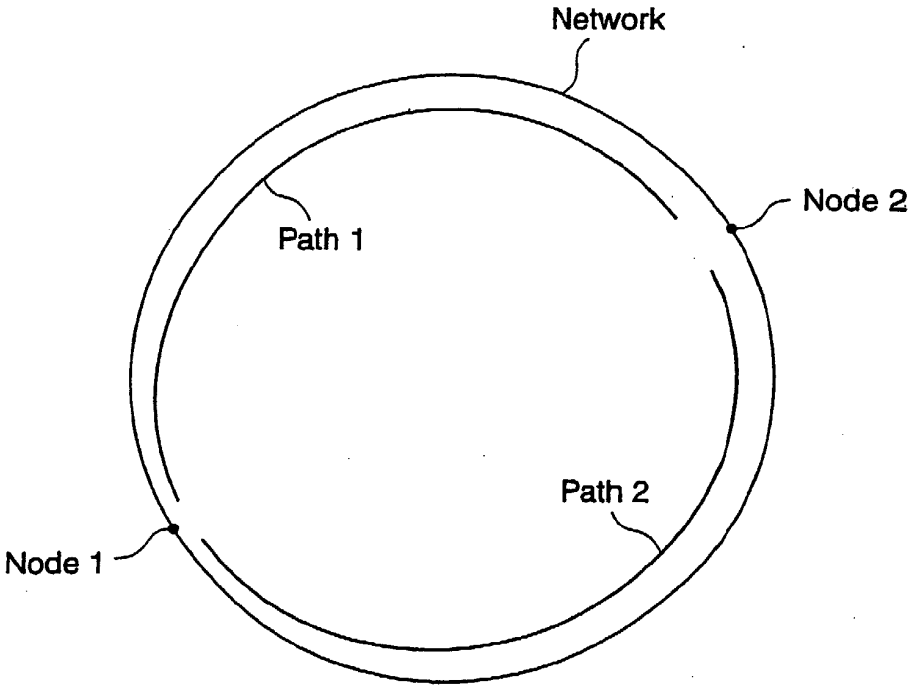
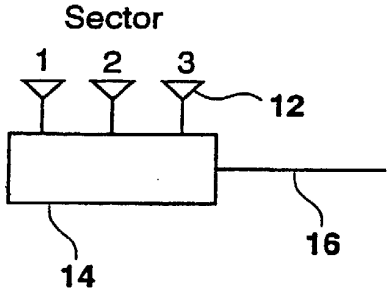



Fig. 9



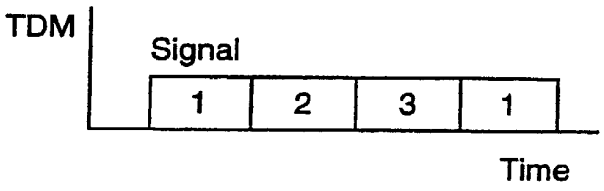




Fig. 10

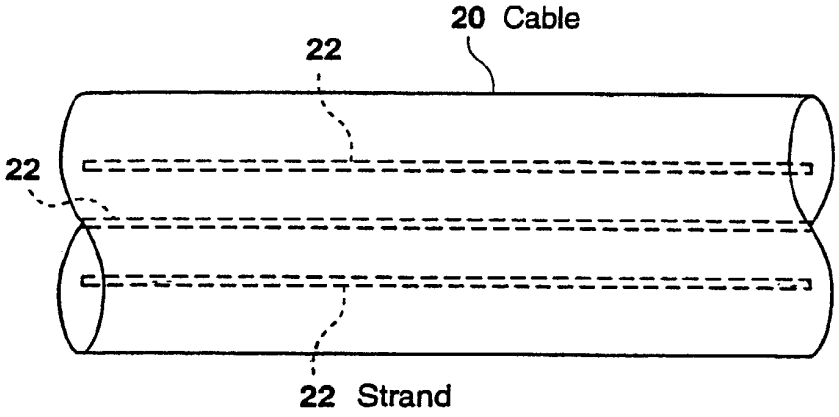

20 Cable
22
22
22 Strand

Fig. 11

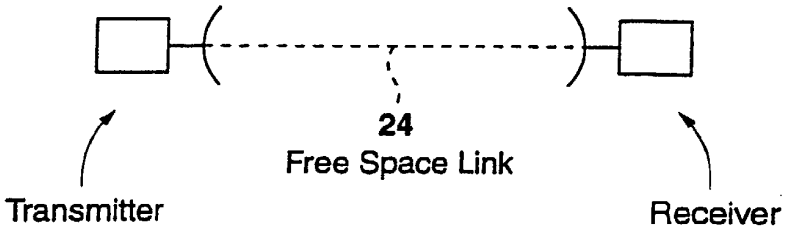

24
Free Space Link
Transmitter
Receiver

Fig. 12

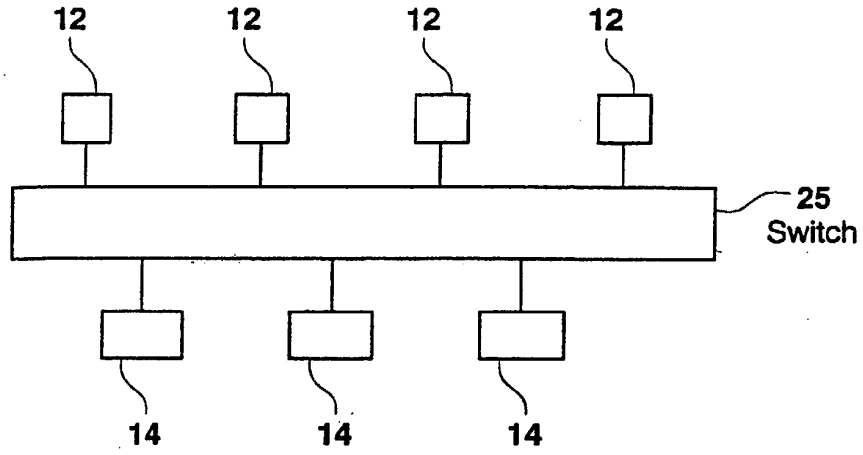



Fig. 13

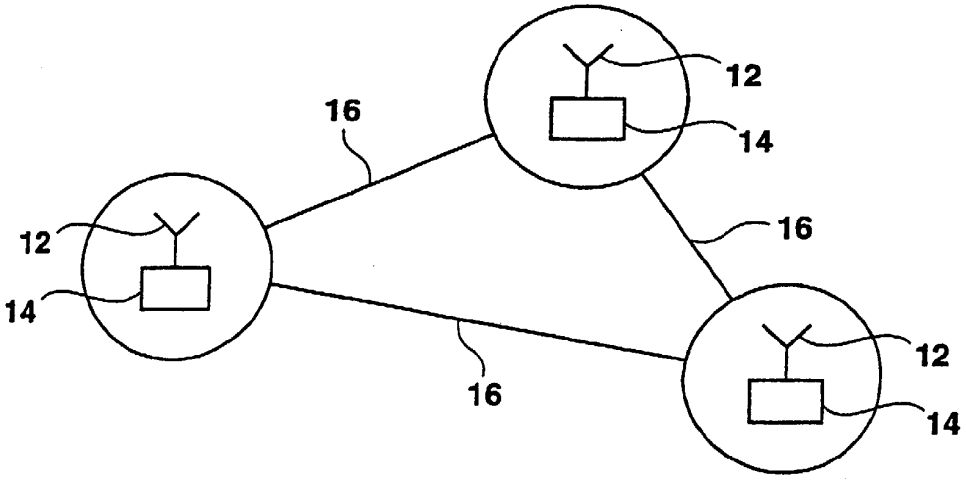
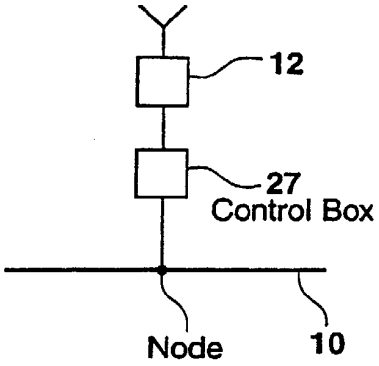



Fig. 14



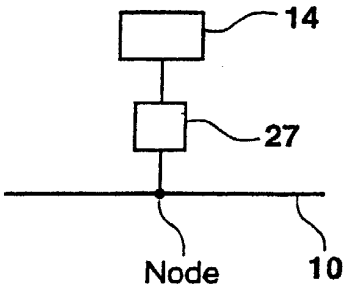




Fig. 15

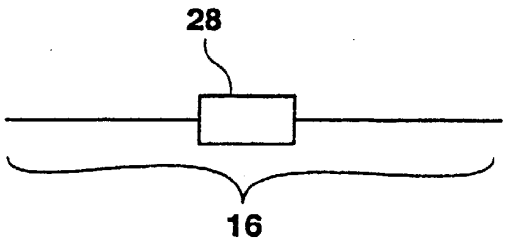



Fig. 16

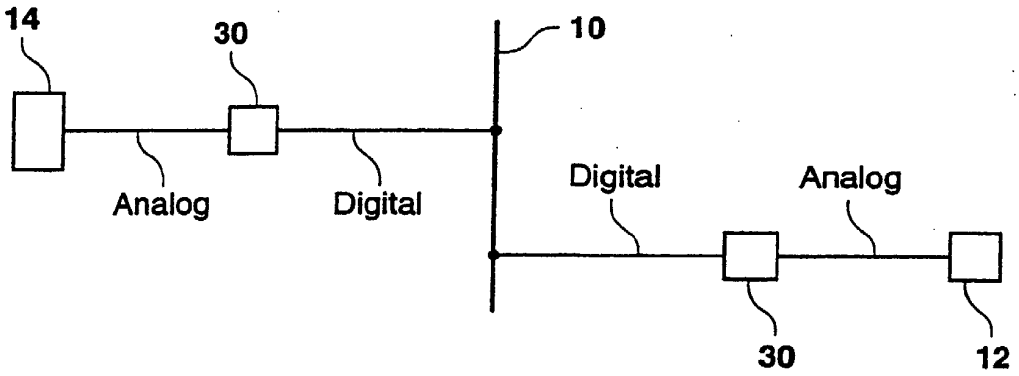



Fig. 17

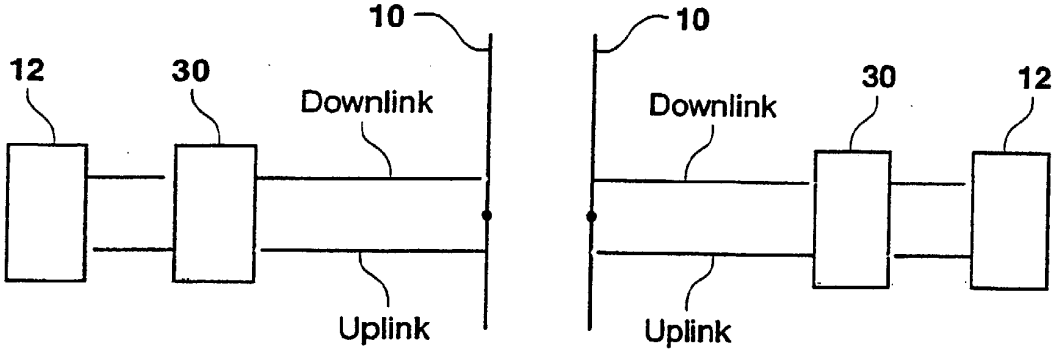

10
10
12
30
Downlink
Downlink
30
12
Uplink
Uplink

Fig. 18

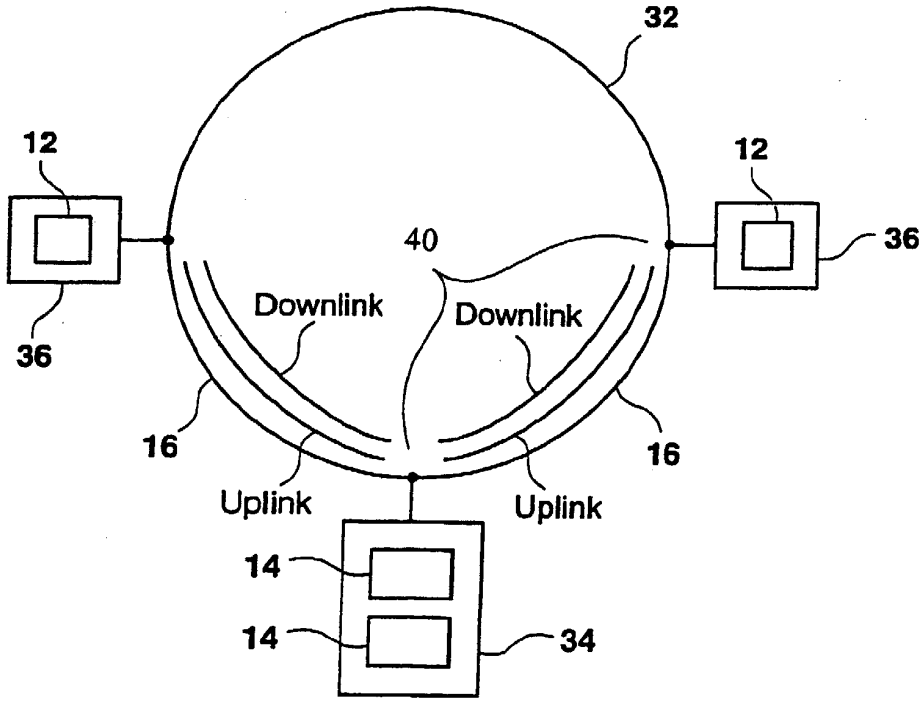

32
12
12
40
36
Downlink
Downlink
36
16
16
Uplink
Uplink
14
14
34

Fig. 19

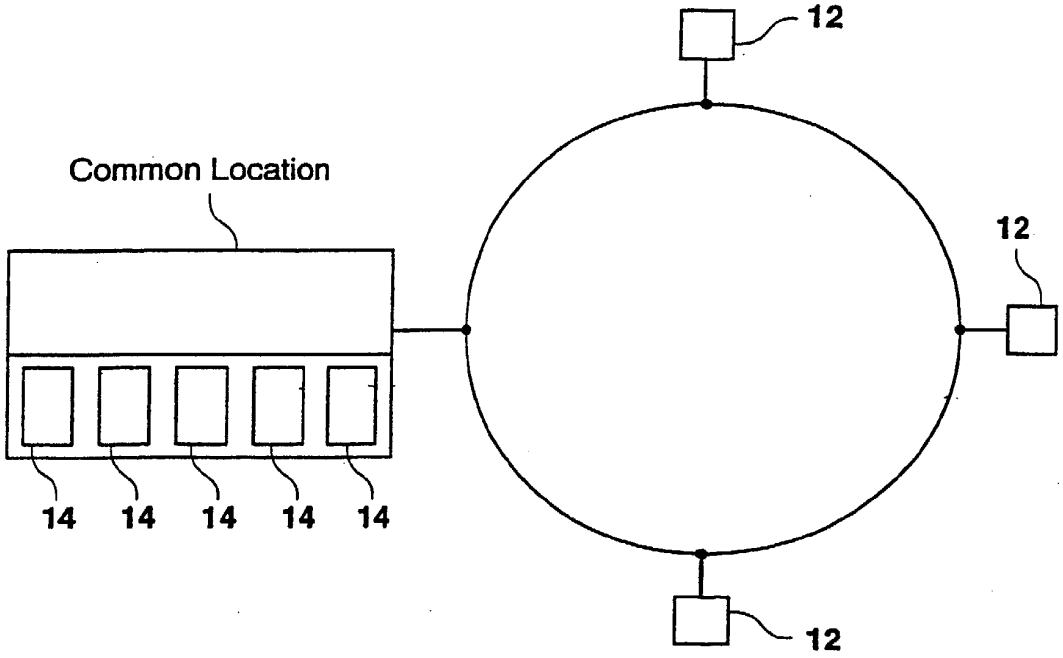

12
Common Location
12
14
14
14
14
14
12

Fig. 20

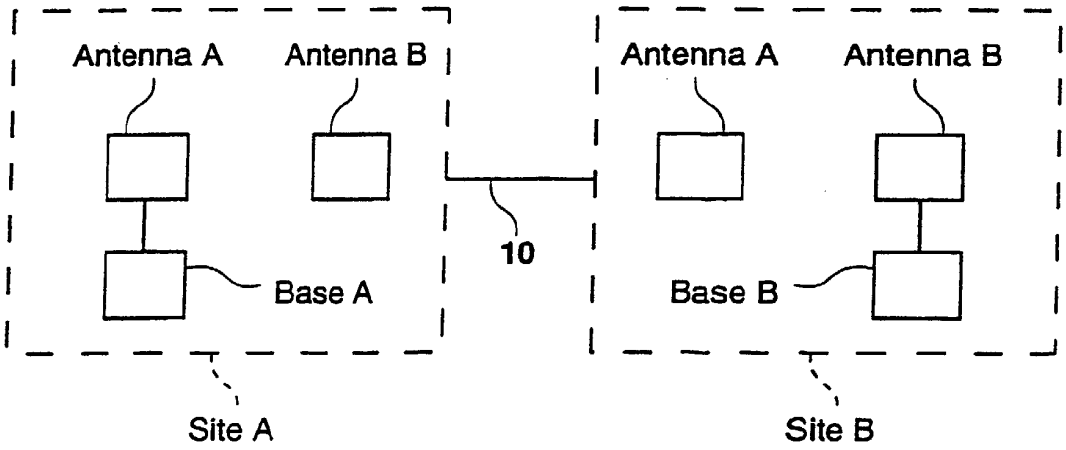

Antenna A
Antenna B
Antenna A
Antenna B
10
Base A
Base B
Site A
Site B

Fig. 21

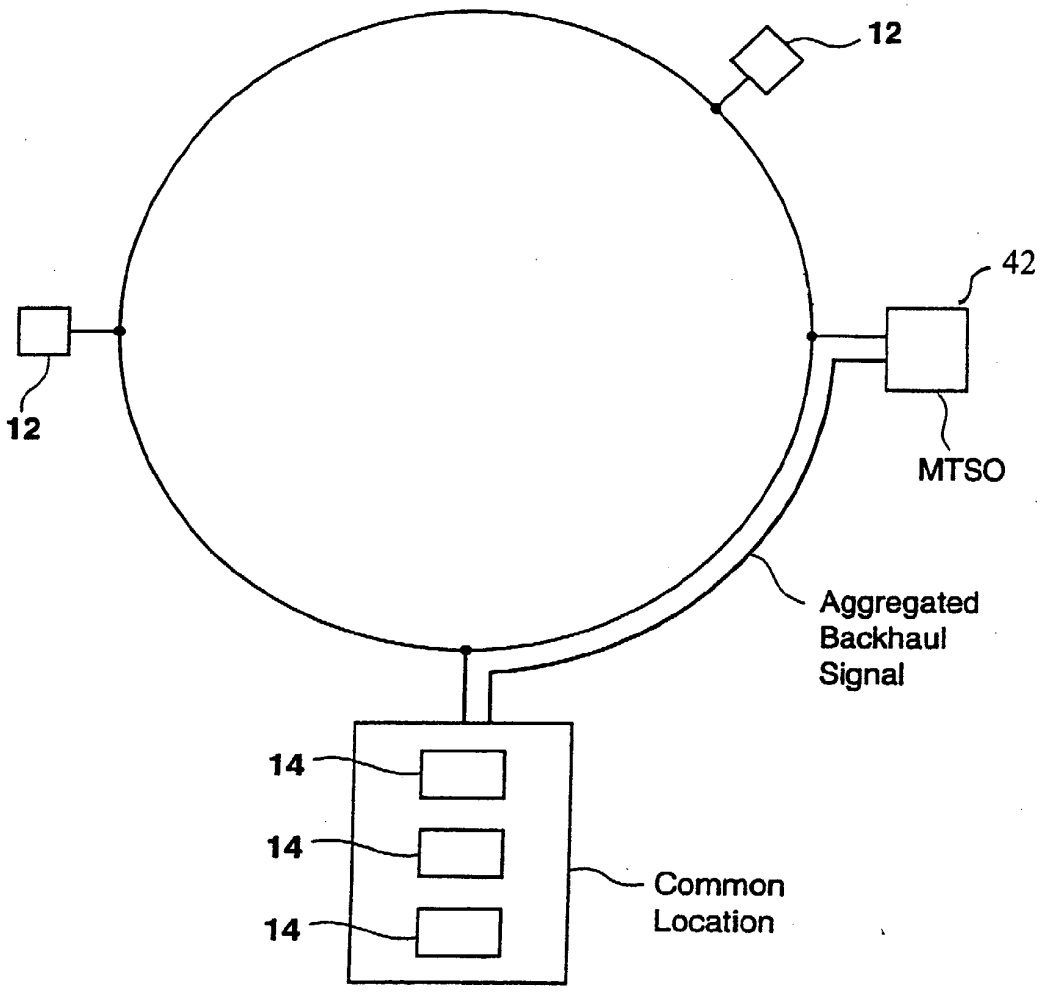

12
42
12
MTSO
Aggregated
Backhaul
Signal
14
14
14
Common
Location

Fig. 22

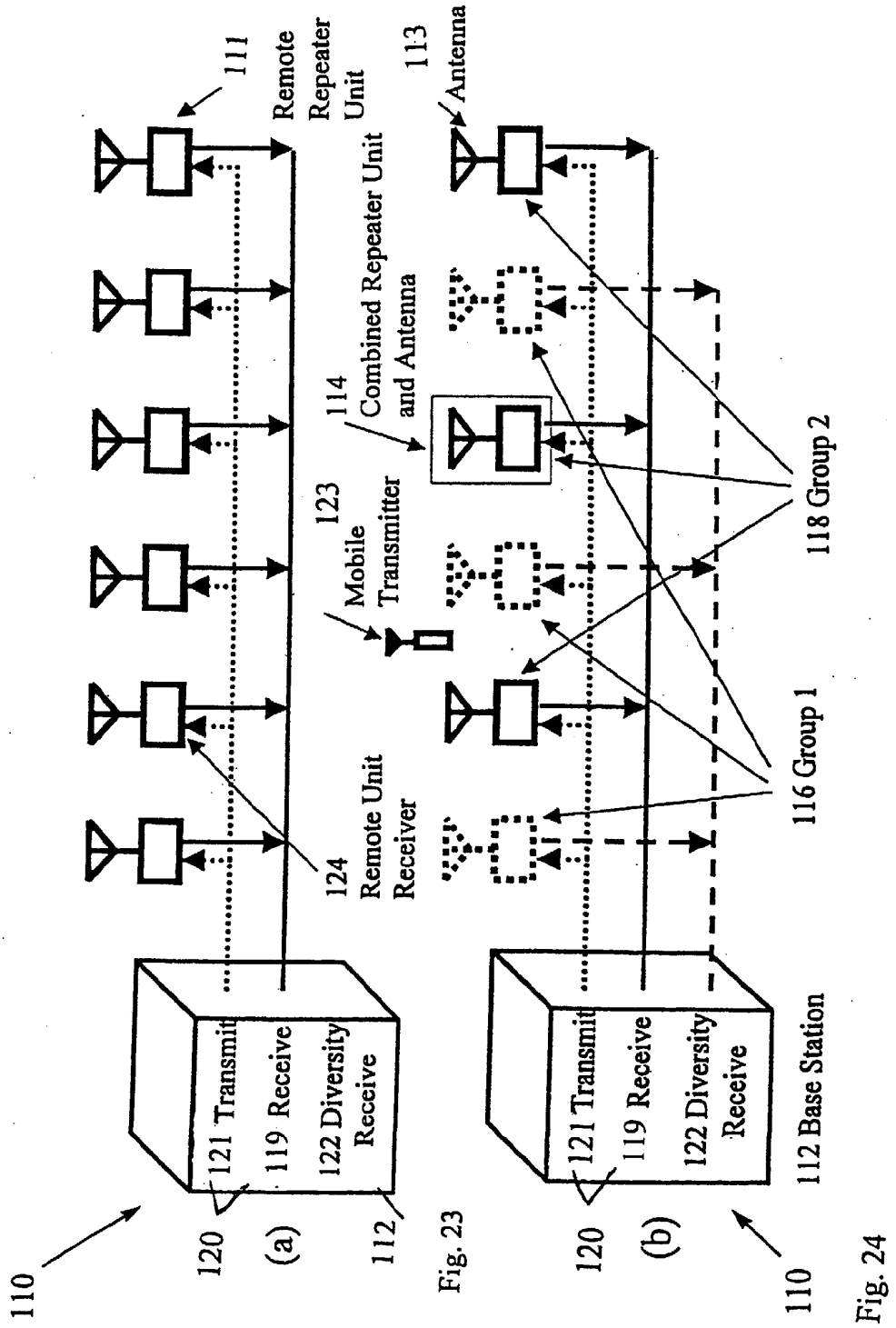

110
120
(a)
121 Transmit
119 Receive
122 Diversity Receive
112
124
Remote Unit Receiver
123
Mobile Transmitter
114
Combined Repeater Unit and Antenna
111
Remote Repeater Unit
113
Antenna
116 Group 1
118 Group 2
120
(b)
121 Transmit
119 Receive
122 Diversity Receive
112 Base Station
110

Fig. 23

Fig. 24

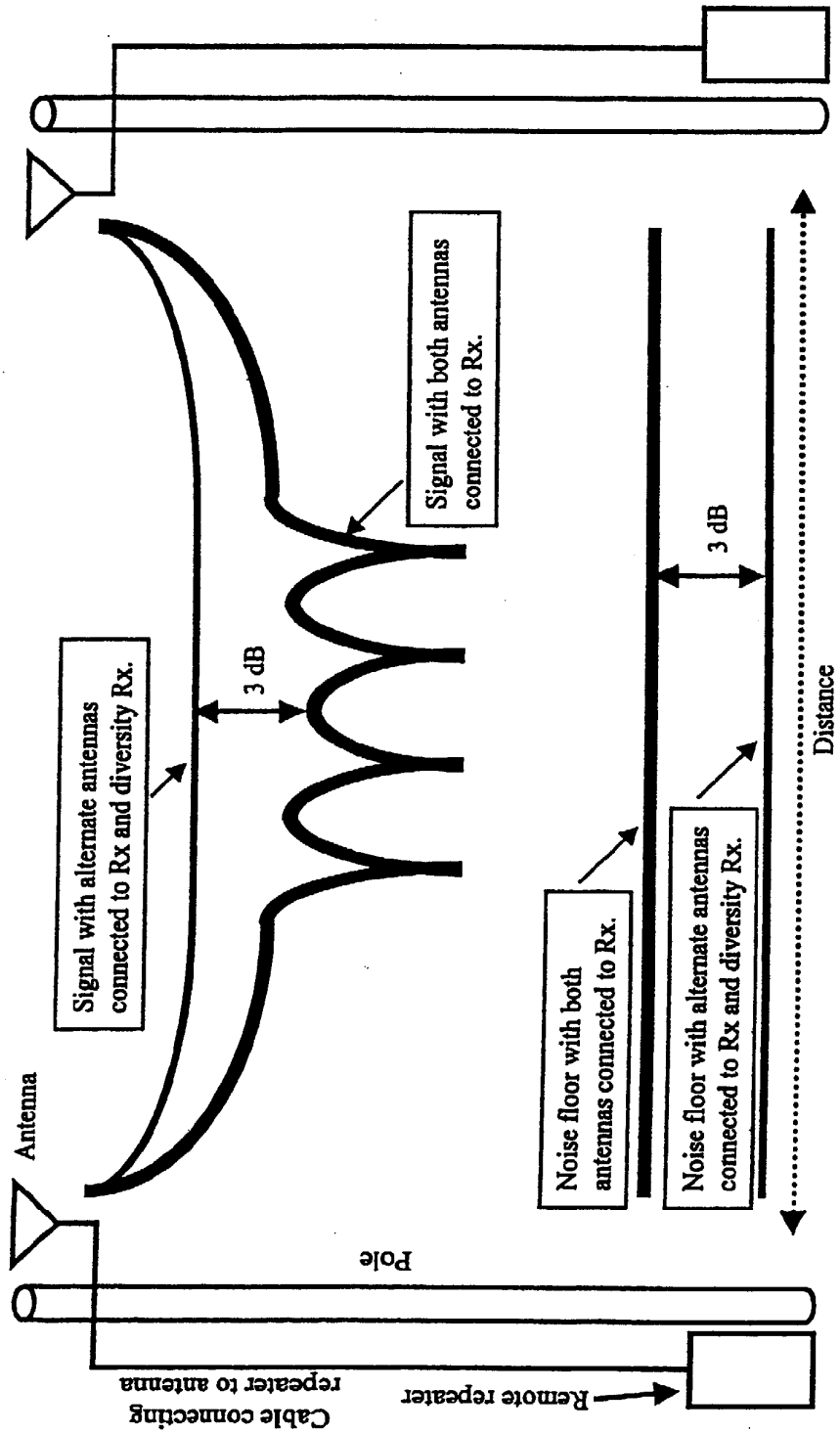

Signal with alternate antennas connected to Rx and diversity Rx.
3 dB
Signal with both antennas connected to Rx.
3 dB
Noise floor with both antennas connected to Rx.
Noise floor with alternate antennas connected to Rx and diversity Rx.
Distance
Antenna
Pole
Cable connecting repeater to antenna
Remote repeater

Fig. 25

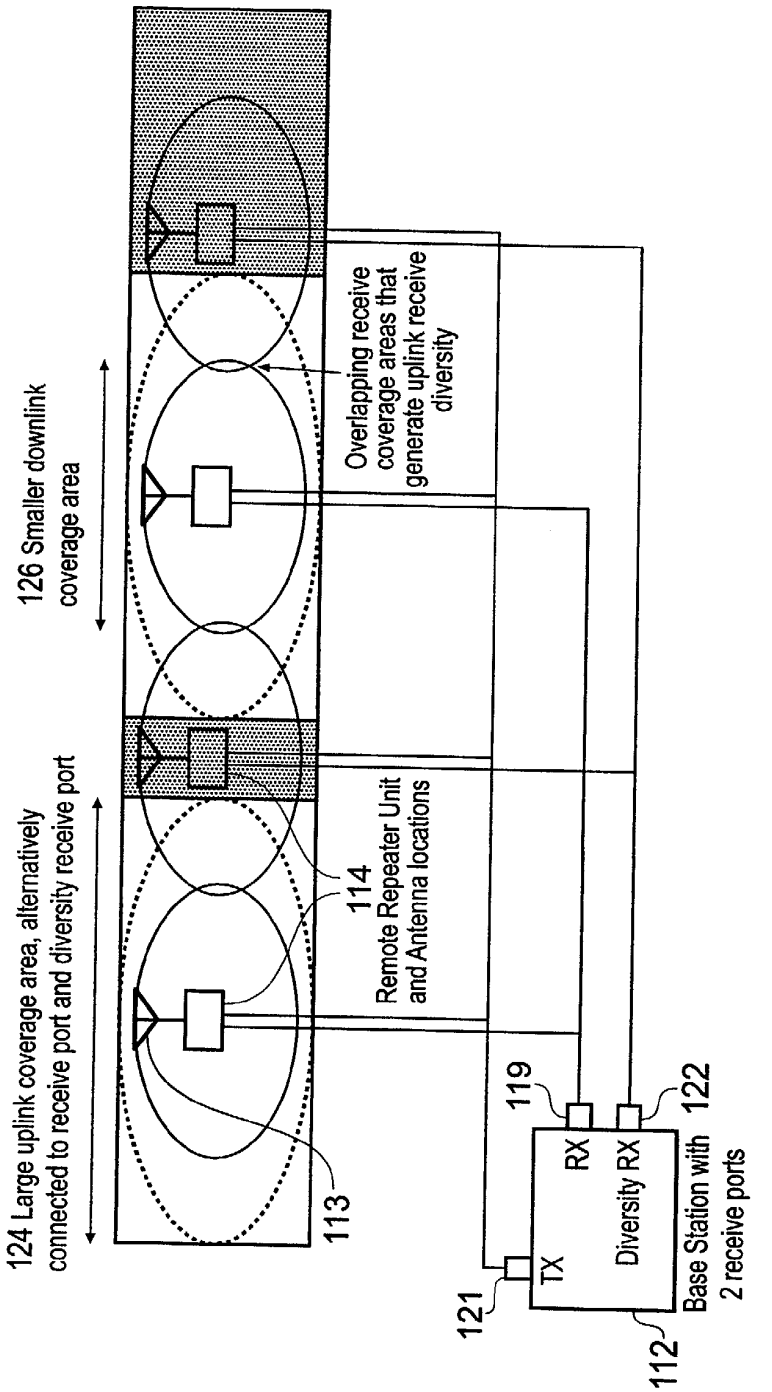

126 Smaller downlink coverage area
Overlapping receive coverage areas that generate uplink receive diversity
124 Large uplink coverage area, alternatively connected to receive port and diversity receive port
114
Remote Repeater Unit and Antenna locations
113
119
RX
Diversity RX
122
TX
121
Base Station with 2 receive ports
112

Fig. 26

# METHOD AND APPARATUS FOR MULTIPLEXING IN A WIRELESS COMMUNICATION INFRASTRUCTURE

## BACKGROUND OF THE INVENTION

### Field of the Invention

This invention relates generally to cellular mobile telecommunication systems, and more particularly to shared networks to distribute base station antenna points and the associated base station transceiver hardware.

### Description of Related Art

Cellular networks are typically deployed by co-locating antennas and base stations at sites that are either bought or leased and can support such installations. Figure 1 illustrates a typical rooftop cellular site, while Figure 2 depicts a typical deployment architecture. The antenna is located close to the base station, generally within 100 feet, and connected to the base station employing lossy RF cable.

An alternate architecture can be employed in which the base station is placed at a central or accessible location, and then remote antennas are connected to the base station using optics or RF cable. Such an architecture is employed where the topology or mobile traffic patterns are appropriate, such as in buildings or on roads. In an in-building application, a base station can be placed in a room, and then the entire building is covered with small antennas, connected to the base station over a cable and/or optical network.

Another application covers outdoor narrow canyons or roads through lightly populated areas. In these areas, it is difficult to site a base station at the desired coverage location. In addition, the geometry of the location may not be reasonable to cover with a conventional base station. A canyon may be a long narrow area with a few cars in it at any given time, in which placing many base stations along the canyon would waste a large amount of capacity. The solution to this problem is to employ a distributed antenna network to cover the canyon, and then connect that network to a base station placed at a location where it is relatively easy to site. This network can employ a point-to-point repeater link, in which the near end is connected to the base station and the far end is

connected to the antennas. The link carries uplink and downlink signals from one or a group of antennas to a base station on a proprietary link.

The links can be optical fiber or some form of RF cabling, and generally include amplification so that the distance is covered with no loss in signal intensity, even if the signal properties are degraded by the link. A power amplifier placed at the remote location is used to amplify the downlink signal, while a low-noise amplifier at the remote location is used in the uplink direction, also to amplify the signal. The repeater architecture allows coverage to be cost-effectively extended to areas that are difficult to site multiple base stations for either financial or physical reasons.

A common implementation to extend coverage is to use a base station and several optical fiber links with remote antenna locations. When the goal is coverage, often multiple fiber links are used on a single base station in order to distribute the signals from the base station over multiple antennas. Such an implementation is illustrated in Figure 3. Three repeaters are connected to one base station, employing power combiners/dividers to split the signal between the multiple repeaters. The remote repeaters are linked optically to the base station unit. On the downlink, the base station transmit signal will be split to cover the various repeaters, and on the uplink the signal from these multiple repeater receivers can be power combined and connected to a base station receive port. That means that the base station is distributing its transmit signal to multiple transmitters on the downlink and receiving power combined signals from multiple receivers on the uplink. This configuration allows one base station to cover a large area that isn't readily covered by a conventional base station through a distributed network.

In addition to the single RXreceive port or TX/RX duplex transmit/receive port, many base stations possess an additional diversity receive port. In a conventional base station, this additional port would be connected to a different receive antenna, as illustrated in Figure 4. The diversity receive port allows for two spatially diverse receive antennas to be used, and they are typically separated by at least (receive wavelength)/2. Diversity receive reduces the likelihood of Raleigh fading hurting uplink reception. In Raleigh fading, multiple signal paths from the mobile transmitter to the BTS antenna cause dramatic oscillations in the received signal intensity from multipath signal addition. If Raleigh fading creates a dramatic signal reduction at one RX antenna, it is

unlikely to create a deep fade at the spatially separated RX antenna at the same time. Hence, spatial receive diversity combats against Raleigh fades. These deep fades are a significant problem in cellular uplink reception. The two receive ports can have separate demodulation receive paths, in which case two demodulated signals can be generated and combined. This can result in up to a 3dB increase in SNR, in addition to the greater immunity to Raleigh fade. Receive diversity can also be implemented in a simpler fashion, by merely choosing the larger signal, in which case the SNR increase is not realized. The diversity concept can be extended to more branches than 2, for greater immunity to fading.

There is a need for a distributed network combined with a base station with reduced and/or minimal Raleigh fade. There is a further need for a distributed network which passes to a base station an improved uplink signal. There is yet another need for distributed network that has a decrease in the uplink noise floor.

## SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a distributed network that connects base stations to remote antennas, and its methods of use, that has a plurality of links with at least a portion providing multiple transmission paths.

Another object of the present invention is to provide a distributed optical network connecting base stations to remote antennas, and its methods of luse, that has a plurality of links with at least one link providing multiple transmission paths by employing multiple optical wavelength multiplexing.

Yet another object of the present invention is to provide a distributed network connecting base stations to remote antennas, and its methods of use, that has a plurality of links with cellular signals that are exchanged over the network and are represented digitally.

Another object of the present invention is to provide a distributed optical network connecting base stations to remote antennas, and its methods of use, that has a plurality of links with at least one link providing multiple transmission paths by employing multiple optical fiber strands.

A further object of the present invention is to provide a distributed network connecting base stations to remote antennas, and its methods of use, where at least one

base station or antenna location is geographically remote from the network and is connected to the network with a free space link.

Another object of the present invention is to provide a distributed network, and its methods of use, that connects base stations to remote antennas, and has a plurality of transmission paths that are shared between different cellular operators.

Another object of the present invention is to provide a distributed network, and its methods of use, that connects base stations to remote antennas, and has base stations co-located at a centralized location, and remote antennas distributed over a geographic area to provide cellular coverage.

An object of the present invention is to provide a distributed antenna system, and its methods of use, that utilizes diversity receive.

Another object of the present invention is to provide a distributed antenna system, and its methods of use, that has an improvement in the uplink signal.

A further object of the present invention is to provide a distributed antenna system, and its methods of use, that has a decrease in uplink noise floor.

Yet another object of the present invention is to provide a distributed antenna system, and its methods of use, that has multiple remote repeater units and their corresponding antennas divided into first and second groups, with each unit in both groups connected to one downlink signal, and the units in the first group coupled to a first receive or transmit/receive port, and the units in the second group coupled to a second diversity receive port.

These and other objects of the present invention are achieved in a network that has a plurality of antennas RF or optically coupled over the network to a plurality of base stations. The base stations are configured to provide cellular transmission. At least a portion of the plurality of base stations are in a common location and at least a portion of the antennas are geographically disbursed. A plurality of links couple the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas.

In another embodiment of the present invention, a network includes a plurality of antennas optically or RF coupled over the network to a plurality of base stations. The base stations are configured to provide cellular transmission. A plurality of links couple

the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas. At least one link is shared by at least two operators on different transmission paths.

In another embodiment of the present invention, a network includes a plurality of antennas coupled over the network to a plurality of base stations. The base stations are configured to provide transmissions which represent cellular signals. A plurality of links couple the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas. At least a portion of the plurality of base stations and antennas belong to different operators.

In another embodiment of the present invention, a network includes a plurality of antennas optically coupled over the network to a plurality of base stations. The base stations are configured to provide cellular transmission. A plurality of optical fiber links couple the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths over at least two optical wavelengths between at least a portion of the base stations with at least a portion of the antennas. Different operators employ different optical wavelengths.

In another embodiment of the present invention, A network includes a plurality of antennas optically coupled over the network to a plurality of base stations. The base stations are configured to provide cellular transmission. A plurality of optical fiber links couple the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas. The plurality of links include at least one fiber cable with a plurality of fiber strands which form multiple transmission paths. At least one link is shared by at least two operators.

In another embodiment of the present invention, a network includes a plurality of antennas optically or RF coupled over the network to a plurality of base stations. The antennas and base stations are configured to transmit and receive digital signals representing cellular signals. The digital signals are exchanged over the network. A plurality of links couple the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas.

In another embodiment of the present invention, a network includes a plurality of remote units and a plurality of base units. Each remote unit is a radiating unit that has at least a portion of the functionality of a base station. A plurality of links couple the plurality of remote units and the plurality of base units. At least one link provides multiple transmission paths between at least a portion of the base units with at least a portion of the plurality of remote units.

In another embodiment of the present invention, a network includes a plurality of antennas optically coupled over the network to a plurality of base stations. The base stations are configured to provide cellular transmission. A plurality of links couple the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas. At least a portion of the plurality of links are fixed optical paths. Each fixed optical path is a stationary optical link between one or more base stations and one or more antennas that is rerouted on a time scale much slower than that of the bit rate over the link, and connects nodes to one another as a virtual circuit.

In another embodiment of the present invention, a method of transmission provides a network that includes a plurality of optical links that couple a plurality of antennas with a plurality of base stations. Multiple transmission paths are provided with at least one link using optical DWDM between at least a portion of the base stations with at least a portion of the antennas. Signals are digitally encoded over the multiple transmission paths.

In another embodiment of the present invention, a method of transmission provides a network with a plurality of links that couple a plurality of antennas with a plurality of base stations. Multiple transmission paths are provided between at least a portion of the base stations with at least a portion of the antennas. Signals are digitally encoded over the multiple transmission paths.

In another embodiment of the present invention, a network includes a plurality of antennas optically coupled over the network to a plurality of base stations. The base stations are configured to provide cellular transmission. A plurality of free space optical links couple the plurality of antennas and the plurality of base stations. At least one link provides multiple transmission paths over at least two optical wavelengths between at least a portion of the base stations with at least a portion of the antennas.

In another embodiment of the present invention, a method of transmission provides a network with a plurality of optical links that couple a plurality of antennas with a plurality of base stations. Multiple transmission paths are provided with at least one link of the plurality of links using optical DWDM between at least a portion of the base stations with at least a portion of the antennas. The DWDM wavelength carriers carry an analog signal representative of an RF signal between the plurality of base stations and the plurality of antennas.

In another embodiment of the present invention, a method of transmission provides a network with a plurality of links that couple a plurality of antennas with a plurality of base stations. At least one base station or antenna location is geographically remote from the network and connected to the network with a free space link. Multiple transmission paths are provided between at least a portion of the base stations with at least a portion of the antennas.

In another embodiment of the present invention, a network includes a plurality of antennas remotely located from and coupled to a base station having a plurality of receive or transmit/receive ports. The plurality of antennas are split into a plurality of groups that is equal in number to a number of the plurality of receive ports. The uplink signals from each grouping of the plurality of antennas are connected to one of the plurality of receive ports of the base stations by signal combination. A plurality of links optically or electrically couple the plurality of remotely located antennas and the plurality of base stations.

In another embodiment of the present invention, a network includes a plurality of antennas coupled by optical links to a least one RF signal combiner on the uplink to produce a single RF combined signal. The RF combined signal is coupled to a base station that has a plurality of receive or transmit/receive ports. The plurality of antennas are split into a plurality of groups that is equal in number to a number of the plurality of receive or transmit/receive ports. Each grouping of the plurality of antennas is connected to one of the plurality of receive or transmit/receive ports of the base stations by signal combination. A plurality of links couple the plurality of antennas and the plurality of base stations.

In another embodiment of the present invention, a network includes a plurality of antennas optically coupled to a base station that has a plurality of receive or

transmit/receive ports. The plurality of antennas are split into a plurality of groups that is equal in number to a number of the plurality of receive or transmit/receive ports. The uplink signals from each grouping of the plurality of antennas are connected to one of the plurality of receive or transmit/receive ports of the base stations by signal combination. A plurality of links couple the plurality of antennas and the plurality of base stations. A coverage area is generated by a downlink signal that is smaller than a coverage area generate by an uplink signal. The coverage area is arranged such that remote nodes connected to different receive ports have larger overlapping uplink coverage areas than overlapping downlink coverage areas.

In another embodiment of the present invention, a network includes a plurality of remote repeater units and their corresponding antennas that are remotely located from and coupled to a base station that has a plurality of receive or transmit/receive ports. The plurality of remote repeater units and their corresponding antennas are split into a plurality of groups that is equal in number to a number of the plurality of receive ports. The uplink signals from each grouping of the plurality of remote repeater units are connected to one of the plurality of receive ports of the base stations by signal combination. A plurality of links couple the plurality of remotely located remote repeater units and their corresponding antennas and the plurality of base stations.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure1 illustrates a prior art cellular site with a set of antennas on a rooftop and connected over a short RF cable to a base station radio/transceiver unit that is then backhauled to the cellular network.

Figure 2 is a schematic diagram of a prior art deployment of cellular network with base station/antenna sites located at strategic points across a geographic area to provide coverage, and each site is backhauled to the cellular network via 1 or more T-1 digital links.

Figure 3 is a schematic diagram of a prior art distributed repeater architecture that includes three remote repeaters optically connected to a base station over a one or more fiber links.

Figure 4 is a schematic diagram of a prior art base station with diversity receive, with the transmit and receive ports of the base station combined with a diplexer and then connected to a primary antenna, and a second antenna is used for diversity reception.

Figure 5 is a schematic diagram of one embodiment of a distributed base station network with a plurality of antennas and base stations that has multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas

Figure 6 is a schematic diagram of a MEMs switch and Add/Drop Multiplexer that can be used with the Figure 1 network.

Figure 7 is a schematic diagram of a SONET router that can be used with the Figure 1 network.

Figure 8 is a schematic diagram of an optical multiplex/demultiplexer that can be used with the Figure 1 network.

Figure 9 is a schematic diagram of a DWDM transmission embodiment of the Figure 1 network.

Figure 10 is a schematic diagram of a point-to-point TDM topology embodiment of the Figure 1 network.

Figure 11 is a schematic diagram of one fiber cable 20 with a plurality of fiber strands which from the multiple transmission paths of the Figure 1 network.

Figure 12 is a schematic diagram of a Figure 5 network that uses free space optical links.

Figure 13 is a schematic diagram of a Figure 5 network where at least a portion of the links are configured to provide a selectable allocation of capacity to at least some of the base stations.

Figure 14 is a schematic diagram of a Figure 5 network with multiple base station sites connected together.

Figure 15 is a schematic diagram of a Figure 5 network that includes a control box for at least a portion of the antennas in order to provide routing to selected base stations.

Figure 16 is a schematic diagram of a Figure 5 network with amplifiers included in the links.

Figure 17 is a schematic diagram of a Figure 5 network that includes a digital transceiver embedded between a base station and the network on a base station side, and a digital transceiver embedded between an antenna and the network at an antenna side.

Figure 18 is a schematic diagram of a Figure 5 network illustrating transmission of down link and up link signals.

Figure 19 is a schematic diagram of a hub and spoke embodiment of the Figure 5 network.

Figure 20 is a schematic diagram of a Figure 5 network with at least two base stations located in a common location and the antennas geographically dispersed.

Figure 21 is a schematic diagram of a Figure 5 network with base stations connected together for different operators and used to extend coverage from each operator to other operators.

Figure 22 is a schematic diagram of a Figure 5 network that directly connects to an MTSO.

Figure 23 is a schematic diagram of one embodiment of the present invention with remote repeater units and their corresponding antennas placed on/near poles on a road and are connected to a single base station and divided into 2 alternating groups, with group being connected to a different receive port.

Figure 24 is a schematic diagram is a schematic diagram of another embodiment of remote repeater units and their corresponding antennas placed on/near poles on a road and are connected to a single base station and divided into 2 alternating groups, with group being connected to a different receive port.

