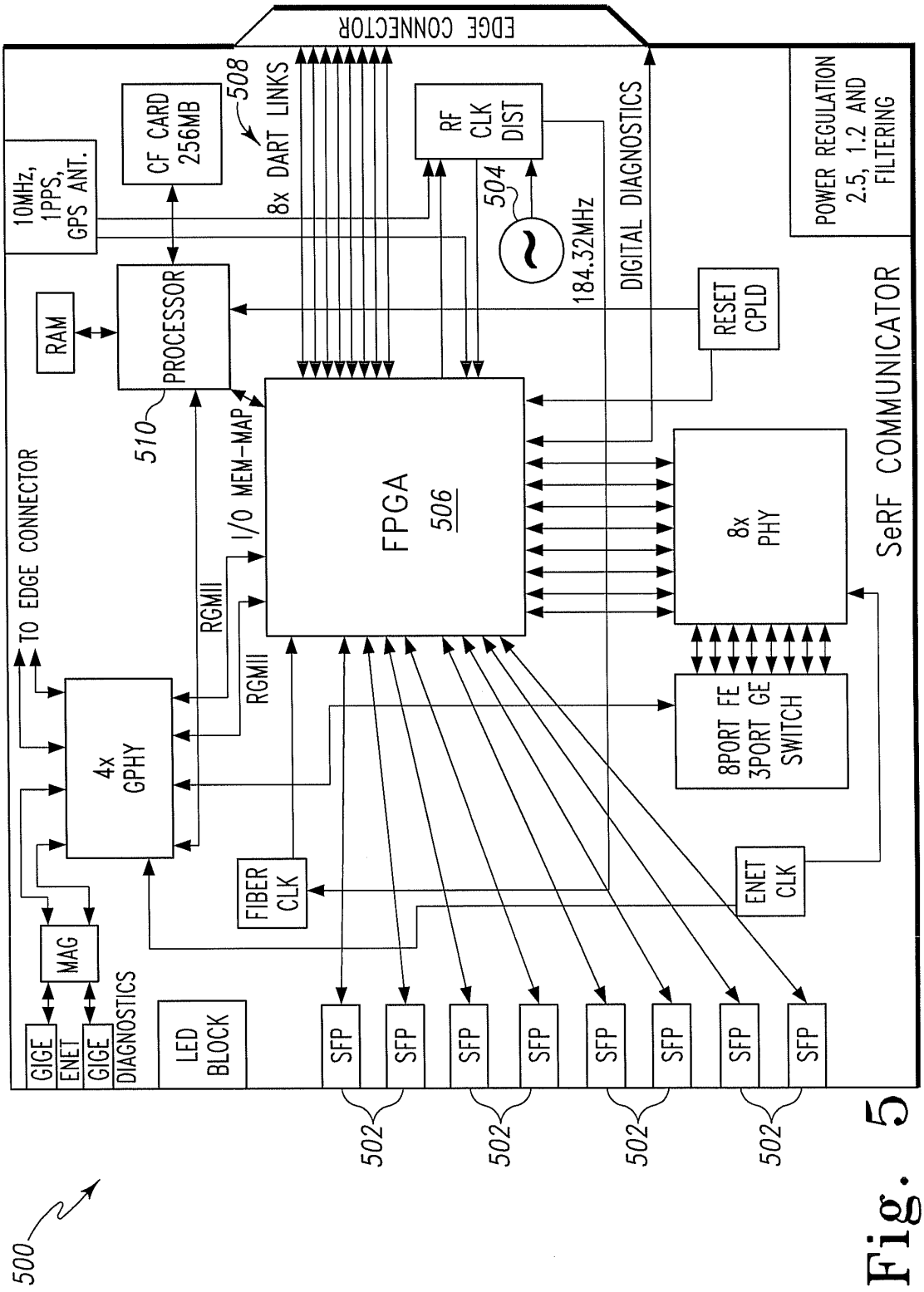

EDGE CONNECTOR
SeRF COMMUNICATOR
10MHz, 1PPS, GPS ANT.
CF CARD 256MB
508
8x DART LINKS
RF CLK DIST
504
184.32MHz
DIGITAL DIAGNOSTICS
POWER REGULATION 2.5, 1.2 AND FILTERING
RAM
PROCESSOR
510
RESET CPLD
I/O MEM-MAP
FPGA
506
8x PHY
TO EDGE CONNECTOR
RGMII
RGMII
4x GPHY
8PORT FE 3PORT GE SWITCH
FIBER CLK
ENET CLK
MAG
GIGE
ENET
GIGE
DIAGNOSTICS
LED BLOCK
SFP
SFP
SFP
SFP
SFP
SFP
SFP
SFP
502
502
502
502
500