Figure 25 is a schematic diagram that illustrates the improvement in signal-to-noise of the Figure 23 and Figure 24 embodiments when diversity receive is employed in multiple antenna application.

Figure 26 is a schematic diagram that illustrates overlapping uplink diversity with differing uplink/downlink coverage areas.

## DETAILED DESCRIPTION

Referring to Figure 5, one embodiment of the present invention is a network 10 that includes a plurality of antennas 12 that are optically coupled over network 10 to a plurality of base stations 14. Base stations 14 are configured to provide wireless cellular

transmission. A plurality of links 16 couple the plurality of antennas 12 and the plurality of base stations 14. At least one link 18 of the plurality of links 16 provides multiple transmission paths between at least a portion of the plurality of base stations 14 with at least a portion of the plurality of antennas 12. In one embodiment, the plurality of antennas 12 and base stations 14 are coupled using RF links to form a network 10. By remotely locating the antenna 12 units from the base stations using such a network 10, numerous advantages are realized.

The plurality of links 16 can be configured to provide multiple transmission paths by frequency division multiplexing (FDM), time division multiplexing (TDM), and the like. Optically coupled networks can be configured to provide multiple transmission paths with wavelength division multiplexing (WDM) and/or multiple fiber strands that comprise a fiber cable. Both of these optical multiplexing techniques allow electrical isolation between different signals, because only the optical fiber and multiplexing components need be shared, not electrical components, optical transmitters, or optical receivers. TDM and FDM can both be combined with WDM to increase the number of transmission paths over a link. If the links 16 are RF microwave links, the multiple transmission paths can be different RF frequency channels.

Optical WDM also allows multiplexing of different signals with very low latency, because no processing or switching operation need be performed, low latency optical directing components can be used exclusively. As illustrated in Figures 6, 7 and 8, optical multiplexing and routing can be performed with low latency passive or switching components including, but not limited to a MEMS switch 18, Add/Drop Multiplexer 20, Optical Multiplexer 24, and the like. Higher latency optical routing components such as a SONET router 22 can be used as well, if the latency budget is acceptable. FDM can also have low latency because RF mixing and combining are low latency operations, no processing or switching need be performed. Low latency is a desirable property for the invention, because placing a network between the antenna 12 and current base stations 14 places strict latency limitations on the network 10, as the network is now part of the conventional "air link" of a cellular system. This element of the link has strict latency constraints in modern cellular protocol standards, such as CDMA and GSM. However, other base station 14 embodiments can compensate for greater latency in this "air link"

portion of the network 10, as it is a very small fraction of total latency in a wireless call. Such base stations permit much more flexible networking technology to be employed.

All or a portion of the links 16 can use optical Figure 6 DWDM (Dense Wavelength Division Multiplexing) for transmission. At least one link 16 can provide multiple transmission paths employing digital transmissions and DWDM multiplexing between at least a portion of the base stations 14 with at least a portion of the antennas 12. DWDM ring networks also can employ protection mechanisms, which can be important in the implementation of this invention, because if a fiber link breaks, multiple cellular sites will go down. Such protection operates by routing the optical signal in the opposite direction along the ring if there is a break. This routing can be accomplished by switching the direction of transmission around the ring on detection of a break, or by always transmitting optical signals between nodes in both directions, creating two paths for redundancy in case of a fiber break.

Some or all of the links 16 can use TDM (Time Division Multiplexing) to create the transmission paths. In one embodiment, the TDM employs SONET TDM techniques. In one embodiment, the TDM is specifically employed from one node to another node on the network 10 to carry multiple distinct RF signals in a point-to-point fashion. In a point-to-point TDM link, several signals are multiplexed together at an originating node, the multiplexed signal is then transported to the terminating node, and then the multiple signals are demultiplexed at the terminating node. Point-to-point TDM topology has the advantage of simplifying the multiplexing of multiple signals together, as opposed to adding and dropping low bit rate signals onto high bit rate carriers. Additionally, as illustrated in Figure 10, the TDM link can carry multiple sectors of a base station 14. Further, the TDM link can carry multiple signals from different operators, carry diversity signals and be used to carry backhaul signals.

All or a portion of the links 16 can employ the SONET protocol, particularly using fixed optical paths. In such an embodiment, the SONET protocol is used to encode the signals, and then they are directed along fixed optical paths in a multiple wavelength optical network 10. A fixed optical path is one that is re-routed infrequently compared to the bit rate of the communication protocol employed over the path. This has the advantage of simplifying routing, since now only wavelengths need be routed. In a more flexible network 10, more complex SONET routing can be employed, for example, the

links 16 can be multiplexed onto a SONET ring. In such a routing scheme, the multiplexing involves routing bits at the carrier bit rate of the ring, rather than routing optical wavelengths.

Different optical wavelengths in a fixed or switched optical path configuration can also employ other protocols. In one embodiment, at least a portion of the links 16 employ Fibre Channel, Gigabit Ethernet, TCP, ATM or another transmission protocol. In one embodiment, at least one optical wavelength carries OA&M signals and in another embodiment, at least one TDM channel carries OA&M signals.

Full SONET routing can be used over the network 10. In such a case, low bit rate cellular signals are added and dropped off of higher bit rate SONET links, with flexible signal routing. SONET's low latency, TDM functionality, and wide availability for optical networking implementations make it a useful protocol for this application. In other embodiments, IP routing is used. Routing protocols can be combined with traffic data to route signals as needed to optimize capacity between a group of base stations 14 and remote antenna 12 nodes.

As noted earlier, network 10 can provide optical multiplexing. In this embodiment, the plurality of links 16 includes a plurality of optical fiber links. As illustrated in Figure 11, at least one fiber cable 20 can be included with a plurality of fiber strands 22 which form the multiple transmission paths. For example, a 192 count fiber cable could be used for 192 fiber strands, allowing 192 signals to be multiplexed on the cable with no other form of multiplexing. Clearly, multiple cables can be exploited in the same way as multiple strands. In another embodiment, at least one optical fiber strand 22 transmits at least two optical wavelengths that form multiple transmission paths. Preferably, all of the optical fiber strands 22 transmit more than one optical wavelength. As an example, 6 strands could carry 32 wavelengths each, providing 192 transmission paths. Beyond this, each path could have 4 signals multiplexed onto it employing TDM, providing 4 x 192 = 768 transmission paths.

Referring to Figure 12, in other embodiments, the plurality of links 16 is a plurality of free space optical links 24. In such links, one or more optical wavelengths are directed through free space. Such links are useful to employ in areas where fiber is expensive or unavailable. The plurality of links 16 can include both optical fibers and free space optical links 24.

At least a portion of the plurality of links can be configured to provide selectable allocation of capacity to at least a portion of the plurality of base stations 14. This can be achieved with a control switching system 25. As illustrated in Figure 9, such a system functions like a switch, in which the RF traffic from the antennas 12 are directed into it, and then redirected into base station 14 transceivers as needed. The switch 25 also takes the downlink channels and distributes them back to the antennas 12. The switch 25 can dynamically allocate the channel capacity of a group of base station transceivers to antennas 12 as needed. The capacity redirection switch 25 can be coordinated with the RF channel allocation, in order that the same frequencies are not used adjacent to each other. The switch allows the base station transceiver capacity to serve the entire geographic region covered by the antennas 12.

Referring to Figure 14, a special case of shared base station transceiver capacity is to connect multiple existing base station 14 sites together, in order that the antennas 12 at these sites can be served by the transceiver capacity of all the base stations 14. The statistics of pooling transceiver capacity to cover larger geographic areas allows fewer base stations 14 to be used than if they were individually connected to single antennas. In addition, populations moving within the larger geographic area are covered by the same transceiver pool, which allows the number of transceivers to be sized with the population, not the geographic coverage area. This reduces the number of base stations 14 required to cover a given geographic area. In another embodiment shown in Figure 15 a control box 27 can be included for each or a portion of the antennas 12 and provide routing to selected base stations 14. The routing by the control boxes 27 can be performed according to a desired schedule. For example, the switch could allocate more channels to highways during commute hours, and more channels to commercial office parks during business hours. One or all of the plurality of the links 16 can include a passive optical device 26. Suitable passive optical devices 26 include but are not limited to OADM's, filters, interleavers, multiplexers, and the like.

All of only a portion of the plurality of links 16 can include one or more optical amplifiers 28, Figure 16. Optical amplifiers 28 are low latency devices that amplify optical signals, overcoming optical losses from fiber and the use of optical components. Such amplifiers 28 are commercially available in configurations that amplify blocks of

wavelengths, which makes DWDM optical networking more feasible, especially given the optical losses sustained in wavelength multiplexing.

The cellular signals exchanged over network 10 can be analog signals or digitized. Analog signals generally involve modulating a laser or optical modulator with the cellular RF signal, or a frequency converted version of this signal. Such implementations have the advantage of simplicity, and can take advantage of WDM, multiple fiber strands 22 on a given fiber cable 20, and FDM. However, for such transmission, the channel properties of the link 16, such as noise figure and spur-free dynamic range, directly impact the signal properties. DWDM networks experience linear and non-linear crosstalk, causing signal interference between different wavelength carriers. This can create problems with analog RF transmission. Digital signals are streams of bits, generated by digitally encoding the analog cellular signal. The analog cellular signal is the signal that would normally be transmitted or received by the base station or the remote mobile units. So a PCS CDMA signal could be an "analog cellular signal." It is not meant to imply that the signal is representative of an analog cellular standard. If the digital representation of the analog cellular signal is transmitted with a sufficient signal-to-noise ratio, it will not be significantly affected by link properties. Furthermore, these digital signals can be digitally protected with various strategies, such as encoding, parity, etc., to further reduce the likelihood of bit errors. By employing digital signals, there is a significant improvement in resistance to crosstalk. Hence DWDM and digital transmission is a powerful combination for exploiting the network 10 to carry the maximum number of cellular signals. Digital signals are furthermore amenable to the use of digital communications equipment and standards, such as routers, IP and SONET.

In one embodiment, the wavelength carriers carry an analog signal representative that is representative of an RF signal between multiple base stations 14 and antennas 12. Different carriers carry different cellular signals. In another embodiment, the wavelength carriers carry a digital signal that is representative of an RF signal between multiple base stations 14 and antennas 12. This digitization can be implemented in two preferred embodiments.

As illustrated in Figure 17, a digital transceiver 30 is embedded between the base station 14 and the network 10 on the base station 14 side, and between the antenna 12

and the network 10 at the antenna 12 side. The coupling can be either a direct connection, or through one or more RF components such as an amplifier, attenuator, gain control block, and the like. The analog cellular signal, which is normally exchanged between these two units, is first converted into a digital signal by the digital transceiver, which is then exchanged over the network 10. After the digital cellular signal is received at the other end of the network, it is reconstituted by the digital transceiver as an analog cellular signal. This signal can be filtered, amplified, attenuated, and the like before being transmitted to the antenna 12, or the base station 14.

The other embodiment is to integrate the digital component into the base station 14 unit and the antenna 12 unit, and not use a separate digital transceiver. Although this can involve digitizing a wireless channel or frequency band, a more sophisticated implementation is to separate the functionality of the base station 14 unit and the antenna 12 unit at a point where the signal is itself digital. Given that the cellular RF signal is a digitally modulated signal, the voice channel is digitized, and base stations 14 are migrating to a digital transmit/receive architecture, there are several intermediate digital signals that could be exchanged. The antenna 12 units, when serving as remote units, can provide conventional base station 14 functionality such as baseband coding, channel coding, modulation/demodulation, channel filtering, band filtering and transmission reception and the like.

The general case is that each antenna 12 location can be configured to receive a downlink cellular signal as a digital stream input that is representative of a single or multiplicity of wireless channels or a segment of wireless spectrum. The antenna 12 then reconstructs and transmits the RF signal. Additionally, uplink cellular signals are received off-air at the antenna 12 that are representative of a single or a multiplicity of wireless channels from at least one mobile unit. At the antenna 12 node the uplink cellular signal is then converted into a single or plurality of bit streams. The bit streams are then transmitted over the network 10 to the base station 14 units. The base station 14 units receive this uplink digital signal and process it. Additionally, they transmit a downlink digital signal to the network 10.

When digital transceiver units are used to perform D/A and A/D functionality between antennas 12 and base stations 14, the analog signals can be frequency down converted before sampling and A/D conversion, and frequency up converted after D/A

conversion. The digital signal can be serialized before transmission and converted back to a parallel signal after transmission. High bit rates, including but not limited to those greater than 500 Mbps, can be employed to create high dynamic range links for improved cellular performance.

Referring to Figure 18, when digital transceivers are employed, at the base station, the digital transceivers 30 digitize the downlink analog cellular signals that are representative of a wireless spectrum band or channel. Thereafter, the digital transceivers 30 pass the downlink digital cellular signals to the network 10. For the uplink at the base station, the digital transceivers 30 receive uplink digital signals representative of a wireless spectrum band or channel from the network, reconstruct the analog cellular signals, and then pass them to the base stations 14. At the antennas 12, for the uplink, the analog cellular signals received on the antenna 12 from the mobile units are converted into digital signals, and transmitted onto the network 10. The downlink digital signals are received by digital transceivers at the antenna 12, and then converted back into analog cellular signals representative of a wireless spectrum band or channel, and passed to the antenna 12.

In various embodiments, network 10 can have different layouts. In one embodiment, at least a portion of the plurality of the links 16 are fixed optical paths. Such paths involve connecting one or more remote nodes to one or more base nodes and rarely dynamically re-routing this path. The optical paths between antennas 12 and base stations 14 can have a one-to-one correspondence, connecting to one antenna 12 node and one base station 14 unit, or alternatively, one or more antennas 12 can be connected to one or more base stations 14 in a non one-to-one embodiment. In another embodiment, the transmission paths of network 10 can be dynamic-routable optical paths flexibly routed between one or a plurality of base stations 14 and one or a plurality of antennas 12.

As illustrated in Figure 19, network 10 can be configured as a hub and spoke network 32. In this embodiment, the plurality of base stations 14 are located in a common node 34 and the plurality of antennas 12 are located at different remote nodes, generally denoted as 36 on the network 32. Optical uplink and downlink connections are spokes 38 that connect the common node 34 and the remote nodes 36. Network 32 can also include at least one set of nodes 40 containing the base stations 14 and/or antennas

12 which are connected by one or more links 16 that are laid out on a segment or a ring. Whether on a segment or a ring, in a preferred implementation the uplink and downlink should be transmitted in opposite directions to equalize the latency, which is important in cellular transmission.

In one embodiment, at least two of the base stations 14 are located in a common location and the antennas 12 are geographically dispersed, Figure 20. Suitable common locations include but are not limited to an environmentally controlled room in a building connected to the network 10. The antennas 12 are placed in areas providing the desired coverage which may have higher real estate costs and/or lower available footprints than the common location, but which can be connected to the network 10.

In various embodiments, at least one link of the plurality of links 16 can be, shared by at least two operators. The operators can be wireless operators, different spectrum bands used by a same cellular operator, different entities. This different operators need not share electrical components when using an optical network. Different operators can be multiplexed onto the network using any of the multiplex methods detailed previously. In a preferred implementation, the different operators can use different optical fibers strands, or different optical wavelengths on the same fiber strand. In another preferred implementation, different operators can employ different wavelengths on free space links. By optically multiplexing multiple operators on the same network 10, the operators can share the costs of constructing, acquiring and maintaining the network 10 without compromising their electrical isolation requirements. In one embodiment, the network 10 can be used to connect together existing base station 14 sites for different operators, and used to extend coverage from one operator to all other operators.

For example, as illustrated in Figure 21, a site built by operator A at site A is connected to a site built by operator B at site B. An antenna 12 for A is placed at site B, connected to a base station 14 for operator A at site A, and an antenna 12 for operator B is placed at site A, connected to a base station 14 for operator B at site B.

In various embodiments, the links 16 provide that at least one optical carrier carries at least one backhaul signal from a base station 14 to a switch (such as an MTSO) or a bridge network. In an RF network, where the links 16 are RF links, the links 16 can

be configured to provide that at least one RF carrier carries at least one backhaul signal from a base station 14 to one of a switch (such as an MTSO) or a bridge network.

Referring now to Figure 22, network 10 can be an optical network that directly connects to a switch 42, including but not limited to an MTSO. Multiple backhaul signals from several base stations can be integrated into one higher bit rate backhaul signal. This allows the network 10 costs to be shared amongst backhaul signals as well, and allows for high bandwidth backhaul to be performed, which is cheaper per bit. The backhaul signals can be digital t-carriers, SONET signals, and the like. Non-backhaul RF signals that share the network 10 with the backhaul signal can be represented digitally to minimize the effects of crosstalk with the digital backhaul signal. Non-backhaul RF signals can have a large wavelength separation from the backhaul signal in order to minimize the effects of crosstalk with the digital backhaul signal.

Some antenna 12 or base station 14 locations are difficult to connect to a network, especially an optical fiber network, because no fiber may exist to the site. In an embodiment of the invention, such a location can be connected to the network 10 with a free space link, either a free space optical link 16 or microwave link 16. This link 16 can be analog or digital, and if digital can be formatted in a proprietary fashion, or as a T-carrier or SONET link.

In another embodiment of the present invention, illustrated in Figure 23, a distributed antenna system 110 utilizes diversity receive and has one or more base stations 112. Each base station 112 is connected to multiple remote repeater units 111 and their corresponding antennas 113, with the combined assembly being object 114. It will be appreciated that the combined assembly 114 can have more than one antenna 113. The downlink RF signal is power divided into multiple signals, and then distributed to individual remote repeater units 111 and their corresponding antennas 113. The uplink RF signals from multiple remote units 114 are power combined. Remote units 114 are split into two or more groups 116 and 118 for each base station 112. Each base station 112 has a simplex receive port 119 or duplex transmit/receive port 120. It also has one or more diversity receive ports 122. Each remote repeater unit 112 in both groups 116 and 118 is connected to one downlink port, either simplex transmit port 121 or duplex transmit/receive port 120. However, only one of the groups 116 or 118 is coupled to the uplink receive port 119 or transmit/receive port 120 and the other group 116 or 118 is

coupled to diversity receive port 122. It will be appreciated that this grouping can be extended to more than one diversity receive port 122. The division and placement of remote repeater unit assemblies 114 into groups 116 and 118 is chosen in order to maximize the potential for diversity receive. The number of groupings of remote repeater units assemblies 114 is equal in number to the total number of receive ports on a base station 112, either simplex receive port 119 or transmit/receive port 120, and then the diversity receive port or ports 122.

This embodiment can be utilized an any distributed antenna system, including but not limited to in-building applications, distributions of antennas 113 in a linear and non-linear arrangement and the like. By way of illustration, and without limitation, a linear coverage area, such as a road, can be covered by a series of remote repeater units 111 with their corresponding antennas 113, the combined assembly 114 placed on poles, at a spacing governed by the location of the poles and the coverage area of antennas 113. All of the poles along a segment are connected to the same base station 112.

As illustrated in Figure 24, each remote repeater unit receiver 124 on an alternate pole is placed into one of two groups 116 or 118. Each group 116 and 118 is power combined and connected to a different receive port. One group is connected to simplex receive port 119 or transmit/receive port 120, one of which will be present in a given base station 112. The other group is connected to diversity receive port 122. A mobile transmitter 123 between the poles that transmits an uplink signal has its signal received by both poles and is correctly discriminated by the receive/diversity receive on the base station 112. This can be extended to more than two groups if more receive or transmit/receive ports are available. When the distributed coverage is not arranged in a linear manner, coverage locations that are adjacent to one another are placed in the two or more different groups 116 and 118. Preferably, coverage areas are arranged into groups to increase the likelihood that a mobile transmission from a given location will be received by the two different receive ports, one by the receive port 119 or the transmit/receive port 120, and the other by the diversity receive port 122. Therefore, the members of groups 116 and 118 are chosen so that, as much as possible, geographically adjacent coverage areas are placed into different groups. Groups 116 and 118 are then coupled and combined. One into the receive port 119 or transmit/receive port 122,

depending on the base station configuration, and the other into the diversity receive port 122.

In this embodiment of the present invention, the effects of Raleigh fade are significantly reduced. Raleigh fade can result from multipath which can occur as the signal travels from mobile transmitter 123 through the air to an antenna 113, or, in a distributed antenna system, due to the combination of signals from multiple antennas 113. This embodiment of the present invention provides two separate receive signals on two different receivers, and it is less likely for a null to occur at the location of both antennas 113 because two adjacent poles have different receive paths. By way of illustration, and without limitation, ~3 dB SNR can be gained from the multiple signal path reception of this embodiment.

Another benefit of this embodiment is that the number of remote repeater units 114 that are power combined on the uplink is divided by the total number of receive ports, comprised of a simplex receive port 119 or transmit/receive port 120, and one or more diversity receive ports 122. This total number is typically two. Because power combination reduces the signal while maintaining the same noise, proportional to the number of signals that are power combined, power combining half the distributed remote repeater units 114 on the uplink yields a 3dB improvement in uplink signal-to-noise ratio using two receive ports versus combining all the distributed remote repeater units 114 into a single receive port 119 or single transmit/receive port 120. Greater improvements result from more receive ports. This is particularly suitable for fiber fed systems because fiber link noise figure can make the link uplink limited. In the repeater systems that are used to implement this type of base station link, the link budget, meaning the coverage area, can often be determined by the uplink noise figure, not the downlink transmit power. However, in any power combined system, this improvement can be realized. By splitting the uplinks into multiple groups 116 and 118, and coupling them into simplex receive port 119 or duplex transmit/receive port 120 and diversity receive ports 122, the performance of system 110 is improved.

The improvement in uplink Raleigh fade, potential improvement in uplink signal, and decrease in uplink noise floor are illustrated in Figure 25. As shown in Figure 25, receive signal no longer experiences extensive Raleigh fading from being the power combined sum of the receive signals from both remote repeater units 114, and is 3 dB

higher in the center between the poles , assuming the BTS has multiple receive paths for each receive port, so it can combine the demodulated signals. In addition, the noise floor drops by 3 dB as the number of poles that are power combined is divided by two.

In certain circumstances, coverage situations can exist in a distributed antenna system in which the coverage areas are downlink limited, not uplink limited. Such a situation is illustrated in Figure 26. In such an area, the uplink coverage area 124 is larger than the downlink coverage area 126. In various embodiments, the present invention places the remote repeater units 111 with their corresponding antennas 113 such that the uplink coverage areas are overlapping, even if the downlink coverage areas are not overlapped. Multiple remote repeater units 114 can receive the same uplink signal, and so they can be coupled to the base station 112 to take advantage of the invention. With two receive ports, remote repeater units 114 are placed into two different groups 116 and 118 to maximize the opportunity for diversity uplink reception, and then one group is power combined and connected to the simplex receive port 119 or duplex transmit/receive port 120 and the other group is power combined and connected to diversity receive port 122. This can be extended to as many groups as the base station 112 has total receive ports.

The foregoing description of preferred embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in this art. It is intended that the scope of the invention be defined by the following claims and their equivalents.

## CLAIMS

1. A method of transmission, comprising providing a network with a plurality of links that couple a plurality of antennas with a plurality of base stations, wherein at least one base station or antenna location is geographically remote from the network and is connected to the network with a free space link,

wherein at least one of the plurality of links provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas, each transmission path of the plurality of transmission paths carrying a signal representative of a respective segment of wireless spectrum that is associated with a respective operator.

2. The method of claim 1, wherein the free space link is an RF link.

3. The method of claim 1, wherein the free space link is an optical link.

4. The method of any of claims 1 to 3, further comprising:
frequency division multiplexing multiple cellular signals onto the free space link.

5. The method of any preceding claim, further comprising:
transporting a digital signal over the free space link representing the cellular signal.

6. The method of claim 5, wherein the digital signal is generated by digitizing a wireless band.

7. The method of claim 5, wherein the digital signal is placed in a format selected from SONET, Gigabit Ethernet, Fibre Channel, TCP, and T-Carrier.

8. The method of any of claims 5 to 7, wherein the digital signal is multiplexed into the network without converting it back into an analog signal.

9. The method of any preceding claim, wherein the base stations are configured to provide cellular transmission.

10. The method of any preceding claim, wherein a plurality of free space optical links couple the plurality of antennas and the plurality of base stations, and at least one link of the plurality of links provides multiple transmission paths over at least two optical wavelengths between at least a portion of the base stations with at least a portion of the antennas.

11. The method of claim 9 or claim 10, wherein cellular signals are exchanged over the network.

12. The method of any of claims 9 to 11, wherein additional transmission paths are created by frequency division multiplexing multiple signals onto the same optical carrier.

13. The method of any of claims 9 to 12, wherein the plurality of links are configured to provide a backhaul signal frequency division multiplexed as a subcarrier on at least one optical carrier from a base station of the plurality of base stations to a switch or a bridge network.

14. A network with a plurality of links that couple a plurality of antennas with a plurality of base stations, wherein at least one base station or antenna location is geographically remote from the network and is connected to the network with a free space link,

wherein at least one of the plurality of links provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas, each transmission path of the plurality of transmission paths carrying a signal representative of a respective segment of wireless spectrum that is associated with a respective operator.

15. The network of claim 14, wherein the free space link is an RF link.

16. The network of claim 14, wherein the free space link is an optical link.

17. The network of claim any of claims 14 to 16, wherein multiple cellular signals are frequency division multiplexed onto the free space link.

18. The method of any of claims 14 to 17, wherein a digital signal is transported over the free space link representing the cellular signal.

19. The network of claim 18, wherein the digital signal is generated by digitizing a wireless band.

20. The network of claim 18, wherein the digital signal is placed in a format selected from SONET, Gigabit Ethernet, Fibre Channel, TCP, and T-Carrier.

21. The network of any of claims 18 to 20, wherein the digital signal is multiplexed into the network without converting it back into an analog signal.

22. The network of any of claims 14 to 21, wherein the base stations are configured to provide cellular transmission.

23. The network of any of claims 14 to 22, wherein a plurality of free space optical links couple the plurality of antennas and the plurality of base stations, and at least one link of the plurality of links provides multiple transmission paths over at least two optical wavelengths between at least a portion of the base stations with at least a portion of the antennas.

24. The network of claim 22 or claim 23, wherein cellular signals are exchanged over the network.

25. The network of any of claims 22 to 24, wherein additional transmission paths are created by frequency division multiplexing multiple signals onto the same optical carrier.

26. The network of any of claims 22 to 25, wherein the plurality of links are configured to provide a backhaul signal frequency division multiplexed as a subcarrier on at least one optical carrier from a base station of the plurality of base stations to a switch or a bridge network.

27. A method according to claim 1 substantially as hereinbefore described with reference to the accompanying drawings.

28. A network according to claim 14 substantially as hereinbefore described with reference to the accompanying drawings.

**Amendments to the claims have been filed as follows**

1. A method of transmission, comprising providing a network with a plurality of links that couple a plurality of antennas with a plurality of base stations, wherein at least one base station or antenna location is geographically remote from the network and is connected to the network with a free space link,

wherein at least one of the plurality of links provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas, each transmission path of the plurality of transmission paths carrying a signal representative of a respective segment of wireless spectrum that is associated with a respective operator.

2. The method of claim 1, wherein the free space link is an RF link.

3. The method of claim 1, wherein the free space link is an optical link.

4. The method of any of claims 1 to 3, further comprising:
frequency division multiplexing multiple cellular signals onto the free space link.

5. The method of any preceding claim, further comprising:
transporting a digital signal over the free space link representing the cellular signal.

6. The method of claim 5, wherein the digital signal is generated by digitizing a wireless band.

7. The method of claim 5, wherein the digital signal is placed in a format selected from SONET, Gigabit Ethernet, Fibre Channel, TCP, and T-Carrier.

8. The method of any of claims 5 to 7, wherein the digital signal is multiplexed into the network without converting it back into an analog signal.

9. The method of any preceding claim, wherein the base stations are configured to provide cellular transmission.

10. The method of any preceding claim, wherein a plurality of free space optical links couple the plurality of antennas and the plurality of base stations, and at least one link of the plurality of links provides multiple transmission paths over at least two optical wavelengths between at least a portion of the base stations with at least a portion of the antennas.

11. The method of claim 9 or claim 10, wherein cellular signals are exchanged over the network.

12. The method of any of claims 9 to 11, wherein additional transmission paths are created by frequency division multiplexing multiple signals onto the same optical carrier.

13. The method of any of claims 9 to 12, wherein the plurality of links are configured to provide a backhaul signal frequency division multiplexed as a subcarrier on at least one optical carrier from a base station of the plurality of base stations to a switch or a bridge network.

14. A network with a plurality of links that couple a plurality of antennas with a plurality of base stations, wherein at least one base station or antenna location is geographically remote from the network and is connected to the network with a free space link,

wherein at least one of the plurality of links provides multiple transmission paths between at least a portion of the base stations with at least a portion of the antennas, each transmission path of the plurality of transmission paths carrying a signal representative of a respective segment of wireless spectrum that is associated with a respective operator.

15. The network of claim 14, wherein the free space link is an RF link.

16. The network of claim 14, wherein the free space link is an optical link.

17. The network of claim any of claims 14 to 16, wherein multiple cellular signals are frequency division multiplexed onto the free space link.

18. The method of any of claims 14 to 17, wherein a digital signal is transported over the free space link representing the cellular signal.

19. The network of claim 18, wherein the digital signal is generated by digitizing a wireless band.

20. The network of claim 18, wherein the digital signal is placed in a format selected from SONET, Gigabit Ethernet, Fibre Channel, TCP, and T-Carrier.

21. The network of any of claims 18 to 20, wherein the digital signal is multiplexed into the network without converting it back into an analog signal.

22. The network of any of claims 14 to 21, wherein the base stations are configured to provide cellular transmission.

23. The network of any of claims 14 to 22, wherein a plurality of free space optical links couple the plurality of antennas and the plurality of base stations, and at least one link of the plurality of links provides multiple transmission paths over at least two optical wavelengths between at least a portion of the base stations with at least a portion of the antennas.

24. The network of claim 22 or claim 23, wherein cellular signals are exchanged over the network.

25. The network of any of claims 22 to 24, wherein additional transmission paths are created by frequency division multiplexing multiple signals onto the same optical carrier.

26. The network of any of claims 22 to 25, wherein the plurality of links are configured to provide a backhaul signal frequency division multiplexed as a subcarrier on at least one optical carrier from a base station of the plurality of base stations to a switch or a bridge network.

27. A method according to claim 1 substantially as hereinbefore described with reference to Figures 5 to 26.

28. A network according to claim 14 substantially as hereinbefore described with reference to Figures 5 to 26.

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| **Application No:** | GB 0311316.4 | **Examiner:** | Hannah Sylvester |
| **Claims searched:** | 1-26 | **Date of search:** | 16 June 2003 |

# Patents Act 1977 : Search Report under Section 17

## Documents considered to be relevant:

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance | |
|---|---|---|---|
| A | - | US2002186436A | (NEXTG) |
| A | - | US5657374A | (ADC TELECOMMUNICATIONS) |

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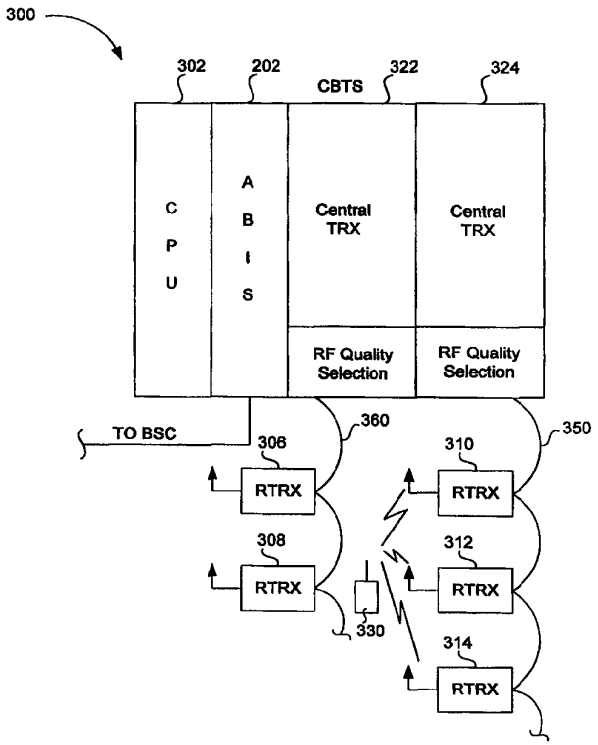
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(57) Abstract

A base transceiver station (BTS) in a cellular communication system having a base station controller (BSC) and a mobile services switching center (MSC). The BSC is configured for facilitating communication between the BSC and a plurality of mobile stations (MS's). The communication with the plurality of the MS's is accomplished via radio frequency (RF) medium. The BTS includes a first interface circuit for coupling the BTS with the BSC. The BTS further includes a processor coupled to the first interface circuit for processing first digital data received from the BSC to form second digital data. There is further included a first central transceiver (CTRX) circuit coupled to the processor. The first CTRX circuit is co–resident with the processor and the first interface circuit. The BTS further includes a first remote transceiver (RTRX) circuit coupled to the first CTRX circuit. The first RTRX circuit includes a first antenna circuit for communicating with a first MS of the plurality of MS's via the RF medium, wherein the first RTRX circuit is implemented in a geographically remote manner from the first CTRX circuit.



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# METHODS AND APPARATUS FOR IMPROVED BASE STATION TRANSCEIVERS

## Background of the Invention

The present invention relates to apparatus and methods for improving cellular communication networks. More particularly, the present invention relates to improved base transceiver stations (BTS) architectures in a cellular communication network.

Cellular communication systems are well known in the art. In a typical cellular communication, the mobile stations (MS's) may transmit and receive voice and/or data with the cellular network and one another utilizing radio waves. To facilitate discussion, Fig. 1 depicts the architecture of a cellular communication network 100 that implements the well-known Global System for Mobile Communication (GSM) standard. Although the GSM cellular network is chosen herein for illustration purposes, it should be borne in mind that the invention disclosed herein is not limited to any particular standard.

In Fig. 1, there is shown a plurality of mobile stations (MS's) 102, 104, and 106, representing the mobile interface with the cellular users. In a typical network, MS's 102, 104 and 106 may be, for example, the mobile handsets or the fixed mobile stations mounted in vehicles. Mobile stations 102, 104, and 106 typically include radio and processing functions for exchanging voice and data via radio waves with transceivers (TRX's) in base transceiver stations (BTS's) 114 and 116. The transceivers (TRX's) are shown in Fig. 1 as transceivers 114a, 114b, 114c, 116a, and 116b. The BTS's may be thought of, in one sense, as the counterpart to the MS's within the cellular network, and its main role is to connect the mobile stations with the rest of cellular communication network 100.



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There is also shown in Fig. 1 a base station controller (BSC) 118, whose function is to monitor and control the BTS's. There may be any number of BSC 118 in a network, whose responsibility includes, among other responsibilities, radio interface management, e.g., the allocation and release of radio channels and handover management. Mobile Services Switching Center (MSC) 120 controls one or more BSC's 118 and provides the basic switching function within the cellular network, including setting-up of calls to and from the MS's. MSC 120 also provides the interface between the cellular network users (via the BSC and BTS) with external networks (e.g., PSTN or public switched telephone network). The components of GSM cellular network 100 are well known to those skilled in the art and are not discussed in great detail here for brevity's sake. Additional information pertaining to GSM and the cellular networks implementing the GSM standard may be found in many existing references including, for example, Redl, Weber & Oliphant, An Introduction to GSM (Artech House Publishers, 1995).

In the prior art, the radio circuitries of the TRX's are typically implemented such that they co-locate with other circuits of the BTS. By way of example, Fig. 2 illustrates in greater detail exemplary prior art BTS 114 of Fig. 1, including TRX's 114a, 114b, and 114c. As is typical, the antennas of the prior art TRX's co-locate with the BTS such that the BTS defines the cell. Although one antenna is shown to facilitate simplicity of illustration, separate transmit and receive antennas may be provided for each TRX, as is well known. Other major functional blocks of BTS 114 includes ABIS interface 202, which implements the circuitry necessary for interfacing between BTS 114 and its BSC. CPU circuit 204 implements the call processing functions, including for example LAPDm processing, speech framing, channel coding, interleaving, burst formatting, ciphering, modulation, and the like.



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The architecture of the prior art BTS is well known and is not discussed here in great detail for simplicity's sake.

It has been found, however, that the conventional BTS architecture has many disadvantages. By way of example, the integration of the radio circuitries of the TRX's and the processing circuitries of the BTS in one unit results in a complex and maintenance-intensive electronic subsystem. Yet prior art BTS's are often installed in locations selected primarily for optimum radio transmission quality such as on top of buildings and other outdoor structures instead of ease of access. These locations, being exposed to the elements, are typically hostile to the delicate and complex electronic circuits of the prior art BTS. Accordingly, these factors tend to render the installation, maintenance, and upgrade of prior art BTS's difficult and expensive.

The integration of the radio circuitries of the TRX's in the prior art BTS also limits the flexibility with which the cell can be modified to accommodate changes in capacity. In the prior art, the BTS, which contains the co-resident TRX antennas, essentially defines the cell. Although some cell shaping may be accomplished by, for example, employing directional antennas, the cell is more or less limited by the transmit power of the antennas in the BTS. Scaling the transmit power upward increases the cell size at the expense of capacity since the use of larger cells reduces the ability to reuse frequencies among neighboring cells. Increasing the transmit power also increases the amount of heat generated, thereby reducing the reliability of the circuitries in the prior art BTS unless fans and/or additional heat dissipation techniques are employed.

In view of the foregoing, there are desired improved BTS architectures for overcoming the disadvantages associated with prior art BTS's. In particular, there are



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desired BTS architectures which offer improved reliability and simplified maintenance, as well as increase the flexibility with which the cell can be modified to accommodate changes in capacity.



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## Summary of the Invention

The invention relates, in one embodiment, to a base transceiver station (BTS) in a cellular communication system having a base station controller (BSC) and a mobile services switching center (MSC). The BSC is configured for facilitating communication between the BSC and a plurality of mobile stations (MS's). The communication with the plurality of the MS's is accomplished via radio frequency (RF) medium. The BTS includes a first interface circuit for coupling the BTS with the BSC. The BTS further includes a processor coupled to the first interface circuit for processing first digital data received from the BSC to form second digital data. There is further included a first central transceiver (CTRX) circuit coupled to the processor. The first CTRX circuit is co-resident with the processor and the first interface circuit. The BTS further includes a first remote transceiver (RTRX) circuit coupled to the first CTRX circuit. The first RTRX circuit includes a first antenna circuit for communicating with a first MS of the plurality of MS's via the RF medium, wherein the first RTRX circuit is implemented in a geographically remote manner from the first CTRX circuit.

In another embodiment, the BTS further includes a second remote transceiver (RTRX) circuit coupled to the first CTRX circuit. The second RTRX circuit includes a second antenna circuit for communicating with the first MS via the RF medium. The first CTRX includes an RF quality selection circuit for selecting one of the first RTRX and the second RTRX for use in communicating with the first MS.

These and other advantages of the present invention will become apparent upon reading the following detailed descriptions and studying the various figures of the drawings.



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## Brief Description of the Drawings

The invention, together with further advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which like reference numbers refer to like structures/items and in which:

To facilitate discussion, Fig. 1 depicts the architecture of a conventional cellular communication network.

Fig. 2 illustrates in greater detail the prior art BTS of Fig. 1.

Fig. 3 illustrates, in accordance with one embodiment of the invention, a concentrated BTS (CBTS), including the remote transceivers (TRX's).

Fig. 4 illustrates, in accordance with one embodiment of the present invention, a CBTS having dynamic configuration capability.

Fig. 5 shows, in accordance with one embodiment of the present invention, a logic block diagram of a remote TRX .

Fig. 6 is a block diagram illustration of the data flow within a prior art GSM BTS module during transmit and receive.

Figs. 7A, 7B and 7C illustrate, in accordance with various embodiments of the present invention, the data flow within the inventive CBTS during transmit and receive.





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## Detailed Description of the Preferred Embodiments

The present invention will now be described in detail with reference to a few preferred embodiments thereof as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth to provide a thorough understanding of the present invention. It will be obvious, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known structures and process steps have not been described in detail to not unnecessarily obscure the present invention.

In accordance with one aspect of the present invention, there is provided a novel and nonobvious concentrated BTS (CBTS) architecture in which the TRX is divided into two TRX subsystems: a central TRX subsystem which co-resides with the CBTS and a remote TRX subsystem which is geographically remote from the CBTS and the central TRX. In accordance with this aspect of the present invention, the remote TRX includes the RF antenna circuitries that are employed for transmitting and receiving signaling and user data with the MS's via RF signals. As the term is employed hereinafter, user data refers to non-voice call data (such as short messages, text, graphics, or voice files, and the like) as well as voice calls between cellular users.

The antenna circuitries in the remote TRX convert the data from a digital format into RF signals for transmission to the MS's and convert RF signals from the MS's into digital data for processing by the cellular network. Although additional processing capabilities may be built into the remote TRX if desired, it is in general preferable to keep the circuitries within the remote TRX simple to simplify maintenance and upgrade. Additionally, since the





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remote TRX may be implemented in hard-to-reach locations (e.g., locations which offer optimal transmission quality such as the top of building or other structures) or be exposed to the elements, simple remote TRX designs promote ruggedness, which reduces maintenance costs.

The remote TRX is coupled to the central TRX at the CBTS through an appropriate transmission medium such as a conductive or a fiber optic medium. Since the CBTS no longer contains the antenna circuitries, the transmission quality no longer depends on the location of the CBTS. Accordingly, it becomes possible to locate the CBTS inside to offer the BTS circuitries greater protection from the elements or to locate the CBTS at a location that is selected for convenient access for maintenance and upgrade.

On the selected transmission medium, an appropriate physical layer protocol is then implemented. In one embodiment, the physical layer represents one of the well known E1, E2, or E3 protocols although any other suitable physical layer protocol may also be employed. Other embodiments could be HDSL, OC3, or OC3 - Optical.

For actual transmission between the remote TRX and its corresponding central TRX at the CBTS, an appropriate transport protocol is also implemented on top of the physical layer protocol. The transport protocol may represent any suitable protocol and may in some cases represent packet-switching or TDM protocols. In the one embodiment, an Asynchronous Transmission Mode (ATM) protocol is employed. In the another embodiment, a Frame Relay protocol is employed.

The central TRX, which is co-resident with the CBTS, includes interface circuits necessary for communicating with the remote TRX's using the aforementioned transport and physical layer protocols.





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The CBTS preferably also includes the bulk of the processing circuitries necessary for preparing the digital data from the cellular network for transmission via the air interface. Such CBTS circuits include, for example, the well known circuits for processing the messages received from the MSC and BSC for call setup and system control, speech processing and ABIS interface circuits. One embodiment also includes channel coding, interleaving, burst formatting, ciphering, and others. In general, the bulk of the circuitries preferably resides in the CBTS since, as mentioned earlier, it is usually desirable to keep the remote TRX design simple and rugged. If maintenance and/or upgrade is required, the fact that the bulk of the circuitries is located with the CBTS (i.e., out of the elements or in an easily accessible location) substantially simplifies these tasks.

The features and advantages of the present invention may be better understood with reference to the figures below. Fig. 3 illustrates, in accordance with one embodiment of the invention, a concentrated BTS (CBTS) 300, including ABIS interface 202. From the perspective of the remainder of the cellular network, e.g., the BSC's and the MSC's that are above CBTS 300, CBTS 300 preferably appears substantially similar to a prior art BTS. As discussed hereinbelow, however, CPU subsystem 302 and the central and remote TRX's of CBTS 300 are substantially different from the CPU subsystem and the TRX's of the prior art.

In CBTS 300, the antenna circuitries are implemented in remote TRX subsystems. With reference to Fig. 3, the antennas are shown on remote TRX's 306, 308, 310, 312, and 314. Although each remote TRX is shown with a single antenna, a remote TRX may be implemented with separate transmit and one or more receive antennas, as is known. Each remote TRX preferably includes the antenna circuits, e.g., the radio interface circuitry, as well as circuitries necessary to process, in the uplink direction, the received RF signals into





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binary data bits to be sent to the central TRX (discussed hereinbelow). Additionally, each remote TRX preferably includes circuitries necessary to process the downlink binary data bits received from the cellular network (via the central TRX) into RF signals to be transmitted to the MS's.

A plurality of central TRX's 322 and 324 are implemented in CBTS 300. Each central TRX is coupled at any given time to a unique set of remote TRX's. In the implementation shown, remote TRX's 306 and 308 are coupled to central TRX 322 while remote TRX's 310, 312, and 314 are coupled to central TRX 324. The coupling between a remote TRX and its central TRX may take place through any appropriate transmission medium including, for example, twisted pairs, co-axial cables, or fiber optics. In one embodiment, the transmission medium represents a twisted pair, and the traffic data, the radio control and status are passed between the central TRX and the remote TRX through an Asynchronous Transfer Mode (ATM) link using a digital baseband physical layer protocol (T1, E1, E2, E3, DS1, DS3, or the like). Although each set of remote TRX's is shown in Fig. 3 to be in a daisy-chain arrangement, individual remote TRX's may be coupled to its associated central TRX in parallel if desired.

In general, any number of remote TRX's may be coupled to a central TRX, and data from each remote TRX may bear an appropriate identifier to permit the central TRX to identify the remote TRX from which the data is sent. In practice, the number of remote TRX's may be limited to a reasonable number to suit the processing capabilities of the central TRX and/or to avoid overwhelming the transmission channel between the remote TRX's and the central TRX (e.g., to avoid overwhelming transmission channel 350 in Fig. 3). If the physical layer framing on transmission channel 350 is E1 (30 DS0s), about 5 or 6 (or more if capacity permits) remote TRX's works well. For E2 physical layer framing,





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about 22 (or more if capacity permits) remote TRX's may be daisy-chained to a central TRX. For E3 physical layer framing, a greater number (e.g., 88 or even more) remote TRX's may be daisy chained due to the greater bit rate on the transmission channel.

It should be appreciated that since it is no longer necessary to position CBTS 300 for optimum RF transmission with the MS's, CBTS 300 may be located anywhere convenient, e.g., in the back office. The remote TRX's, being smaller, simpler, and more rugged, may advantageously be positioned throughout the cell for optimum transmission quality and capacity.

As the antenna circuits are remoted from the CBTS (e.g., via cabling), the CBTS needs not be considered the base of the cell. With the present invention, each central TRX now effectively defines an aggregate cell, which is made up of the radio cells of the associated remote TRX's. The remote TRX's themselves, being remoted from the central TRX (e.g., via cabling) may be dispersed anywhere within the cell and may even be interspersed among remote TRX's which are associated with other central TRX's. It should be appreciated that the multiplicity of sets of remote TRX's, as well as their ease of positioning, offers the service provider flexibility in cell shaping in a manner that is simply unattainable in the prior art.

The individual radio cell may of course be shaped further using traditional antenna techniques, e.g., using directional antennas or increasing the transmit power. If transmit power is increased, the additional heat and power generated do not pose a danger to the processing circuitries of the CBTS as in the case of the prior art BTS circuitries, which are co-resident with the antennas of the prior art TRX's. On the other hand, it is typically the case that a given area previously covered by a high power TRX may be covered as well by





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multiple remote TRX's, each transmitting at a lower power level. In this manner, a given area may be covered with an array of simple, rugged and lower power remote TRX's, thereby substantially reducing the costs of implementing the BTS's, as well as minimizing the potential for cell-to-cell interference, and/or improving frequency reuse. The ability to employ lower power antennas while offering equivalent or better coverage in a given area is yet another advantage of the present invention.

In an antenna diversity application, each central TRX essentially represents a separate RF channel during use, data from a given MS in the cell may be picked up by more than one remote TRX's. Accordingly, the central TRX preferably includes RF quality selection circuitries for selecting the remote TRX whose transmission quality is the best so that the selected remote TRX may be employed for communication with the MS during the call. In the antenna diversity application, since each central TRX and its associated set of remote TRX's represent an RF channel at any given time, an MS communicating on that channel may be picked up by more than one remote TRX. With reference to Fig. 3, for example, RF signals from MS 330 may be picked up by the antennas within the set of remote TRX's containing remote TRX's 310, 312, and 314. Central TRX 324 preferably includes RF quality selection circuitries for selecting among the set of remote TRX's 310, 312, and 314 the remote TRX which offers the best transmission quality. If remote TRX 312 is found to offer the best transmission quality, central TRX 324 may employ the antennas within remote TRX 312 for subsequent communication with MS 330. Selection may be made, in one embodiment, by comparing the receive equalizer quality and the Receive Signal Indicator Strength (RSSI) from the various remote TRX's and selecting the best from those received. In a TDMA system (GSM) this selection may be done for each TDMA burst.





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In Fig. 3, each set of remote TRX's is shown directly coupled to its associated central TRX via the appropriate transmission medium. In one embodiment, routing resources may be provided in both the remote TRX's and the CBTS to facilitate dynamic assignment of, for example, CBTS Digital Signal Processing (DSP) resources to remote TRXs of the aggregate cells. Fig. 4 shows such an implementation wherein remote TRX's 402, 404, 406, 408, and 410 of CBTS 400 are daisy-chained to routing circuit 412. In one embodiment, routing circuit 412 represents an Asynchronous Transfer Mode (ATM) routing circuit. A database, table, or intelligent algorithm controlling routing circuit 412 determines which remote TRX is assigned to which of central TRX's 420, 422, and 424. In this case, each remote TRX's may be associated with a unique ATM address and provided with appropriate ATM framing circuits to packetize the demodulated RF data for transmission to routing circuit 412 or to depacketize the ATM data packets sent from routing circuit 412. Traffic data, radio control, and status data may be packed, in one embodiment, into the ATM cells for transmission between a remote TRX and its associated central TRX at up to about two bursts per cell. Analogous techniques may be employed if a Frame Relay Protocol is used.

The use of routing circuit 412 advantageously facilitates dynamic DSP assignment of the aggregate cells associated with central TRX's 420 and 422 to handle changes in capacity requirements. The dynamic configuration may be accomplished by simply changing the routing table or database that routing circuit 412 uses to route data between the central TRX's and the remote TRX's. By way of example, at time $T_0$ remote TRX 402 may be routed to central TRX 420, remote TRX 404 may be routed to central TRX 422, and remote TRX's 406, 408, and 410 may be routed to central TRX 424. If capacity in the vicinity of remote TRX's 408 and 410 increases at time $T_1$, either temporarily or permanently, dynamic DSP assignment may be employed to route data from remote TRX 410 to its own central





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TRX 424, remote TRX 408 to its own central TRX 422, and redistribute the remaining remote TRX's 402, 404, and 406 to central TRX 420. Since the area in the vicinity of remote TRX 408 and the area in the vicinity of remote TRX 410 do not have to share central TRX's after reconfiguration, more capacity may be handled in these areas. As can be appreciated by those skilled in the art, dynamic DSP assignment substantially simplifies the task of redistributing capacity when remote and/or central TRX's are added or removed from the CBTS.

In general, there is no limit to the number of central TRX's that may be implemented in a given CBTS. In practice, the number of central TRX's are scaled corresponding to the processing (and routing if the Dynamic DSP Assignment implementation is desired) capabilities of the CBTS. Since each additional central TRX adds an additional RF channel to the BTS, it is desirable to endow CPU 302 of Figs. 3 and 4 with sufficient processing capabilities to ensure that all calls are properly handled. By way of example, in one non-antenna diversity application, each remote radio may provide one GSM frequency channel ( 8 traffic channels). Depending on the design of the CTRX, one CTRX can process any number of RTRXs (around 8 to 16 in one example). In some embodiments, parallel processing techniques may be employed to enable the CBTS to handle a large number of central TRX's. Such CPU scaling exercise is within the skills of those skilled in the art given this disclosure.

Fig. 5 shows, in accordance with one embodiment of the present invention, a logic block diagram of a remote TRX, e.g., remote TRX 402 of Fig. 4.

Remote TRX 402 includes a radio subcircuit 502, whose basic function is to transmit and receive user data over the air. Two antennas are shown coupled to radio subcircuit 502:



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a transmit antenna 504 and a receive antenna 506. Although two antennas are shown herein, both receive and transmit antennas may be integrated into a single antenna, as is known.

Radio interface subcircuit 508 receives packetized data from physical layer framing/transport framing interface subcircuit 510 and formats the downlink data into bursts for transmission to radio subcircuit 502, along with the frequency and power information for the burst. In one embodiment the frequency information itself is recovered from a Global Positioning System (GPS) terminal and synchronized to the proper specification (e.g., GSM specification) using timing phase locked loop (PLL) subcircuit 512. On the receive side, radio interface subcircuit 508 takes the demodulated data out of receive antenna 506 and packetizes it for transmission to the central TRX via the daisy-chain transmission medium 518 (which may implement, for example, the E1 protocol). In one embodiment, radio interface subcircuit 508 is implemented using a field programmable gate array (FPGA).

Digital Signal Processing (DSP) subcircuit 514 performs the modulation of the binary signals received from the cellular network for transmission via transmit antenna 504, demodulation of the RF signal received via receive antenna 506, as well as signal equalization. In one embodiment, DSP subcircuit 514 is implemented by a general purpose Digital Signal Processor (DSP).

A read-only memory subcircuit 520 stores configuration data for configuring remote TRX 402 upon start up. Microcontroller 522 provides house-keeping functions such as status checks, diagnostics, and power management. In one embodiment, microcontroller 522 may be employed to take remote TRX 402 out of the daisy-chained loop if remote TRX 402 is found to be defective, e.g., by connecting the input and output of the remote TRX together. Microcontroller 552 also oversees the communication between the remote TRX



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and its central counterpart. In one embodiment, all communication between the remote TRX and the central TRX is performed via the aforementioned physical layer framing/transport framing interface subcircuit 510. Physical layer framing/transport framing interface subcircuit 510 performs the tasks of formatting and driving data to the CBTS; receiving and deformatting data received from the CBTS; and supervising, controlling and monitoring the health of the connection.

The transport framing protocol is, in one embodiment, a packetized protocol where the data packet contains a preamble, or header, containing an address of the receiver. It may also contain a packet type identifier, serial number, time stamp, and other control information. The termination of the packet contains error correcting fields. Data flow between RTRX and CBTS is mapped to the transport protocol packets so that one transport packet typically corresponds to one radio TDMA burst. Frequency, power and user data may be included in each downlink (RTRX to MS) transport packet. Receive quality status, signal strength and user data may be part of the uplink (MS to RTRX) transport packet.

The packetized transport protocol also allows system-defined transport packets that are not transmitted over the air. The definition of the system messages may depend on the partition of functions between the CTRX and RTRX. An exemplary type of system message may be a specially defined timing packet. This timing packet is broadcasted to all remote radios and is used to synchronize the TDMA frames of all remote radios. One embodiment may use the Global Positioning Satellite network as a time reference. A time stamp may be passed to remote radios and each remote radio may calculate the time delay through the network from a local GPS reading relative to the time stamp. Another system transport packet may be call setup information that is transported only once per mobile call session.



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An example would be the encryption key to cipher the user data. Remote radio status and control information would be another example of a system transport packet.

The use of the packet transport protocol between remote radios and CBTS allows the service provider great flexibility in physical connectivity of the radio network. The capacity of the communication medium becomes, in one embodiment, a function of traffic load, rather than control demands of the physical radios. This flexibility was previously unavailable in the prior art.

As can be appreciated from Fig. 5, the design of a remote TRX is deliberately kept simple to promote ruggedness and simplify maintenance. In one embodiment, the remote TRX preferably includes the subcircuits necessary for interfacing the remote TRX with the physical layer framing and transport framing protocols (e.g., E1 and ATM), digital signal processing subcircuits for equalization and demodulation of the received RF data, and the RF radio subcircuits themselves. All other circuits traditionally associated with the prior art TRX's and BTS are preferably kept in the concentrated BTS (CBTS). In one embodiment, the CBTS may include circuits for interfacing the central TRX with the physical layer framing and transport framing protocols (e.g., E1 and ATM) to communicate with the remote TRX, digital signal processing subcircuits for convolution encoding, decoding, bit interleaving, and burst formatting. Additionally, the CBTS may also include the interface to the BSC.

The division of labor between the remote TRX and the central TRX within the CBTS may be better understood with reference to the exemplary implementations of Figs. 6 and 7. Fig. 6 is a block diagram illustration of the data flow within a prior art GSM BTS module during transmit and receive. With reference to Fig. 6, data to be transmitted to the MS's are





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received from the BSC via an ABIS interface 602. Speech De-framing block 604 extracts the digital data from the ABIS frame and passes it to Channel Coding block 606, whose purpose is to package the extracted digital data for eventual transmission using the RF medium. The data is then interleaved on a multiplicity of bursts to minimize the risk of losing consecutive bits during transmission in Interleaving block 608. The bursts are then formatted in Burst Formatting block 610 and optionally ciphered for security in Cipher block 612. Thereafter, the digital data is modulated (e.g., using Gaussian Minimum-Shift Keying) for transmission to the MS's as RF signals via Tx Radio block 616.

On the receive side, RF signals from the MS's are received at Rx Radio block 650, and demodulated into digital data and equalized in Demodulation/Equalization block 652. Deciphering, if any, is performed in Deciphering block 654. Burst Formatting block 656 extracts user data and from the speech frame and builds it with the appropriated midamble into a 148 bit burst. Thereafter, De-Interleaving block 658 reassembles the data from groups of bursts. The digital data is then stripped using Channel Decoding block 660 to extract the user data. Speech Framing block 662 frames the stripped digital data into ABIS frames for transmission to the BSC. The functional blocks of Fig. 6 are well known to those skilled in the GSM art. As mentioned, circuitries necessary for implementing the functional blocks of Fig. 6 are typically implemented in one box in the prior art, i.e., these circuits are co-resident in the prior art BTS.

To contrast, Fig. 7A illustrates, in accordance with one embodiment of the present invention, the data flow within the inventive CBTS during transmit and receive. In Fig. 7A, ABIS interface block 602, as well as blocks 604, 606, 608, 610, and 612 on the downlink path and blocks 654, 656, 658, 660, and 662 in the uplink path perform substantially the same functions as corresponding blocks in Fig. 6. As these blocks have been discussed





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earlier, they will not be repeated here for brevity's sake. To facilitate remote communication between the central TRX in the CBTS and the remote TRX, additional physical layer framing and transport framing functional blocks have been added. On the transmit side, these are shown as transport framing interface blocks 702 and 708, with transport framing interface block 702 being co-resident with the CBTS and its counterpart transport framing interface block 708 being implemented in the remote TRX. The transport framing may employ the well known ATM protocol or Frame Relay protocol, as mentioned earlier.

Also on the transmit side, physical layer framing for communication between the remote TRX and the central TRX is implemented via physical layer framing interface blocks 704 and 706, with physical layer framing interface block 704 being co-resident with the CBTS and its counterpart physical layer framing interface block 706 being implemented in the remote TRX. In one embodiment, as the ciphered digital data is outputted from Cipher block 612, it is packetized into ATM frames (block 702) and framed for transmission via the E1 protocol (block 704). This data is transmitted to the remote TRX via the transport link 710. Upon receiving the data, the remote TRX extracts the data from the E1 frame (block 706) and de-packetizes the data (block 708). The de-packetized data is then modulated (block 614) and transmitted out to the MS's via transmit radio block 616.

Note that line 720 signifies the demarcation between the functional blocks implemented in the remote TRX and those implemented in the CBTS/central TRX. In practice, the functional blocks above line 720 in Fig. 7A are typically implemented in a single CBTS/central TRX box (and even on the same backplane in some cases). The functional blocks below line 720 of Fig. 7A are implemented in the remote TRX, which is typically located some distance away from the CBTS/central TRX. This is in contrast to the





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prior art BTS of Fig. 6 wherein all the major blocks shown therein are co-resident with the BTS.

On the receive side of Fig. 7A, RF signals from the MS's are received by Rx radio block 650 and demodulated into digital data in Demodulation/Equalization block 652. The demodulated data, as well as the RF quality data obtained in the equalization process, is then transmitted to the central TRX in the CBTS via transport framing interface blocks 760 and 766. Again, physical layer framing interface blocks 762 and 764 are provided to facilitate framing of the demodulated data for transmission via the physical layer protocol. If multiple remote TRX's are provided in an antenna diversity application, for example, optional RF quality selection block 768 may be employed to select among the remote TRX's one which offers the best transmission quality. Note that this selection may be performed prior to any transmission of user data, e.g., as the called MS answers a page from the network. Thereafter, data from the selected remote TRX is deciphered (if desired), formatted, de-interleaved, channel decoded, and framed via blocks 654, 656, 658, 660, and 662 in the manner discussed in connection with Fig. 6 prior to being transmitted to the BSC via ABIS interface block 602.

Although the division between the remote TRX and the central TRX occurs in between the ciphering and modulation blocks in the transmit direction and the deciphering and demodulation/equalization blocks in the receive direction, such is not a limitation of the invention. In fact, it is contemplated that the split between the remote and central TRX's may occur anywhere in the transmit and receive paths. Fig. 7B illustrates one exemplary application wherein the split between the remote and central TRX's occurs between other blocks of the BTS. In Fig. 7B, the split between the remote and central TRX's occurs between the speech de-framing and channel coding blocks in the transmit path and between





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the speech framing and channel decoding blocks in the receive paths. Of course the split may take place between any other blocks if desired.

Note that it is not necessary that the split between the remote and central TRX's be symmetrical in the transmit and receive paths. Fig. 7C illustrates one exemplary application wherein the split between the remote and central TRX's is asymmetrical such that there is more transmit path circuitries in the central TRX than there are receive path circuitries. Again, the exact locations in the transmit and receive paths where the remote and central TRX's may be split are implementation specific.

As can be appreciated from the foregoing, the invention allows the remote TRX's to be implemented as simple, rugged, and low-maintenance remote antennas. These remote TRX's may then be deployed throughout the area to be covered, with the bulk of the delicate and expensive circuitries being implemented in the CBTS and located out of the elements and/or in an easy-to-access location for maintenance and upgrade. In the antenna diversity application, the use of multiple simple remote TRX's advantageously minimizes duplication of logic, as only simple remote radios (instead of the entire TRX as in the case of the prior art) need to be duplicated. The logic in the CBTS may be shared by multiple radios.

Since multiple remote TRX's may be coupled to a single central TRX in the antenna diversity application, the inventive architecture offers great flexibility in configuring the cell. Cell shaping is no longer limited to modifying antenna shape and transmit range around the BTS. With the inventive CBTS architecture, cabling can be run from a central TRX to any number of geographically dispersed remote TRX's to form an aggregate cell out of the geographically dispersed radio cells. With multiple central TRX's per CBTS, the service provider is given great latitude in configuring the cell.





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As mentioned, multiple inexpensive low-power remote TRX's may now be employed in place of the high power TRX of the prior art to cover the same area. Beside reducing the costs of the radio circuits, the invention also promotes frequency reuse since each radio cell (associated with each remote TRX) may be made smaller. Also as discussed, the ability to dynamically associate one or more remote TRX with a given central TRX offers the service provider great flexibility in reconfiguring the cell to adapt to changes in capacity using the existing set of remote/central TRX's or additional remote/central TRX's.

While this invention has been described in terms of several preferred embodiments, there are alterations, permutations, and equivalents which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.





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## Claims

1. In a cellular communication system having a base station controller (BSC) and a mobile services switching center (MSC), a base transceiver station (BTS) for facilitating communication between said BSC and a plurality of mobile stations (MS's), said communication with said plurality of said MS's being accomplished via radio frequency (RF) medium, comprising:

a first interface circuit for coupling said BTS with said BSC;

a processor coupled to said first interface circuit for processing first digital data received from said BSC to form second digital data;

a first central transceiver (CTRX) circuit coupled to said processor, said first CTRX circuit being co-resident with said processor and said first interface circuit; and

a first remote transceiver (RTRX) circuit coupled to said first CTRX circuit, said first RTRX circuit including a first antenna circuit for communicating with a first MS of said plurality of MS's via said RF medium, wherein said first RTRX circuit is implemented in a geographically remote manner from said first CTRX circuit.

2. The base transceiver station of claim 1 further comprising:

a second remote transceiver (RTRX) circuit coupled to said first CTRX circuit, said second RTRX circuit including a second antenna circuit for communicating with said first





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MS via said RF medium, said first CTRX includes an RF quality selection circuit for selecting one of said first RTRX and said

second RTRX for use in communicating with said first MS.

3. The base transceiver station of claim 2 wherein said second RTRX circuit and said first RTRX circuit are daisy-chained with said first RTRX directly coupled to said first CTRX and said second RTRX directly coupled to said first RTRX.

4. The base transceiver station of claim 2 further comprising:

a second central transceiver (CTRX) circuit coupled to said processor, said second CTRX circuit being co-resident with said processor and said first interface circuit;

a third remote transceiver (RTRX) circuit coupled to said second CTRX circuit, said third RTRX circuit including a third antenna circuit for communicating with a second MS of said plurality of MS's via said RF medium, wherein said third RTRX circuit is implemented in a geographically remote manner from said second CTRX circuit.

5. The base transceiver station of claim 4 wherein said first RTRX circuit and said third RTRX circuit are coupled to said first CTRX and said second CTRX respectively via a routing circuit.





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6. The base transceiver station of claim 5 wherein said routing circuit is an Asynchronous Mode Transfer (ATM) routing circuit.

7. The base transceiver station of claim 5 wherein said routing circuit is a Frame Relay routing circuit.





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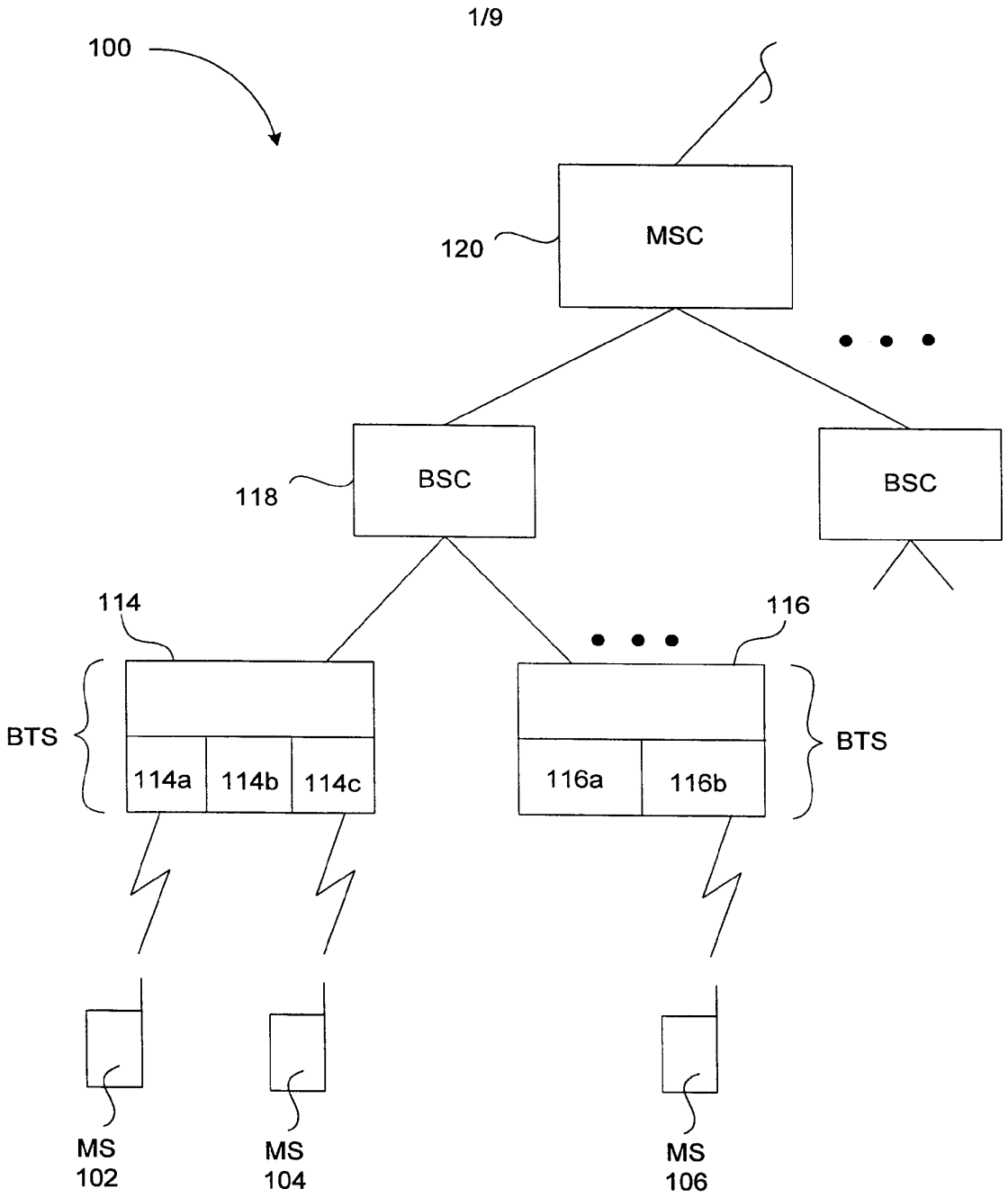



FIG. 1



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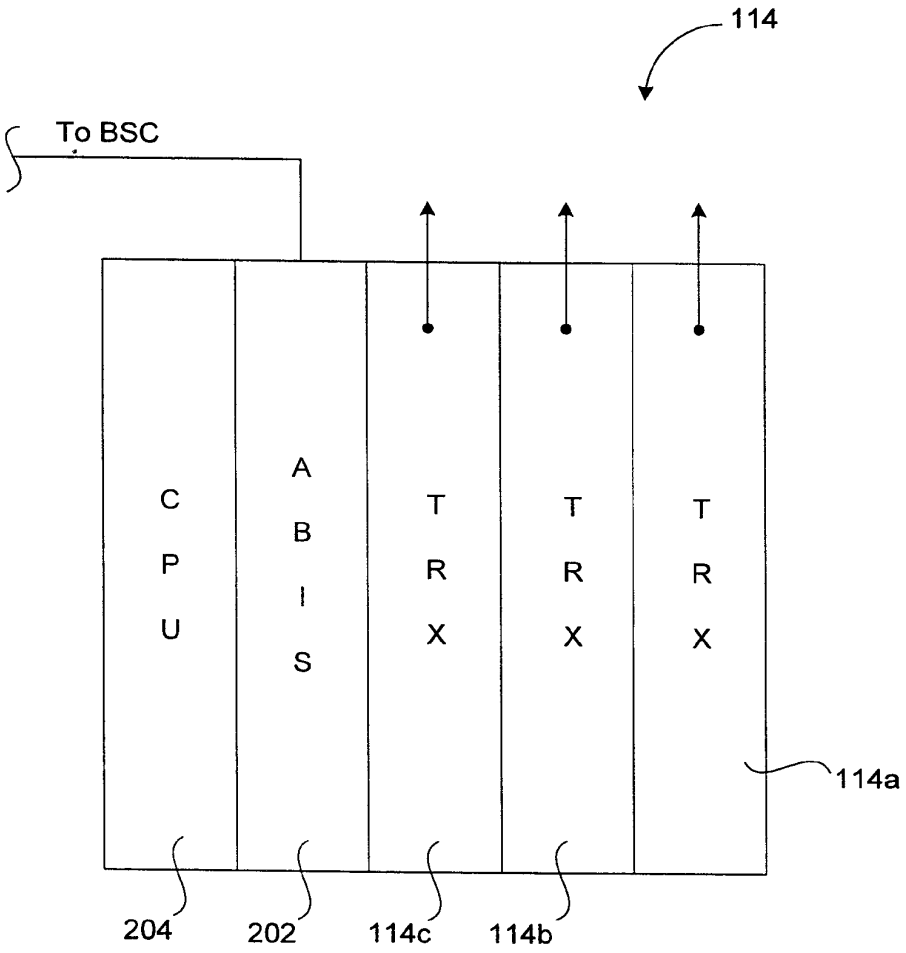



FIG. 2



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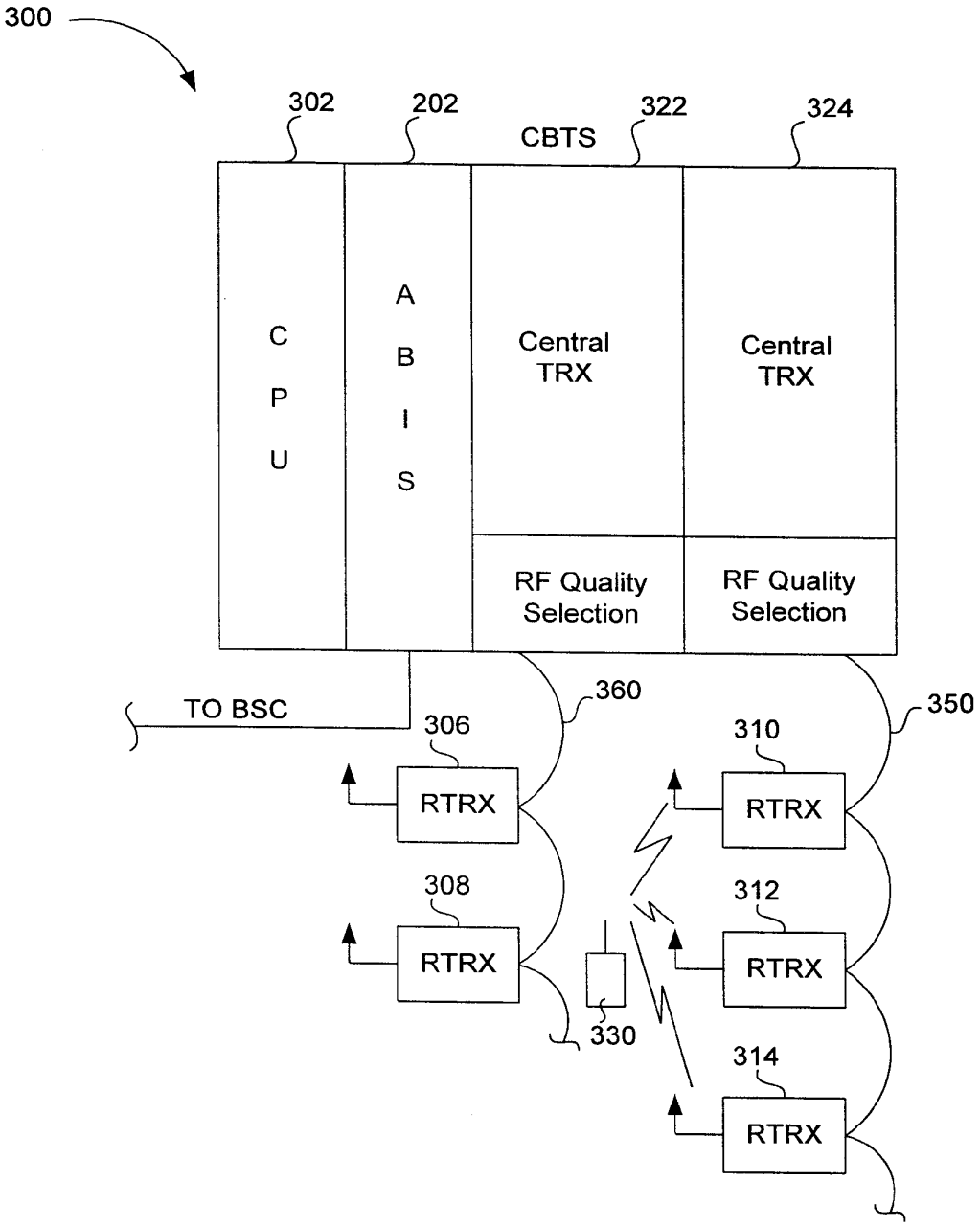



FIG. 3



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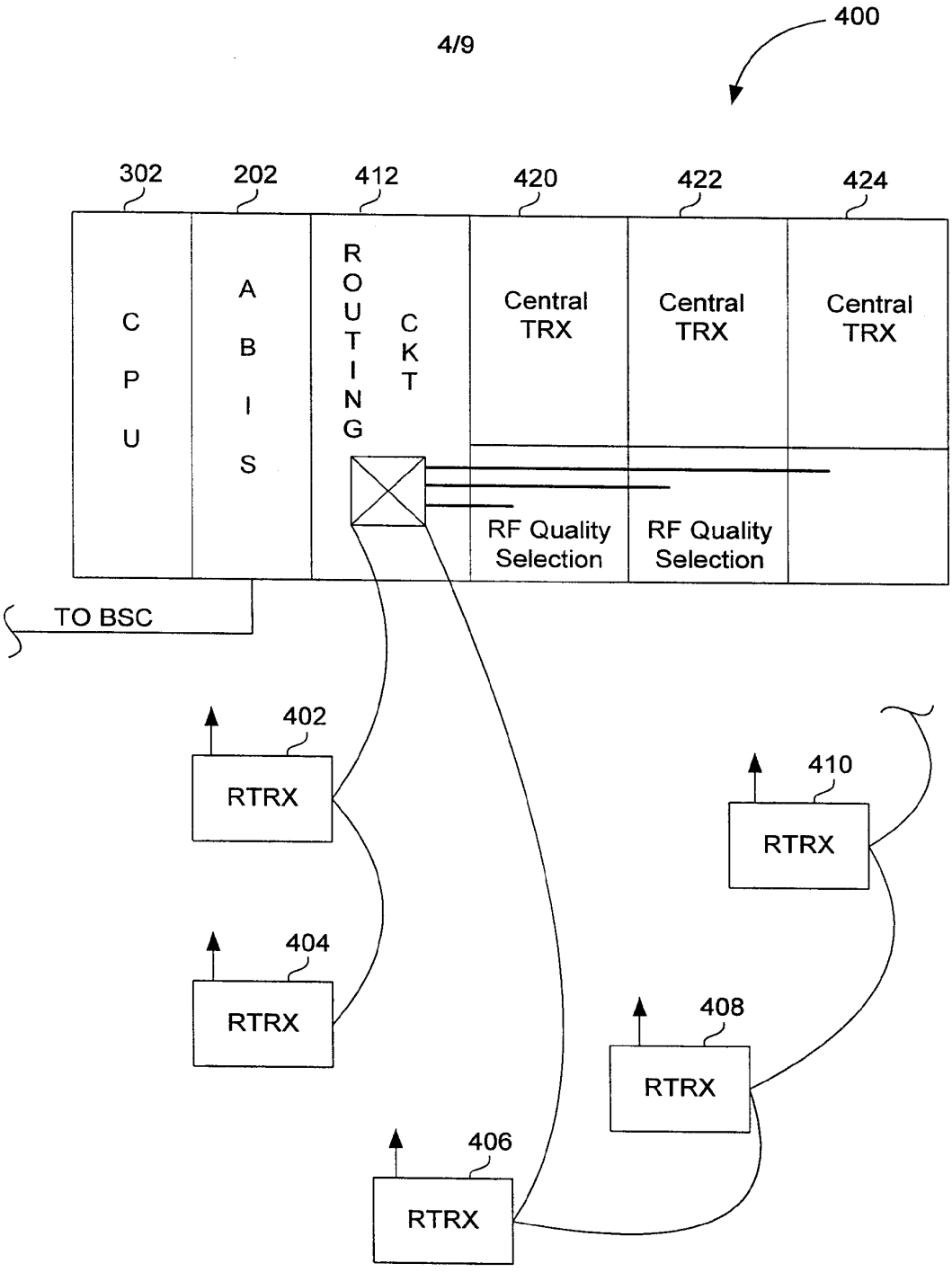



FIG. 4



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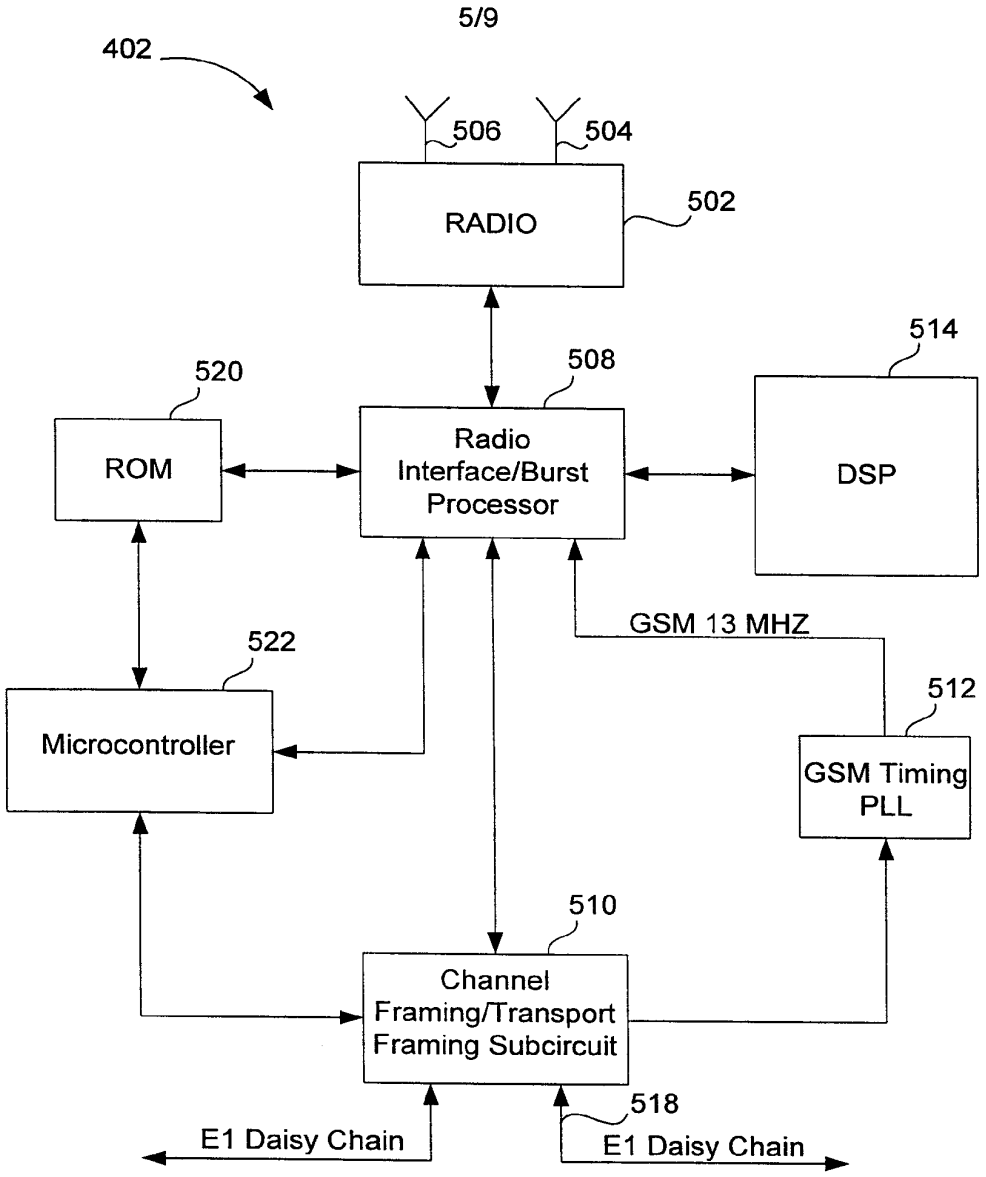



FIG. 5



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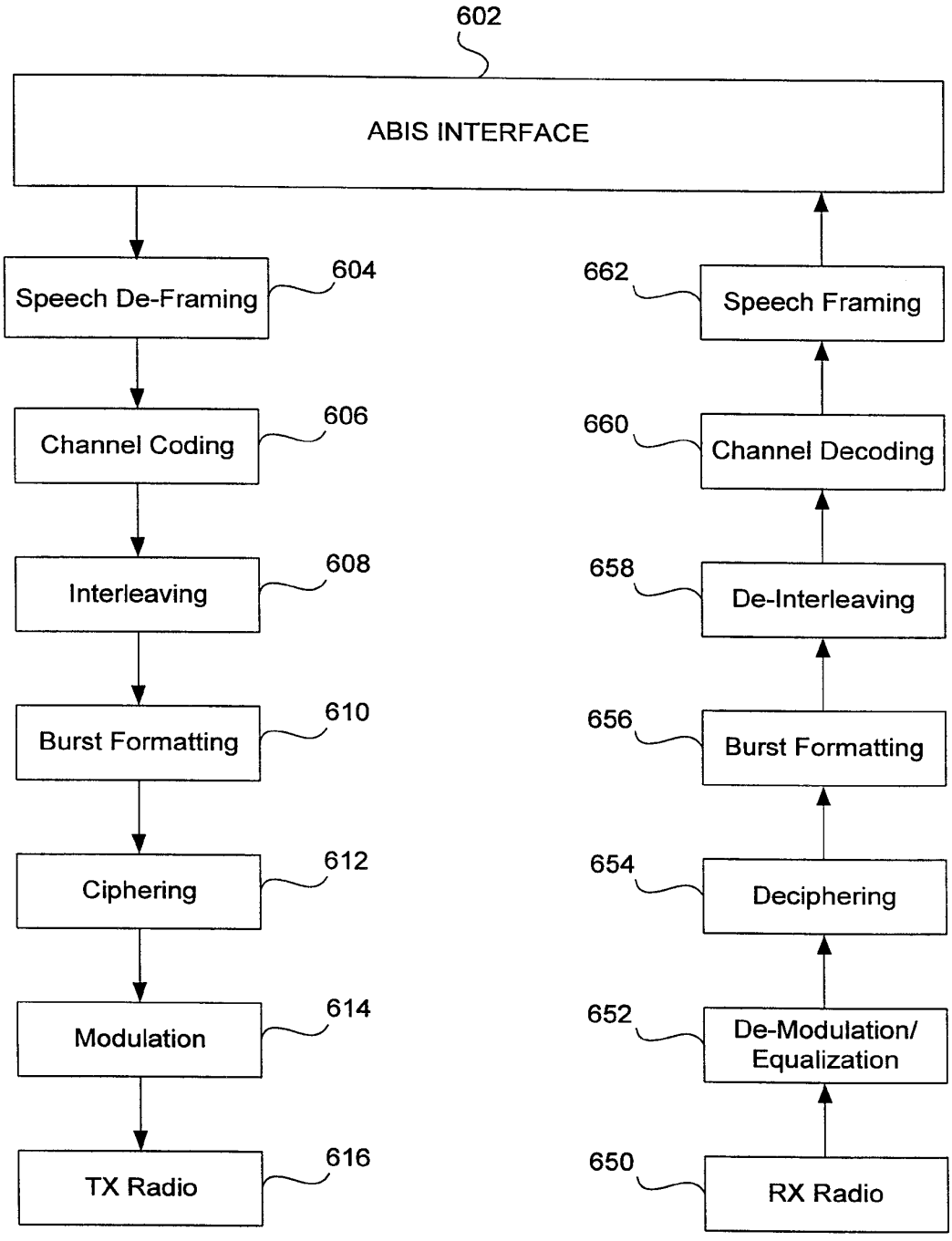



FIG. 6



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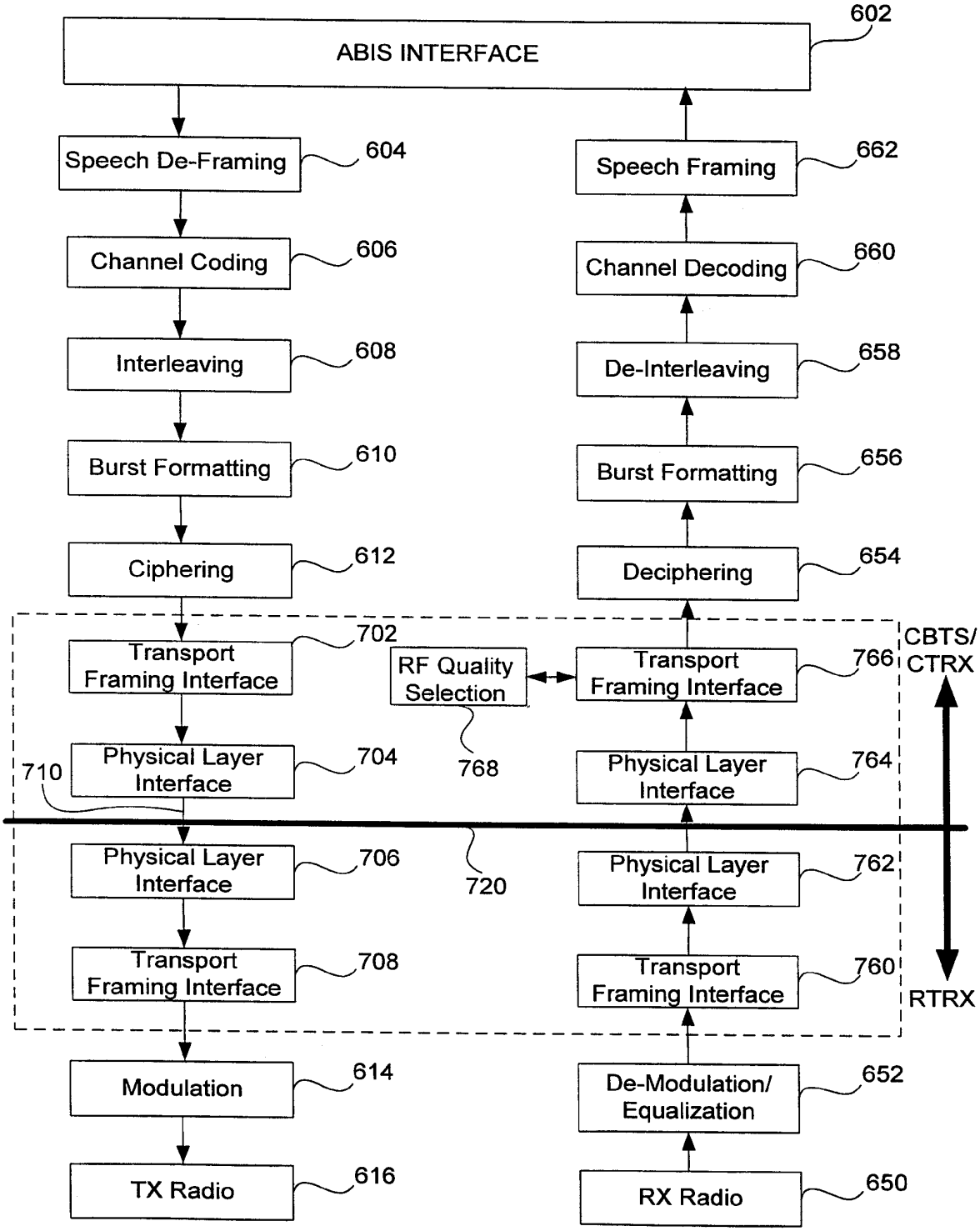



FIG. 7A



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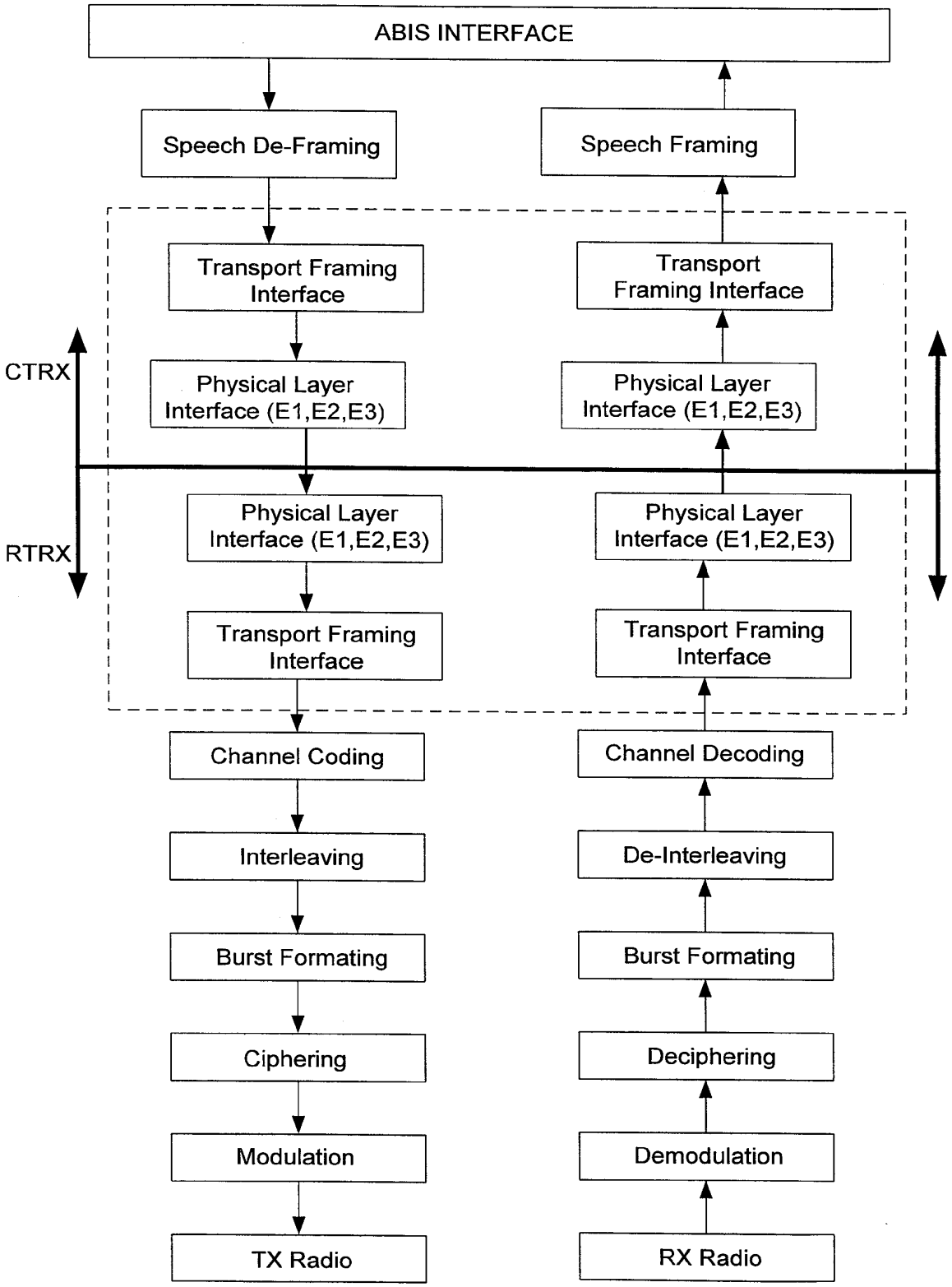



FIG. 7B



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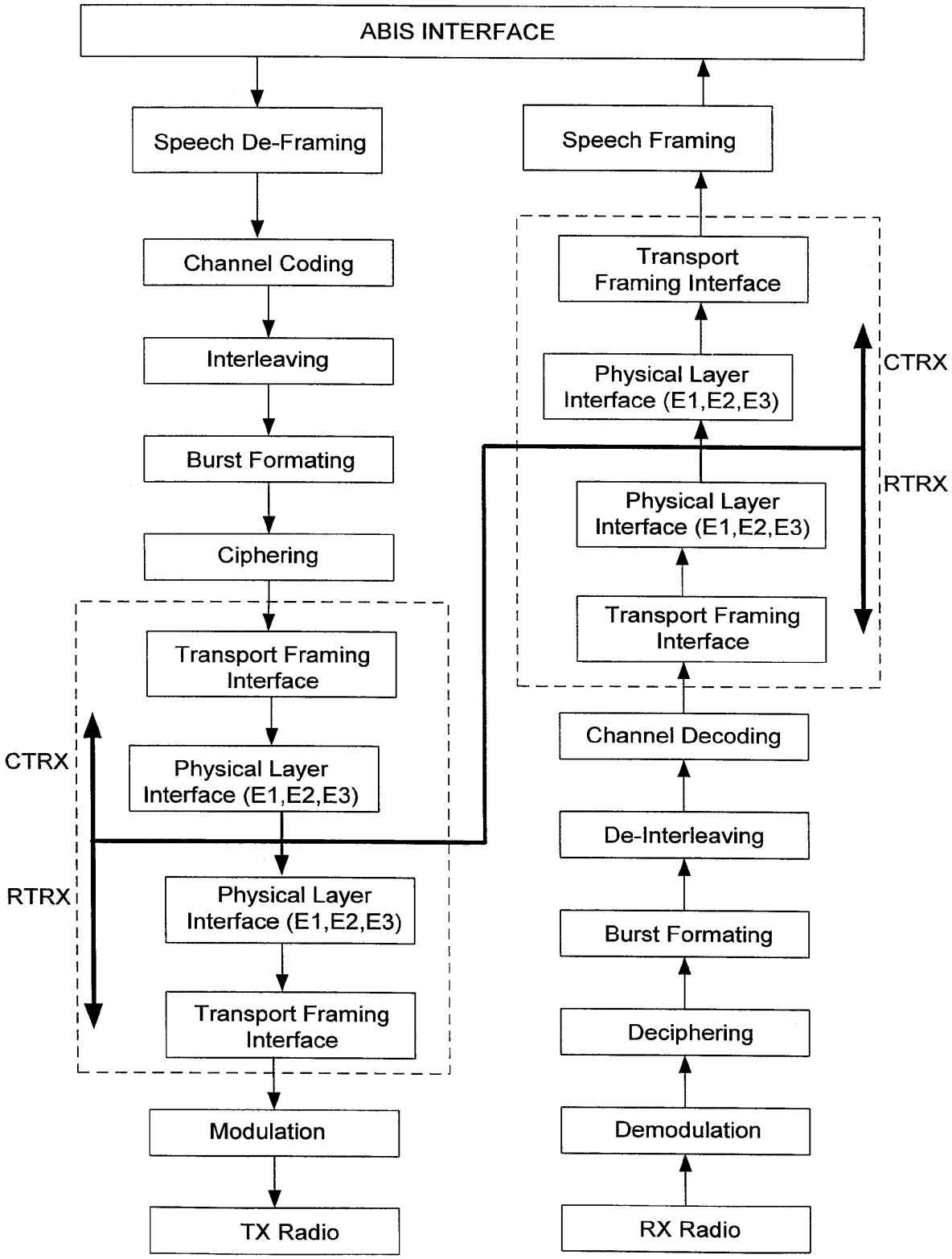



FIG. 7C



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# INTERNATIONAL SEARCH REPORT

Inte ional Application No
PCT/US 98/16984

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 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 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 | US 5 555 260 A (RINNBÄCK ET AL.)<br>10 September 1996<br>see figure 2<br>see column 7, line 1 - line 10 | 1 |
| A | *Idem* | 4 |
| Y | EP 0 440 081 A (STANDARD ELEKTRIC LORENZ AG.) 7 August 1991<br>see abstract; figures 1,2 | 1,4,7 |
| Y | WO 96 27269 A (NOKIA TELECOMMUNICATIONS OY.) 6 September 1996<br>see page 4, line 13 - line 22; figure 1 | 1,4,7 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 3 December 1998 | 14/12/1998 |

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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Danielidis, S |

1

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/16984

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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# Electronic Acknowledgement Receipt

| | |
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| **EFS ID:** | 3828271 |
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| **International Application Number:** | |
| **Confirmation Number:** | 1589 |
| **Title of Invention:** | DISTRIBUTED REMOTE BASE STATION SYSTEM |
| **First Named Inventor/Applicant Name:** | Robert J. Koziy |
| **Customer Number:** | 34206 |
| **Filer:** | David Fogg/Julia Sisterman |
| **Filer Authorized By:** | David Fogg |
| **Attorney Docket Number:** | 100.829US01 |
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| **Warnings:** | | | | | |
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| 2 | Information Disclosure Statement (IDS) Filed (SB/08) | 00134296.PDF | 744907<br>4745c6dc1ec7c4ce3d28dbd86fbe8fc01f071abd | no | 4 |
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| **Information:** | | | | | |
| 3 | Foreign Reference | 00134292.PDF | 1824280<br>f3b5a2a0584c641e814d7059fae80cebfbaa93f3 | no | 51 |
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| 4 | Foreign Reference | 00134293.PDF | 1340945<br>650581c73ef67824b4cced255aca347fa08f9709 | no | 38 |
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| **Information:** | | | | | |
| 5 | NPL Documents | 00133045.PDF | 492728<br>1f6257e6e9ec406ff1844d4b6c9176494db0ebb6 | no | 14 |
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|---|---|---|
| Applicant(s) | Koziy | CERTIFICATION STATEMENT |
| Serial No. | 11/627,255 | |
| Filing Date | 1/25/2007 | |
| Group Art Unit | | |
| Examiner Name | | |
| Confirmation No. | 1589 | |
| Attorney Docket No. | 100.829US01 | |
| Title: A DISTRIBUTED REMOTE BASE STATION SYSTEM | | |

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Applicant hereby certifies 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 application and that this communication was not received by any individual designated in §1.56(c) more than thirty days prior to the filing of the information disclosure statement.