Fig. 5

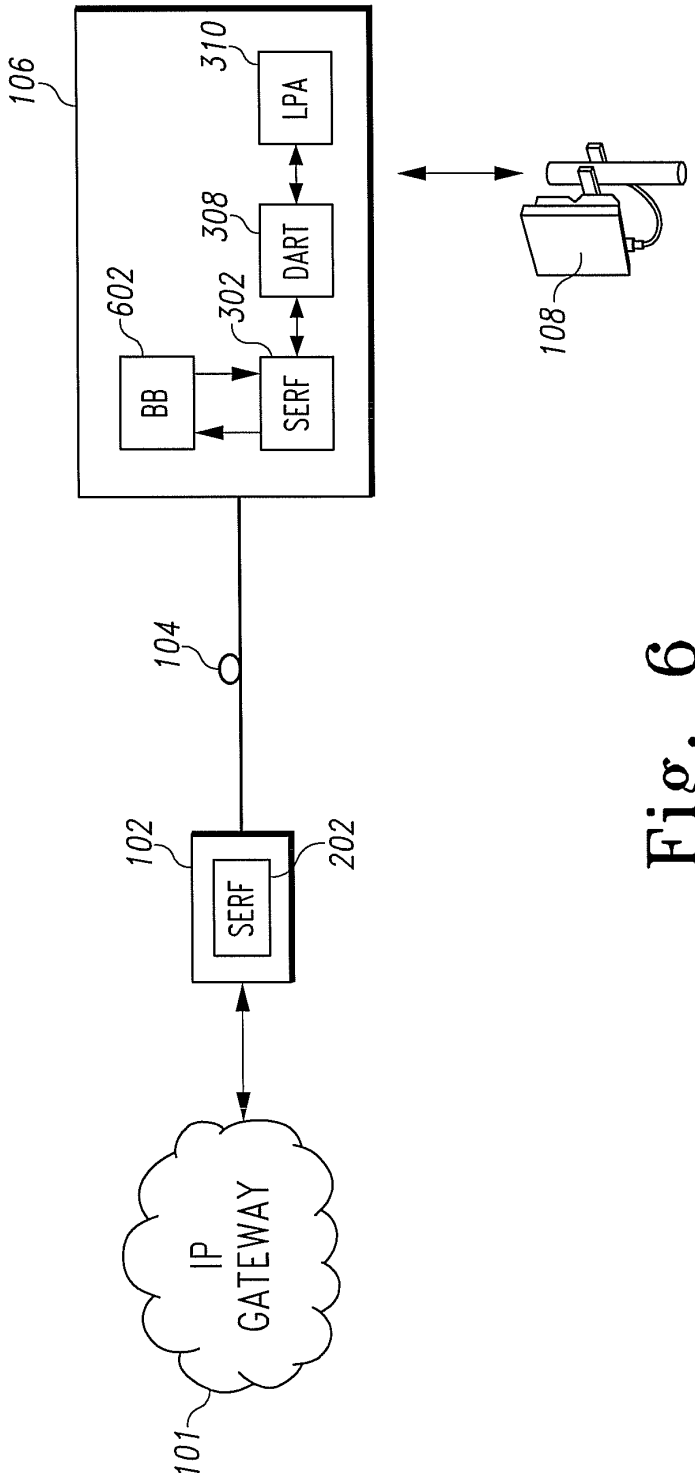

106
310
LPA
308
DART
602
302
BB
SERF
108
104
102
SERF
202
IP
GATEWAY
101

Fig. 6

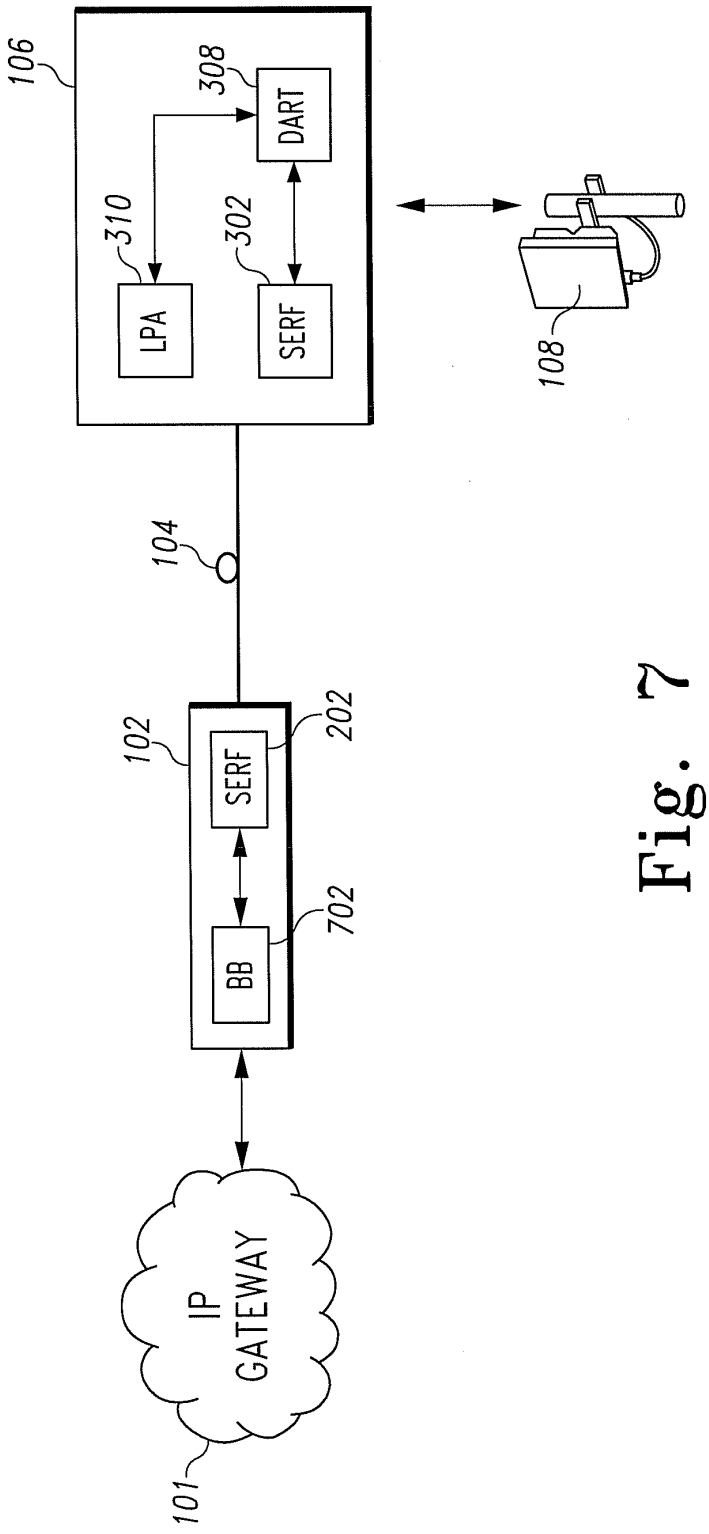