Respectfully submitted,

Date: August 22, 2008

/David N. Fogg/

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Reg. No. 35138

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| 11/627,255 | 01/25/2007 | Robert J. Koziy | 100.829US01 |

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FOGG & POWERS LLC
10 SOUTH FIFTH STREET
SUITE 1000
MINNEAPOLIS, MN 55402

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Date Mailed: 07/31/2008

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**Publication No.**US-2008-0181171-A1
**Publication Date:**07/31/2008

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8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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|---|---|---|
| | 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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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).

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☐ 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 |
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| Name/Print | Fogg, David N. | Registration Number | 35138 |

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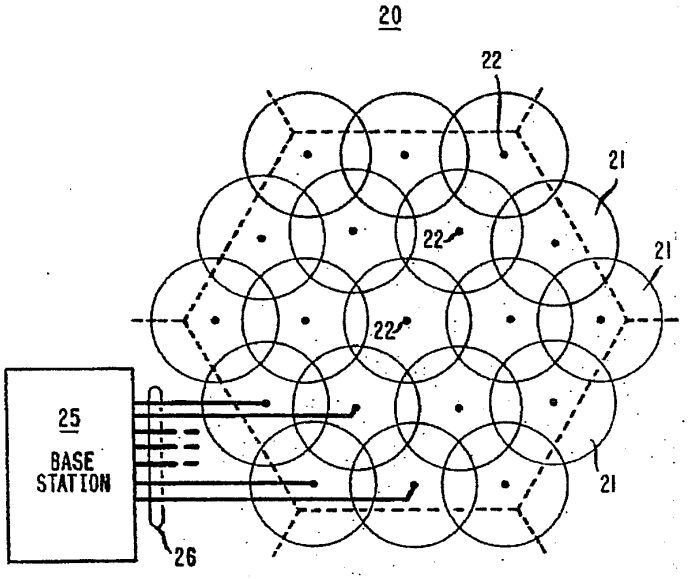
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(72) Chu, Ta-Shing, US
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(51) Int.Cl. [6] H04J-14/02, H04Q-7/22
(30) 1989/04/04 (333,490) US

(54) **RADIO MOBILE MICROCELLULAIRE A FIBRE OPTIQUE**
(54) **OPTICAL FIBER MICROCELLULAR MOBILE RADIO**




(57) Système de communication microcellulaire. Comprend des connections à fibres optiques reliant une station de base et des transducteurs optiques-RF situés dans une grille serrée. Des signaux en bande radio sont modulés directement sur des sorties laser au moyen de fibres optiques aux fins de transmissions à destination et en provenance d'unités mobiles. Les transducteurs optiques-RF, logés dans des boîtiers, sont montés sur des poteaux de téléphone ou d'électricité afin de servir les téléphones mobiles et portatifs d'une région microcellulaire, par exemple une région métropolitaine congestionnée où l'espace nécessaire à une station de base sur toit est très limité et coûteux.

(57) A microcellular communication system includes optical fiber connections between a base station and opto-RF transducers located in a closely spaced grid. Radio-band signals are modulated directly onto laser outputs through the optical fibers for both transmission to mobile units or from the mobile units. The opto-RF transducers, housed in canisters, are mounted on telephone or power poles to provide radio link coverage to mobile and portable phones located in a microcell area, e.g., in a congested metropolitan area where space for a roof-top base station is very limited and expensive.

Industrie Canada Industry Canada

# OPTICAL FIBER MICROCELLULAR MOBILE RADIO

**Abstract**

A microcellular communication system includes optical fiber connections between a base station and opto-RF transducers located in a closely spaced grid. Radio-band signals are modulated directly onto laser outputs through the optical fibers for both transmission to mobile units or from the mobile units. The opto-RF transducers, housed in canisters, are mounted on telephone or power poles to provide radio link coverage to mobile and portable phones located in a microcell area, e.g., in a congested metropolitan area where space for a roof-top base station is very limited and expensive.

# OPTICAL FIBER MICROCELLULAR MOBILE RADIO

This invention relates to a mobile radio system having a plurality of cells which reuse transmitting carrier frequencies.

## Background of the Invention

There is an ever increasing demand for more capacity in cellular mobile radio. In the current 900 MHz, UHF cellular systems, only 20 MHz are available for each direction of transmission between a base station and mobile units. By separating the overall 20 MHz band into a number N of sub-bands and assigning each sub-band to a different set of geographical cells in a regular array of cells which cover a large region, the frequencies are reused. Co-channel interference is minimized by assuring that the ratio of cell radius to the distance to the next cell which uses the same frequency sub-band is small. In the regular pattern of cells, this ratio is made smaller by increasing the number N and is independent of the absolute cell size used in the pattern. Typically, the number $N = 21$, which assures negligible co-channel interference and allows 16 channels per sub-band. By making the scale of the pattern smaller, more users per square mile are accommodated with the same overall bandwidth.

Previously, cellular radio system operators have increased capacity by subdividing the cell area and reusing assigned frequencies in closer geographic areas. Whereas a typical cell radius is eight miles, subdivisions down to a cell radius of one mile or smaller are often needed. In such small cell areas, appropriate choices of base station locations become very restricted because public facilities may not be available where needed, and private locations are likely to be prohibitively expensive. For many small cells, a residential location may be the only available choice. People in residential areas often object to the base station antenna tower because its height, typically 100 to 150 feet, makes it an eyesore; and its radiated power, typically 400 to 1,200 watts, is perceived to be an environmental health hazard.

Another problem arises when one considers the use of not yet allocated bandwidth in the 10 to 60 GHz, or millimeter wave, frequency spectrum for providing very large capacity mobile communication service. Propagation loss and Doppler frequency shifts are more severe for millimeter waves than for the currently used UHF signals. The increased Doppler shift requires each channel to use more bandwidth than at the channels in UHF

systems. To fully utilize the bandwidth in the 10 to 60 GHz frequency range, with time division multiplexing for example, it is necessary to minimize the spread in time delays. To reduce propagation loss and the spread in time delays, any millimeter wave mobile radio system design must strongly favor line of sight operation.

The above problems of mobile radio need base station antennas to be placed geographically very close to the mobile units, but the conventional means of carrying the signals between the base station and remote antennas by means of coaxial RF transmission lines is prohibitively expensive because of their large transmission losses.

**Summary of the Invention**

The above problems are solved in accordance with the preferred from of the present invention by placing many antennas, associated with a single base station, at grid points near the mobile units and using an optical fiber network for interconnecting the antennas with the base station. Optical wavelength carriers are analog modulated with multiplexed RF mobile radio channels for transmission through the optical fiber network. The modulated optical wavelength carriers are analog detected from the optical fibers so that the RF channels are distributed to the grid of antennas without distortion. Received RF channels also are collected from the grid of antennas for modulating laser outputs which are transmitted through the optical fibers to the base station.

In accordance with one aspect of the invention there is provided a mobile radio system having a base station and a plurality of mobile units, the system comprising a plurality of opto-RF transducers; a distribution network using optical fibers interconnecting the base station with the opto-RF transducers; and means for transducing multiplexed subcarrier channels onto and off of optical carriers in the fiber distribution network, for transducing multiplexed subcarrier channels onto an optical carrier on a fiber from the base station, and for transducing multiplexed subcarrier channels off of an optical carrier on a fiber to the base station.

A

In accordance with another aspect of the invention there is provided a mobile radio microcell transducer arrangement comprising a laser; an antenna for transmitting and receiving radio signals including multiplexed mobile radio channels in different ranges of frequencies; means for converting an optical carrier modulated with mobile radio channels in a first band of frequencies into an electrical signal to be applied to the antenna; and circulator means for coupling the electrical signal in the first band of frequencies to the antenna for radiating to mobile units and for coupling an electrical signal, received in a second band of frequencies from the mobile units through the antenna, to the laser for modulating the optical output with the electrical signal in the second band of frequencies.

**Brief Description of the Drawing**

A better understanding of the invention may be obtained by reading the subsequent detailed description with reference to the drawing wherein:

FIG. 1 shows a grid of microcell opto-RF transducer radiation and reception coverage of a mobile radio cell;

FIG. 2 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and opto-RF transducers with a separate fiber for each direction of optical transmission for each transducer;

FIG. 3 is a schematic diagram of an alternative opto-RF transducer for operation with a separate fiber for each direction of optical transmission;

FIG. 4 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and opto-RF transducers with a separate fiber providing bidirectional optical transmission for each transducer;

FIG. 5 is a schematic diagram of an alternative opto-RF transducer for operation with a fiber providing bidirectional optical transmission;

FIG. 6 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and a group of opto-RF transducers wherein a single optical detector receives all signals through a fiber from a group of the opto-RF transducers and wherein a single laser transmits through another fiber to all of the opto-RF transducers in that group; and

FIG. 7 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and a group of opto-RF transducers wherein all optical signals pass through a single optical fiber.

**Detailed Description**

Referring now to FIG. 1, there is shown a mobile telecommunication cell 20 generally bounded by a heavy dotted line. Adjacent cells are only indicated in part. In the prior art, a base station is located within and serves that cell 20. That base station transmits to and receives from mobile units some number of frequency multiplexed information channels. A typical base station handles sixteen separate channels for reception and transmission. Multiplexed signals developed within the base station are fed via coaxial cable to an antenna located effectively at the center of the cell. That antenna radiates the multiplexed signals to mobile units within or near the cell 20.

Those mobile units receive the radiated signal and separate their assigned channels. Concurrently each of the mobile units transmits a channel to the base station antenna. All of the channels transmitted from the mobile units are multiplexed in the air and at the antenna. This multiplexed signal is transmitted from the antenna through a coaxial cable to the base station where the various channels are separated and the voice signals detected for delivery to a central office.

In our new arrangement, radiation coverage of the cell 20 is accomplished in an entirely different manner. Several microcell opto-RF transducers 22 are positioned within the cell 20 so that the entire cell area is covered in an over-lapping grid-like microcell pattern of radiation 21 of the same RF signals from the transducers 22. A base station 25 may be located within the cell 20 but more generally can be located outside of the cell. The transducers 22 are interconnected with the base-station 25 via a network of optical fibers 26.

Mobile units within the cell 20 communicate by way of two way radio signals to the transducers 22. All sixteen channels being transmitted from the base station 25 are distributed to all of the transducers. Also all sixteen channels can be received from the mobile units at any of the transducers and are transmitted via the optical fibers 26 to the base station 25. Thus the transducers act as a grid-like distributed antenna for both transmitting and receiving the frequency division multiplex signals.

Referring now to FIG. 2, there is shown a detailed block diagram of the base station 25 which is arranged to transmit and receive frequency multiplexed FM signals in several channels. On the transmit side of the base station, the FM subcarrier channels, frequency multiplexed on a radio frequency transmission line, are applied to a star splitter, or power splitter, 30. At each of the output ports of the power splitter, the signal modulates a laser 32 for transmitting the frequency multiplexed channels on an optical carrier through an optical fiber 26. The opto-RF transducers 22 include an optical detector 27 for converting the optical signal to an electrical radio frequency signal which is amplified if required and is used for radiating from an antenna 35 to the mobile units within range. Only one opto-RF transducer is shown in detail but others are indicated by a separate block 22 and two series of dots.

In response to the radiated signals, the receiving mobile units transmit a radio frequency signal which is received by an antenna 37 of the opto-RF transducer 22. The received radio frequency signal is amplified, if required, and modulates a laser 38 that produces an optical signal which is transmitted through another optical fiber 39 to the base station 25. This optical signal includes frequency division multiplexed signals from all mobile units transmitting within the relevant microcell. At the base station, an optical detector 40 converts the optical signal to an electrical signal and

applies it to an input port of a star coupler, or power combiner, 41. At the output port of the power combiner, the electrical signal, including sixteen FM channels, is fed into the base station in accordance with prior art techniques.

Referring now to FIG. 3, there is shown an alternative opto-RF transducer 42 which may be substituted for the opto-RF transducer 22 of FIG. 2. It is noted that the opto-RF transducer 42 also interconnects with two optical fibers 26 and 39, each of which transmits optical signals in one direction. Detector 27 and laser 38 perform the same functions as in FIG. 2. Electrical signals, in an RF band $\lambda 1$, from the detector 27, however, are applied to a port of a circulator 43 which directs them to an antenna 45 for radiating to the mobile units within the microcell.

Electrical signals, in a different RF band f2 and radiated back from the mobile units, are received by the same antenna 45 in the opto-RF transducer 42. The electrical signals are applied to the circulator 43 which directs them to the laser 38. These electrical signals, received from the antenna 45, are amplified if required. As in the arrangement of FIG. 2, the laser output signal is modulated by the frequency multiplexed FM signals in several channels.

Referring now to FIG. 4, there is shown a detailed block diagram of a mobile radio base station 25 which is arranged to transmit and receive frequency multiplexed FM signals in several channels. On the transmit side of the base station 25, the FM subcarrier channels, frequency multiplexed on a radio frequency transmission line, are applied to a star splitter, or power splitter 30. At each of the output ports of the power splitter, the signal modulates a laser 52 for transmitting the frequency multiplexed channels on an optical carrier $\lambda 1$ through an optical fiber 53 to a wavelength multiplexer 54. The multiplexed optical carrier is directed by the multiplexer 54 to an optical fiber 55. An opto-RF transducer 62 includes a wavelength multiplexer 56 and an optical detector 57 for converting the optical signal on the fiber 55 to an electrical radio frequency signal which is radiated from an antenna 60 at a power, limited to approximately ten watts for the combined carriers, to mobile units within a microcell range of the antenna. The electrical signal is amplified by an amplifier 59 if required. Radiation from the antenna 60 is in a first band f1 of RF frequencies and, typically, may be at one watt for the combination of

carriers.

In response to those transmitted signals, the receiving mobile units transmit a radio frequency signal which is received by an antenna 61. The received radio frequency signal is in a second band of frequencies which are separated from and do not interfere with the first band of frequencies. When received at the antenna 61, the radio frequency signal is amplified by an amplifier 63, if required, and modulates a laser 64 that produces an optical signal at a wavelength $\lambda 2$ which is transmitted through the wavelength multiplexer 56 to the optical fiber 55. This optical signal includes frequency multiplexed signals received from all mobile units transmitting within the relevant microcell. Thus, optical carrier signals of different wavelengths $\lambda 1$ and $\lambda 2$ are transmitted in opposite directions on the single fiber 55. RF carriers are multiplexed onto both optical carriers.

At the base station location, the wavelength multiplexer 54 directs the optical signal wavelength $\lambda 2$ to an optical detector 66. Such detector converts the optical signal to an electrical signal and applies it to an input port of a star coupler, or power combiner, 41. At the output port of the power combiner, the electrical signal including sixteen FM channels is fed into the base station 25 in accordance with known techniques.

Referring now to FIG. 5, there is shown an alternative opto-RF transducer 72 which can be substituted for the transducer 62 of the arrangement of FIG. 4. It is noted that the single optical fiber 55, which transmits optical carriers in both directions, applies the wavelength $\lambda 1$ to the wavelength multiplexer 56 and receives the wavelength $\lambda 2$ from the wavelength multiplexer 56. Optical detector 57 and laser 64 operate as in the arrangement of FIG. 4. Electrical signals including the combined RF carriers detected from the optical carrier $\lambda 1$ are amplified, if required, by an amplifier 68 and are applied to a circulator 69. Those RF channels, which have a combined power limited to approximately ten watts, are directed to an antenna 70 for radiation to mobile units within a microcell range of the antenna. These RF channels are in a first RF band of frequencies f1.

RF channel signals returned from the mobile units are received at the same antenna 70 and are applied to the circulator 69. These RF channels are transmitted in a separate RF band of frequencies f2 which does not interfere with the band of frequencies that is transmitted from he antenna 70. Circulator 69 directs the received RF channels to the laser 64.

The signals are amplified in an amplifier 71, if required.

Thus the opto-RF transducer 72 is arranged to interconnect with a single optical fiber carrying two different wavelength optical carriers for opposite directions of transmission and to include a single antenna arranged for radiating and receiving RF channels in different frequency bands f1 and f2. For the transmitted RF channels, their combined power typically is approximately one watt and is limited to approximately ten watts to produce the microcell coverage. RF signals, received from mobile units is at typical mobile unit power level.

Referring now to FIG. 6, there is shown the base station 25 which is arranged to transmit and receive frequency multiplexed FM signals in several channels. On the transmit side of the base station, the FM subcarrier channels, frequency multiplexed on a radio frequency transmission line, are used for modulating a laser 75 for transmitting the frequency multiplexed channels on an optical carrier through an optical fiber 76. The optical signal is applied to a star coupler 80 for distribution through optical fibers 81 to opto-RF transducers 82. The star coupler 80 can be located remote from he base station 25. In those opto-RF transducers, a detector 83 converts the optical signal to an electrical radio frequency signal which is used for radiating from each antenna 87 to mobile units located within microcell range. Transmitted radio frequency signals include several channels in a first band of frequencies. The radiated power is limited to approximately ten watts for the combined channels. Typically the combined power is approximately one watt for each microcell.

Responding mobile units transmit radio frequency signals which are received by any microcell antenna 89 that is within microcell range. Channel signals transmitted from the mobile units are multiplexed in air and at the antenna 89. They are in a different band of frequencies than the band transmitted from the antenna 87. The received radio frequency signal modulates a laser 90 producing an optical signal that is transmitted through another optical fiber 92 to a star coupler, or power combiner, 95. Optical signals from the several fibers 92 are combined and transmitted through a single optical fiber 97 to a detector 98 at the location of the base station 25. The optical signal includes frequency division multiplexed signals from all mobile units transmitting within relevant microcells. Power levels received from he mobile units are typical for mobile radio units.

At the base station location, the detector 98 converts the optical signal to an electrical signal including sixteen FM channels and applies that signal to the base station 25, in accordance with standard techniques. Opto-RF transducer 42 from FIG. 3 can be substituted for opto-RF transducer 82 for operating with a single antenna.

Referring now to FIG. 7, there is shown the base station 25 arranged for transmitting and receiving frequency multiplexed FM signals in many channels. To transmit, the FM subcarrier channels, frequency multiplexed on a radio frequency line, are used for modulating the output of a laser 102. The laser 102 transmits the frequency multiplexed channels on an optical carrier through a wavelength multiplexer 103 and an optical fiber 104. The optical carrier for the signal being transmitted is at a wavelength $\lambda 1$. From the fiber 104, the optical signal is applied to a port of a star coupler, or power splitter 105. The star coupler 105 can be located remote from the base station 25. Each of several output ports of the power splitter 105 connects with a separate optical fiber 106 for distributing the optical signal to a group of opto-RF transducers 107. Such transducers include a wavelength multiplexer 108 for directing the optical carrier to $\lambda 1$ an optical detector 109 for converting to an electrical radio frequency signal that is radiated from the group of antennas 110 to any mobile units within range of the microcell radiation coverage. Combined channel power is limited to approximately ten watts and typically is approximately one watt for covering a microcell.

Concurrently the mobile units transmit back to the base station 25 via a radio frequency signal that is received at one or more antennas 112 and is applied to modulate a laser 115 in the opto-RF transducer 107. This radio frequency signal is a combination of channels in a band of frequencies that is different from the band radiated from antenna 110. The optical carrier, modulated by the received radio frequency signal, is transmitted through the optical fibers 106 to the star coupler 105. This receiving optical carrier has a wavelength $\lambda 2$ that is separate from the transmitting optical carrier so that the two optical carriers do not interfere with each other. Optical signals from all of the fibers 106 are added incoherently within the star coupler 105 and the resulting composite optical signal is transmitted through the optical fiber 104 to the wavelength multiplexer 103 where it is directed to the receiving port of the base station 25. At the base station

location, the optical signal is detected in a detector 117 and is converted to a sixteen channel electrical signal that is applied to the base station 25 according to known practice.

Although the foregoing embodiments have been described as an example with sixteen channel operation, the invention also is well suited for a mobile communication network that operates with many more than sixteen channels from a base station.

Microcell radiation coverage is much more precisely defined than that of presently used base station antenna towers. As a result the number N of sub-bands can be greatly reduced with microcells because of reduced co-channel interference. This results in more frequency channels per sub-band and allows more users per square mile and greater frequency reuse. Since microcells in a given call radiate and receive the same sub-band, there is no call handoff between microcells only at the regular cell boundaries.

The fibers connecting the microcells to the base station can be reconnected at the base station to a multiple of new sub-band transceivers. This provides the ability to sub-divide a cell into multiple channel sub-cells by reconfiguring the fiber network to the opto-RF transducers. This aspect of the invention overcomes the difficulty of installing new base stations and antenna towers when sub-dividing cells.

Appended claims define the described embodiments of the invention together with other embodiments which are obvious in view thereof.

Claims:

1. A mobile radio system having a base station and a plurality of mobile units, the system comprising

a plurality of opto-RF transducers;

a distribution network using optical fibers interconnecting the base station with the opto-RF transducers; and

means for transducing multiplexed subcarrier channels onto and off of optical carriers in the fiber distribution network, for transducing multiplexed subcarrier channels onto an optical carrier on a fiber from the base station, and for transducing multiplexed subcarrier channels off of an optical carrier on a fiber to the base station,

wherein each opto-RF transducer is operable to receive a plurality of subcarrier channels from said base station and any of said plurality of subcarrier channels from at least one of said plurality of mobile units such that said at least one of said plurality of mobile units may establish bidirectional communication with the base station via any of said opto-RF transducers.

2. A mobile radio system, in accordance with claim 1, wherein the plurality of opto-RF transducers, in response to optical response to received radio signals transmitted from the mobile units, signals on the fibers, radiate radio signals to mobile units and, in modulate optical signals on at least one fiber for transmission to the base station.

3. A mobile radio system, in accordance with claim 2, wherein the radiated and received radio signals are included in a millimeter wave band.

4. A mobile radio system, in accordance with claim 2, wherein received radio signals are added together incoherently in the distribution network to provide the combined signal at the base station.

5. A mobile radio system, in accordance with claim 1, wherein the subcarrier transducing means and the opto-RF transducers time division multiplex channels onto the optical carrier in the fiber distribution network.

6. A mobile radio system, in accordance with claim 1, wherein the subcarrier transducing means and the opto-RF transducers frequency division multiplex channels onto the optical carrier in the fiber distribution network.

7. A mobile radio microcell transducer comprising

a first antenna for transmitting radio signals including multiplexed mobile radio channels in a first range of frequencies, said first range of frequencies defining a plurality of subcarrier transmit channels;

a second antenna for receiving radio signals including multiplexed mobile radio channels in a second range of frequencies, said second range of frequencies defining a plurality of subcarrierreceive channels;

a laser, responsive to the received radio signals, for producing an optical carrier modulated by the mobile radio channels in the second range of frequencies; and

means for transducing another optical carrier modulated by the mobile radio channels in the first range of frequencies into an electrical signal including the mobile radio channels having a combined power of ten watts or less.

8. A mobile radio microcell transducer, in accordance with claim 7, further comprising

a first optical fiber for receiving the modulated optical carrier produced by the laser; and

a second optical fiber for applying another modulated optical carrier to the transducing means.

9. A mobile radio microcell transducer arrangement comprising

a laser;

an antenna for transmitting and receiving radio signals including multiplexed mobile radio channels in different ranges of frequencies, each range of frequencies defining a plurality of subcarrier channels;

means for converting an optical carrier modulated with mobile radio channels in a first band of frequencies into an electrical signal to be applied to the antenna; and

circulator means for coupling the electrical signal in the first band of frequencies to the antenna for radiating to mobile units and for coupling an electrical signal, received in a second band of frequencies from the mobile units through the antenna, to the laser for modulating the optical output with the electrical signal in the second band of frequencies.

10. A mobile radio microcell transducer arrangement in accordance with claim 9, further comprising

a first optical fiber for receiving the electrical signal modulated laser output;

a second optical fiber for applying the mobile radio channels modulated optical output to the circulator means.

11. A mobile radio microcell transducer arrangement, in accordance with claim 10, wherein

the electrical signal applied to the antenna in the first band of frequencies has a combined power of ten watts or less.

12. A mobile radio microcell transducer arrangement comprising

a first antenna for transmitting radio signals including multiplexed mobile radio channels in a first range of frequencies, said first range of frequencies defining a plurality of subcarrier transmit channels;

a second antenna for receiving radio signals including multiplexed mobile radio channels in a second range of frequencies, said second range of frequencies defining a plurality of subcarrier receive channels;

laser means, responsive to the received radio signals, for producing an optical carrier modulated by the mobile radio channels in the second range of frequencies;

means for transducing another optical carrier modulated by the mobile radio channels in the first range of frequencies into an electrical signal including the mobile radio channels;

an optical fiber; and



means for optical wavelength multiplexing a first optical wavelength from the optical fiber to the transducing means;

the multiplexing means for wavelength multiplexing a second optical wavelength from the laser means to the optical fiber.

13. A mobile radio microcell transducer arrangement, in accordance with claim 12, wherein

the electrical signal applied to the antenna has a combined channel power of ten watts or less.

14. A mobile radio microcell transducer arrangement comprising a laser;

an antenna for transmitting and receiving radio signals including multiplexed mobile radio channels in different ranges of frequencies, each range of frequency defining a plurality of subcarrier channels;

means for converting an optical carrier modulated with mobile radio channels in a first band of frequencies into an electrical signal to be applied to the antenna;

circulator means for coupling the electrical signal in the first band of frequencies to the antenna for radiating to mobile units and for coupling an electrical signal, received in a second band of frequencies from the mobile units through the antenna, to the laser for modulating the optical output with the electrical signal in the second band of frequencies;

an optical fiber;

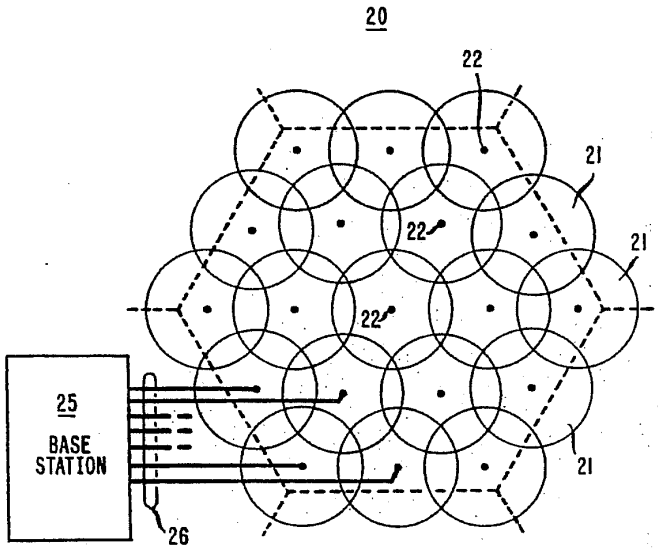
means for wavelength multiplexing a first optical wavelength from the optical fiber to the transducing means;

the multiplexing means for wavelength multiplexing a second optical wavelength from the laser means to the optical fiber.

15. A mobile radio microcell transducer arrangement, in accordance with claim 14, wherein

the electrical signal applied to the antenna has a combined channel power of ten watts or less.

FIG. 1




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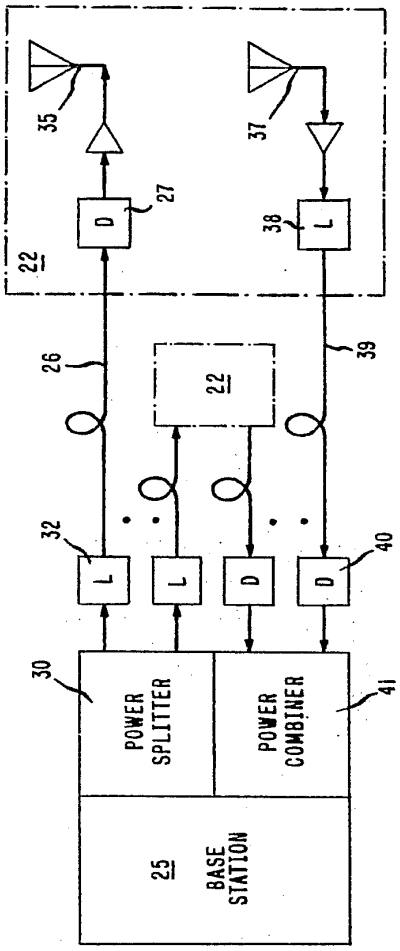



FIG. 2

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FIG. 3

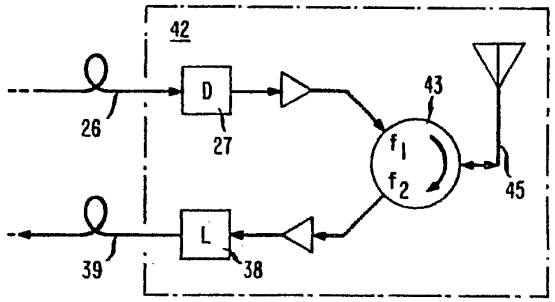
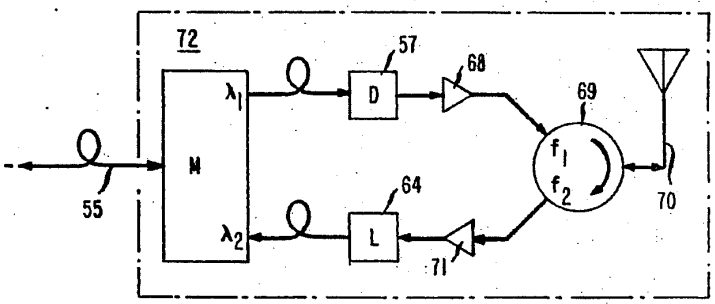



FIG. 5




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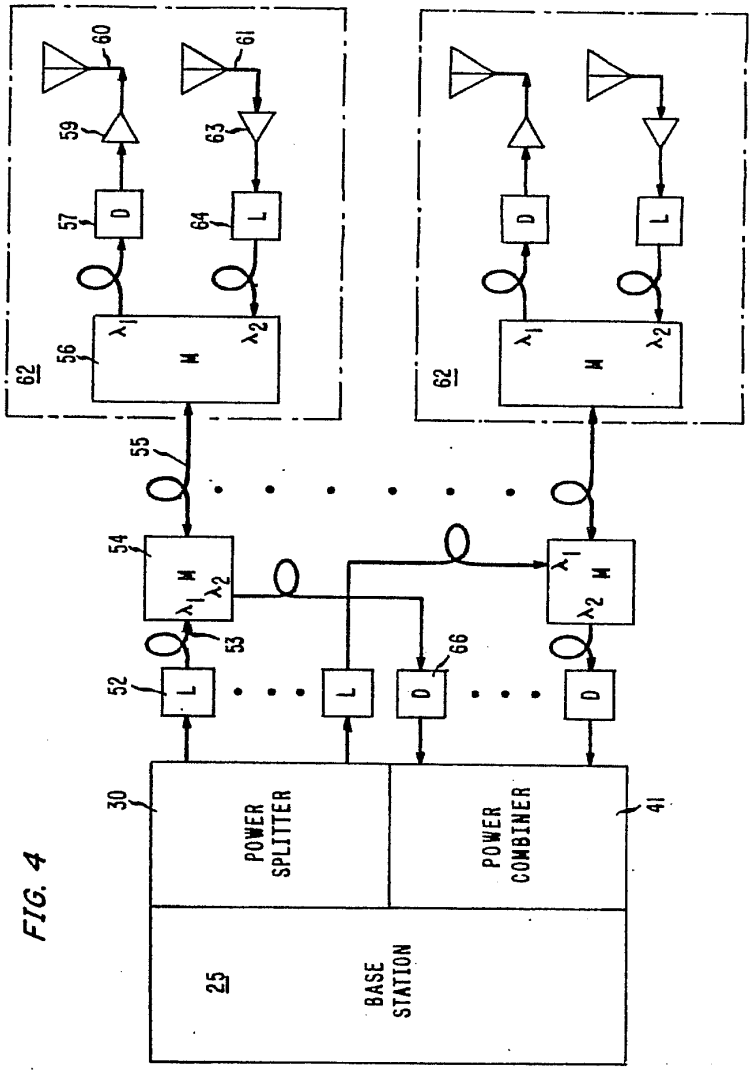



FIG. 4

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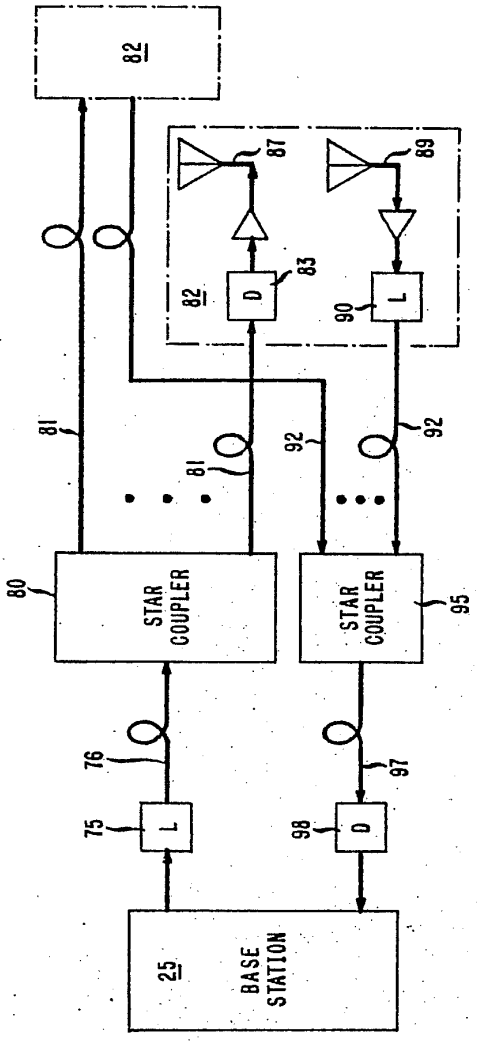



FIG. 6

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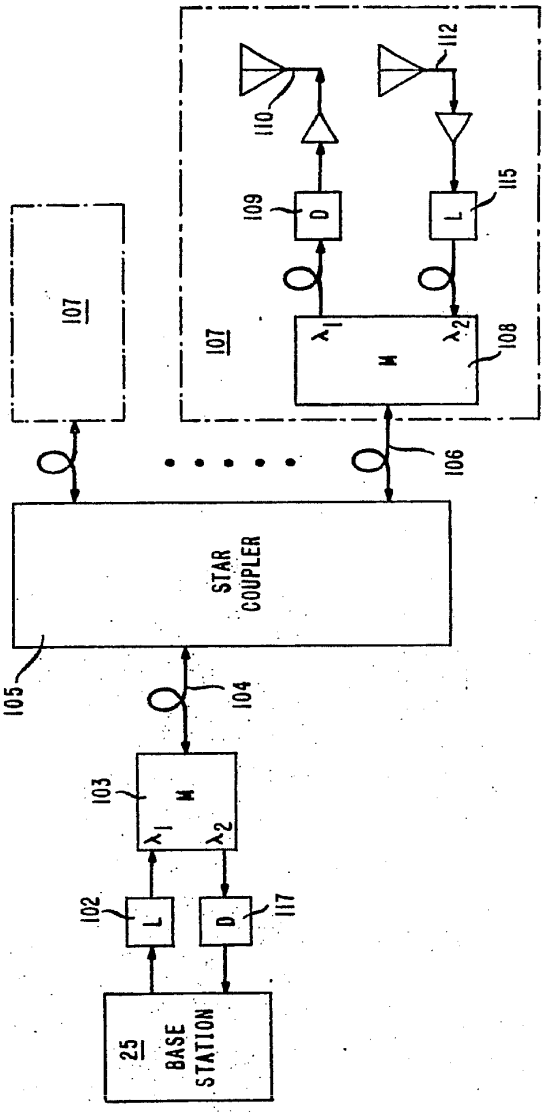



FIG. 7

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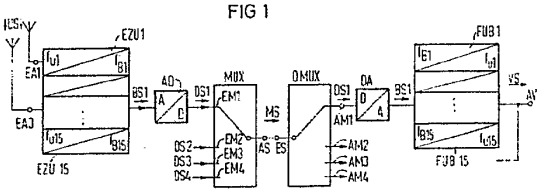
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DE 36 03 977 A1
DE 35 22 859 A1
DE 32 08 308 A1

Prüfungsantrag gem. § 44 PatG ist gestellt

(54) **Verfahren zur digitalen Übertragung von Hörrundfunksignalen**

Verfahren zur digitalen Übertragung von Hörrundfunksignalen über Breitbandkanäle, bei dem empfangene UKW-Hörrundfunksignale (US1, US2, ...) aus der Zwischenfrequenzlage in Ton-Basisbandsignale (BS11, BS12, ...) umgesetzt werden, alle in die Basisbandlage umgesetzten Ton-Basisbandsignale (BS11, BS12, ...) geschlossen abgetastet und in ein Digitalsignal (DS1) umgesetzt werden, das übertragen und empfangsseitig in analoge UKW-Hörrundfunksignale rückumgesetzt wird.

FIG 1




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## Patentansprüche

1. Verfahren zur digitalen Übertragung von Hörrundfunksignalen über Breitbandkanäle, **dadurch gekennzeichnet,**
daß empfangene UKW-Hörrundfunksignale *(US 1, US 2, ...)* einzeln aus der Zwischenfrequenzlage *($f_{ZF}$)* in Ton-Basisbandsignale *(BS 11, BS 12, ...)* mit unterschiedlichen Trägerfrequenzen umgesetzt werden,
daß alle Ton-Basisbandsignale *(BS 11, BS 12, ...)* geschlossen abgetastet und in ein Digitalsignal *(DS 1)* umgesetzt werden,
daß das Digitalsignal *(DS 1)* übertragen wird und
daß empfangsseitig das Digitalsignal *(DS 1)* in analoge UKW-Hörrundfunksignale rückumgesetzt wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß amplitudenmodulierte Kurz-, Mittel- und Langwellen-Hörrundfunksignale *(K-M-L)* zunächst in frequenzmodulierte Signale umgesetzt und anschließend ebenfalls in Ton-Basisibandsignale *(BS 13)* umgesetzt werden.

3. Verfahren nach Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß jeder bei der Abtastung der Ton-Basisbandsignale erhaltene Abtastwert mit 9 oder 10 Bits quantisiert wird.

4. Verfahren nach einem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß ein Kanalabstand der Ton-Basisbandsignale *(BS 11, BS 12, ...)* von 400 KHz vorgesehen ist.

5. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß mehrere Digitalsignale *(DS 1, DS 2, DS 3, DS 4)* zu einem Multiplexsignal zusammengefaßt werden.

6. Verfahren zur digitale Übertragung von Hörrundfunksignalen über Breitbandkanäle, dadurch gekennzeichnet,
daß der UKW-Bereich in mindestens drei Frequenzteilbänder *(FT 1, FT 2, FT 3)* aufgeteilt wird,
daß die UKW-Hörrundfunksignale *(US 11, US 12, ...)* jedes Frequenzteilbandes *(FT 1, FT 2, FT 3)* in Ton-Basisbandsignale *(BS 11, BS 12, ...)* eines Basisbandes *(BB 1)* umgesetzt werden,
daß die Ton-Basisbandsignale *(BS 11, BS 12, ...)* jedes Basisbandes *(BB 1, BB 2, BB 3)* geschlossen abgetastet und in Digitalsignale *(DS 1, DS 2, DS 3)* umgesetzt werden,
daß die Digitalsignale *(DS 1, DS 2, DS 3)* zu einem Multiplexsignal *(MS)* zusammengefaßt und übertragen werden und
daß empfangsseitig das Multiplexsignal in die Digitalsignale *(DS 1, DS 2, DS 3)* aufteilt wird, in analoge Basisbandsignale *(BS 1, BS 2, BS 3)* umgewandet und in den UKW-Bereich umgesetzt wird.

7. Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß die abgetasteten Ton-Basisbandsignale *(BS 11, BS 12, ...)* mit 8 oder 9 Bits codiert werden.

8. Verfahren nach Anspruch 6 oder Anspruch 7, dadurch gekennzeichnet, daß die UKW-Hörrundfunksignale *(US 1, US 2, ...)* in Frequenzteilbändern zunächst in den Video-Zwischenfrequenzbereich *($f_V$)* umgesetzt werden und anschließend in die Basisbandlage *(BB 1, ...)* umgesetzt werden.

9. Verfahren nach Anspruch 9, dadurch gekennzeichnet, daß eine Rückumsetzung der Basisbandsignale *(BS 1, BS 2, BS 3)* in UKW-Hörrundfunksignale über den Video-Zwischenfrequenzbereich *($f_V$)* erfolgt.

10. Verfahren nach Anspruch 5 oder einem der Ansprüche 6 bis 9, dadurch gekennzeichnet, daß die Digitalsignale *(DS 1, DS 2, DS 3)* synchron übertragen werden.



## Beschreibung

Die Erfindung betrifft ein Verfahren zur digitalen Übertragung von Hörrundfunksignalen über Breitbandkanäle.

Die Versorgung von Hörrundfunkteilnehmern erfolgt in zunehmendem Maße über Breitband-Verteilnetze. In Rundfunkempfangsstellen werden die empfangenen Hörrundfunksignale zunächst signalmäßig aufbereitet, bevor sie über Glasfaserkabel oder Koaxialkabel zu einer Breitband-Verteilstelle und von hier zu den Teilnehmern gelangen. Die Übertragung zwischen Rundfunkempfangsstelle und Breitband-Verteilstelle kann prinzipiell mit demodulierten analogen Rundfunksignalen erfolgen. Eine solche Übertragung wäre jedoch extrem aufwendig und mit Qualitätseinbußen verbunden. Die demodulierten Rundfunksignale können auch digitalisiert werden, um anschließend über einen Multiplexkanal übertragen zu werden. Durch die Demodulation, Digitalisierung und Digital-Analog-Umsetzung mit anschließender erneuter Modulation würden jedoch ebenfalls Qualitätseinbußen auftreten. Der Aufwand für die Übertragungseinrichtung wäre zwar geringer, der Aufwand für die Demodulations- und Modulationseinrichtungen jedoch weiterhin erheblich.

Aufgabe der Erfindung ist es, ein kostengünstiges Übertragungsverfahren für Hörrundfunksignale über Verbindungen eines Breitbandnetzes anzugeben.

Die Aufgabe wird durch die im Patentanspruch 1 angegebene Merkmale gelöst.

Außerdem wird eine mit geringerem Aufwand realisierbare Weiterbildung angegeben.

Vorteilhafte Ausbildungen der Erfindung sind den Unteransprüchen zu entnehmen.

Es ist besonders vorteilhaft, daß die aufbereiteten Empfangssignale in die Ton-Basisbandsignale mit dem gewünschten Tonträgerabstand umgesetzt werden, um anschließend geschlossen abgetastet und digitalisiert zu werden. Hierbei können unterschiedliche Antennen zum optimalen Empfang der Rundfunksignale eingesetzt werden und die Empfangssignale individuell aufbereitet werden. Die geschlossene Abtastung aller Empfangssignale eines Ton-Basisbandes bedingt nur einen geringen Schaltungsaufwand.

Die Umsetzung in Normbitraten ist vorteilhaft, da bereits bestehende Übertragungseinrichtungen verwendet werden können. Empfangsseitig erfolgt die Rückumsetzung in analoge Signale, die im allgemeinen wieder in eine höhere Frequenzlage, beispielsweise das UKW-Rundfunkband umgesetzt werden. Eine Demodulation und erneute Modulation ist bei diesem Verfahren nicht notwendig.

Eine Quantisierung mit 9 oder 10 Bits je Abtastwert ergibt bereits einen ausgezeichneten Geräuschspannungsabstand. Aber auch bei 8 Bits Auflösung je Abtastwert und Synchronenbetrieb ergibt bereits einen Geräuschabstand nach CCIR Rec. 468 von größer 60 dB. Neben den heutige Qualitätsansprüche zufriedenstellenden UKW-Rundfunksendern können selbstverständlich auch amplitudenmodulierte Signal übertragen werden. Aus Gründen der Störsicherheit ist es je-

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doch zweckmäßig, die AM-Rundfunksignale vorher zu demodulieren und in FM-Rundfunksignale vor der Übertragung umzusetzen.

Anstelle der Umsetzung einzelner Hörrundfunksignale in den Ton-Basisbandbereich ist theoretisch auch die geschlossene Umsetzung des gesamten UKW-Bereichs in den Ton-Basisbandbereich möglich. Die bei der Digitalisierung erforderlichen Abtasteinrichtungen sowie Analog-Digital-Umsetzer sind jedoch beim heutigen Stand der Technik noch nicht zu realisieren. Deshalb wird der UKW-Bereich in mehrere Teilbänder aufgeteilt, die jeweils in einen Ton-Basisbandbereich zwischen ca. 0 und 7 MHz umgesetzt werden. Durch Zwischenumsetzung der UKW-Teilbänder in den Video-Zwischenfrequenzbereich können bereits vorhandene Umsetzer- und Signalaufbereitungseinrichtungen verwendet werden.

Ausführungsbeispiele der Erfindung werden anhand von Figuren näher erläutert. Es zeigt

**Fig.** 1 ein Prinzipschaltbild zur Realisierung der Erfindung mit Einzelkanalumsetzung,

**Fig.** 2 einen Frequenzplan,

**Fig.** 3 einen Frequenzplan zur Umsetzung von amplitudenmodulierten Empfangssignalen,

**Fig.** 4 ein Prinzipschaltbild zur Umsetzung von UKW-Teilbändern,

**Fig.** 5 einen Frequenzplan hierzu,

**Fig.** 6 ein Blockschaltbild zur Einzelkanalumsetzung und

**Fig.** 7 ein Blockschaltbild zur UKW-Teilbandumsetzung.

Das in **Fig.** 1 dargestellte Prinzipschaltbild enthält bis zu 15 Empfangs-Zwischenfrequenzumsetzer *EZU* **1** bis *EZU* **15**. An die Antenneneingänge — in **Fig.** 1 sind nur zwei Antenneneingänge *EA* **1** und *EA* **3** dargestellt — können verschiedenen Empfangsantennen angeschlossen sein. Die Ausgänge der Empfangs-Zwischenfrequenzumsetzer sind zusammengeführt und mit dem Eingang eines ersten Analog-Digital-Umsetzers *AD* **1** verbunden. Dessen Ausgang ist mit dem ersten Eingang *EM* **1** einer Multiplexeinrichtung *MUX* verbunden, über deren Streckenausgang *AS* ein Multiplexsignal über einen Breitbandkanal zu dem Streckeneingang *ES* einer Demultiplexeinrichtung *DMUX* übertragen wird. An den ersten Ausgang *AM* **1** der Demultiplexeinrichtung ist ein erster Dialog-Analog-Umsetzer *DA* **1** angeschaltet, dessen Ausgang mit den Eingängen von Basisband-Frequenzumsetzern *FUB* **1** bis *FUB* **15** verbunden ist. Die Ausgänge der Basisband-Frequenzumsetzer sind ebenfalls zusammengeführt, so daß an dem gemeinsamen Verteilerausgang *AV* die Rundfunksignale, beispielsweise im ursprünglichen UKW-Bereich, abgegeben werden.

Der Frequenzplan zum Prinzipschaltbild nach **Fig.** 1 ist in **Fig.** 2 dargestellt.

Die Aufgabe der Empfangs-Zwischenfrequenzumsetzer *EZU* ist die Aufbereitung von einzelnen Empfangssignalen *US*. Um gute Ergebnisse zu erzielen können zunächst unterschiedliche Richtantennen verwendet werden. Ein einzelnes Empfangssignal — hier beispielsweise ein UKW-Hörrundfunksignal *US* **1** wird zunächst — wie in **Fig.** 2 dargestellt — in die Zwischenfrequenzlage ($f_{ZF}$ = 10,7 MHz) umgesetzt, geregelt und begrenzt. Das so aufbereitete Zwischenfrequenzsignal wird in die Basisbandlage umgesetzt, einem ersten Basisband *BB* **1** zugeordnet und hier als Ton-Basisbandsignal *BS* **11** bezeichnet. Die Empfangs-Zwischenfrequenzumsetzer können hierbei so ausgelegt werden, daß die Abstände der Trägerfrequenzen zwischen den umgesetzten Empfangssignalen *BS* **11**, *BS* **12** mindestens 400 kHz betragen. Das erste Basisband *BB* **1** umfaßt beispielsweise einen Frequenzumfang zwischen 200 kHz und 6,2 Mhz, wobei die Trägerfrequenzen zwischen 0,4 MHz und 6,0 MHz liegen. Die Summe der umgesetzten Empfangssignale *BS* **11**, *BS* **12**, ... bilden das Basisbandsignal *BS* **1**. Das Basisbandsignal *BS* **1** wird von einem ersten Analog-Digital-Umsetzer *AD* **1** geschlossen abgetastet und digitalisiert. Die Quantisierung erfolgt mit 9 oder 10 Bits je Abtastwert, wobei ein erstes Digitalsignal *DS* **1** mit einer Normbitrate von 139 264 kbit/s nach CCITT-Rec. 703 erzeugt wird. Bei plesiochronem Betrieb werden Störabstände von mehr als 60 dB erreicht. Bei Synchronenbetrieb erhöht sich wegen des fehlenden Stopf-Jitters der Störabstand nochmals um ca. 6 dB. Das erste Digitalsignal kann direkt übertragen werden oder vorher mit weiteren Digitalsignalen *DS* **2** bis *DS* **4** zu einem Multiplexsignal *MS* zusammengefaßt werden, wie dies im Prinzipschaltbild nach **Fig.** 1 dargestellt ist.

Empfangsseitig wird das erste Digitalsignal *DS* **1** in das erste Basisbandsignal *BS* **1** rückumgesetzt. Über die Basisband-Frequenzumsetzer *FUB* **1** bis *FUB* **15** können die UKW-Hörrundfunksignale in Verteilsignale *VS* umgesetzt, die beispielsweise wieder im UKW-Rundfunkband ausgesendet werden. Bis zu 15 UKW-Hörrundfunksignale können bei einem Frequenzabstand der Trägerfrequenzen von 400 kHz bei einer Normbitrate von 139 264 kbit/s übertragen werden. Selbstverständlich können auch noch weitere Hörrundfunksignale in weitere Basisbänder *BB* **2**, *BB* **3** und Digitalsignale *DS* **2**, *DS* **3** umgesetzt und übertragen werden. Die weiteren Digitalsignale *DS* **2** bis *DS* **4** können aber auch beispielsweise Fernsehprogramme beinhalten.

Selbstverständlich können nicht nur UKW-Hörrundfunksignale übertragen werden. Ebenso ist die Übertragung von Kurz-, Mittel- und Langwellen-Hörrundfunksignalen möglich (**Fig.** 3). Die amplitudenmodulierten Kurz-, Lang- und Mittelwellen-Empfangssignale werden zunächst in die AM-Zwischenfrequenzlage ($F_{ZA}$ = 460 kHz) umgesetzt und demoduliert, z. B. das Empfangssignal *MS* **13**. Anschließend wird der FM-Zwischenfrequenzträger ($f_{ZF}$ = 10,7 MHz) frequenzmoduliert und das frequenzmodulierte Signal wird nach einer weiteren Frequenzumsetzung als Ton-Basisbandsignal *BS* **13** in das erste Basisband *BB* **1** eingefügt. Selbstverständlich ist auch ein Einfügen eines umgesetzten Hörrundfunksignals in die Verteilsignale bei einer Breitband-Verteilstelle möglich.

Die digitalisierten Hörrundfunksignale eines Basisbandes können als Digitalsignal über alle geeignete digitalen Kanäle und zwischen unterschiedlichen Einrichtungen übertragen werden. Der Einsatz der Erfindung ist überall da zweckmäßig, wo eine größere Anzahl von Hörrundfunksignalen übertragen werden soll. Sie eignet sich daher beispielsweise zur Übertragung zwischen verschiedenen Rundfunk-Empfangsstellen und Verteilstellen eines Breitbandnetzes. Selbstverständlich ist es auch möglich, die Digitalsignale direkt bis zum Teilnehmer zu übertragen, der dann die Umsetzung in analoge Signale durchführen muß.

Um den sogenannten Stopf-Jitter zu vermeiden, sollte beim Multiplexbetrieb eine synchrone Übertragung der Digitalsignale erfolgen. In **Fig.** 4 ist eine Variante der Erfindung dargestellt. Bei dieser erfolgt keine Umsetzung von einzelnen UKW-Empfangssignalen, sondern die Umsetzung ganzer Frequenzteilbänder (**Fig.** 5). Zur

Umsetzung eines Frequenzteilbandes ist in diesem Ausführungsbeispiel die Reihenschaltung eines ersten Empfangsfrequenzumsetzers *EU* 1, eines ersten Zwischenfrequenzumsetzers *ZFU* 1 und eines ersten Analog-Digital-Umsetzers *AD* 1 vorgesehen. Das vom ersten Analog-Digital-Umsetzer *AD* 1 abgegebene Digitalsignal *DS* 11 wird über die Multiplexeinrichtungen *MUX* und *DMUX* übertragen. Die Rückumsetzung in den UKW-Bereich erfolgt über die Reihenschaltung eines ersten Digital-Analog-Umsetzers *DA* 1, eines ersten Basisbandumsetzers *BBU* 1 und eines ersten Zwischenfrequenz-Rückumsetzers *ZRU* 1.

Der gesamte UKW-Bereich wird beispielsweise in 3 Frequenzteilbänder *FT* 1, *FT* 2 und *FT* 3 aufgeteilt (**Fig.** 5), die separat digitalisiert und übertragen werden. Am Verteilerausgang *AV* werden die drei rückumgesetzten Frequenzteilbänder zum ursprünglichen UKW-Bereich zusammengefaßt. Im angegebenen Ausführungsbeispiel erfolgt zunächst eine Zwischenumsetzung jedes Frequenzteilbandes *FT* 1, *FT* 2, *FT* 3 des UKW-Frequenzbereiches $f_u$ in Zwischenfrequenzsignale *ZFS* 1, ... des Video-Zwischenfrequenzbereichs $f_V$, da hier bereits die notwendigen Bandpässe zur Verfügung stehen. Die Frequenzteilbänder *FT* 1 bis *FT* 3 bzw. die Zwischenfrequenzsignale werden jeweils in Basisbandsignale *BS* 1, *BS* 2, *BS* 3 der Basisbänder *BB* 1, *BB* 2, *BB* 3 umgesetzt, die hier zwischen ca. 0 Hz und 7 MHz liegen. Dieser Frequenzbereich ist so gewählt, daß auch ein Farbfernsehsignal in den Basisbandbereich umgesetzt werden kann, wobei die Bildträgerfrequenz bei 1,25 MHz liegt. Jedes Basisbandsignal *BS* 1, *BS* 2, *BS* 3 wird geschlossen abgetastet und digitalisiert. Es ist dabei eine 8-Bit- oder 9-Bit-Auflösung möglich. Die Abtastfrequenz wird so gewählt, daß wieder die Normbitrate von 139 264 kbit/s erzeugt wird. Vier Digitalsignale *DS* 1 bis *DS* 4 können zu einem Multiplexsignal *MS* zusammengefaßt und übertragen werden. Empfangsseitig wird jedes Digitalsignal zunächst in ein Basisbandsignal rückumgewandelt und anschließend in den UKW-Bereich umgesetzt. Hierbei kann die Rückumsetzung auch wieder über den Video-Zwischenfrequenzbereich erfolgen, wobei dem Basisbandsignal *BS* 1 das Zwischenfrequenzsignal *ZFS* 1 entspricht. Die drei Frequenz-Teilbänder werden wieder zum UKW-Bereich zusammengefaßt.

Nachteilig bei der Umsetzung von Frequenzteilbändern ist, daß die UKW Empfangssignale nicht individuell aufbereitet werden können.

In **Fig.** 6 sind Blockschaltbilder der Empfangs-Zwischenfrequenzumsetzer dargestellt. Der erste Empfangs-Zwischenfrequenzumsetzer *EZU* 1 ist für die Umsetzung von UKW-Empfangssignalen geeignet. Außerdem ist ein Empfangs-Zwischenfrequenzumsetzer *EZA* 1 für amplitudenmodulierte Signale dargestellt, der zunächst das empfangene Signal demoduliert und dann ein frequenzmoduliertes Signal erzeugt, das vom Zwischenfrequenzbereich in den Basisbandbereich umgesetzt wird.

In **Fig.** 7 ist ein Empfangsumsetzer dargestellt, wie er im Prinzipschaltbild nach **Fig.** 4 Verwendung findet. Er enthält einen Eingangsteil *ET*, der zunächst einen UKW-Teilbereich in den Video-Zwischenfrequenzbereich $f_V$ umsetzt. Das Zwischenfrequenzsignal wird in einem Zwischenfrequenzteil *ZFT* bandbegrenzt, amplitudenbegrenzt und geregelt. In einem Umsetzerteil *UT* wird das Zwischenfrequenzsignal *ZFS* 1 in den Basisbandbereich umgesetzt. Das Basisbandsignal *BS* 1 wird entsprechend **Fig.** 5 dem ersten Analog-Digital-Umsetzer *AD* 1 zugeführt. Von der Umsetzung der amplitudenmodulierten Empfangssignale abgesehen, ist eine Demodulation und erneute Modulation der Signale nicht notwendig. Hierdurch werden Qualitätseinbußen vermieden.

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Fig. : 11 : 1: 11

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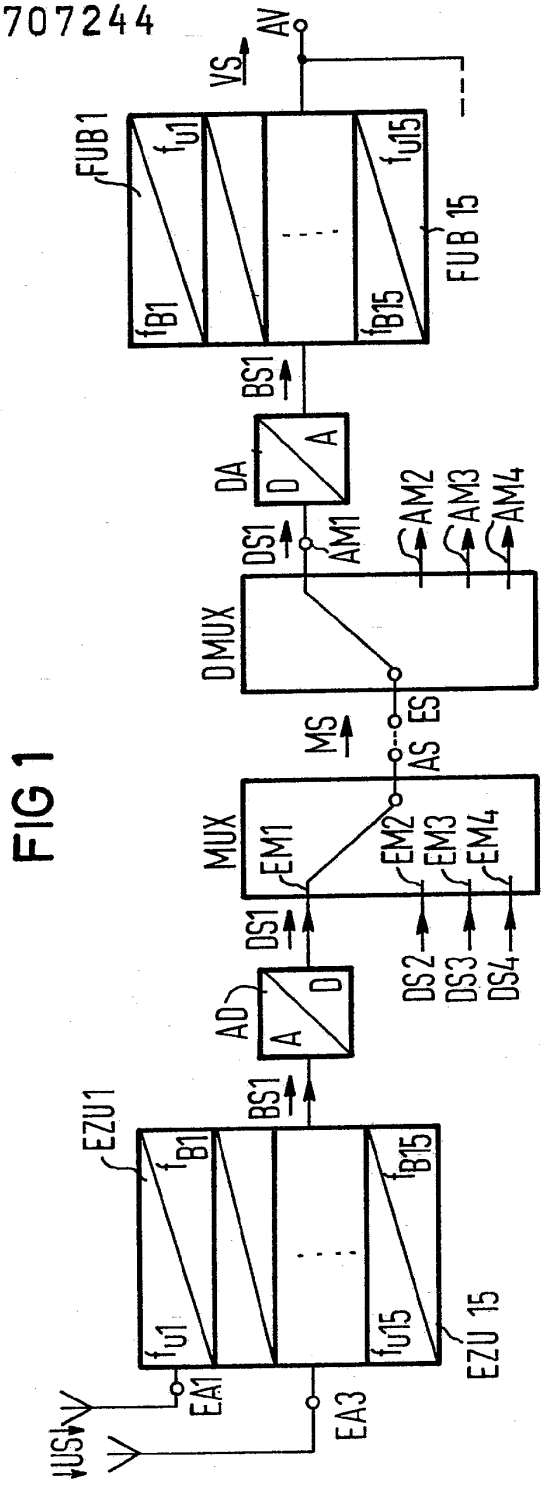
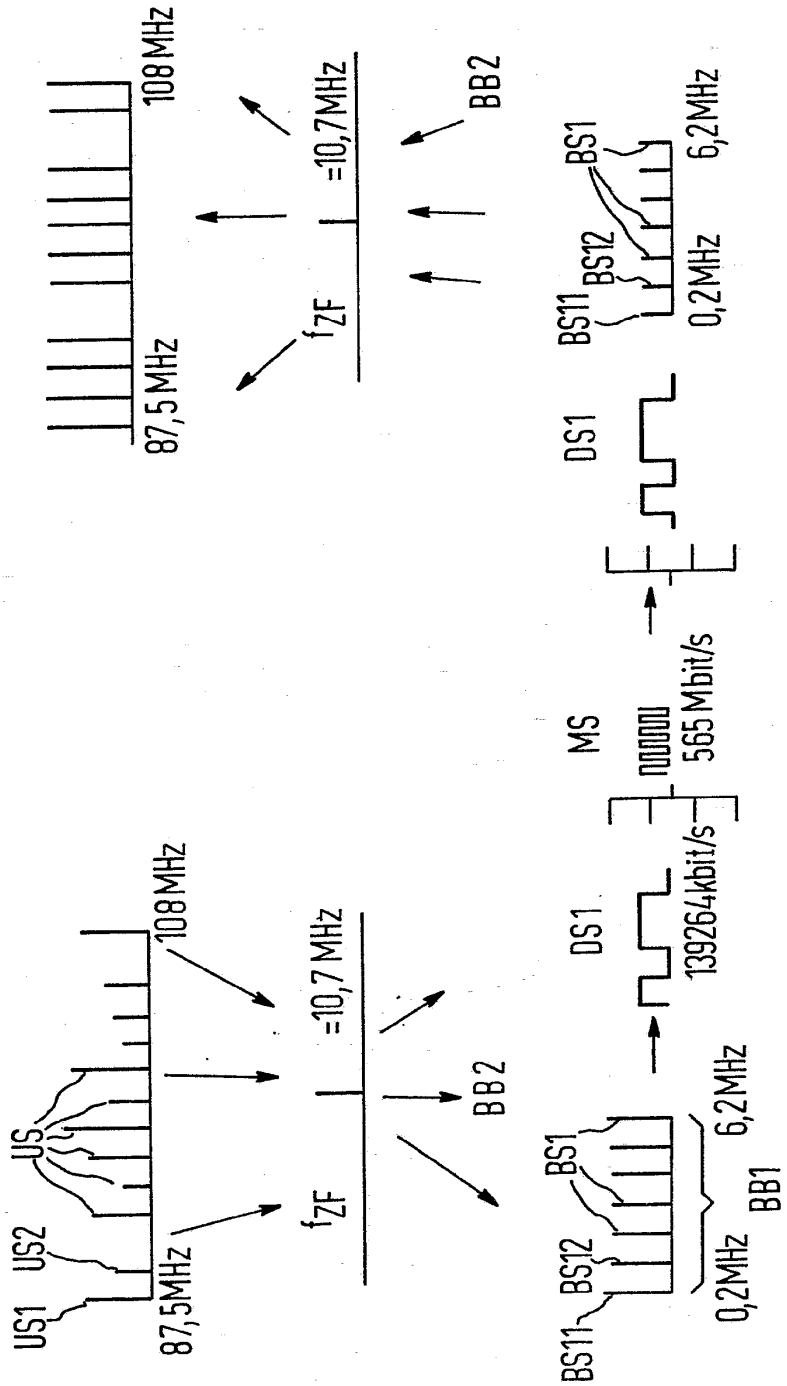



FIG 1

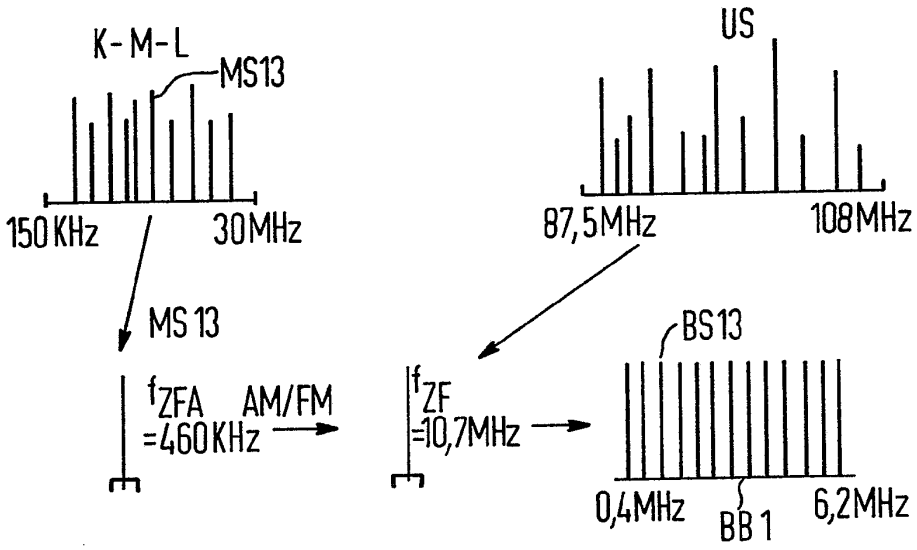
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FIG 2


108 MHz
87,5 MHz
=10,7MHz
$f_{ZF}$
BB2
DS1
BS11
BS12
BS1
0,2MHz
6,2MHz
MS
565 Mbit/s
139264kbit/s
US
US2
US1
BB1

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FIG 3



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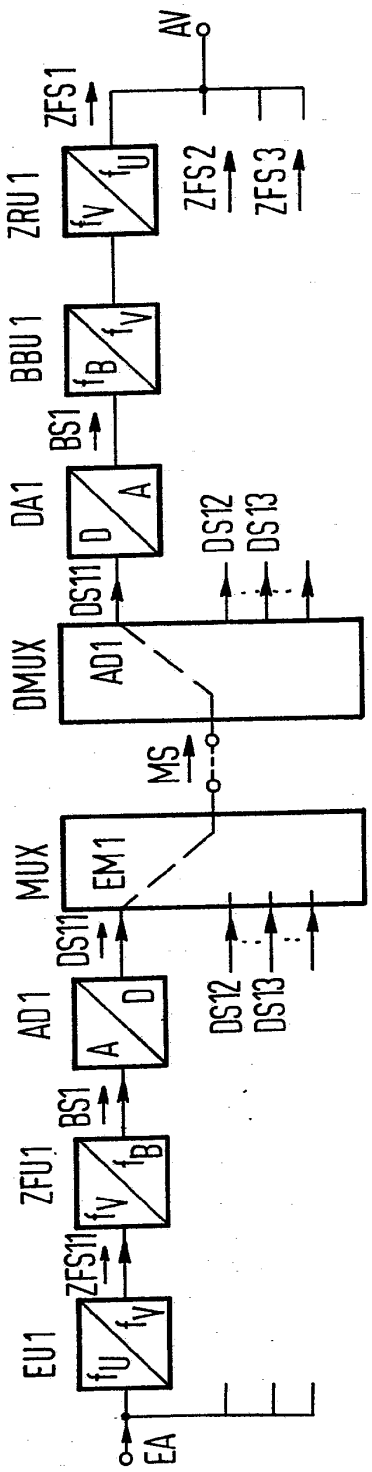
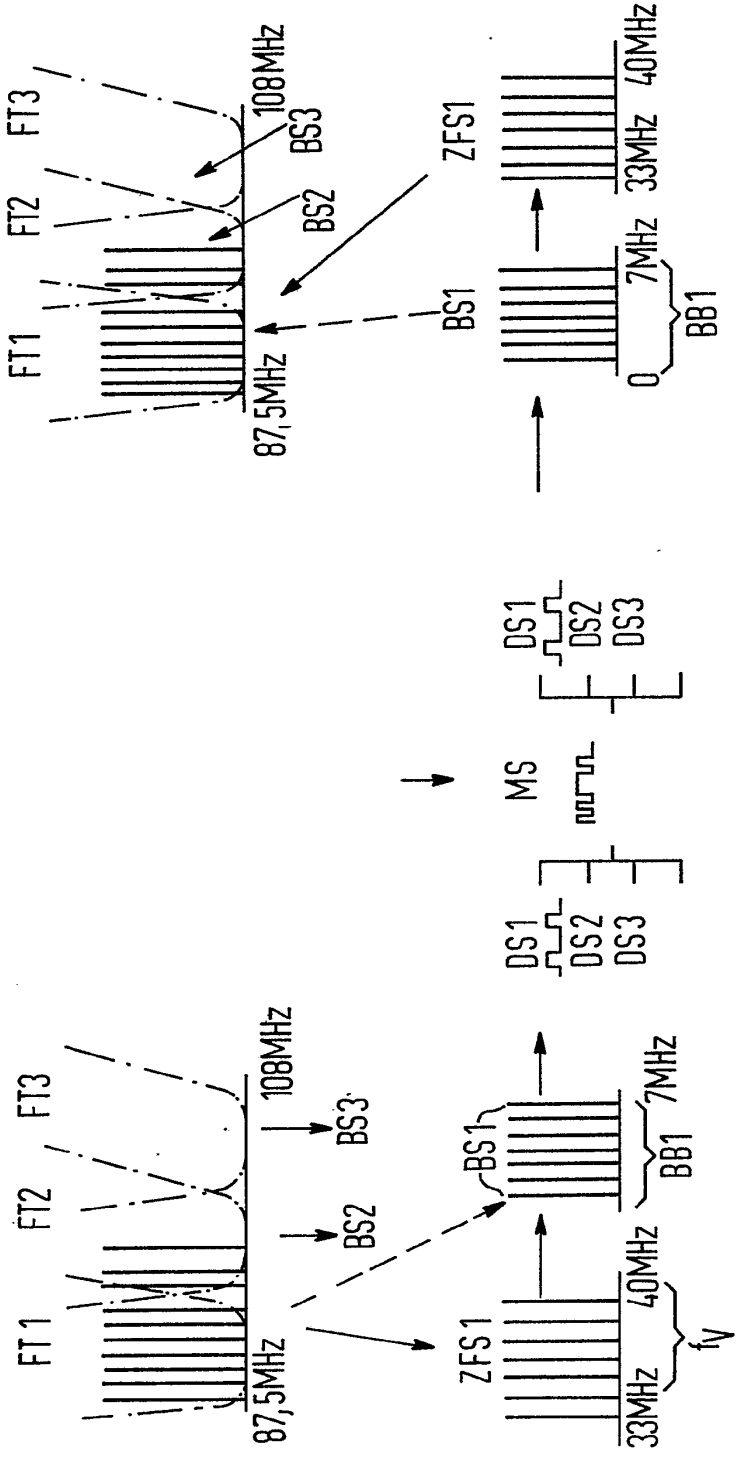



FIG 4

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FIG 5


FT1
FT2
FT3
87,5MHz
108MHz
BS1
BS2
BS3
ZFS1
33MHz
40MHz
7MHz
BB1
0
MS
DS1
DS2
DS3
fv

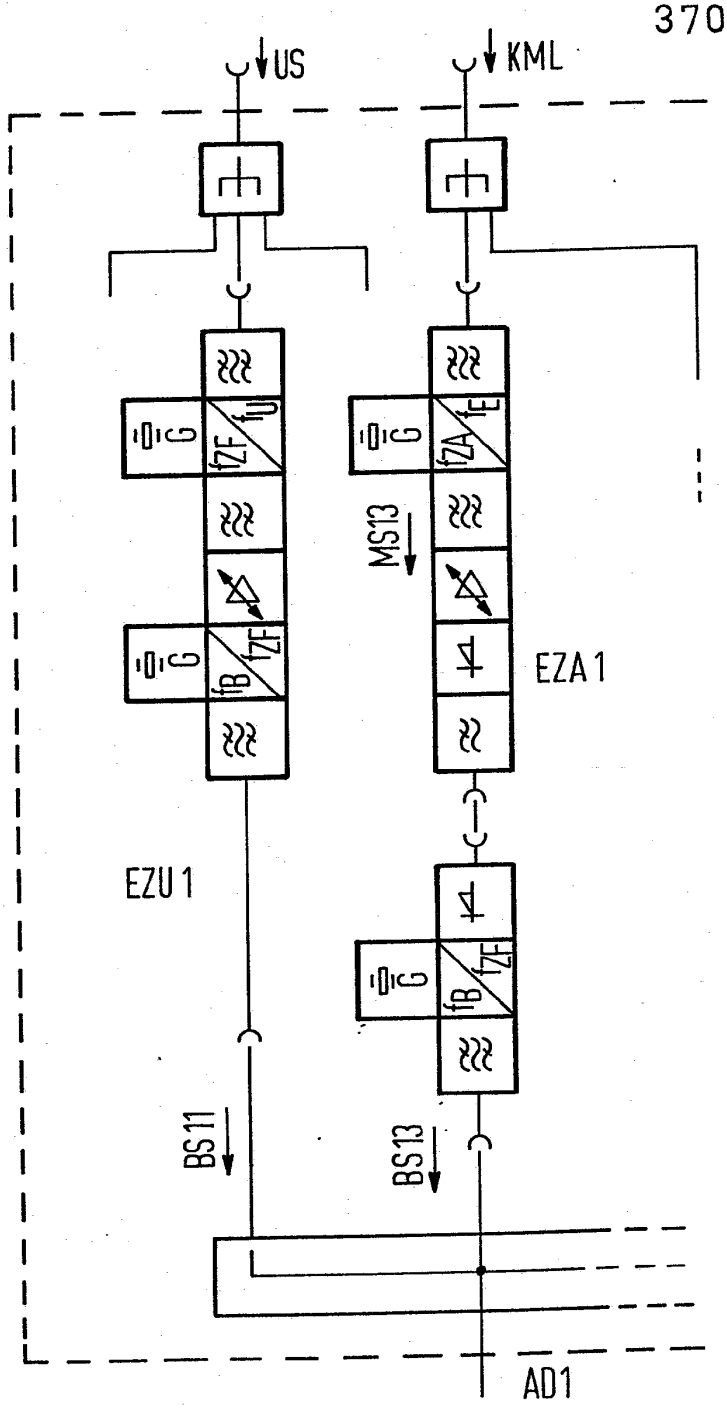
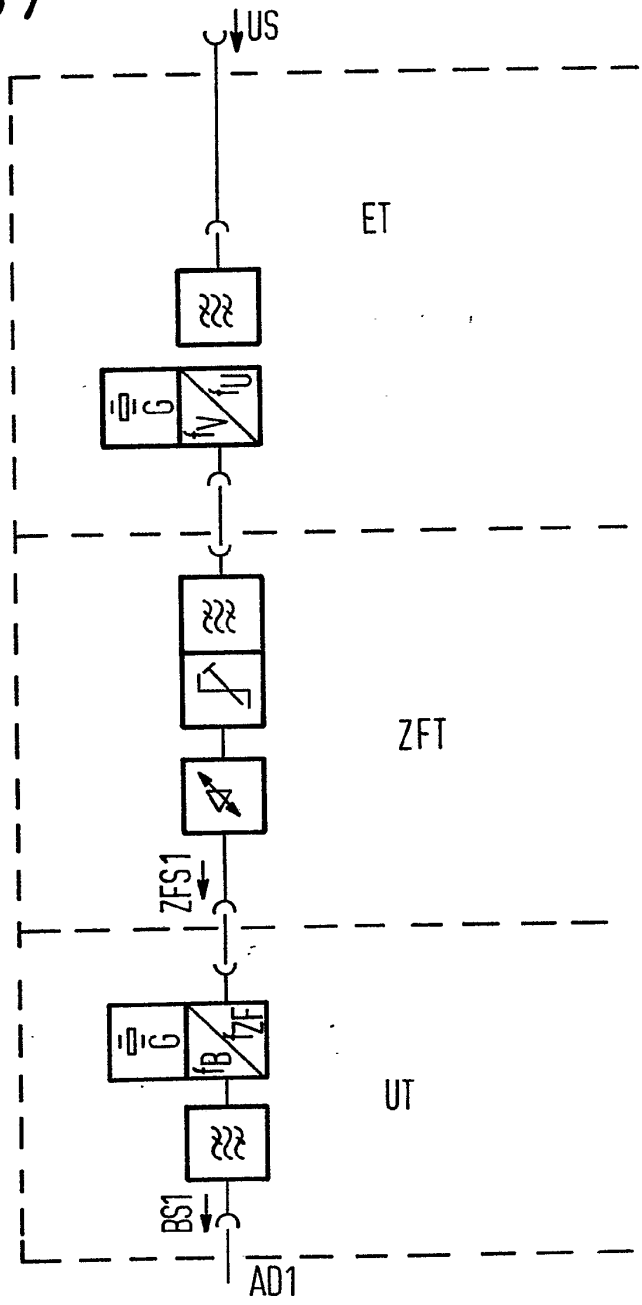



FIG6

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FIG 7



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(54) **Funktelefonsystem.**

(57) Es wird ein Funktelefonsystem für ein in Funkzellen aufgeteiltes Funkgebiet vorgeschlagen, bei dem neben in Kraftfahrzeugen eingebauten mobilen Funktelefonen auch in der Hand zu haltende mobile Funktelefone eingesetzt werden können. Wegen der vergleichsweise kleinen Sendeleistung von in der Hand zu haltenden mobilen Funktelefonen (H) wird jede Funkzelle (Z1) in n Empfangszellen (E11, E12 ...) aufgeteilt. Jede Empfangszelle enthält einen ortsfesten Mehrkanalfunkempfänger (BE11, BE12, ...). Die zentrale Funkstation (B1') enthält m Funksender (BS1, BS2 ...). Von der zentralen Funkstation aus werden die Mehrkanalfunkempfänger auf einen freien Sprachkanal der m Sprachkanäle umgeschaltet.

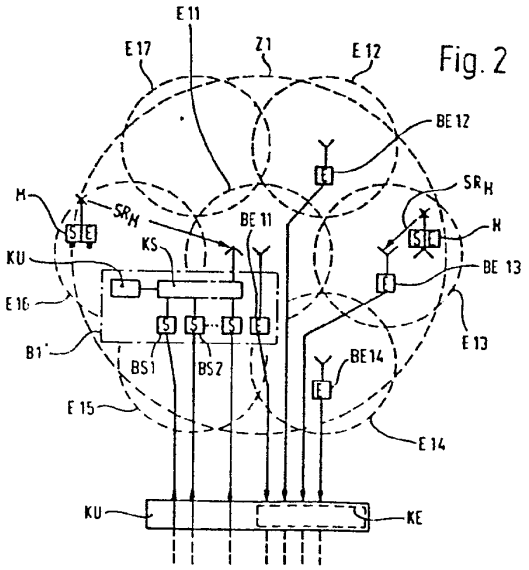



Fig. 2

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# Funktelefonsystem

## Stand der Technik

Die Erfindung betrifft ein Funktelefonsystem nach der im Oberbegriff des Anspruchs 1 angegebenen Gattung.

Es sind Funktelefonsysteme bekannt (z. B. Funkschau, 1984, Heft 7, Seiten 57 bis 59), bei denen ein Funkgebiet in Funkzellen mit je einer zentralen Funkstation aufgeteilt ist. Innerhalb des gesamten Funkgebietes können mobile Funktelefone operieren und über die zentralen Funkstationen mit Teilnehmern eines Telefonnetzes in Verbindung treten. Ein Nachteil der bekannten Funktelefonsysteme besteht darin, daß in der Hand zu haltende mobile Funktelefone nicht eingesetzt werden können. Die Sendeleistung derartiger Funktelefone beträgt nämlich wegen der geringen Batteriekapazität nur etwa 1/10 bis 1/3 der Sendeleistung eines in einem Kraftfahrzeug eingebauten mobilen Funktelefons. Aufgrund der Beziehung $P \sim E^2 \cdot r^2$, worin P die Sendeleistung des Funktelefons, E die Feldstärke und r der Senderadius bzw. die Reichweite sind, kann bei 1/10 der Sendeleistung nur noch mit etwa 1/3 der Reichweite gerechnet werden. Für die umgekehrte Übertragungsrichtung von der zentralen Funkstation zu einem in der Hand zu haltenden mobilen Funktelefon besteht dagegen dieses Problem nur in geringerem Maße, sofern die Antenne des Funktelefons entsprechend optimiert ist. In einem Funkversorgungsgebiet, das in der üblichen Weise in Funkzellen bestimmter Größe aufgeteilt ist, können bisher somit neben Kraftfahrzeug-Funkstationen keine in der Hand zu haltenden mobilen Funktelefone eingesetzt werden, ohne Einschränkungen der Reichweite und Übertragungsqualität in Kauf nehmen zu müssen.

...

Aufgabe der Erfindung

Der vorliegenden Erfindung liegt die Aufgabe zugrunde, ein Funktelefonsystem derart umzugestalten, daß bei geringem zusätzlichen Aufwand neben in Kraftfahrzeugen eingebauten mobilen Funktelefonen auch in der Hand zu haltende mobile Funktelefone mit vergleichsweise kleiner Sendeleistung ohne die erwähnten Einschränkungen zum Einsatz gelangen können.

Vorteile der Erfindung

Das erfindungsgemäße Funktelefonsystem mit den kennzeichnenden Merkmalen des Anspruchs 1 eignet sich auch für in der Hand zu haltende mobile Funktelefone geringer Reichweite, ohne daß für diese ein höherer technischer Aufwand nötig ist. Der Zusatzaufwand für das Gesamtsystem ist ebenfalls sehr gering. Als weiterer Vorteil ist anzusehen, daß sich die Übertragungsqualität innerhalb des gesamten Funktelefonsystems deutlich verbessert.

Mit den in den Unteransprüchen aufgeführten Maßnahmen sind vorteilhafte Weiterbildungen und Verbesserungen des im Anspruch 1 angegebenen Funktelefonsystems möglich. Besonders vorteilhaft ist ein Funktelefonsystem, bei dem die zentrale Funkstation mit der Umschaltung eines Mehrkanalempfängers auf einen freien Sprachkanal gleichzeitig das diesem Sprachkanal entsprechende Mehrkanalfunksendegerät der zentralen Funksendestation aktiviert und eine gemeinsame Koppel- und Übertragungseinrichtung der zentralen Funkstation die Sprechverbindungswege umschaltet. Damit ist der Vorteil verbunden, daß normale Vierdraht-Koppelfelder verwendet werden können.

Zeichnung

Ein Ausführungsbeispiel der Erfindung ist in der Zeichnung an Hand zweier Figuren dargestellt und in der nachfolgenden Beschreibung näher erläutert. Die Zeichnung zeigt in

Fig. 1 ein stark vereinfachtes Blockschaltbild eines bekannten Funktelefonsystems,

...

Fig. 2 ein Blockschaltbild einer erfindungsgemäßen Funkzelle in einer ersten Ausführungsform und

Fig. 3 ein Blockschaltbild einer erfindungsgemäßen Funkzelle in einer zweiten Ausführungsform.

Beschreibung der Erfindung

Bekannte Funktelefonsysteme weisen nach Fig. 1 mindestens ein Funkgebiet auf, das in mehrere Funkzellen Z1, Z2 ... aufgeteilt ist, die sich teilweise überlappen. Jede Funkzelle, die in der Zeichnung der Einfachheit halber die Form eines Kreises hat, enthält in oder nahe ihrem Mittelpunkt eine ortsfeste zentrale Funkstation B1, B2 ... mit m Funksende- und m Funkempfangsgeräten BS1, BS2 ..., BE1, BE2 ... entsprechend m verschiedenen Sprachkanälen. Die Funksendegeräte sind über eine gemeinsame Koppelanordnung KS mit einer Sendeantenne S und die Funkempfangsgeräte über eine gemeinsame Koppelanordnung KE mit einer Empfangsantenne E verbunden; andere Antennenanordnungen sind ebenfalls denkbar. Jedes Funksende- und Funkempfangsgerät einer zentralen Funkstation steht beispielsweise über eine Vierdrahtleitung V1, V2 ... mit einer Koppel- und Übertragungseinrichtung KÜ in Verbindung. An die zuletzt genannte Einrichtung schließt sich ein Telefonnetz P mit Teilnehmerstationen TN1, TN2 ... an. Die Koppel- und Übertragungseinrichtung enthält in bekannter Weise Mittel zum Feststellen der Übertragungsqualität, zum Umschalten der zentralen Funkstation beim Zellenwechsel und dergleichen.

Innerhalb einer Funkzelle, zum Beispiel der Funkzelle Z1, operieren mobile Funktelefone M11, M12 ..., die vorzugsweise in Kraftfahrzeugen eingebaut sind. Die Sendeleistungen der Funksende- und Funkempfangsgeräte BS1, BS2 ..., BE1, BE2 ... der zentralen Funkstationen B1, B2 ... sowie der mobilen Funktelefone M11, M12, M21 ... sind derart bemessen, daß ein einwandfreier Funkverkehr in beiden Richtungen möglich ist. In Fig. 1 ist der Senderadius $SR_B$ der ortsfesten Funkstation B1 eingetragen, der gleichzeitig dem Radius der Funkzelle Z1 entspricht.

...

Besteht nun der Wunsch, in das Funktelefonsystem auch in der Hand zu haltende mobile Funktelefone H einzubeziehen, so ergibt sich wegen der geringeren Sendeleistung dieser Geräte ein kleinerer Senderadius $SR_H$; vgl. Fig. 1. Nach der Erfindung wird deshalb jede Funkzelle, zum Beispiel die Funkzelle Z1 in Fig. 2, in n Empfangszellen, zum Beispiel E11 ... E 17, aufgeteilt. In jeder Empfangszelle befindet sich in zentraler Lage ein ortsfester Mehrkanalempfänger BE11, BE12 ... Eine zentrale Funkstation B1' enthält im Vergleich zu der zentralen Funkstation B1 in Fig. 1 m/n ortsfeste Mehrkanalfunkempfänger, in Fig. 2 den Empfänger BE11 und m ortsfeste Funksender BS1, BS2 ... Der Senderadius $SR_H$ der in der Hand zu haltenden mobilen Funktelefone H reicht dann in jedem Fall aus, einen der ortsfesten Mehrkanalfunkempfänger, zum Beispiel BE13, zu erreichen. Die ortsfeste zentrale Funkstation B1' ist mit einer Kanalumschalteinrichtung KU versehen, die dafür sorgt, daß die Mehrkanalfunkempfänger, zum Beispiel der Funkempfänger BE12, von der zentralen Funkstation B1' aus auf jeweils einen der m möglichen Sprachkanäle umgeschaltet werden. Wechselt ein mobiles Funktelefon H von einer Empfangszelle in eine benachbarte Empfangszelle, zum Beispiel von E13 nach E12, so schaltet die Kanalumschalteinrichtung KU den Empfänger BE12 auf einen passenden Funkkanal um und nimmt gleichzeitig eine Umschaltung der Kanalsprechwege in dem Empfangskoppelfeld KE vor. Die Umschaltungen gehen so schnell vor sich, daß die Teilnehmer den Umschaltvorgang kaum wahrnehmen.

In einer alternativen Ausführungsform des erfindungsgemäßen Funktelefonsystems schaltet die Kanalumschalteinrichtung KU nicht nur die Mehrkanalfunkempfänger auf einen bestimmten Funkkanal, sondern sie schaltet auch gleichzeitig den auf den betreffenden Funkkanal abgestimmten zentralen Funksender BS1, BS2 ... um. Die ortsfesten Mehrkanalfunkempfänger BE11, BE12 ... und die ortsfesten Funksender BS1, BS2 ... stehen vorzugsweise über je eine Zweidrahtleitung mit der Koppel- und Übertragungseinrichtung KÜ (vgl. Fig. 1) in Verbindung.

...

In der Praxis haben in der Hand zu haltende mobile Funktelefone H nur etwa 1/10 der Sendeleistung von in Kraftfahrzeugen eingebauten mobilen Funktelefonen. Wie bereits eingangs erwähnt, beträgt damit der Senderadius der in der Hand zu haltenden mobilen Funktelefone nur etwa 1/3 des Senderadius eines in einem Kraftfahrzeug eingebauten mobilen Funktelefons, woraus sich ergibt, daß die Empfangszellen E11, E12 ... ebenfalls nur etwa 1/10 der Fläche der normalen Funkzellen Z1, Z2 ... aufweisen dürfen.

Bei ausgedehnten Funktelefonnetzen werden die größeren Sendezellen von einem Netz kleinerer Empfangszellen in größerer Anzahl überlagert. In den Randgebieten der Sendezellen können den Empfangszellen E auch mehrere Sendezellen, zum Beispiel Z1, Z2, Z3, zugeordnet sein; vgl. Fig. 3, Empfangszelle E2 und Sendezellen Z1, Z2, Z3.

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EK/PLI Scht-Li
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Ansprüche

1. Funktelefonsystem für ein in Funkzellen aufgeteiltes Funkgebiet, das je Funkzelle eine zentrale Funkstation mit auf m verschiedene Sprachkanäle abgestimmten Funkgeräten aufweist und in welchem mehrere mobile Funktelefone operieren, die über die zentrale Funkstation und mit dieser verbundene Koppel- und Obertragungseinrichtungen mit Teilnehmern eines drahtgebundenen Telefonnetzes in Verbindung treten können, dadurch gekennzeichnet, daß bei einem Einsatz von in der Hand zu haltenden mobilen Funktelefonen (H) vergleichsweise kleiner Sendeleistung jede Funkzelle (Z1) in n Empfangszellen (E11, E12 ...) mit je einem ortsfesten Mehrkanalfunkempfänger (BE11, BE12 ...) aufgeteilt ist, daß die zentrale Funkstation (B1') m Funksender (BS1, BS2 ...) enthält und daß von der zentralen Funkstation aus die Mehrkanalfunkempfänger wahlweise auf einen freien Sprachkanal der m Sprachkanäle umschaltbar sind.

2. Funktelefonsystem nach Anspruch 1, dadurch gekennzeichnet, daß die zentrale Funkstation (B1') mit der Umschaltung eines Mehrkanalempfängers (BE11) auf einen freien Sprachkanal gleichzeitig das diesem Sprachkanal entsprechende Mehrkanal-Funksendegerät (BS1) der zentralen Funksendestation aktiviert und daß eine gemeinsame Koppel- und Obertragungseinrichtung (KO) der zentralen Funkstation die Sprechverbindungswege umschaltet.

3. Funktelefonsystem nach Anspruch 1, dadurch gekennzeichnet, daß einzelnen Empfangszellen (E1) mehrere Sendezellen (Z1, Z2, Z3) zugeordnet sind.