106
308
DART
310
302
LPA
SERF
108
104
102
202
SERF
BB
702
IP
GATEWAY
101

Fig. 7

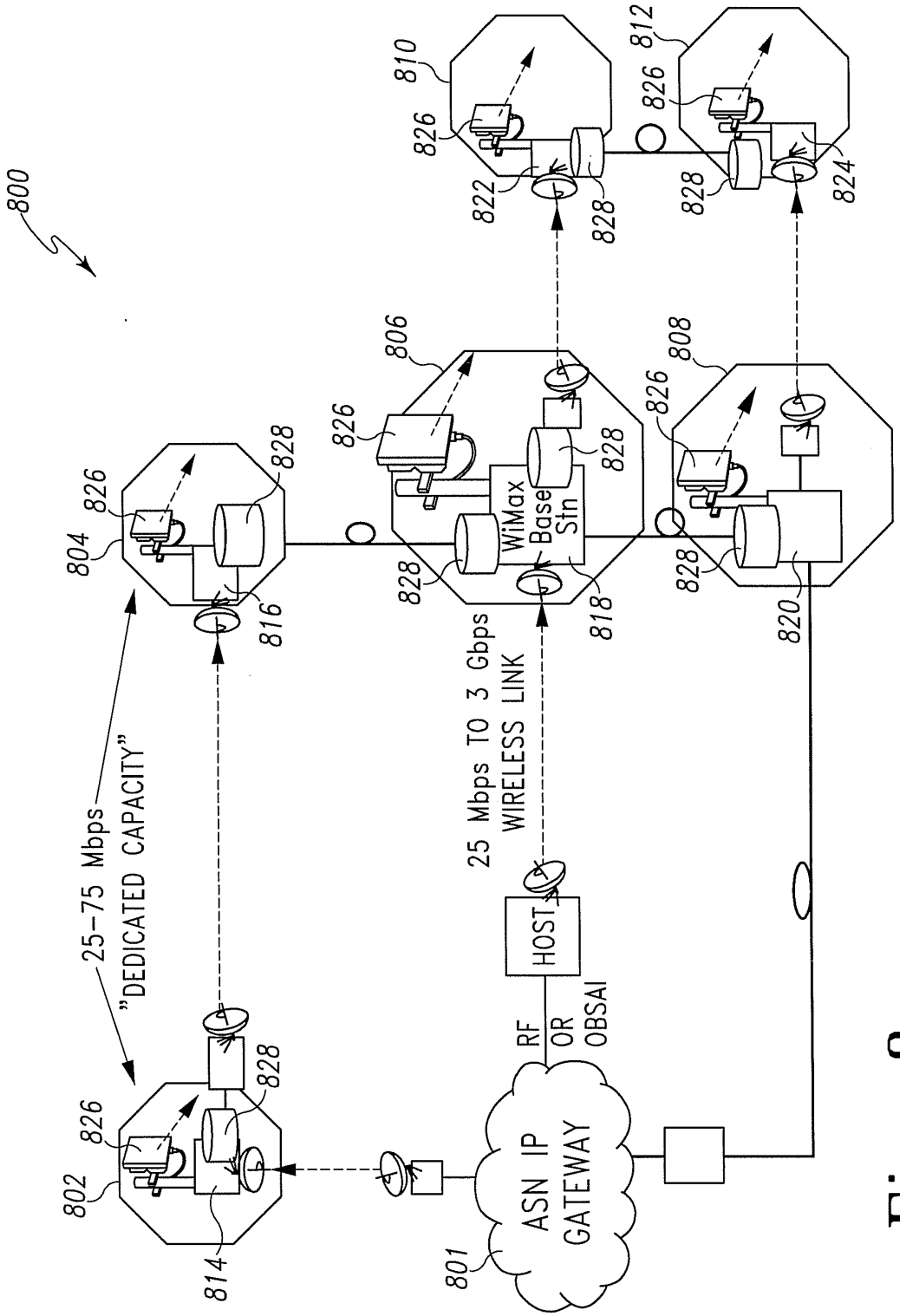

800
802
804
806
808
810
812
814
816
818
820
822
824
826
828
801
WiMax Base Stn
HOST
ASN IP GATEWAY
RF OR OBSAI
25-75 Mbps "DEDICATED CAPACITY"
25 Mbps TO 3 Gbps WIRELESS LINK