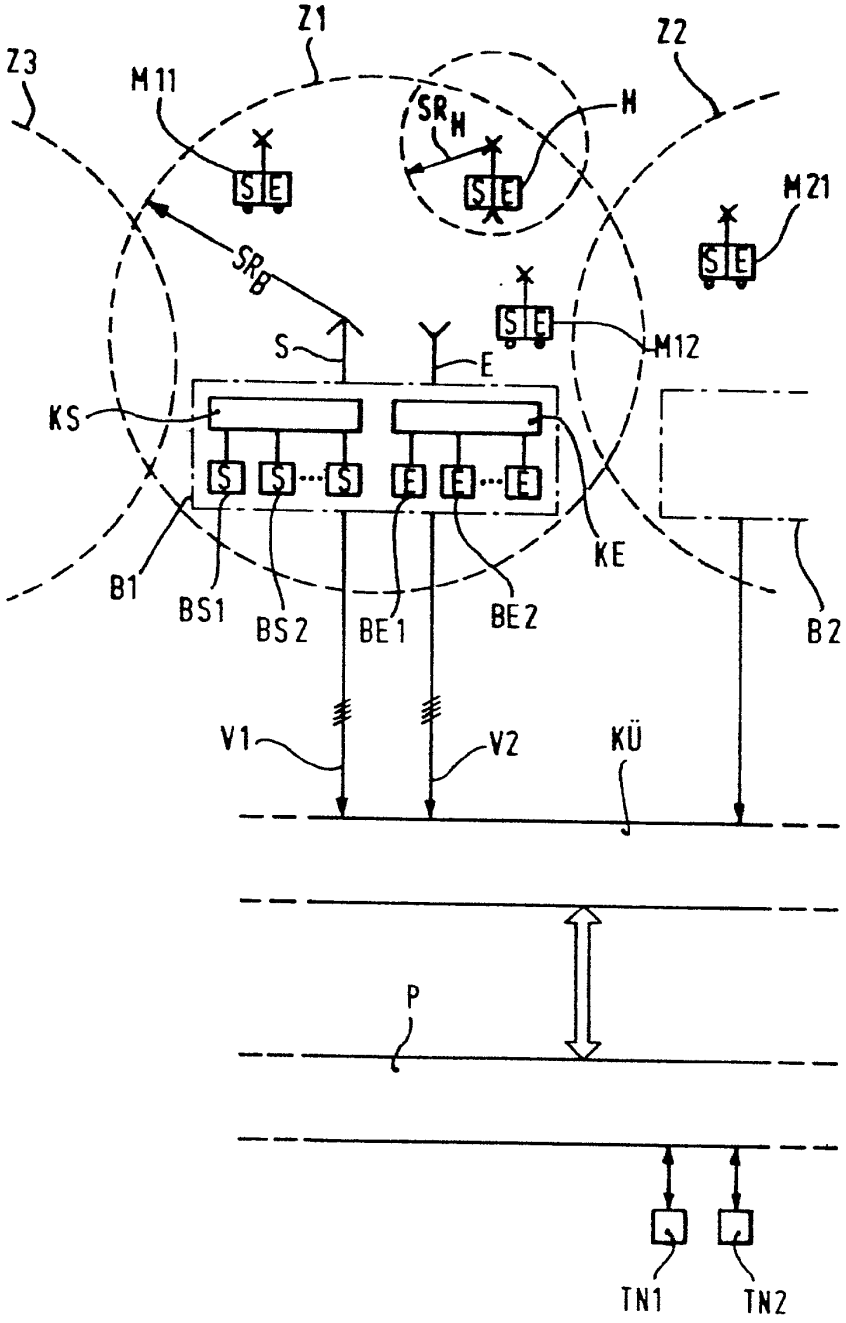

Z1
Z2
Z3
M11
M21
M12
H
SRH
SRB
S
E
KS
KE
B1
BS1
BS2
BE1
BE2
B2
V1
V2
KÜ
P
TN1
TN2

Fig.1

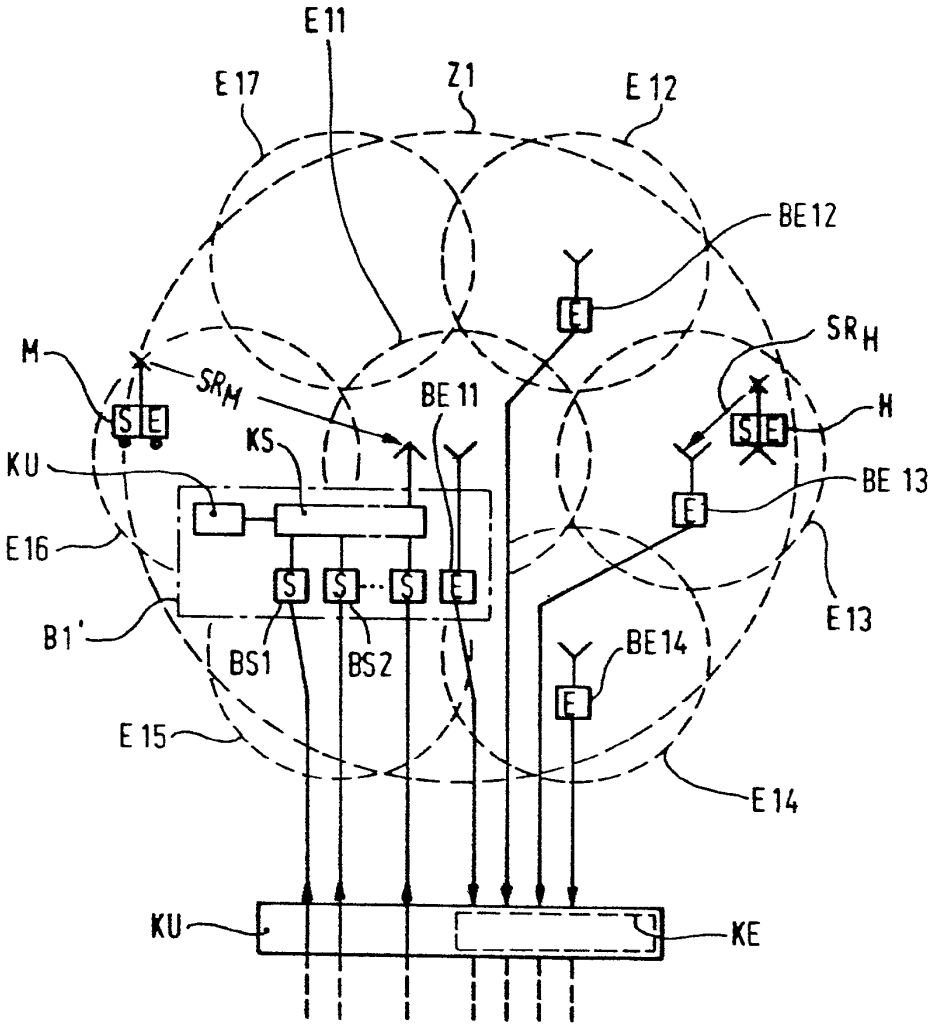

E11
E17
Z1
E12
BE12
SRH
M
SRM
BE11
H
KS
KU
BE13
E16
E13
B1'
BS1
BS2
BE14
E15
E14
KU
KE

Fig. 2

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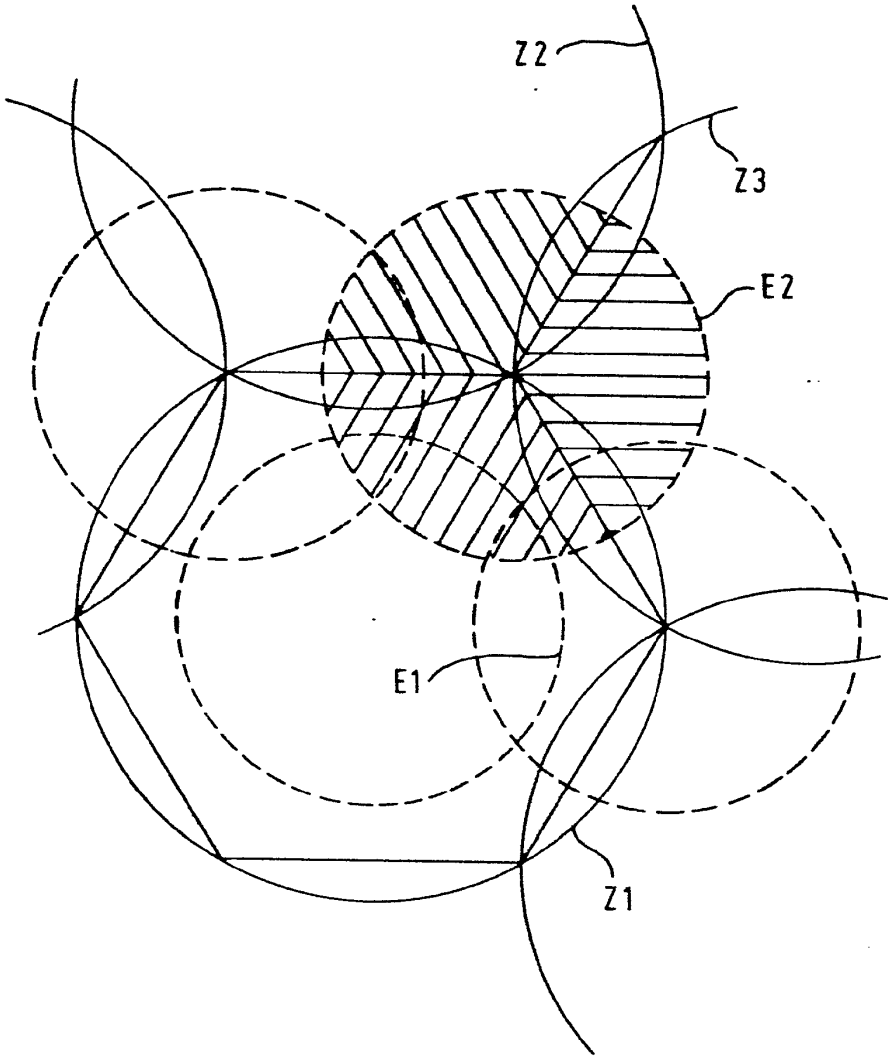



Fig. 3

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## (54) Private branch radio communication system using optical fibers.

(57) A private branch radio communication system includes a portable radio transmitter (1) and a portable radio receiver (4). The system further includes first and second repeaters (2, 3) respectively located in first and second areas (P1, P2) within a given premises and coupled to each other through an optical fiber cable (5). A radio signal output from the portable radio transmitter (1) is converted into an optical signal by the first repeater (2), and is then supplied to the second repeater (3) through the optical fiber cable (5), and converted into a radio signal which is received by the portable radio receiver (4).

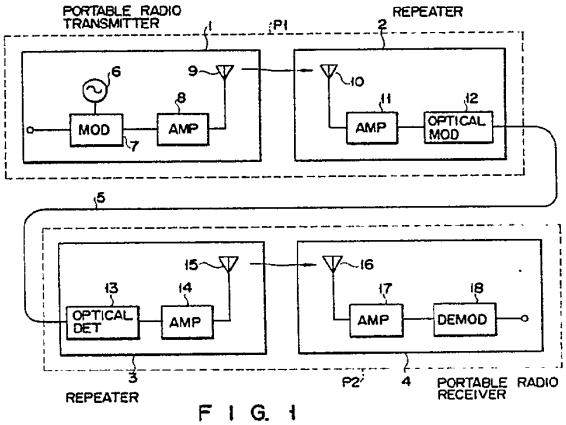



FIG. 1

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# Private branch radio communication system using optical fibers

The present invention relates to a private branch radio communication system and, more particularly, to a private branch radio communication system using optical fibers.

On sites such as power plants or substations, large numbers of personnel may be engaged in jobs related to each other, but often doing so in widely separated locations throughout the site. For this reason, a radio communication system is generally used to enable personnel to communicate with each other, with each worker carrying a portable radio transceiver while doing his job, and exchanging information with other personnel, as and when required.

This type of radio communication system utilizes a relatively weak radio wave, this being because if a strong radio wave were to be used, it might interfere with the operation of various electronic devices located on the same premises.

If radio communication is to be performed in a building, especially in a so-called intelligent building in which various systems, such as the air conditioning system, for example, are computer-controlled, a very weak radio wave, e.g., a radio wave having a field intensity of 500 μV/m or less which is measured at, for example, a position 3 m away from a radio wave source, should preferably be used in order to prevent erroneous operation of various electronic devices in the building, as a result of radio interference. However, in buildings, the transmitting of radio waves tends to be hindered by walls, pillars, and the like. Therefore, when a weak radio wave is, for the aforestated reasons, used for communication within a building, satisfactory communication from the ground floor to the uppermost floor cannot be achieved. For this reason, radio communication using a weak radio wave can be employed only for private branch communication within a confined area, e.g., within one floor of a building, but not throughout all floors of the building. As a result, the range through which personnel can move and remain in communication is undesirably limited.

Accordingly, it is an object of the present invention to provide a private branch radio communication system using a weak radio wave but capable of providing excellent radio communication over a wide area, such as throughout a given premises or site.

According to the present invention, there is provided a private branch radio communication system comprising a portable radio transmitter for modulating a signal and outputting the modulated signal as a radio signal in a first area within a given premises, a first repeater, located in the first area, for receiving the radio signal transmitted from the radio transmitter and outputting an optical signal corresponding to the signal received; an optical transmission medium for transmitting the optical signal output from the first repeater to a second area within the premises, a second repeater, located in the second area, for receiving the optical signal output from the first repeater and transmitted by the optical transmission medium, and generating a radio signal corresponding to the signal received in the second area, and a portable radio receiver for receiving the radio signal output from the second repeater in the second area and demodulating the signal received.

In the above-described private branch radio communication system, the first and second repeaters are, as described above, located in the first and second areas, respectively, and are coupled to each other through an optical fiber cable. As a result, a radio signal generated from the portable radio transmitter is not transmitted directly from the first area to the second area by radio transmission, but is first converted into an optical signal by the first repeater in the first area, the optical signal is then transmitted through the optical fiber cable to the second repeater in the second area, and is converted by the second repeater back into a radio signal which is received by the portable radio receiver.

As described above, since communication between the first and second areas is accomplished not by direct radio transmission but by means of an optical fiber cable, therefore even if the first and second areas are, for example, different floors in a building, or even different buildings, communication between the first and second areas is free from interference caused by obstacles to transmission, such as walls and pillars in the building or, in the latter case, other buildings in-between. Therefore, even when using a weak radio wave generated by a portable transmitter, the present invention is able to provide excellent private branch radio communication over a wide-ranging area.

In addition, since an optical signal transmitted through an optical fiber cable is not an electrical signal, such a signal is therefore free from electrical influences caused by various other electrical signal lines and it, in turn, does not adversely influence such signal lines.

Thus, the private branch radio communication system of the present invention, using a weak radio wave and an optical signal, provides excellent private branch radio communication while at the same time having minimal adverse influence on various other electrical devices and telephone lines.



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This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram showing a private branch radio communication system according to a first embodiment of the present invention;

Fig. 2 is a block diagram showing a private branch radio communication system according to a second embodiment of the present invention;

Fig. 3 is a block diagram showing a private branch radio communication system according to a third embodiment of the present invention;

Fig. 4 is a circuit diagram showing an embodiment of an arrangement of an optical multiplexer used in the private branch radio communication system in Fig. 3;

Fig. 5 is a circuit diagram showing an embodiment of an arrangement of a first repeater used in the private branch radio communication system in Fig. 1;

Fig. 6 is a circuit diagram showing an embodiment of an arrangement of a second repeater used in the private branch radio communication system in Fig. 1;

Fig. 7 is a circuit diagram showing an embodiment of an arrangement of a repeater used in the private branch radio communication system in Fig. 3; and

Fig. 8 is a circuit diagram showing an arrangement of a portable radio transceiver used in the private branch radio communication system in Fig. 3.

Fig. 1 shows a private branch radio communication system according to a first embodiment of the present invention. Referring to Fig. 1, a first area P1 represents a specific place in a specific building or site, e.g., a specific floor in a building, and a second area P2 represents a place separated from the first area P1 by a relatively large distance, e.g., another floor in the same building as that of the first area P1, or another place within the same site as that of the first area P1.

This private branch communication system is designed to transmit a radio signal generated by a portable radio transmitter 1 used in the first area P1 to a portable radio receiver 4 used in the second area P2. In this system, the portable radio transmitter 1 and a repeater 2 are arranged in the first area P1. The radio transmitter 1 is carried by, e.g., a worker and is freely moved in the first area P1. The repeater 2 is fixed in a specific place of the first area P1. Similarly, the portable radio receiver 4 and a repeater 3 are arranged in the second area P2. The radio receiver 4 can be freely moved in the second area P2, and the repeater 3 is fixed in a specific place of the second area P2. The repeaters 2 and 3 are coupled to each other through an optical fiber cable 5.

The portable radio transmitter 1 comprises a modulator 7 including an oscillator 6, an amplifier 8, and a transmitting antenna 9. The radio transmitter 1 modulates a carry signal by a modulation signal to be transmitted, e.g., a speech signal by using the modulator 7, and amplifying the modulated signal by using the amplifier 8, thus radiating the amplified signal in air as a radio signal through the antenna 9. The repeater 2 comprises a receiving antenna 10, an amplifier 11, and an optical modulator 12. The repeater 2 receives a radio signal output from the radio transmitter 1 through the antenna 10, amplifies the received signal by using the amplifier 11, and converts the signal into an optical signal by using the optical modulator 12, thus supplying the signal to the optical fiber cable 5.

The repeater 3 comprises an optical detector 13, an amplifier 14, and a transmitting antenna 15. The repeater 3 converts the optical signal, which is transmitted from the repeater 2 through the optical fiber cable 5, into an electrical signal by using the optical detector 13, and amplifies the electrical signal by using the amplifier 14, thereby radiating the amplified signal in air as a radio signal through the antenna 15. The portable radio receiver 4 comprises a receiving antenna 16, an amplifier 17, and a demodulator 18. The radio receiver 4 receives a radio signal output from the repeater 2 through the antenna 16, and amplifies the received signal by using the amplifier 17, thereby demodulating the signal by using the demodulator 18. As a result, the modulation signal (speech signal in this case) is extracted from the received signal.

Since both the radio transmitter 1 and the repeater 2 are present in the first area P1, communication therebetween can be satisfactorily performed by using a weak radio wave (e.g., a radio wave having a field intensity of 500 $\mu$V/m or less which is measured at a position separated from the radio transmitter 1 by 3 m). Similarly, since both the radio receiver 4 and the repeater 3 are present in the second area P2, communication therebetween can be satisfactorily performed by using a weak radio wave (e.g., a radio wave having a field intensity of 500 $\mu$V/m or less which is measured at a position separated from the repeater 3 by 3 m).

Since signal transmission over a relatively large distance from the first area P1 to the second area P2 is performed not by radio transmission but by means of the optical fiber cable 5, a signal from the first area P1 is transmitted to the second area P2 without loss caused by radio wave obstacles such as walls and pillars in a building, or buildings in a site. Therefore, even if a radio wave output from the radio transmitter 1 is weak, a radio signal can



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satisfactorily be transmitted to the radio receiver 4 in an excellent state.

In addition, since an optical signal transmitted through the optical fiber cable 5 is not an electrical signal, the signal is free from electrical influences from various other electrical signal lines and does not influence them.

A signal to be transmitted by this private branch radio communication system is not limited to a speech signal, but may include image signals or various data signals. In addition, it may include analog or digital signals.

Fig. 5 shows a detailed arrangement of the repeater 2. As shown in Fig. 5, a circuit including a constant-voltage source 121 and a laser diode 122 is used as the optical modulator of the repeater 2. In this circuit, a light-emitting diode may be used in place of the laser diode 122.

Fig. 6 shows a detailed arrangement of the repeater 3. As shown in Fig. 6, a circuit including a photodiode 131 is used as the optical detector 13 of the repeater 13.

Since the repeaters 2 and 3 respectively perform only electrical/optical conversion and optical/electrical conversion, they can be realized by simple circuit arrangements respectively shown in Fig. 5 and Fig. 6.

Fig. 2 shows a private branch communication system according to a second embodiment of the present invention. This system is designed to realize duplex simultaneous communication between first and second areas P1 and P2. Referring to Fig. 2, a portable radio transceiver 21 and two-way repeater 22 are arranged in the first area P1. The radio transceiver 21 is carried by, e.g., a worker and is moved within the first area P1. The repeater 22 is fixed in a specific place of the first area P1. Similarly, a portable radio transceiver 24 and a two-way repeater 23 are arranged in the second area P2. The transceiver 24 is moved within the second area P2, and the repeater 23 is fixed in a specific place of the second area P2. The repeaters 22 and 23 are coupled to each other through optical fiber cables 5A and 5B.

The portable radio transceiver 21 includes a transmitting section 21A, a receiving section 21B, and a transmitting/receiving antenna 21C. The transmitting and receiving sections 21A and 21B respectively correspond to the transmitter 1 and the receiver 4 shown in Fig. 1. The radio transceiver 21 modulates and amplifies a signal to be transmitted, e.g., a speech signal by using the transmitting section 21A, and radiates the resultant signal in air as a radio signal having a carrier frequency f1 through the antenna 21C. In addition, the radio transceiver 21 receives a radio signal having a carrier frequency f1′ through the antenna 21C, and amplifies and demodulates the received signal by using the receiving section 21B. As a result, the modulation signal (speech signal in this case) is extracted from the received signal.

The two-way repeater 22 comprises a transmitting/receiving antenna 22C, an electrical/optical signal converting section 22A, and an optical/electrical signal converting section 22B. The electrical/optical converting section 22A and the optical/electrical modulator 22B respectively correspond to the repeaters 2 and 3 shown in Fig. 1. The repeater 22 receives a radio signal output from the transceiver 21 through the antenna 22C, and converts the received signal into an optical signal by using the electrical/optical converting section 22A, thereby supplying the signal to the optical fiber cable 5A. In addition, the repeater 22 converts an optical signal supplied through the optical fiber cable 5B into an electrical signal by using the optical/electrical converting section 22B, and radiates the converted signal in air as a radio signal having the carrier frequency f1′ through the antenna 22C.

The two-way repeater 23 comprises a transmitting/receiving antenna 23C, an optical/electrical converting section 23A and an electrical/optical signal converting section 23B. The electrical/optical signal converting section 23B and the optical/electrical modulator 23A respectively correspond to the repeaters 2 and 3 shown in Fig. 1. The repeater 23 converts an optical signal supplied through the optical fiber cable 5A into an electrical signal by using the optical/electrical signal converting section 23A, and radiates the converted signal in air as a radio signal having the carrier frequency f1 through the antenna 23C. In addition, the repeater 23 receives a radio signal having the frequency f1′ output from the transceiver 24 through the antenna 23C, and converts the received signal into an optical signal by using the electrical/optical converting section 23B, thereby supplying the signal to the optical fiber cable 5B.

The portable radio transceiver 24 comprises a transmitting/receiving antenna 24C, a transmitting section 24A, and a receiving section 24B. The transmitting and receiving sections 24A and 24B respectively correspond to the transmitter 1 and the receiver 4 shown in Fig. 1. The radio transceiver 24 modulates and amplifies a signal to be transmitted, e.g., a speech signal by using the transmitting section 24A, and radiates the resultant signal in air as a radio signal having the carrier frequency f1′ through the antenna 24C. In addition, the transceiver 24 receives a radio signal having the carrier frequency f1 through the antenna 24C, and amplifies and demodulates the received signal by using the receiving section 24B. As a result, the modulation signal (speech signal in this case) is



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extracted from the received signal.

Since the private branch radio communication system of the second embodiment employs different carrier frequencies for transmission and reception, duplex communication can be realized. In addition, since the two-way repeaters 22 and 23 are respectively distributed in the first and second areas P1 and P2, communication between the portable transceivers 21 and 24 can be performed by using a weak radio wave as in the first embodiment.

In this embodiment, the two optical fiber cables 5A and 5B are used for signal transmission between the repeaters 22 and 23. However, by properly utilizing optical components, signal transmission between the repeaters can be realized by a single optical fiber cable. Also, with the arrangement of the second embodiment, one-way alternate communication can be realized.

Fig. 3 shows a private branch radio communication system according to a third embodiment of the present invention. This system is designed to realize duplex communication not only between the two areas P1 and P2 as described in the first and second embodiments but also between arbitrary areas of a plurality of areas. In this system, the premises are divided into five areas P11 to P15. A two-way repeater and one portable radio transceiver or more are arranged in each area. More specifically, a two-way repeater Ra and two portable radio transceivers Ka1 and Ka2 are arranged in the area P11, a two-way repeater Rb and two portable radio transceivers Kb1 and Kb2 are arranged in the area P12, a two-way repeater Rc and a portable radio transceiver Kc1 are arranged in the area P13, a two-way repeater Rd and two portable radio transceivers Kd1 and Kd2 are arranged in the area P14, and a two-way repeater Re and two portable radio transceivers Ke1 and Ke2 are arranged in the area P15. A each range of these areas P11 to P15 is setting so that a weak radio wave can sufficiently propagate in the each area.

The repeater Ra is coupled to transmitting and receiving optical fiber cables 30a and 30b. Similarly, the repeaters Rb, Rc, Rd, and Re are respectively coupled to transmitting and receiving optical fiber cables 30b and 31b, 30c and 31c, 30d and 31d, and 30e and 31e.

An optical multiplexer 32 includes input ports coupled to the optical fiber cables 30a to 30e, and output ports coupled to the optical fiber cables 31a to 31e. The multiplexer 32 multiplexes all the optical signal supplied through the cables 30a to 30e, and outputs a multiplexed signal to the optical fiber cables 31a to 31e, respectively.

An operation of the above-described system will be described below. Assume that ten frequencies f1 to f5 and $f1'$ to $f5'$ are respectively assigned to the transceivers Ka1 to Ke1. In this system, if a specific portable radio transceiver transmits a radio signal having the frequency f1, another portable radio transceiver which receives the signal sends back a radio signal having the frequency $f1'$ as a response signal. Therefore, in this system, five channels allowing simultaneous communication are ensured, i.e., a first channel using the frequencies f1 and $f1'$, a second channel using the frequencies f2 and $f2'$, a third channel using the frequencies f3 and $f3'$, a fourth channel using the frequencies f4 and $f4'$, and a fifth channel using the frequencies f5 and $f5'$.

Each of the radio transceivers Ka1 to Ke1 can radiate a radio signal having any one of the frequencies f1 to f5 and $f1'$ to $f5'$, and can receive a radio signal having any of the frequencies f1 to f5 and $f1'$ to $f5'$. In addition, each of the units Ka1 to Ke1 has a function of detecting a frequency used by another unit. With this function, each of the units Ka1 to Ke1 can output a radio signal by using an unused frequency, i.e., a free channel, thus preventing radio interference.

Speech communication using the system shown in Fig. 3 will be described below in a state wherein all of the above-described first to fifth channels are used.

Radio signals generated by this system are ten signals denoted by V1 to V5 and $V1'$ to $V5'$ respectively corresponding to the carrier frequencies f1 to f5 and $f1'$ and $f5'$. If these radio signals V1 to V5 and $V1'$ to $V5'$ are signals having amplitude-modified waves, the radio signals V1 to V5 and $V1'$ to $V5'$ can be represented as follows:

$$V1 = A(1 + si(t)\sin(2\pi f1t))$$
$$V2 = A(1 + sj(t)\sin(2\pi f2t))$$
$$V3 = A(1 + sk(t)\sin(2\pi f3t))$$
$$V4 = A(1 + sp(t)\sin(2\pi f4t))$$
$$V5 = A(1 + sq(t)\sin(2\pi f5t))$$
$$V1' = A(1 + si'(t)\sin(2\pi f1't))$$
$$V2' = A(1 + sj'(t)\sin(2\pi f2't))$$
$$V3' = A(1 + sk'(t)\sin(2\pi f3't))$$
$$V4' = A(1 + sp'(t)\sin(2\pi f4't))$$
$$V5' = A(1 + sq'(t)\sin(2\pi f5't))$$

where A is a constant and si(t), sj(t), sk(t), sp(t), sq(t), $si'(t)$, $sj'(t)$, $sk'(t)$, $sp'(t)$, and $sq'(t)$ are modulation signals such as speech signals. For example, with respect to the radio signal V1 for speech communication which is transmitted from a given transceiver, the radio signal $V1'$ is sent back from another transceiver as a response signal. Similarly, with respect to the radio signals V2, V3, V4, and V5, the radio signals $V2'$, $V3'$, $V4'$ and $V5'$ are respectively sent back as response signals.

When the radio signals V1 to V5 are respectively generated in the areas P11 to P15, these signals are respectively converted into optical signals by the repeaters Ra to Re so as to be trans-



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mitted to the optical fiber cables 30a to 30e. The signals V1 to V5 are multiplexed by the optical multiplexer 32, and the multiplexed signal V1 + V2 + V3 + V4 + V5 is supplied to the optical fiber cables 31a to 31e. As a result, the multiplexed signals V1 + V2 + V3 + V4 + V5 are received by the repeaters Ra to Re. Thereafter, the multiplexed signals V1 + V2 + V3 + V4 + V5 are generated as radio signals in the areas P11 to P15.

In this manner, a signal transmitted from each portable radio transceiver is commonly supplied to the respective areas P11 to P15. Since the transceivers Ka1 to Ke1 can receive radio signals of all the frequencies, a transceiver as a source, i.e., a source operator must specify a transceiver as a destination, i.e., a destination operator. If the source operator transmits a signal for specifying a destination operator, e.g., a specific call code like a telephone number prior to transmission of a radio signal for speech communication in the same manner as in a known normal paging system, this problem can be solved. More specifically, the source operator superposes a call signal for specifying a destination operator on the frequency of a free channel (one of the frequencies f1, f2, f3, f4, and f5) and transmits it. Since the call signal is distributed to all the areas P11 to P15, a destination operator in any area can receiver the call signal.

When a specific portable radio transceiver calls another specific portable radio transceiver in this manner, the called transceiver sends back a response signal. In this case, if the call signal has the carrier frequency f1, the called radio transceiver sends back the response signal V1′ having the carrier frequency f1′. Similarly, the response signal V2′ having the carrier frequency f2′ is sent back with respect to a call signal having carrier frequency f2.

Similar to the above-described transmission signals V1 to V5, the response signals V1′ to V5′ thus generated are supplied to the optical multiplexer 32 through the optical fiber cables 30a to 30e and are multiplexed by the multiplexer 32. The multiplexed signal V1′ + V2′ + V3′ + V4′ + V5′ is commonly supplied to all the areas P11 to P12.

As described above, in the system of the third embodiment, since transmission signals from the respective areas are multiplexed by the optical multiplexer 32, and the multiplexed signal is supplied to all the areas, duplex communication can be performed between arbitrary areas.

Fig. 4 shows a detailed arrangement of the optical multiplexer 32. The multiplexer 32 comprises optical/electrical signal converters 33a to 33e, an adder 34 including resistors R1a to R1e and R2, an amplifier 36, and electrical/optical signal converters 35a to 35e. In the optical multiplexer 32 having the above arrangement, the signals V1 to V5 input as optical signals are respectively converted into electrical signals by the converters 33a to 33e, and are added to each other by the adder 34. The added signal V1 + V2 + V3 + V4 + V5 is amplified by the amplifier 36. The amplified signal is then supplied to converters 35a to 35e, and hence the signals V1 + V2 + V3 + V4 + V5 are supplied to the optical fiber cables 31a to 31e as optical signals, respectively.

Fig. 7 shows a detailed arrangement of each of the repeaters Ra to Re used in the system of the third embodiment shown in Fig. 3. Since the repeaters Ra to Re have the same arrangement, Fig. 7 shows an arrangement corresponding to the repeater Ra. Referring to Fig. 7, a transmitting/receiving antenna 72, a receiving section including an amplifier 73 and an electrical/optical signal converter 74, and a transmitting section including an amplifier 78 and an optical/electrical signal converter 77 are coupled to a hybrid circuit 71. An optical fiber cable 30a is coupled to the electrical/optical signal converter 74. An optical fiber cable 31a is coupled to the optical/electrical signal converter 77. The amplifiers 73 and 78 are respectively designed to cover all the frequency bands used in this system. The hybrid circuit 71 is designed to cause a signal to flow in a direction indicated by a solid arrow and not to flow in a direction indicated by a broken arrow.

Fig. 8 shows a detailed arrangement of each of the portable radio transceivers Ka1 to Ke1 used in the system of the third embodiment shown in Fig. 3. Each transceiver includes a hybrid circuit 80, a transmitting/receiving antenna 81, a receiving section 82, and a transmitting section 83.

The receiving section 82 includes a tuner 87, a detector 84, a call code detector 86, and a channel selecting circuit 88. The tuner 87 is constituted by 10 resonators respectively corresponding to the carrier frequencies f1 to f5 and f1′ to f5′, as shown in Fig. 8. The tuner 87 selectively outputs a channel selection signal from one of terminals T1 to T5′ in accordance with a received carrier frequency. For example, when a radio signal having the carrier frequency f1 is received, a channel selection signal is output from the terminal T1 and is supplied to the channel selecting circuit 88. Upon reception of the channel selection signal from the terminal T1, the circuit 88 turns on a lamp (not shown) for indicating that the frequency f1 is used, and at the same time, controls the tuner 87 not to receive signals other than the frequency f1 until the contents of a call code are checked by the call code detector 86. Similarly, when a channel selection signal is supplied from the terminal T2, the circuit 88 turns on a lamp (not shown) indicating that the



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frequency f2 is used, and at the same time, controls the tuner 87 not to receive signals other than the frequency f2 until the contents of a call code are checked by the call code detector 86. Such a control operation for channel selection by the channel selecting circuit 88 can be realized by various methods, e.g., a method of selectively interrupting supply of a power source voltage VC to each portion of a resonator.

The detector 84 is used to extract a modulation signal such as a speech signal from a signal received by the tuner 87. The extracted modulation signal is output to a terminal 85, and at the same time, is supplied to the call code detector 86. The call code detector 86 has a pre-assigned self code and compares it with a call code supplied from another radio transceiver. If they coincide with each other, the detector 86 generates a signal for turning on a switch S2 of the transmitting section 83.

The transmitting section 83 includes an oscillator 90, a transmission frequency switching circuit 89, a modulator 91, and switches S1 and S2. The circuit 89 is used to manually select carrier frequencies for transmission. For example, when the lamp for indicating that the carrier frequency f1 is used is turned on by the channel selecting circuit 88, the frequency f1 will not be used (since the frequency $f1'$ is also used, the frequency $f1'$ will not be used) and an unused frequency is selected. The modulator 91 modulates a carrier wave having a frequency selected by the circuit 89 by using a modulation signal such as a speech signal. The modulated signal is then radiated in air from the transmitting/receiving antenna 81 when one of the switches S1 and S2 is ON. The switch S1 is manually operated and is set in an ON state when signal transmission is to be performed. The switch S2 is controlled by an output signal from the call code detector 86 and is automatically set in an ON state when a call code is transmitted from another radio transceiver to its own channel.

As has been described above, according to the private branch radio communication system of the present invention, by combining a transmission medium using radio waves with a transmission medium using optical fibers, excellent communication can be provided in a wide range covering the entire premises even when a weak radio wave is used.

## Claims

1. A private branch radio communication system characterized by comprising:
a portable radio transmitter (1) for modulating a signal and outputting the modulated signal as a radio signal in a first area within a given premises;
a first repeater means (2), located in the first area, for receiving the radio signal transmitted from said radio transmitter (1) and outputting an optical signal corresponding to the signal received;
an optical transmission medium (5) for transmitting the optical signal output from said first repeater to a second area within said premises;
a second repeater means (3), located in the second area, for receiving the optical signal output from said first repeater means (2) and transmitted by said optical transmission medium, and generating a radio signal corresponding to the signal received in the second area;
and a portable radio receiver (4) for receiving the radio signal output from said second repeater (3) in the second area and demodulating the signal received.

2. A system according to claim 1, characterized in that said portable radio transmitter (1) outputs a radio signal having a field intensity allowing the signal to be received in any part of the first area.

3. A system according to claim 1, characterized in that said second repeater means (3) outputs a radio signal having a field intensity allowing the signal to be received in any part of the second area.

4. A system according to claim 1, characterized in that said first and second repeater means (2, 3) are located in the first and second areas, respectively.

5. A system according to claim 1, characterized in that said first repeater means (2) includes a receiving antenna (10) and an electrical/optical converting means (12) for converting a radio signal received by said receiving antenna (10) into an optical signal.

6. A system according to claim 1, characterized in that said second repeater means (3) includes an optical/electrical converting means (13) for converting an optical signal transmitted through said optical transmission medium (5) into an electrical signal, and a transmitting antenna (15) for outputting, as a radio signal, the electrical signal output from said optical/electrical converting means (13) in the second area.

7. A private branch radio communication system characterized by comprising:
a first portable radio transceiver (21) for modulating a signal and generating the modulated signal as a radio signal in a first area within a given premises, and for receiving the radio signal generated in the first area and demodulating the signal received;
a second portable radio transceiver (24), for modulating a signal and generating the modulated signal as a radio signal in a second area within said premises, and for receiving the radio signal generated in the second area and demodulating the



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signal received;
an optical transmission medium (5A, 5B) for coupling the first and second areas to each other;
a first two-way repeater means (22), arranged in the first area, for receiving the radio signal output from said radio transceiver (21) and supplying an optical signal corresponding to the signal received to said optical transmission medium (5A, 5B) and for receiving an optical signal transmitted through said optical transmission medium (5A, 5B) and generating a radio signal corresponding to the signal received in the first area; and
a second two-way repeater means (23), arranged in the second area, for receiving the optical signal output from said first repeater means (22) and transmitted through said optical transmission medium (5A, 5B), and generating a radio signal corresponding to the signal received in the second area and for receiving the radio signal output from said radio transceiver (24) and supplying an optical signal corresponding to the signal received to said optical transmission medium (5A, 5B).

8. A system according to claim 7, characterized in that said first portable radio transceiver (21) outputs a radio signal having a field intensity allowing the signal to be received in any part of the first area.

9. A system according to claim 7, characterized in that said second portable radio transceiver (24) outputs a radio signal having a field intensity allowing the signal to be received in any part of the second area.

10. A system according to claim 7, characterized in that said first two-way repeater means (22) outputs a radio signal having a field intensity allowing the signal to be received in any part of the first area.

11. A system according to claim 7, characterized in that said second two-way repeater means (23) outputs a radio signal having a field intensity allowing the signal to be received in any part of the second area.

12. A system according to claim 7, characterized in that said first and second two-way repeaters (22, 23) are located in the first and second areas, respectively.

13. A system according to claim 7, characterized in that said first two-way repeater means (22) includes a transmitting/receiving antenna (22C), electrical/optical signal converting means (22A) for converting a radio signal received by said transmitting/receiving antenna (22C) into an optical signal, and optical/electrical signal converting means (22B) for converting, into an electrical signal, an optical signal transmitted through said optical transmission medium (5A, 5B) and supplying the electrical signal to said transmitting/receiving antenna (22C).

14. A system according to claim 7, characterized in that said second two-way repeater means (23) includes a transmitting/receiving antenna (23C), electrical/optical signal converting means (23A) for converting a radio signal received by said transmitting/receiving antenna (23C) into an optical signal, and optical/electrical signal converting means (23B) for converting, into an electrical signal, an optical signal transmitted through said optical transmission medium (5A, 5B) and supplying the electrical signal to said transmitting/receiving antenna (23C).

15. A private branch radio communicating system characterized by comprising:
a plurality of portable radio transceivers (Ka1 - Ke1);
a plurality of two-way repeater means (Ra - Re), distributed throughout a plurality of areas (P11 - P15) within a given premises, for receiving radio signals generated in the respective areas where the repeater means are distributed and supplying optical signals corresponding to the signals received to a first optical transmission medium (30a - 30e), and for receiving optical signals input through a second optical transmission medium (31a - 31e) and generating radio signals corresponding to the signals received in the respective areas; and
optical signal multiplexing means (32) for multiplexing the optical signals output from said plurality of two-way repeater means (Ra - Re) and supplied through said first optical transmission medium (30a - 30e), and supplying the multiplexed optical signal to said plurality of two-way repeater means (Ra - Re) through said second optical transmission medium (31a - 31e).

16. A system according to claim 15, characterized in that said plurality of portable radio transceivers (Ka1 - Ke1) are distributed throughout said plurality of areas (P11 - P15).



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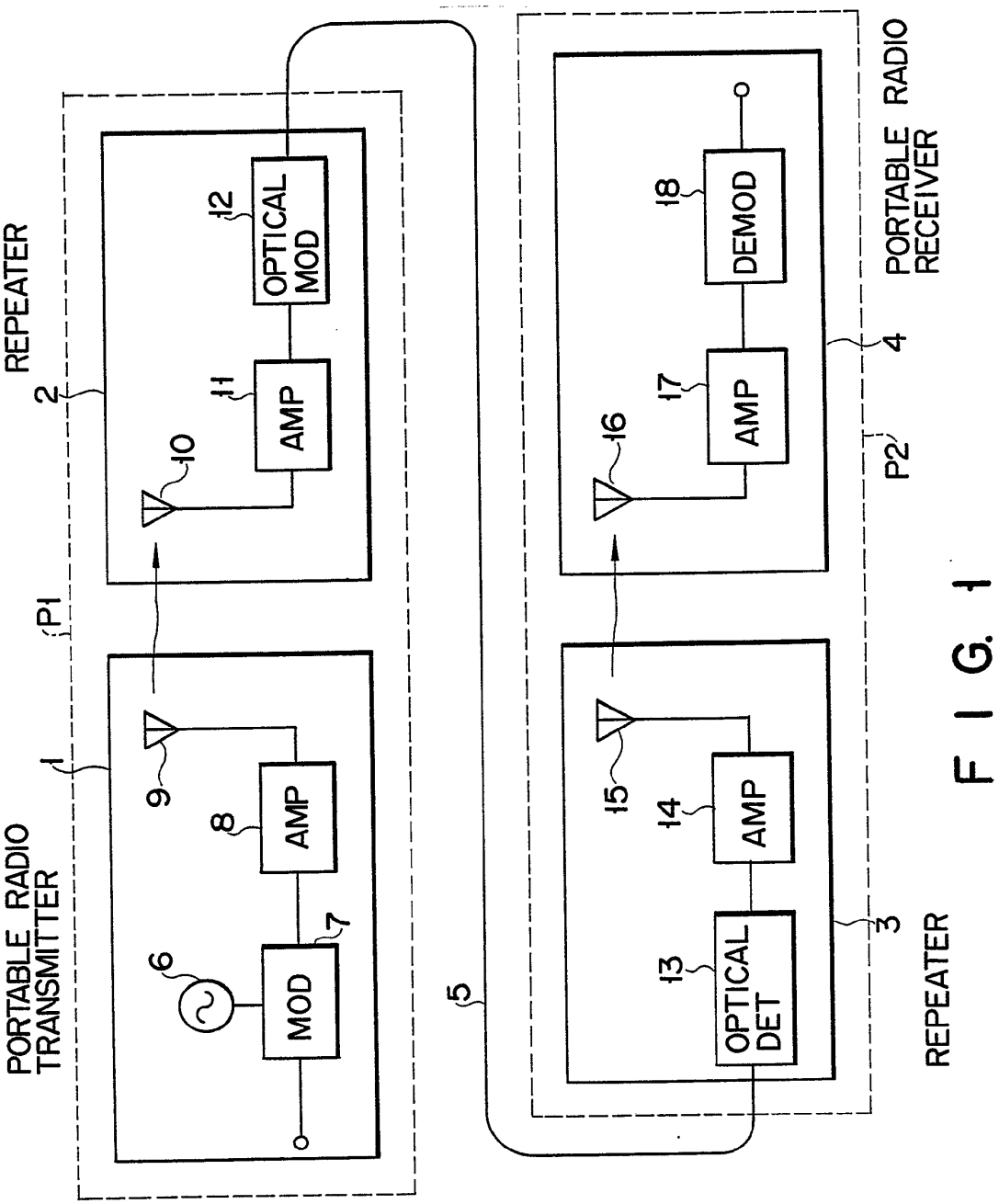

PORTABLE RADIO TRANSMITTER
REPEATER
REPEATER
PORTABLE RADIO RECEIVER
P1
P2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
MOD
AMP
AMP
OPTICAL MOD
OPTICAL DET
AMP
DEMOD

FIG. 1

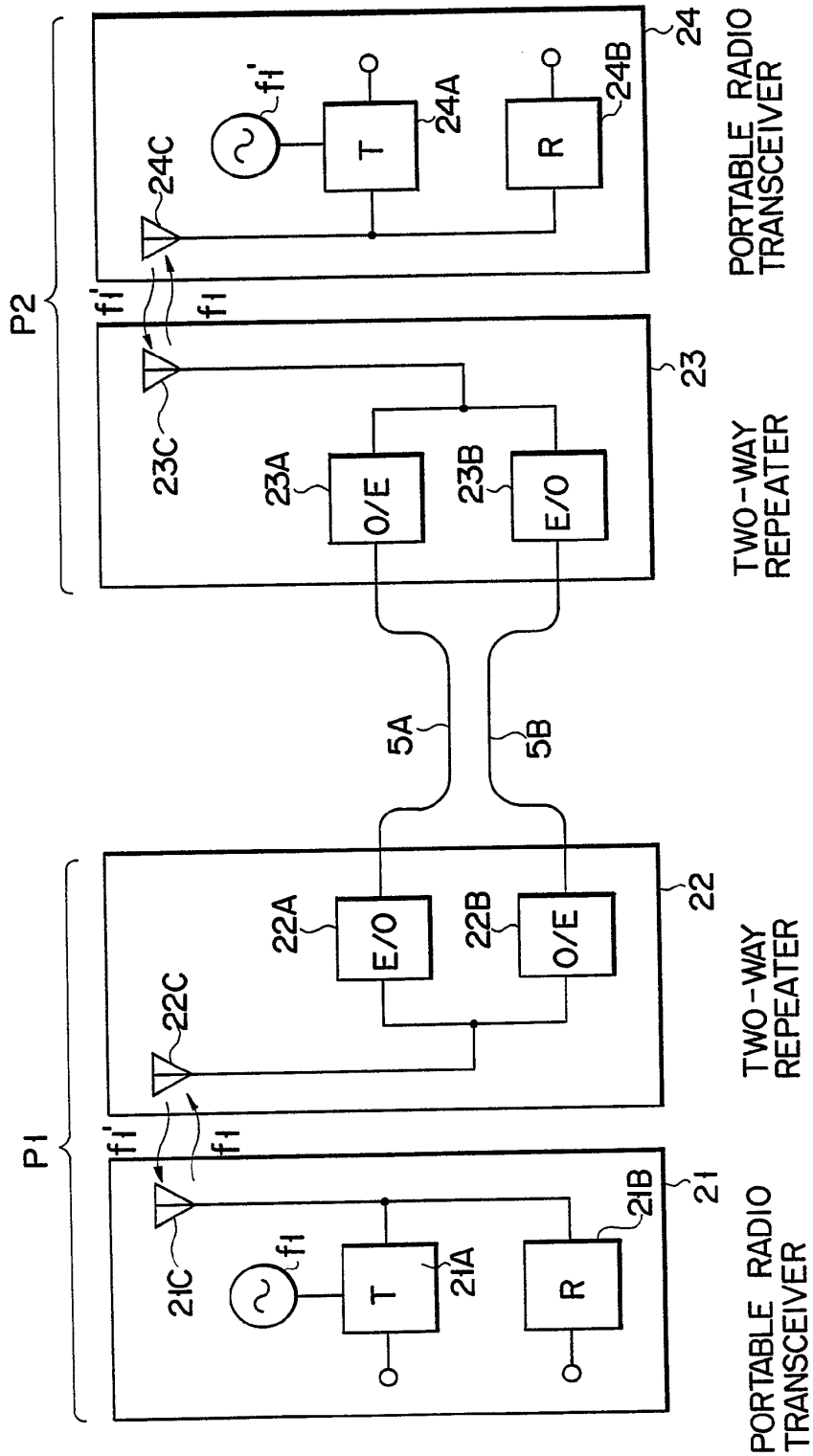

P2
P1
24
PORTABLE RADIO TRANSCEIVER
24C
f1'
T
24A
R
24B
f1'
f1
23
TWO-WAY REPEATER
23C
23A
O/E
23B
E/O
5A
5B
22
TWO-WAY REPEATER
22C
22A
E/O
22B
O/E
f1'
f1
21
PORTABLE RADIO TRANSCEIVER
21C
f1
T
21A
R
21B

FIG. 2

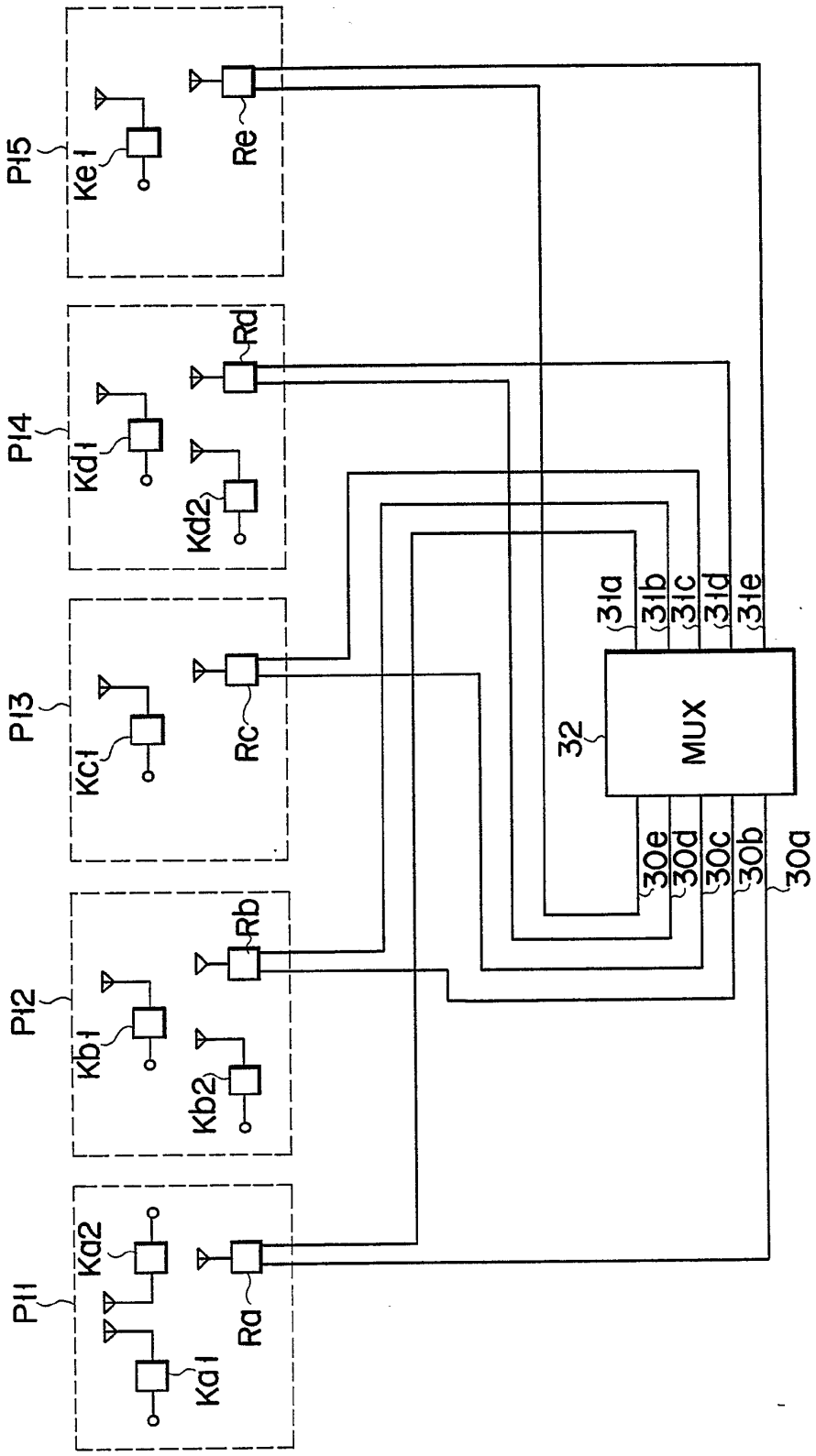
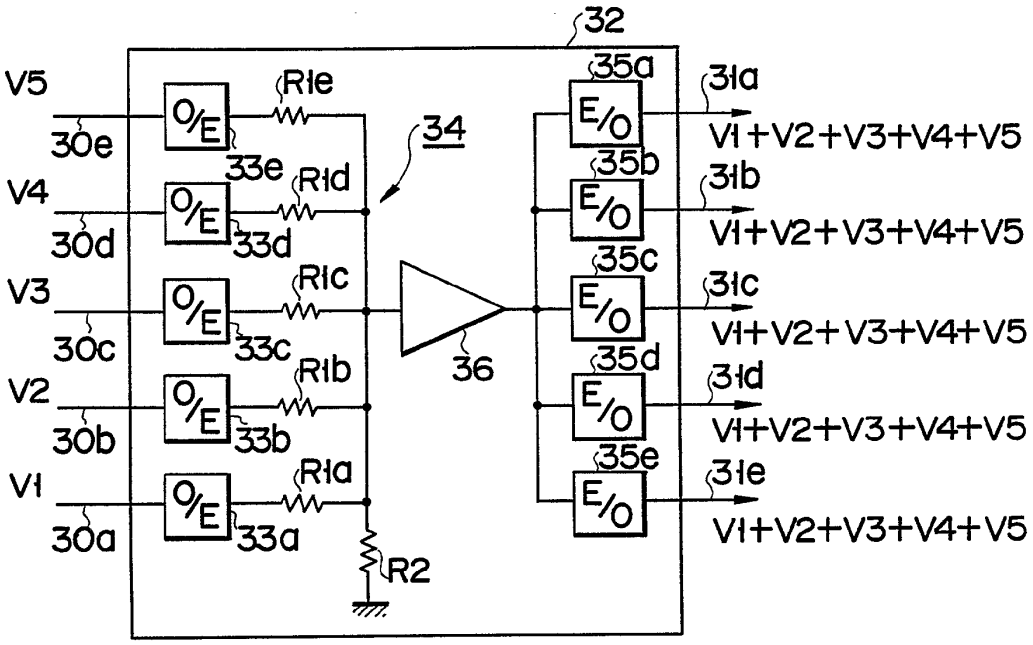
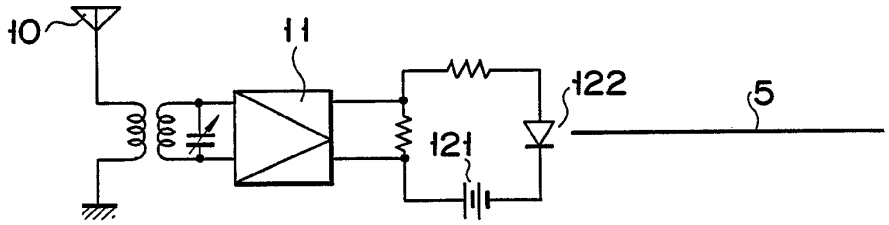

P15
Ke1
Re
P14
Kd1
Kd2
Rd
P13
Kc1
Rc
P12
Kb1
Kb2
Rb
P11
Ka2
Ka1
Ra
31a
31b
31c
31d
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30e
30d
30c
30b
30a

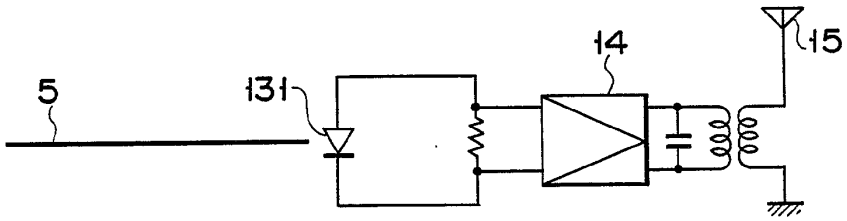
FIG. 3



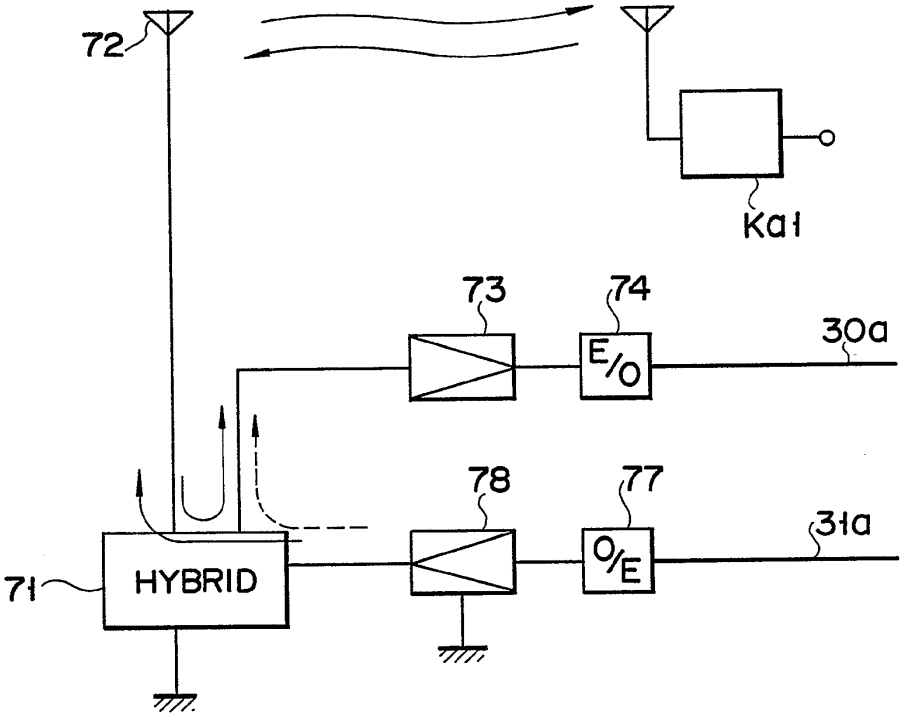

F I G. 4




F I G. 5




F I G. 6




F I G. 7

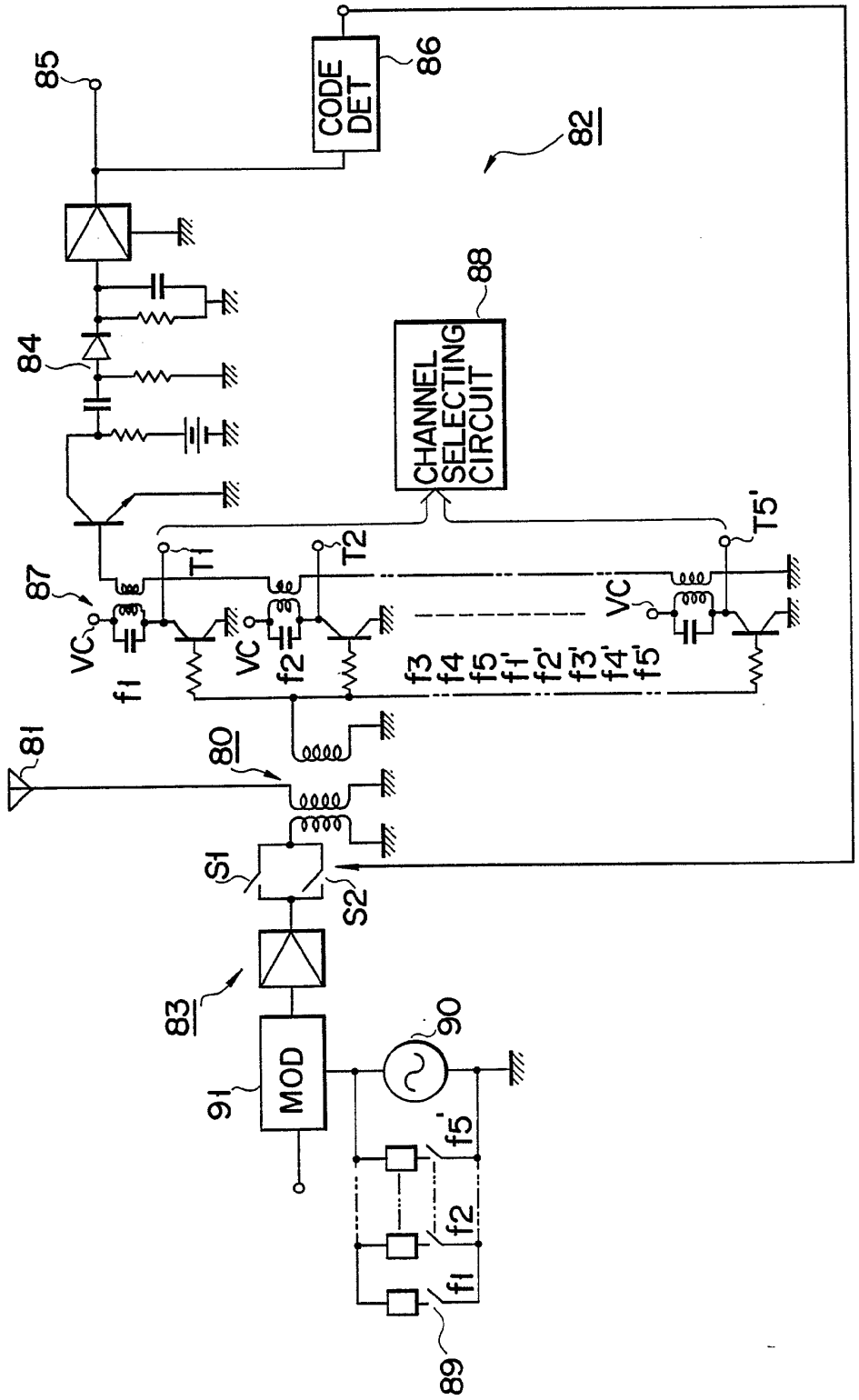

85
CODE DET
86
82
88
CHANNEL SELECTING CIRCUIT
84
87
T1
T2
T5'
VC
f1
f2
f3
f4
f5
f1'
f2'
f3'
f4'
f5'
81
80
S1
S2
83
MOD
91
90
f5'
f2
f1
89

FIG. 8

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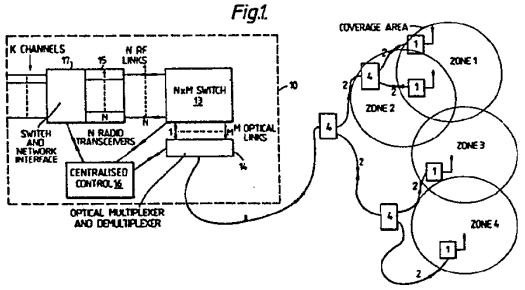
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## (54) Communicationssystem.

(57) A communications system has a base centre with radio transceivers 15 for providing a number of radio frequency (RF) communications links and a plurality of fixed radio ports 1 through which RF signals can be transmitted and received over the air. A fibre optic network (2, 4) interconnects the RF transceivers 15 and the fixed radio ports 1, and carrys the RF signals by means of optical signals. There are plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports. A matrix switch 13 selectively interconnects the transceivers and the radio ports through the fibre optic network.

Fig.1.




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# COMMUNICATIONS SYSTEM

The present invention relates to a communications system, and in particular to a system for interconnecting mobile radio (RF) units to a fixed network or system e.g. PSN, ISDN, LAN or PBX.

At present, for example, in a cellular radio system mobile radio (RF) units communicate with fixed base stations which have radio transceivers that are connected to a switching control centre which is in turn coupled to the PSTN. In the proposed Telepoint system, cordless telephones (CTs) will be able to access the PSTN via radio communication with fixed base stations equiped with radio transceivers which are directly connected to the PSTN. In both these examples radio transceivers and base stations proliferate in the connection between the mobile user and the PSTN, or other network. These systems are therefore complicated and expensive. Future systems will want to provide improved coverage including the provision of many small radio "cells", and hence many base stations and radio transceivers will be required.

Difficulties in finding appropriate base station sites and the costs of equipping them may make such conventional developments impracticable; certainly they reduce the commercial attractiveness of such projects. The present invention seeks to provide a communication system of simplified structure and improved performance.

According to a first aspect the invention provides a communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted and received over the air; a fibre optic network for interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports.

The present invention also provides a communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted andreceived over the air; a fibre optic network for interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports; and a matrix switch for selectively interconnecting the transceivers and the radio ports through the fibre optic network.

The present invention allows for centralisation of transceivers into base centres, and the consequent advantages in terms of technical and commercial gain, by having the transceivers selectively connectable through the fibre optic network to the RF ports.

The RF Communication linking may for example, be time division multiplexed (TDM) or frequency division multiplexed (FDM).

A preferred embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, wherein:

- Figure 1 is a schematic block diagram of a communications system according to a preferred embodiment of the invention;
- Figure 2a is a schematic block diagram of an optical matrix switch which can form part of the preferred embodiment;
- Figure 2b is a schematic block diagram of an RF matrix switch which can form part of the preferred embodiment; and
- Figure 3 is a schematic view of another embodiment of the invention.

The preferred embodiment illustrated in Figure 1 is a multi-user, area coverage radio distribution system using an optical network 2,4 to link the fixed radio distribution ports 1 to a centralised radio and other signal processing base centre 10. An important feature of the system is the use of an optical carrier modulated, e.g. amplitude modulated, with a radio frequency (RF) signal.

In both the base centre 10 and RF ports 1 there are, arranged in different ways, radio/optical interfaces which can place an RF signal onto an optical carrier or conversely recover an RF signal from an optical carrier. The modulation of the optical carrier may be achieved by driving a suitable laser device with the input RF signal so that output of the laser is effectively intensity or amplitude modulated by the RF signal. With this method, a suitable optical detector receiving the amplitude modulated optical signal can produce a direct RF output. In the present specification, the term radio/optical interface is used in this context.

The radio ports 1 each have a radio/optical interface which receives and transmits radio carriers from and to roaming radio equipment. The radio carriers to be sent/received from the centralised location are placed onto/taken off an optical carrier, e.g. as described above. The optical net-



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work 2,4 linking the radio ports 1 to the base centre 10 is generally conventional, having optical links carrying RF carrier/carriers on optical carrier/carriers. Each optical link is shown as bidirectional. However, separate links could be provided for each direction. Within the optical system are optical multiplexers/demultiplexers (M+D) 4. Each multiplexer concentrates a number of optical carriers, say X, onto a fewer number of optical links than X. The demultiplexersplits a number of optical carriers onto individual optical links.

At the base centre 10 the optical system 2,4 is connected to an optical multiplexer and demultiplexer (M+D) 14. The M+D 14 is connected (illustratively) by M optical lines to an NxM matrix switch 13, which will be described below in more detail. The NxM matrix switch 13 has N RF links to a number (N) radio transceivers 15. The radio transceivers 15 are connected through a switch 17 to a number (K) channels of another network which may be ISDN, cellular, LAN, PBX etc. K may be greater than or equal to N. Also in the base centre 10, a central unit 16 is connected to the switch 17, NxM matrix switch, and M+D 14 to control optical, RF, and baseband routing and switching, and coordinate the allocation of RF carriers and channels in conjunction with mobile equipment.

A central part of the base centre 10 is the NxM matrix switch 13. This multiplexes many of the N radio carriers onto any of the M optical transmission lines, i.e. none, one or more of the radio carriers may be on any one of the optical carriers at any one time. The NxM matrix switch 13 may be configured in one of two ways, as shown in Figures 2a and 2b. In each case, the radio/optical interface places the RF carriers to be transmitted from the central transceivers onto the optical carrier(s) and takes off, from the optical carrier(s), the RF carriers to be received by the central transceivers. The switching may be optical (Figure 2a), in which case the radio/optical interface is on the radio "side" of the switch, or the switch may be a radio (RF) matrix switch (Figure 2b), in which case the radio optical interface is on the optical system "side" of the switch. In either case, the overall result is that the N radio lines can be multiplexed onto the M optical lines.

The advantages of the system of the preferred embodiment are profound. A user can access the external network through any of the radio ports 1 with a suitable RF transceiver, e.g. a cordless telephone (CT), and be connected to a free one of the N transceivers 15. Provided the RF capacity was available, all N transceivers could be employed in calls to/from a particular one of the radio ports 1, or as would be more likely, the usage of the transceivers would be distributed among the radio ports of the system. Here lies a key advantage of the system: the centralisation of the radio transceivers. In the present system the radio transceivers are centralised, allowing more economic use and facilitating maintenance etc. Other significant advantages include the possibility of handover between ports covering different zones or areas, by simply switching between optical carriers, i.e. by switching within the NxM matrix switch 13. Also the use of diversity can easily be achieved centrally through switching or combining links to 2 or more ports, to improve performance of mobiles covered by those ports. Further, advantageous use of the RF system can be achieved because any of the carriers allocated to the service, rather than a given subset, can be dynamically assigned by the centralised base, to a given zone or cell. Thus an RF carrier may be allocated to both zone 1 and zone 4, but to different users. At another time, RF carrier may be assigned to just zone 3. The total number of users may remain more or less constant for the whole system, but user density within the system may vary. For example, all the users may shift from zone 1 down to zone 4, with all the central transceivers continually active. If transceivers were placed remotely in each of the zones, the same number of transceivers as that at a centrallocation would be required in each of the zones to meet the peak traffic demand during the day, even though they could remain idle for much of the time. Four times the number of transceivers of the centralised configuration would then be required for the system of Figure 1, hence the improved trunking performance of the centralised scheme, minimising the cost of providing transceivers, the quantity of equipment in the field and affording a potential reduction in maintenance and installation costs.

Handover requires a change of base transceiver as a mobile transits zones. This need no longer be necessary as the switch, block 3, simply switches the active transceiver for a given mobile from one zone to another as the mobile makes the transition. Thus handover break is reduced to a potentially very short optical or RF switch time compared to the much longer period required to switch between transceivers.

The spectrum efficiency of many radio distribution systems are increased if the RF transmissions within the system are synchronised. This is difficult if transceivers are spread over several locations, but more straightforward when they are centralised.

An alternative embodiment of the invention is shown in Figure 3 and is very similar to that of Figure 1, except that the optical system does not incorporate multiplexing/demultiplexing. Thus there are no M+Ds 4 and the M outputs of NxM switch 13 are connected directly to the radio ports 1. There is therefore a permanent 1 to 1 correspondence between the optical lines in the NxM switch



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13 and the radio ports 1.

The embodiment of the invention described is based on the use of frequency division multiple access, where each communications link is on a separate radio frequency. As an alternative, time division multiple access could beused, where each communication link exists on separate time slots on a single radio channel. In this case there may still be multiple transceivers in the base centre 10 to cope with the traffic demand and hence provide frequency/timeslot reuse at the radio distribution ports 1. The connection from the transceivers 15 to the matrix switch 13 will then be by N radio links with P timeslots each, making NxP links in total to the matrix switch 13 from the transceivers 15. An extension of this approach is the possibility of a hybrid time and frequency division access system, with multiple radio carriers and several timeslots on each.

An example of a form of an RF switch is shown in Figure 4. The figure shows the RF matrix switch in a three distribution point system demonstrator. The RF matrix switch interconnects the four radio transceivers 51 (with their associated isolator circuits 52) to the three circuits each of which feeds a distribution point via a pair of fibres. Bi-directional RF connections for all the combinations of base unit and D.P. are made via switches that allow either through connection or isolation of the connection path. These switches are under computer control.

The signals from/to the radio transceiver 51 are split/combined in four 3 way combiners 53 (these are actually 4 way combiners with the spare output feeding to the scanning receiver 52) with each output/input passing through a switch that can isolate that output/input. From the switches the signals go to the inputs of one of the three 4 way combiners 55 and hence to/from the D.P.s via one of the three RF/optical interfaces 56.

These switches are under microprocessor control and allow the RF matrix to switch any transceiver to any combination of the distribution points and conversely a distribution point to any combination of the transceivers. Thus a base unit can feed all the distribution points simultaneously then by changing the switches feed only one distribution point.

Two examples of the elements for optical switch and shown in Figure 5. There are two basic technologies; (i) Bulk Optic Devices and (ii) Guided Wave Devices.

A bulk optic switch element, shown in Figure 5-(a), uses mechanical or physical reorientation of the optical path to achieve the switching of the incoming optical signals between output ports. An example of this type of switch is presented below for a single input switchable between two outputs. Other switch configurations using this as a basic building block facilitate 2x2 and 2x4 switches.

A guided wave device switch element, shown in Figure 5(b), uses the electro-optic effect to change the optical propagation characteristics of switch waveguides through the application of electric fields. An example of this device type is the Mach Zender Inteferometer (MZI) shown in Figure 5(b). This type of switch can be extended from a simple 2x2 to a non-blocking 8x8 switch matrix.

## Claims

1. A communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted and received over the air; a fibre optic network for interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports.

2. A communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted and received over the air; a fibre optic network for interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports; and a matrix switch for selectively interconnecting the transceivers and the radio ports through the fibre optic network.

3. A communications system as claimed in claim 2 wherein the RF links are frequency division multiplexed.

4. A communications system as claimed in claim 2 wherein the RF links are time division multiplexed.

5. A communications system as claimed in claim 2, 3 or 4, wherein there is means for combining RF signals to or from one or more of the RF ports.

6. A communications system as claimed in any one of claims 2 to 5 wherein the matrix switch is for switching optical signals and between the op-



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tical matrix switch and the one or more RF transceivers there are one or more RF/optical interfaces.

7. A communications system as claimed in any of claims 2 to 5 wherein the matrix switch is for switching RF signals, and between the RF matrix switch and the fibre optic network there are one or more RF/optical interfaces.

8. A communications system as claimed in any preceding claim wherein there is multiplexing/demultiplexing of the optical signals in the fibre optic network.

9. A communications system as claimed in any preceding claim wherein the fibre optic network incorporates wavelength routing of optical signals.

10. A communication system as described in any preceding claim which call handover is between radio ports is controlled in the base centre through switching the radio transceiver from one radio port to another radio port by the matrix switch.

11. A communication system as claimed in any preceding claim which diversity operation is provided by combining or switching between two or more radio points in the matrix switching.

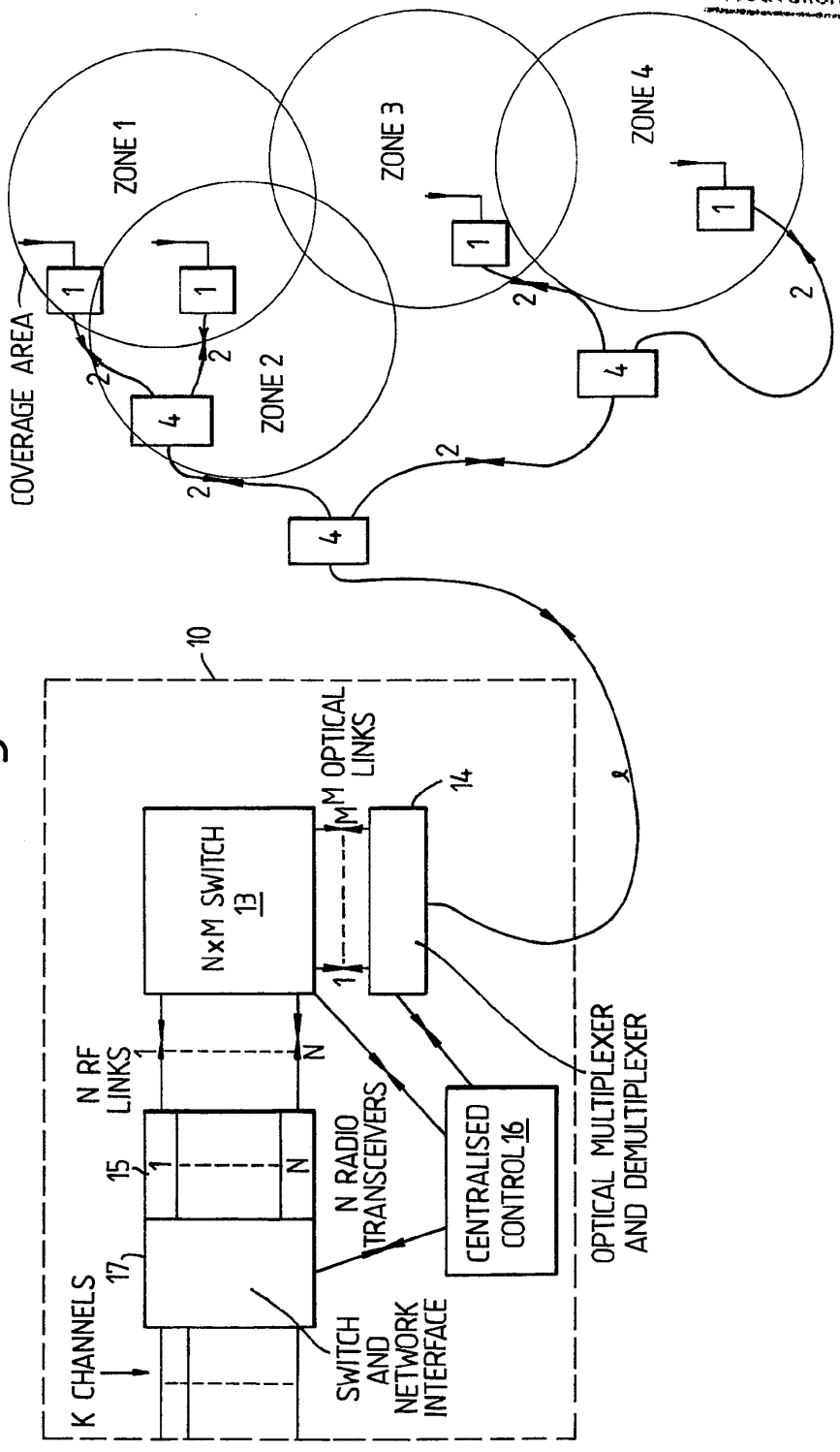
12. A communication system as claimed in any preceding claim which dynamic channel allocation is controlled in the base centre.



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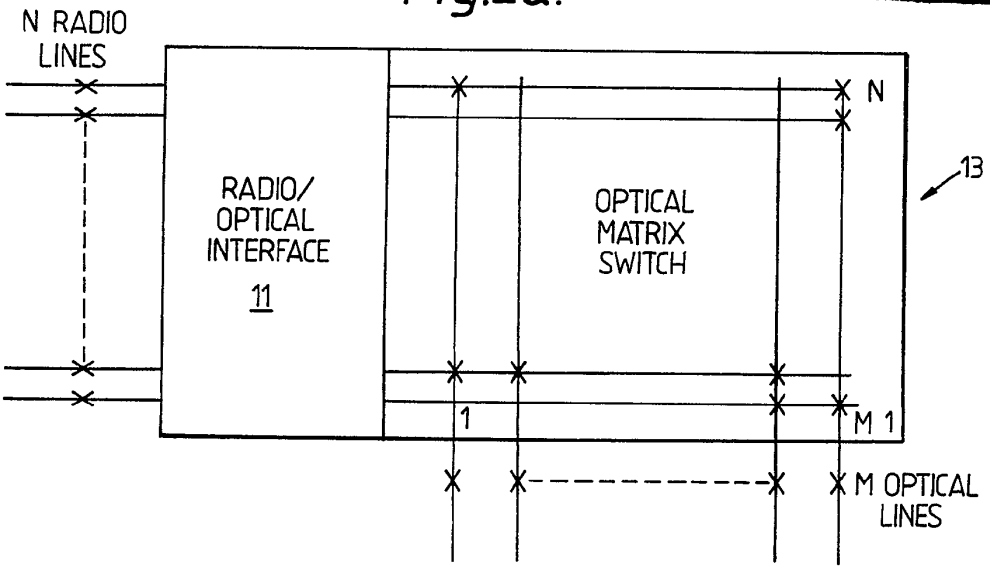
eu eingereicht / Newly filed
Nouvellement déposé

Fig.1.



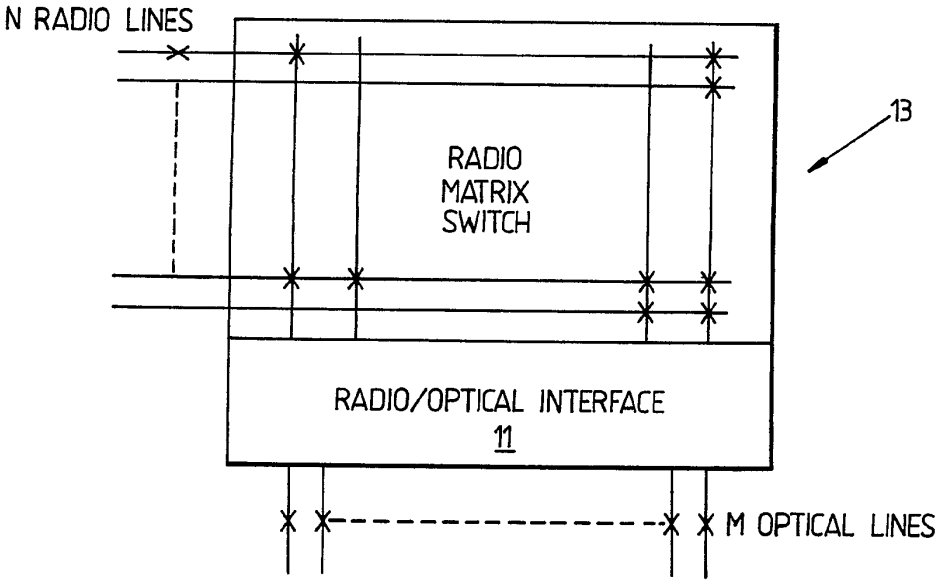
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Fig.2a.



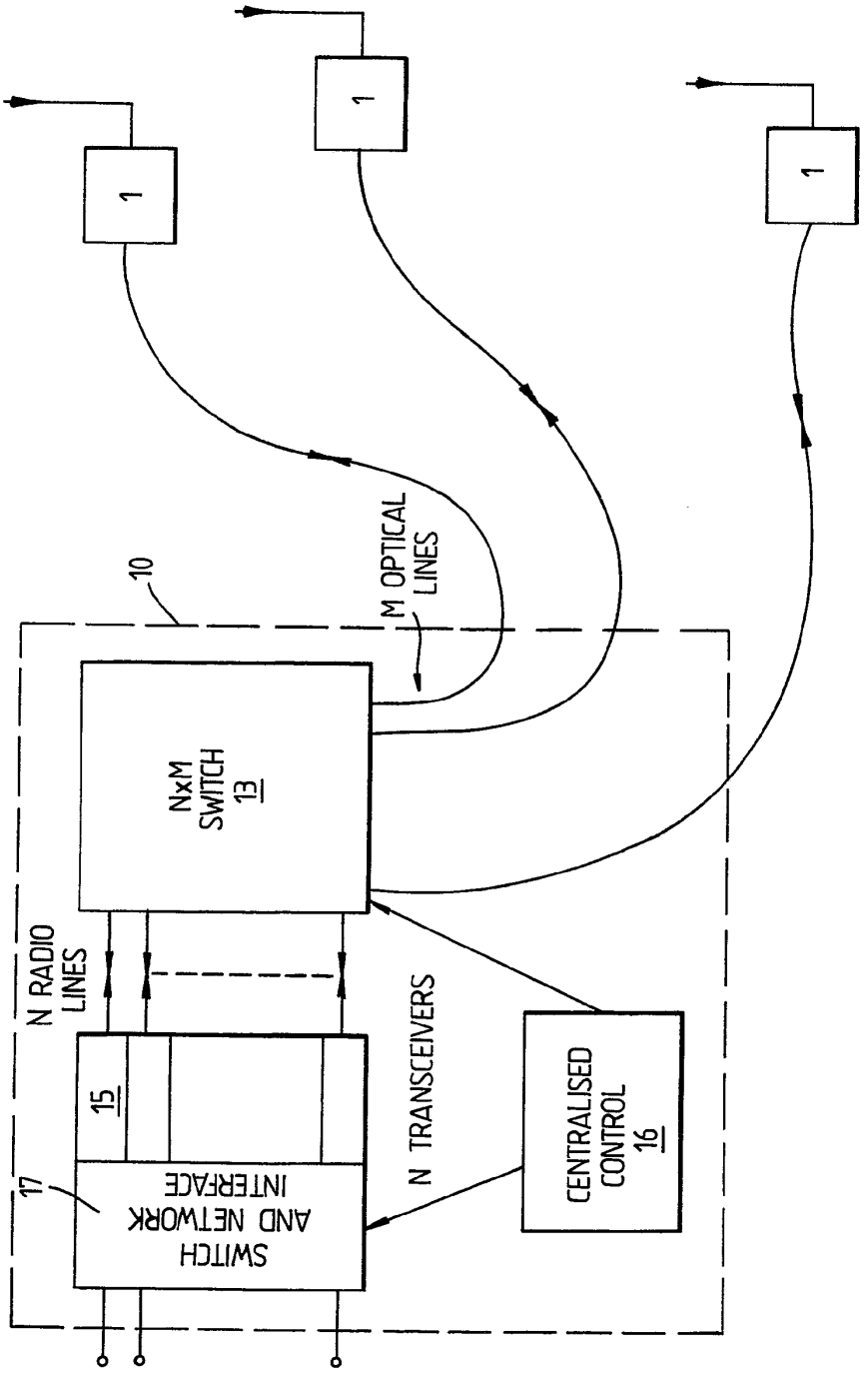

* DENOTES CONNECTION OF A COLUMN TO A ROW THUS COLUMN M IS SHOWN CONNECTED TO ROWS 1, N-1 AND N

Fig.2b.



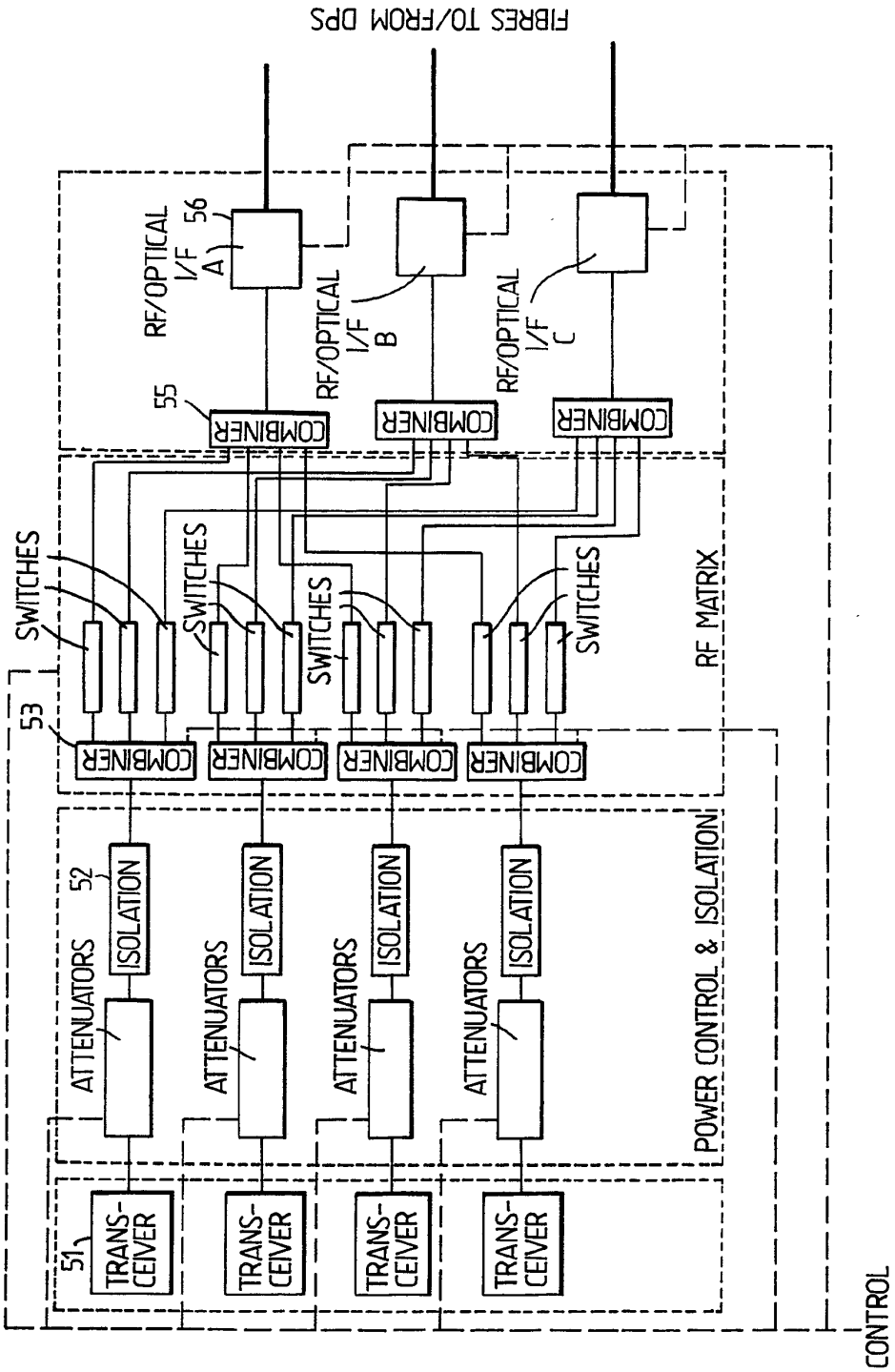
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Nouvellement déposé

Fig.3.



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Fig.4.



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Nouvellement déposé

Fig.5a.

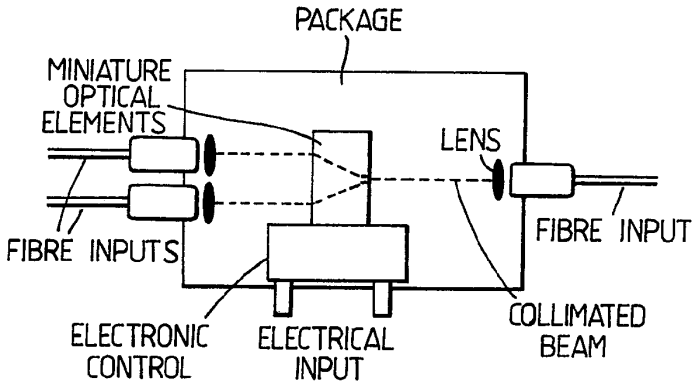
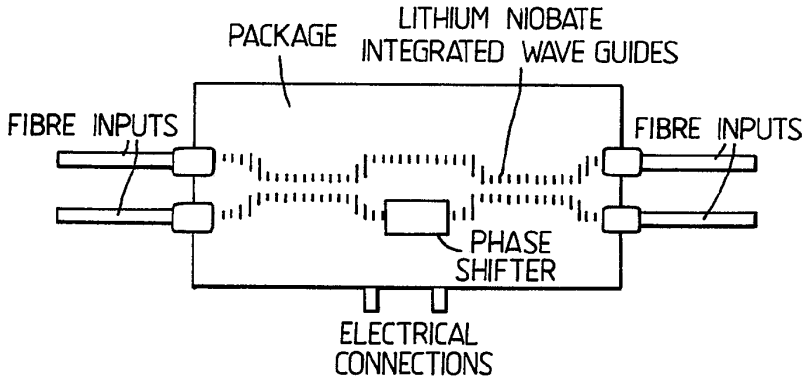



Fig.5b.



European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 89 31 1656

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
|---|---|---|---|
| A | PROCEEDINGS OF THE IEEE, vol. 75, no. 4, April 1987, pages 436-477, IEEE, New York, US; D.C. COX: "Universal digital portable radio communications" * Page 441, right-hand column, paragraph IV; page 452, right-hand column, paragraph e, lines 1-15; page 456, right-hand column, lines 19-25; page 457, right-hand column, paragraph 3 - page 459, right-hand column, paragraph c; page 465, left-hand column, paragraph c - right-hand column, paragraph 7 * --- | 1-5,11-12 | H 04 Q 7/04<br>H 04 B 7/26<br>H 04 M 1/72 |
| A | GB-A-2 138 652 (STD. TELEPHONES AND CABLES) * Page 1, lines 1-54; page 1, line 76 - page 2, line 10; page 2, lines 28-62; page 2, line 98 - page 3, line 35 * --- | 1,2,4 | |
| A | EP-A-0 233 963 (ANT) * Page 6, lines 13-31; page 6, line 49 - page 7, line 5; page 7, line 42 - page 12, line 11 * --- | 2-4,7,10,12 | TECHNICAL FIELDS SEARCHED (Int. Cl.5)<br>H 04 B<br>H 04 M<br>H 04 Q |
| A | DE-A-3 135 231 (S.E.L.) * Page 5, line 18 - page 6, line 15; page 7, lines 1-13; page 8, line 1 - page 9, line 20 * --- | 1,2,5,8 | |
| A | EP-A-0 156 336 (S.E.L.) * Page 2, line 12 - page 4, line 27 * --- | 1,2,4,10 | |
| A | PATENT ABSTRACTS OF JAPAN, vol. 5, no. 15 (E-43)[687], 29th January 1981, page 87 E 43; & JP-A-55 143 854 (NIPPON DENSHIN DENWA KOSHA) 10-11-1980 ----- | 1,2,5,11 | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 08-02-1990 | GERLING J.C.J. |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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& : member of the same patent family, corresponding document

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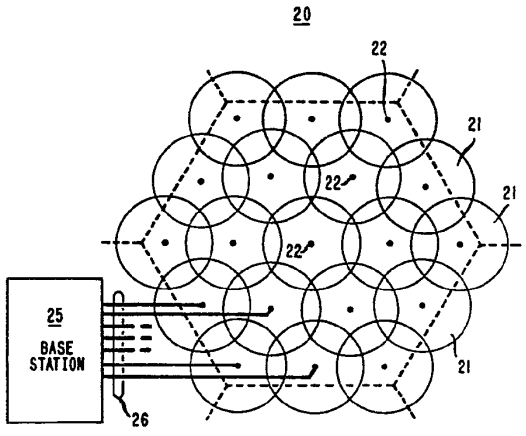
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## (54) Optical fiber microcellular mobile radio.

(57) A microcellular communication system includes optical fiber connections (26) between a base station (25) and opto-RF transducers (22) located in a closely spaced grid. Radio-band signals are modulated directly onto laser outputs through the optical fibers for both transmission to mobile units or from the mobile units. The opto-RF transducers, housed in canisters, are mounted on telephone or power poles to provide radio link coverage to mobile and portable phones located in a microcell area, e.g., in a congested metropolitan area where space for a roof-top base station is very limited and expensive.

FIG. 1




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# OPTICAL FIBER MICROCELLULAR MOBILE RADIO

This invention relates to a mobile radio system having a plurality of cells which reuse transmitting carrier frequencies.

## Background of the Invention

There is an ever increasing demand for more capacity in cellular mobile radio. In the current 900 MHz, UHF cellular systems, only 20 MHz are available for each direction of transmission between a base station and mobile units. By separating the overall 20 MHz band into a number N of sub-bands and assigning each sub-band to a different set of geographical cells in a regular array of cells which cover a large region, the frequencies are reused. Co-channel interference is minimized by assuring that the ratio of cell radius to the distance to the next cell which uses the same frequency sub-band is small. In the regular pattern of cells, this ratio is made smaller by increasing the number N and is independent of the absolute cell size used in the pattern. Typically, the number N = 21, which assures negligible co-channel interference and allows 16 channels per sub-band. By making the scale of the pattern smaller, more users per square mile are accommodated with the same overall bandwidth.

Previously, cellular radio system operators have increased capacity by subdividing the cell area and reusing assigned frequencies in closer geographic areas. Whereas a typical cell radius is eight miles, subdivisions down to a cell radius of one mile or smaller are often needed. In such small cell areas, appropriate choices of base station locations become very restricted because public facilities may not be available where needed, and private locations are likely to be prohibitively expensive. For many small cells, a residential location may be the only available choice. People in residential areas often object to the base station antenna tower because its height, typically 100 to 150 feet, makes it an eyesore; and its radiated power, typically 400 to 1,200 watts, is perceived to be an environmental health hazard.