Fig. 8

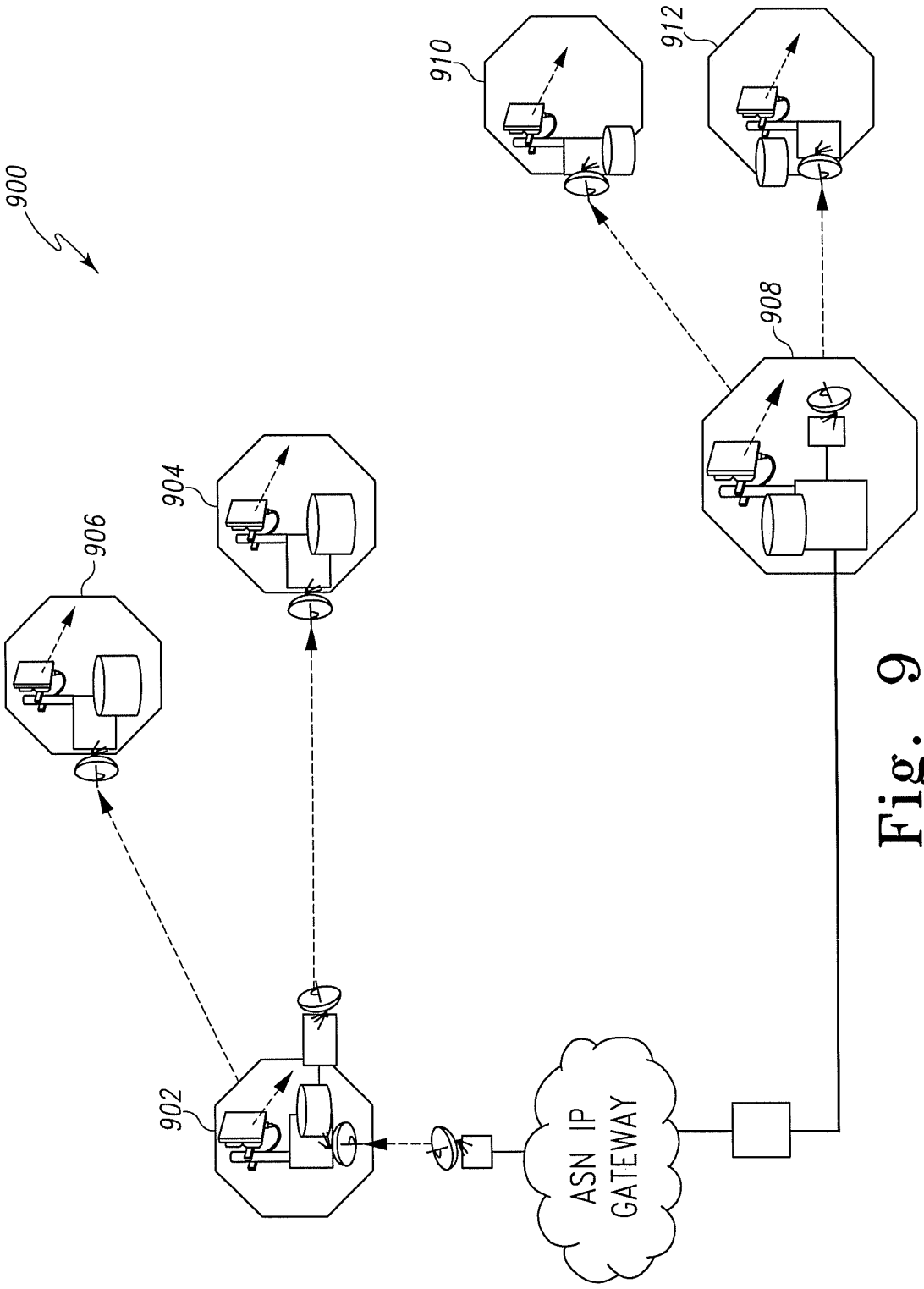


Fig. 9

Application Data Sheet

Application Information

Application Type::	Regular
Subject Matter::	Utility
Suggested classification::	N/A
Suggested Group Art Unit::	N/A
CD-ROM or CD-R?::	None
Number of CD disks::	None
Number of copies of CDs::	N/A
Sequence submission?::	N/A
Computer Readable Form (CRF)?::	N/A
Number of copies of CRF::	N/A
Title ::	A DISTRIBUTED REMOTE BASE STATION SYSTEM
Attorney Docket Number::	**100.829US01**
Request for Early Publication?::	No
Request for Non-Publication?::	No
Suggested Drawing Figure::	N/A
Total Drawing Sheets::	9
Small Entity?::	No
Petition included?::	No
Petition Type::	N/A
Licensed US Govt. Agency::	N/A
Contract or Grant Numbers::	N/A
Secrecy Order in Parent Appl.?::	N/A

Initial 1/25/2007

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Applicant Information

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State or Province of mailing address::	MN
Country of mailing address::	US

Initial 1/25/2007

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State or Province of Residence::	MN
Country of Residence::	US
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State or Province of mailing address::	MN
Country of mailing address::	US
Postal or Zip Code of mailing address::	55424

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Fax Number:	(612) 332-4731
E-Mail address::	docketing@fogglaw.com

Representative Information

Initial 1/25/2007

Representative Customer Number::	34206	

Domestic Priority Information

Application ::	Continuity Type::	Parent Application::	Parent Filing Date::

Foreign Priority Information

Country::	Application number::	Filing Date::	Priority Claimed::
			Yes or No?
			Yes or No?
			Yes or No?
			Yes or No?
			Yes or No?

Assignee Information

Assignee name:: ADC Telecommunications, Inc.

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City of mailing address:: Eden Prairie

State or Province of mailing address:: MN

Country of mailing address::

Postal or Zip Code of mailing address:: 55344-2252

Initial 1/25/2007

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Electronic Acknowledgement Receipt

EFS ID:	1466409
Application Number:	11627255
International Application Number:	
Confirmation Number:	1589
Title of Invention:	A DISTRIBUTED REMOTE BASE STATION SYSTEM
First Named Inventor/Applicant Name:	Robert Koziy
Customer Number:	34206
Filer:	David Fogg/Lisa Gentry
Filer Authorized By:	David Fogg
Attorney Docket Number:	100.829US01
Receipt Date:	25-JAN-2007
Filing Date:	
Time Stamp:	18:01:23
Application Type:	Utility

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)
1		00088118.pdf	1267576	yes	33

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Specification	1	15
	Claims	16	19
	Abstract	20	20
	Drawings	21	29
	Application Data Sheet	30	33
Warnings:			
Information:			
	Total Files Size (in bytes):	1267576	

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

PTO/SB/06 (12-04)
Approved for use through 7/31/2006. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 11/627,255

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))							300
SEARCH FEE (37 CFR 1.16(k), (i), or (m))							500
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))							200
TOTAL CLAIMS (37 CFR 1.16(i))	27 minus 20 =	7	X$ 25		OR	X$50	350
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4 minus 3 =	* 1	X$100			X$200	200
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			180			360	
1			TOTAL	0		TOTAL	1550

APPLICATION AS AMENDED – PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					180		OR	360	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/06 (07-06)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 11/627,255	Filing Date 01/25/2007	☐ To be Mailed

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☐		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1)		(Column 2)	(Column 3)					
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/JASON B. EADDY/

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