Another problem arises when one considers the use of not yet allocated bandwidth in the 10 to 60 GHz, or millimeter wave, frequency spectrum for providing very large capacity mobile communication service. Propagation loss and Doppler frequency shifts are more severe for millimeter waves than for the currently used UHF signals. The increased Doppler shift requires each channel to use more bandwidth than at the channels in UHF systems. To fully utilize the bandwidth in the 10 to 60 GHz frequency range, with time division multiplexing for example, it is necessary to minimize the the spread in time delays. To reduce propagation loss and the spread in time delays, any millimeter wave mobile radio system design must strongly favor line of sight operation.

The above problems of mobile radio need base station antennas to be placed geographically very close to the mobile units, but the conventional means of carrying the signals between the base station and remote antennas by means of coaxial RF transmission lines is prohibitively expensive because of their large transmission losses.

## Summary of the Invention

The above problems are solved in accordance with the present invention by placing many antennas, associated with a single base station, at grid points near the mobile units and using an optical fiber network for interconnecting the antennas with the base station. Optical wavelength carriers are analog modulated with multiplexed RF mobile radio channels for transmission through the optical fiber network. The modulated optical wavelength carriers are analog detected from the optical fibers so that the RF channels are distributed to the grid of antennas without distortion. Received RF channels also are collected from the grid of antennas for modulating laser outputs which are transmitted through the optical fibers to the base station.

## Brief Description of the Drawing

A better understanding of the invention may be obtained by reading the subsequent detailed description with reference to the drawing wherein:

FIG. 1 shows a grid of microcell opto-RF transducer radiation and reception coverage of a mobile radio cell;

FIG. 2 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and opto-RF transducers with a separate fiber for each direction of optical transmission for each transducer;

FIG. 3 is a schematic diagram of an alternative opto-RF transducer for operation with a separate fiber for each direction of optical transmission;

FIG. 4 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and opto-RF transducers with a separate fiber providing bidirectional optical transmission for each transducer;



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FIG. 5 is a schematic diagram of an alternative opto-RF transducer for operation with a fiber providing bidirectional optical transmission;

FIG. 6 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and a group of opto-RF transducers wherein a single optical detector receives all signals through a fiber from a group of the opto-RF transducers and wherein a single laser transmits through another fiber to all of the opto-RF transducers in that group; and

FIG. 7 is a schematic diagram of an optical fiber distribution network between a mobile radio base station and a group of opto-RF transducers wherein all optical signals pass through a single optical fiber.

## Detailed Description

Referring now to FIG. 1, there is shown a mobile telecommunication cell 20 generally bounded by a heavy dotted line. Adjacent cells are only indicated in part. In the prior art, a base station is located within and serves that cell 20. That base station transmits to and receives from mobile units some number of frequency multiplexed information channels. A typical base station handles sixteen separate channels for reception and transmission. Multiplexed signals developed within the base station are fed via coaxial cable to an antenna located effectively at the center of the cell. That antenna radiates the multiplexed signals to mobile units within or near the cell 20.

Those mobile units receive the radiated signal and separate their assigned channels. Concurrently each of the mobile units transmits a channel to the base station antenna. All of the channels transmitted from the mobile units are multiplexed in the air and at the antenna. This multiplexed signal is transmitted from the antenna through a coaxial cable to the base station where the various channels are separated and the voice signals detected for delivery to a central office.

In our new arrangement, radiation coverage of the cell 20 is accomplished in an entirely different manner. Several microcell opto-RF transducers 22 are positioned within the cell 20 so that the entire cell area is covered in an over-lapping grid-like microcell pattern of radiation 21 of the same RF signals from the transducers 22. A base station 25 may be located within the cell 20 but more generally can be located outside of the cell. The transducers 22 are interconnected with the base-station 25 via a network of optical fibers 26.

Mobile units within the cell 20 communicate by way of two way radio signals to the transducers 22. All sixteen channels being transmitted from the base station 25 are distributed to all of the transducers. Also all sixteen channels can be received from the mobile units at any of the transducers and are transmitted via the optical fibers 26 to the base station 25. Thus the transducers act as a grid-like distributed antenna for both transmitting and receiving the frequency division multiplex signals.

Referring now to FIG. 2, there is shown a detailed block diagram of the base station 25 which is arranged to transmit and receive frequency multiplexed FM signals in several channels. On the transmit side of the base station, the FM subcarrier channels, frequency multiplexed on a radio frequency transmission line, are applied to a star splitter, or power splitter, 30. At each of the output ports of the power splitter, the signal modulates a laser 32 for transmitting the frequency multiplexed channels on an optical carrier through an optical fiber 26. The opto-RF transducers 22 include an optical detector 27 for converting the optical signal to an electrical radio frequency signal which is amplified if required and is used for radiating from an antenna 35 to the mobile units within range. Only one opto-RF transducer is shown in detail but others are indicated by a separate block 22 and two series of dots.

In response to the radiated signals, the receiving mobile units transmit a radio frequency signal which is received by an antenna 37 of the opto-RF transducer 22. The received radio frequency signal is amplified, if required, and modulates a laser 38 that produces an optical signal which is transmitted through another optical fiber 30 to the base station 25. This optical signal includes frequency division multiplexed signals from all mobile units transmitting within the relevant microcell. At the base station, an optical detector 40 converts the optical signal to an electrical signal and applies it to an input port of a star coupler, or power combiner, 41. At the output port of the power combiner, the electrical signal, including sixteen FM channels, is fed into the base station in accordance with prior art techniques.

Referring now to FIG. 3, there is shown an alternative opto-RF transducer 42 which may be substituted for the opto-RF transducer 22 of FIG. 2. It is noted that the opto-RF transducer 42 also interconnects with two optical fibers 26 and 30, each of which transmits optical signals in one direction. Detector 27 and laser 38 perform the same functions as in FIG. 2. Electrical signals, in an RF band $\lambda 1$, from the detector 27, however, are applied to a port of a circulator 43 which directs them to an antenna 45 for radiating to the mobile units within the microcell.

Electrical signals, in a different RF band f2 and radiated back from the mobile units, are received by the same antenna 45 in the opto-RF transducer



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42. The electrical signals are applied to the circulator 43 which directs them to the laser 38. These electrical signals, received from the antenna 45, are amplified if required. As in the arrangement of FIG. 2, the laser output signal is modulated by the frequency multiplexed FM signals in several channels.

Referring now to FIG. 4, there is shown a detailed block diagram of a mobile radio base station 25 which is arranged to transmit and receive frequency multiplexed FM signals in several channels. On the transmit side of the base station 25, the FM subcarrier channels, frequency multiplexed on a radio frequency transmission line, are applied to a star splitter, or power splitter 30. At each of the output ports of the power splitter, the signal modulates a laser 52 for transmitting the frequency multiplexed channels on an optical carrier $\lambda 1$ through an optical fiber 53 to a wavelength multiplexer 54. The multiplexed optical carrier is directed by the multiplexer 54 to an optical fiber 55. An opto-RF transducer 62 includes a wavelength multiplexer 56 and an optical detector 57 for converting the optical signal on the fiber 55 to an electrical radio frequency signal which is radiated from an antenna 60 at a power, limited to approximately ten watts for the combined carriers, to mobile units within a microcell range of the antenna. The electrical signal is amplified by an amplifier 59 if required. Radiation from the antenna 60 is in a first band f1 of RF frequencies and, typically, may be at one watt for the combination of carriers.

In response to those transmitted signals, the receiving mobile units transmit a radio frequency signal which is received by an antenna 61. The received radio frequency signal is in a second band of frequencies which are separated from and do not interfere with the first band of frequencies. When received at the antenna 61, the radio frequency signal is amplified by an amplifier 63, if required, and modulates a laser 64 that produces an optical signal at a wavelength $\lambda 2$ which is transmitted through the wavelength multiplexer 56 to the optical fiber 55. This optical signal includes frequency multiplexed signals received from all mobile units transmitting within the relevant microcell. Thus, optical carrier signals of different wavelengths $\lambda 1$ and $\lambda 2$ are transmitted in opposite directions on the single fiber 55. RF carriers are multiplexed onto both optical carriers.

At the base station location, the wavelength multiplexer 54 directs the optical signal wavelength $\lambda 2$ to an optical detector 66. Such detector converts the optical signal to an electrical signal and applies it to an input port of a star coupler, or power combiner, 41. At the output port of the power combiner, the electrical signal including sixteen FM channels is fed into the base station 25 in accordance with known techniques.

Referring now to FIG. 5, there is shown an alternative opto-RF transducer 72 which can be substituted for the transducer 62 of the arrangement of FIG. 4. It is noted that the single optical fiber 55, which transmits optical carriers in both directions, applies the wavelength $\lambda 1$ to the wavelength multiplexer 56 and receives the wavelength $\lambda 2$ from the wavelength multiplexer 56. Optical detector 57 and laser 64 operate as in the arrangement of FIG. 4. Electrical signals including the combined RF carriers detected from the optical carrier $\lambda 1$ are amplified, if required, by an amplifier 68 and are applied to a circulator 68. Those RF channels, which have a combined power limited to approximately ten watts, are directed to an antenna 70 for radiation to mobile units within a microcell range of the antenna. These RF channels are in a first RF band of frequencies f1.

RF channel signals returned from the mobile units are received at the same antenna 70 and are applied to the circulator 69. These RF channels are transmitted in a separate RF band of frequencies f2 which does not interfere with the band of frequencies that is transmitted from he antenna 70. Circulator 69 directs the received RF channels to the laser 64. The signals are amplified in an amplifier 71, if required.

Thus the opto-RF transducer 72 is arranged to interconnect with a single optical fiber carrying two different wavelength optical carriers for opposite directions of transmission and to include a single antenna arranged for radiating and receiving RF channels in different frequency bands f1 and f2. For the transmitted RF channels, their combined power typically is approximately one watt and is limited to approximately ten watts to produce the microcell coverage. RF signals, received from mobile units is at typical mobile unit power level.

Referring now to FIG. 6, there is shown the base station 25 which is arranged to transmit and receive frequency multiplexed FM signals in several channels. On the transmit side of the base station, the FM sub carrier channels, frequency multiplexed on a radio frequency transmission line, are used for modulating a laser 75 for transmitting the frequency multiplexed channels on an optical carrier through an optical fiber 76. The optical signal is applied to a star coupler 80 for distribution through optical fibers 81 to opto-RF transducers 82. The star coupler 80 can be located remote from he base station 25. In those opto-RF transducers, a detector 83 converts the optical signal to an electrical radio frequency signal which is used for radiating from each antenna 87 to mobile units located within microcell range. Transmitted radio frequency signals include several channels in a first



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band of frequencies. The radiated power is limited to approximately ten watts for the combined channels. Typically the combined power is approximately one watt for each microcell.

Responding mobile units transmit radio frequency signals which are received by any microcell antenna 89 that is within microcell range. Channel signals transmitted from the mobile units are multiplexed in air and at the antenna 89. They are in a different band of frequencies than the band transmitted from the antenna 87. The received radio frequency signal modulates a laser 90 producing an optical signal that is transmitted through another optical fiber 92 to a star coupler, or power combiner, 95. Optical signals from the several fibers 92 are combined and transmitted through a single optical fiber 97 to a detector 98 at the location of the base station 25. The optical signal includes frequency division multiplexed signals from all mobile units transmitting within relevant microcells. Power levels received from he mobile units are typical for mobile radio units.

At the base station location, the detector 98 converts the optical signal to an electrical signal including sixteen FM channels and applies that signal to the base station 25, in accordance with standard techniques. Opto-RF transducer 42 from FIG. 3 can be substituted for opto-RF transducer 82 for operating with a single antenna.

Referring now to FIG. 7, there is shown the base station 25 arranged for transmitting and receiving frequency multiplexed FM signals in many channels. To transmit, the FM subcarrier channels, frequency multiplexed on a radio frequency line, are used for modulating the output of a laser 102. The laser 102 transmits the frequency multiplexed channels on an optical carrier through a wavelength multiplexer 103 and an optical fiber 104. The optical carrier for the signal being transmitted is at a wavelength $\lambda 1$. From the fiber 104, the optical signal is applied to a port of a star coupler, or power splitter 105. The star coupler 105 can be located remote from the base station 25. Each of several output ports of the power splitter 105 connects with a separate optical fiber 106 for distributing the optical signal to a group of opto-RF transducers 107. Such transducers include a wavelength multiplexer 108 for directing the optical carrier to $\lambda 1$ an optical detector 109 for converting to an electrical radio frequency signal that is radiated from the group of antennas 110 to any mobile units within range of the microcell radiation coverage. Combined channel power is limited to approximately ten watts and typically is approximately one watt for covering a microcell.

Concurrently the mobile units transmit back to the base station 25 via a radio frequency signal that is received at one or more antennas 112 and is applied to modulate a laser 115 in the opto-RF transducer 107. This radio frequency signal is a combination of channels in a band of frequencies that is different from the band radiated from antenna 110. The optical carrier, modulated by the received radio frequency signal, is transmitted through the optical fibers 106 to the star coupler 105. This receiving optical carrier has a wavelength $\lambda 2$ that is separate from the transmitting optical carrier so that the two optical carriers do not interfere with each other. Optical signals from all of the fibers 106 are added incoherently within the star coupler 105 and the resulting composite optical signal is transmitted through the optical fiber 104 to the wavelength multiplexer 103 where it is directed to the receiving port of the base station 25. At the base station location, the optical signal is detected in a detector 117 and is converted to a sixteen channel electrical signal that is applied to the base station 25 according to known practice.

Although the foregoing embodiments have been described as an example with sixteen channel operation, the invention also is well suited for a mobile communication network that operates with many more than sixteen channels from a base station.

Microcell radiation coverage is much more precisely defined than that of presently used base station antenna towers. As a result the number N of sub-bands can be greatly reduced with microcells because of reduced co-channel interference. This results in more frequency channels per sub-band and allows more users per square mile and greater frequency reuse. Since microcells in a given call radiate and receive the same sub-band, there is no call handoff between microcells only at the regular cell boundaries.

The fibers connecting the microcells to the base station can be reconnected at the base station to a multiple of new sub-band transceivers. This provides the ability to sub-divide a cell into multiple channel sub-cells by reconfiguring the fiber network to the opto-RF transducers. This aspect of the invention overcomes the difficulty of installing new base stations and antenna towers when sub-dividing cells.

Appended claims define the described embodiments of the invention together with other embodiments which are obvious in view thereof.

## Claims

1. A mobile radio system having a base station (25) and a plurality of mobile units, CHARACTERIZED BY

a plurality of opto-RF transducers (22),

a distribution network using optical fibers (26,39)



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interconnecting the base station with the opto-RF transducers, and

means (32,27,38,40) for transducing multiplexed subcarrier channels onto and off optical carriers in the fiber distribution network, for transducing multiplexed subcarrier channels onto an optical carrier on a fiber from the base station, and for transducing multiplexed subcarrier channels off an optical carrier on a fiber to the base station.

2. A system as claimed in claim 1, wherein the plurality of opto-RF transducers, in response to optical signals on the fibers, serves to radiate radio signals to mobile units and, in response to received radio signals transmitted from the mobile units, serves to modulate optical signals on at least one fiber for transmission to the base station.

3. A system as claimed in claim 2, wherein the radiated and received radio signals lie in a millimeter wave band.

4. A system as claimed in claim 2 or 3 wherein received radio signals are added together incoherently in the distribution network to provide the combined signal at the base station.

5. A system as claimed in claim 1, wherein the sub-carrier transducing means and the opto-RF transducers serve to time division multiplex channels onto the optical carrier in the fiber distribution network.

6. A system as claimed in claim 1, wherein the subcarrier transducing means and the opto-RF transducers serve to frequency multiplex channels onto the optical carrier in the fiber distribution network.

7. A mobile radio microcell transducer arrangement (22) CHARACTERIZED BY

a first antenna (35) for transmitting radio signals including multiplexed mobile radio channels in a first range of frequencies,

a second antenna (37) for receiving radio signals including multiplexed mobile radio channels in a second range of frequencies,

a laser (38), responsive to the received radio signals, for producing an optical carrier modulated by the mobile radio channels in the second range of frequencies, and

means (27) for transducing another optical carrier modulated by the mobile radio channels in the first range of frequencies into an electrical signal including the mobile radio channels having a combined power of ten watts or less.

8. A transducer as claimed in claim 7, including

a first optical fiber (39) for receiving the modulated optical carrier produced by the laser (38); and

a second optical fiber (26) for applying another modulated optical carrier to the transducing means (27).

9. A mobile radio microcell transducer arrangement (42) CHARACTERIZED BY

a laser (38),

an antenna (45) for transmitting and receiving radio signals including multiplexed mobile radio channels in different ranges of frequencies,

means (27) for converting an optical carrier modulated with mobile radio channels in a first band of frequencies into an electrical signal to be applied to the antenna, and

circulator means (43) for coupling the electrical signal in the first band of frequencies to the antenna for radiating to mobile units and for coupling an electrical signal, received in a second band of frequencies from the mobile units through the antenna, to the laser for modulating the optical output with the electrical signal in the second band of frequencies.

10. An arrangement as claimed in claim 9, including

a first optical fiber (39) for receiving the electrical signal modulated laser output; and

a second optical fiber (26) for applying the mobile radio channels modulated optical carrier to the converting means (27).

11. A mobile radio microcell transducer arrangement (62) CHARACTERIZED BY

a first antenna (60) for transmitting radio signals including multiplexed mobile radio channels in a first range of frequencies,

a second antenna (61) for receiving radio signals including multiplexed mobile radio channels in a second range of frequencies,

laser means (64), responsive to the received radio signals, for producing an optical carrier modulated by the mobile radio channels in the second range of frequencies,

means (57) for transducing another optical carrier modulated by the mobile radio channels in the first range of frequencies into an electrical signal including the mobile radio channels;

an optical fiber (55), and

means (56) for optical wavelength multiplexing a first optical wavelength ($\lambda_1$) from the optical fiber to the transducing means,

and for wavelength multiplexing a second optical wavelength ($\lambda_2$) from the laser means to the optical fiber.

12. A mobile radio microcell transducer arrangement (72) CHARACTERIZED BY a laser (64);

an antenna (70) for transmitting and receiving radio signals including multiplexed mobile radio channels in different ranges of frequencies,

means (57) for converting an optical carrier modulated with mobile radio channels in a first band of frequencies into an electrical signal to be applied to the antenna,

circulator means (69) for coupling the electrical signal in the first band of frequencies to the antenna for radiating to mobile units and for coupling



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an electrical signal, received in a second band of frequencies from the mobile units through the antenna, to the laser for modulating the optical output with the electrical signal in the second band frequencies,
an optical fiber (55),
and means (M) for wavelength multiplexing a first optical wavelength ($\lambda_1$) from the optical fiber to the converting means, and
for wavelength multiplexing a second optical wavelength ($\lambda_2$) from the laser means to the optical fiber.

13. An arrangement as claimed in any one of claims 9 to 12 wherein, in operation,
the electrical signal applied to the antenna has a combined channel power of ten watts or less.



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FIG. 1

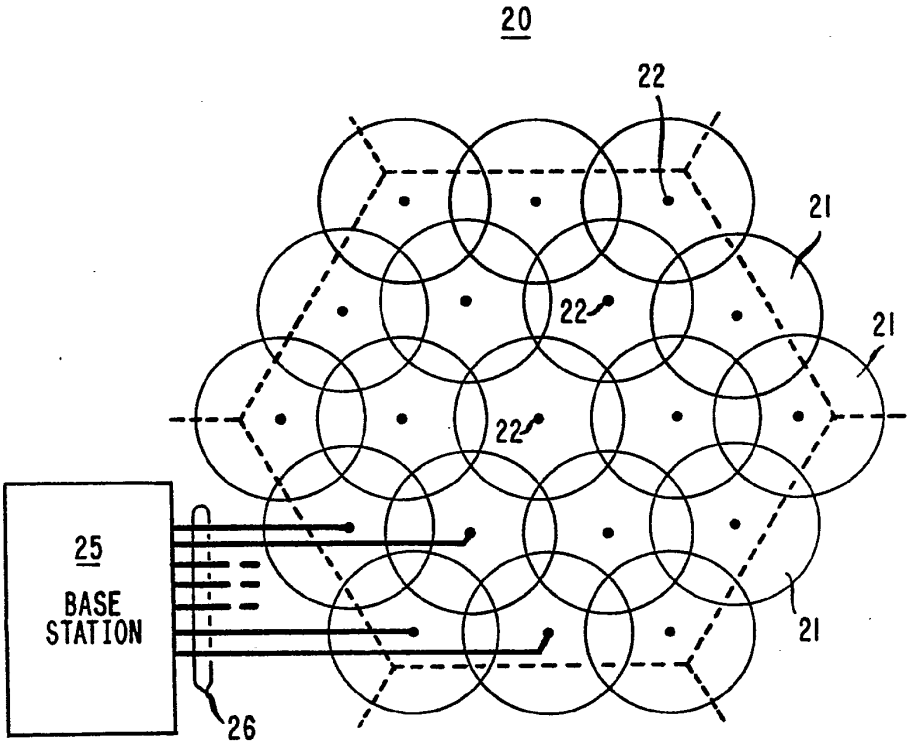


FIG. 2

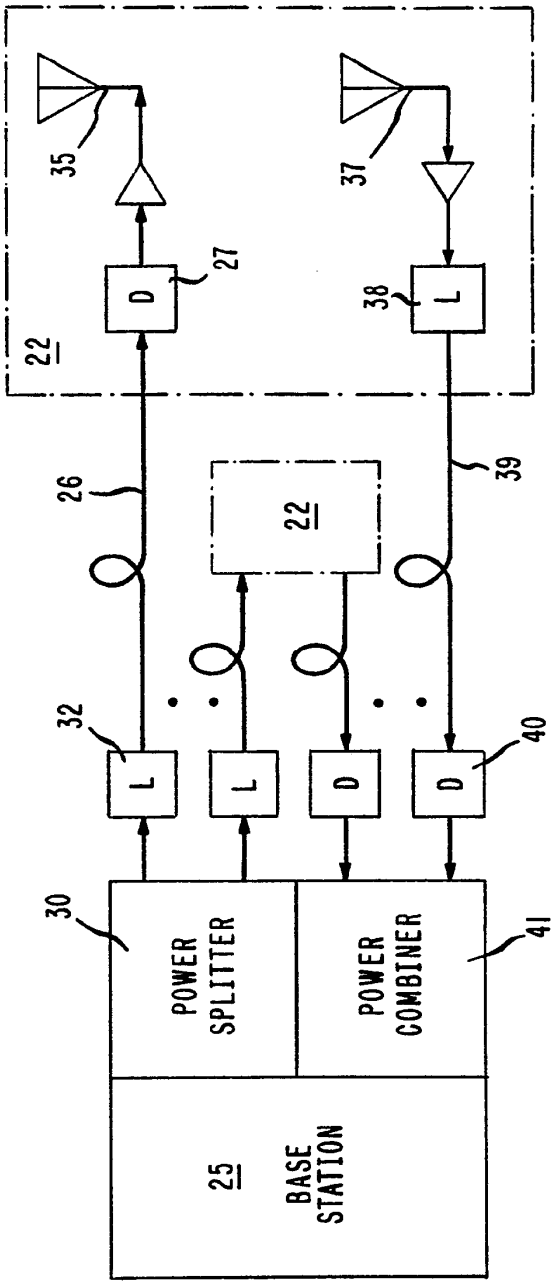

35
37
D
27
38
L
22
26
22
39
32
L
L
D
D
40
30
POWER SPLITTER
POWER COMBINER
41
25
BASE STATION

FIG. 3

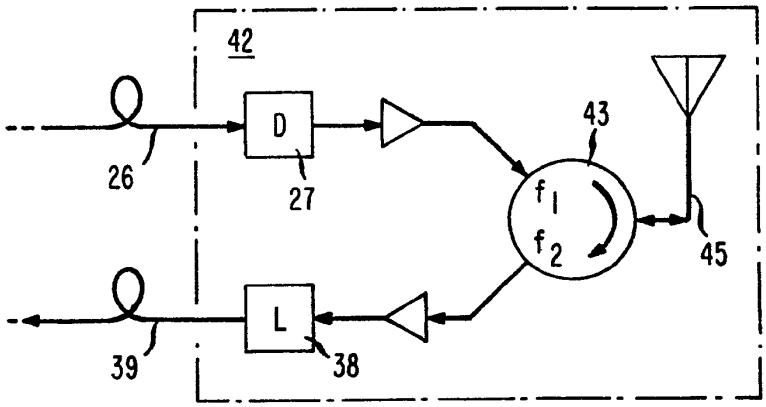
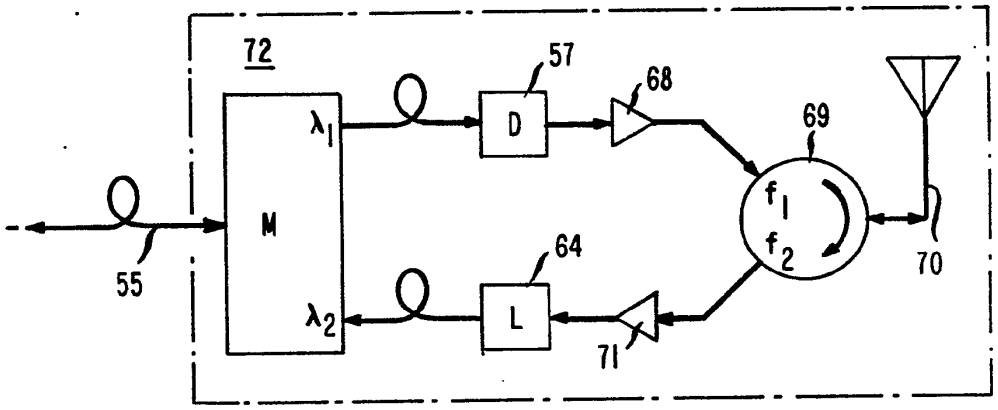

42
D
26
27
43
$f_1$
$f_2$
45
L
39
38

FIG. 5


72
57
68
69
$\lambda_1$
D
$f_1$
$f_2$
70
55
M
64
$\lambda_2$
L
71

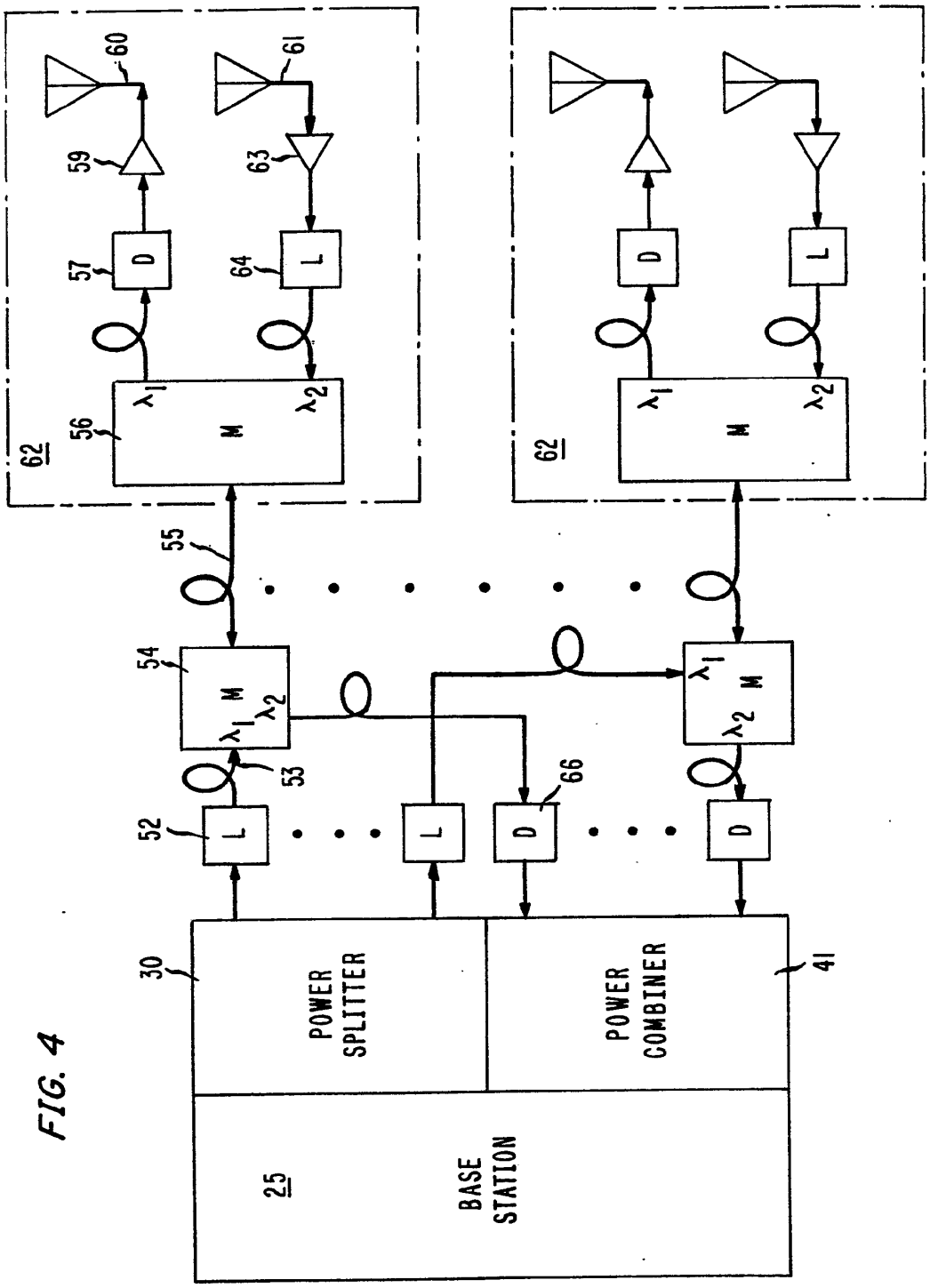

60
61
59
63
57
D
64
L
56
λ1
M
λ2
62
55
54
53
52
66
30
POWER SPLITTER
POWER COMBINER
41
25
BASE STATION

FIG. 4

FIG. 6

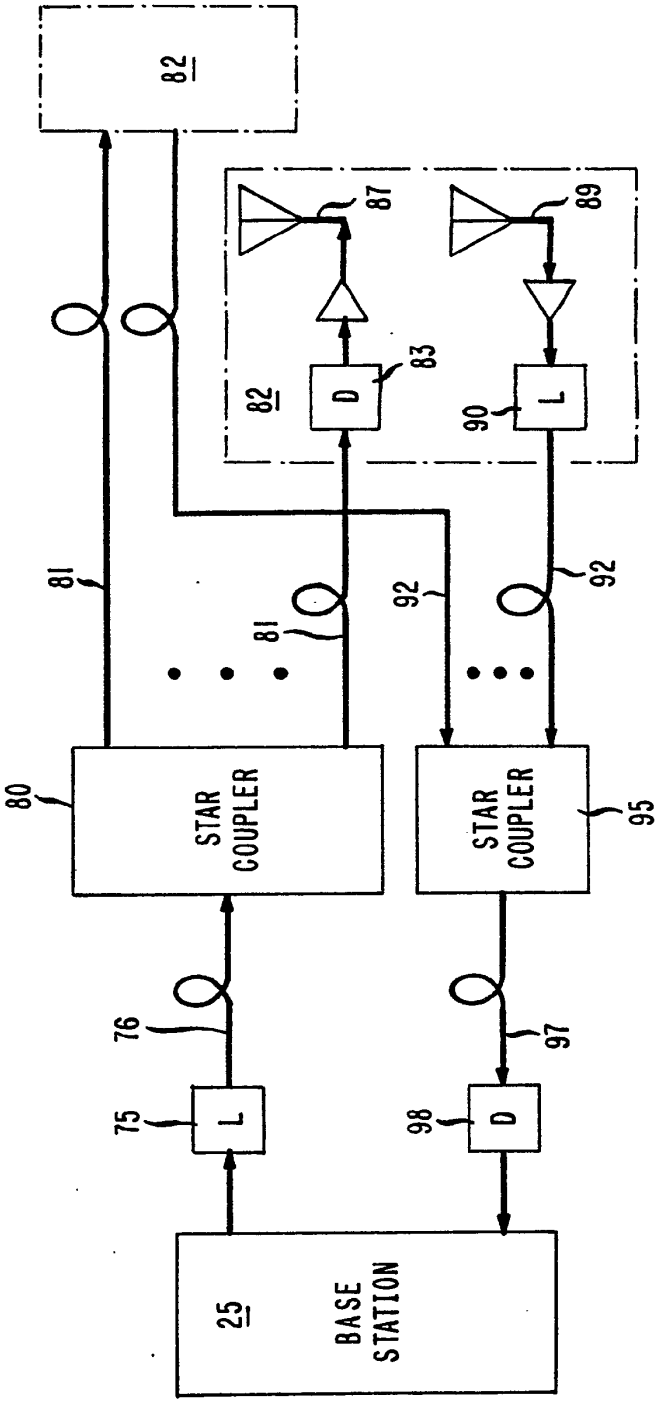
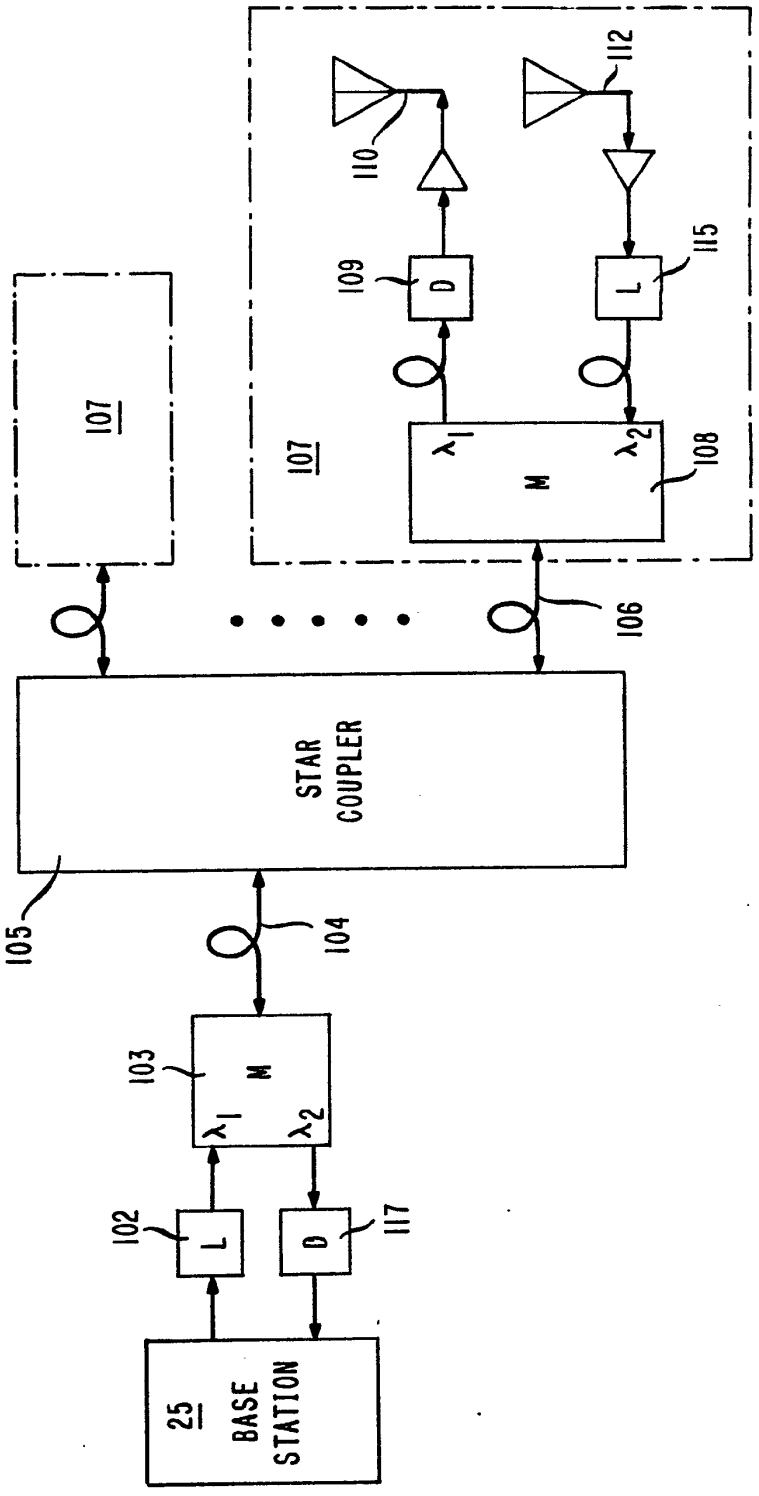

82
87
89
82
83
D
90
L
81
81
92
92
80
STAR COUPLER
STAR COUPLER
95
76
97
75
L
98
D
25
BASE STATION

FIG. 7


25
BASE STATION
102
L
D
117
103
M
λ1
λ2
104
105
STAR COUPLER
106
107
107
109
D
110
112
115
L
108
M
λ1
λ2

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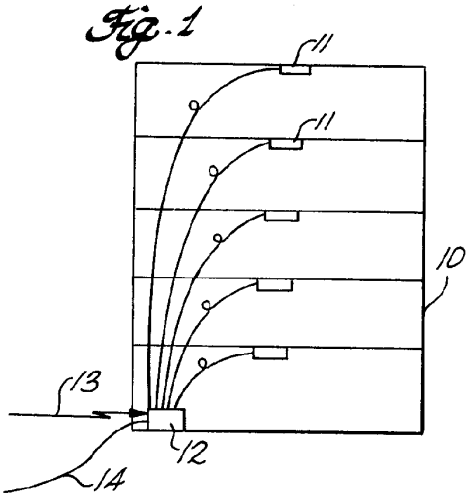
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## (54) Optical fiber RF signal distribution system.

(57) A fiber optic RF signal distribution system has a plurality of antenna stations (11), each station including an RF antenna. A central RF signal distribution hub (12) receives and transmits signals within and external to the system. A pair of optical fibers (28,31) connects each antenna station (11) directly to the distribution hub (12) with the connections being in a star configuration. A connectorized laser module permits direct coupling of a distributed feedback semiconductor laser to the end of each optical fiber (28,31) without an intervening connector. The module accepts an APC connector (29) with the angled end of its optical fiber in an aperture plane in a connector housing (41). A distributed feedback laser (39) is mounted in the connector housing with a lens for illuminating the aperture plane and hence, the end of the fiber at an acute angle to the axis of the fiber. Furthermore, the illumination is defocused at the aperture plane for loose optical coupling to the fiber and minimized reflection to the DFB laser (39).

Fig. 1




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This invention concerns a local area wireless network using optical fibers for distributing signals to and from short range antenna stations. A semiconductor laser is mounted in a connector housing for illuminating the angled end of an optical fiber in a connector for minimized reflection interference. A connectorized photodiode is also used for receiving signals from an optical fiber.

Wireless cellular telephone and similar communication systems have proliferated rapidly and are expected to expand dramatically in numbers of users. Furthermore, whereas present cellular telephone systems have a limited capacity sufficient for voice communications and limited handling of data, much broader band systems are expected for handling vast amounts of information for personal and business communications. New systems are needed for this expanding utilization.

It is common practice to increase the overall system capacity by dividing the system into ever smaller cellular units known as microcells. Optical fibers have heretofore been used to interconnect cellular base stations with large microcells, but it has not been considered cost effective to use fiber optics for smaller microcells. Thus, a low cost optical fiber signal distribution system is desirable for use in such microcells or for local area distribution of other RF signals.

In an RF signal distribution system, an individual building or a campus of buildings might, for example, have numerous short range RF antennas scattered within the building or buildings. Communications from outside this microcell or group of microcells are to and from a base station which is connected to an RF signal distribution hub for the building or buildings. Signals are transmitted and received between the hub and the scattered RF antennas for communicating with telephones or data transceivers within the microcell. Such a local network may also serve as a wireless PBX or LAN for communications within the microcell.

There are a number of advantages to such a system. For example, by handling some of the communication paths in a microcell instead of an entire cell of a cellular system, the capacity of the cell can be increased. The bandwidth that can be used for data transmission can be larger when such local area networks are used. Since a telephone or other portable device needs to communicate only over a short range, its power requirements can be decreased, thereby increasing its battery lifetime.

It is important, however, since a large number of antenna stations are needed in such a microcell, that each of the stations have a low cost. This low cost includes not only the components used, but also the ease of assembling a system with a few standardized devices to keep assembly and installation costs low.

It would be desirable to have a low cost reliable optical fiber system for such an RF signal distribution system for a number of reasons. Optical fibers and the lasers and photodetectors used with them are capable of handling very high data rates at low cost. The attenuation by fibers is very low; negligibly low for in-building distances. The RF levels at the antenna stations are therefore nearly independent of their distance from a distribution hub. Fiber is light, flexible and requires relatively little labor to install. Special electrical shielding is not required for preventing radio interference. Such systems can operate with very high reliability and low power consumption. However, no suitable low cost fiber optic systems or components are known.

There is, therefore, provided in practice of this invention a fiber optic RF signal distribution system for a building, for example, having a plurality of antenna stations distributed through the building, with each antenna station including an RF antenna. A single RF signal distribution hub receives and transmits signals within the system. A pair of optical fibers connects each antenna station directly to the RF signal distribution hub.

A typical RF signal distribution system has an RF signal distribution hub for receiving and transmitting signals external to the system or communicating signals within the system. A plurality of electrical to optical converters at the hub convert received electrical signals to outgoing optical signals. Preferably, such an electrical to optical converter comprises an RF modulated distributed feedback semiconductor laser. Similarly, a number of optical to electrical converters at the hub convert incoming optical signals from an optical fiber to electrical signals for transmission outside or back into the system. Conventional photodiodes are suitable optical to electrical converters.

The RF signal distribution hub communicates with a plurality of antenna stations by optical fibers. Each of the antenna stations has an RF antenna, a photodetector for sensing outgoing optical signals and means for connecting the photodetector to the antenna for broadcasting an outgoing RF signal. For incoming optical signals, each antenna station comprises a laser and means for connecting the antenna to the laser for converting an incoming RF signal to an incoming optical signal.

The electrical signals may be reconverted to an optical signal for transmission external to the RF signal distribution system. Similarly, the external signals may be originally received as optical signals and converted to electrical signals for processing before being reconverted to an optical signal for distribution in the system.

This invention provides a low cost RF signal distribution system having an electrical to optical connector housing for receiving a connector with an angled end of an optical fiber, such as a standard angled physical contact (APC) connector. An RF modulated distributed feedback semiconductor laser is mounted



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in the housing with a lens adjacent to the laser for directing light to an aperture plane in the housing. The laser and the lens are offset from the axis of the housing so that light from the laser passes through the aperture plane at an acute angle relative to the axis of the housing. Furthermore, the laser and lens are spaced so that the area of the aperture plane illuminated by the laser is larger than the end of an optical fiber. An APC connector can be mounted in the housing with the angled end of its optical fiber in the aperture plane for illumination by the laser.

These and other features and advantages of the invention will be appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 illustrates schematically a building having an RF signal distribution hub and fiber optics connected to a number of RF antennas;

FIG. 2 illustrates schematically such a hub connected to antenna stations;

FIG. 3 illustrates schematically an exemplary fiber optic transceiver for use in such a system;

FIG. 4 illustrates schematically a fiber optic antenna station;

FIG. 5 illustrates in perspective an electrical to optical connector housing;

FIG. 6 is a schematic diagram of such an electrical to optical connector housing;

FIG. 7 is a longitudinal cross section through such a connector housing;

FIG. 8 is a transverse cross section through an optical isolator for use in the housing of FIG. 7; and

FIG. 9 is a schematic diagram of a photodiode in a connector housing.

An RF signal distribution system for a multi-floor building 10 has one or more antenna stations 11 distributed through the building. Each of the antenna stations includes an RF antenna for broadcasting signals to and receiving signals from devices within range of the antenna. Such an antenna station is small and unobtrusive, appearing not much different from the smoke detectors which are ubiquitous in homes, offices and hotels. Antenna stations may be located above drop ceilings in business buildings and not be seen at all. Several such antenna stations may be placed on ceilings or walls on each floor of such a building. Alternatively, such short range antenna stations may be located in several adjacent buildings. The building has one or more RF signal distribution hubs 12 for communicating inside or outside the building.

For purposes of this description a convention has been adopted. A "received signal" means a signal received from outside the system. A "transmitted signal" is a signal transmitted to outside the system. An "outgoing signal" refers to a signal transmitted from the RF signal distribution hub to an antenna station or user. An "incoming signal" is a signal transmitted from an antenna to the RF signal distribution hub. The same convention is used, for example, for designating the optical fibers used in the system as "outgoing" or "incoming".

Signals external to the system may be transmitted and received as radio signals 13 as in a cellular network or may be transmitted and received via a fiber optic cable 14 or copper wires 15. The hub also includes an RF interface unit 16 which converts a received signal into an outgoing RF electrical signal at 17 and converts an incoming RF signal at 18 into a transmitted signal for transmission outside the system. The outgoing RF signal is applied to one or more fiber optic transceivers 21 which convert the RF electrical signal to an optical signal. The outgoing RF signal passes through an RF splitter 19 for application to several fiber optic transceivers. Similarly, multiple incoming RF signals from several transceivers are summed in an RF combiner 20.

In the case of signals entirely within the system, i.e. from one antenna station to another antenna station or between two devices within a sector, incoming optical signals are converted to electrical signals via fiber optic transceivers, processed by the RF interface unit, routed by an local area network server or the like (not shown) and returned as outgoing signals to appropriate fiber optic transceivers.

Each fiber optic transceiver serves a sector of the building. Such a sector may be a floor of the building, a suite of offices, a department or the like. Each sector is served by an antenna station 22. A fiber optic cable 23 connects each of the antenna stations with one of the fiber optic transceivers. Each of the fiber optic cables comprises an outgoing optical fiber for conveying an optical signal from the transceiver to the antenna station and an incoming optical fiber for conveying an incoming signal from the antenna station to the receiver. Typically, the cable also includes a DC power supply circuit for operating the antenna station, or the antenna stations may be locally powered.

In some cases it may be more economical to use a combination of fiber optic and coaxial cables for serving a sector. In such a situation one may add antennas 38 to a sector's antenna station 22 by connecting the antennas to a coaxial cable 24 by RF couplers 25.

The antenna stations are connected to the RF signal distribution hub by fiber optic cables arranged in a star configuration. A conventional network may have the stations connected in a loop or "daisy chain" where each station is connected in turn to the next station around the loop. Another common network configuration is tree and branch as is used for cable television signals, for example, where a signal from a central station goes to a remote location where it is



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split into branches for a number of users.

The fiber optic system provided in practice of this invention has a star configuration or hub and spoke. By having each antenna station 22 connected directly to the RF signal distribution hub, it becomes quite easy to install additional antenna stations. For example, a connection need be made only at the antenna station and at the hub. There is a reliability benefit in that if a connector cable or laser is defective, only one antenna station is degraded and the balance of the network is still operable. In the event individual antenna stations become defective, they can be easily identified and replaced.

A star configuration for a fiber optic local area system has several advantages in addition to robustness and reliability. Such a star configuration system is easily installed since identical cabling and connectors can be used between the hub and the distributed RF antenna stations. Furthermore. the optical fiber connections in a star configuration can be simple and all connections can be identical. The attenuation of optical fibers is negligible throughout a building or campus of buildings so that no specific site engineering is required to assure that a system operates properly for a given installation. Such a system is easily expanded or modified. Such a system has low power consumption.

FIG. 3 illustrates schematically an exemplary fiber optic transceiver 21. An outgoing RF signal is applied to an amplifier 26 and semiconductor laser diode 27. The laser is adjacent to the end of an outgoing optical fiber 28 in a conventional angled physical contact (APC) connector 29. An "outgoing" optical fiber carries a signal from the RF signal distribution hub to an antenna station.

An incoming signal arrives at the fiber optic transceiver from an antenna station by way of an incoming optical fiber 31 with a separate connector 32 to the transceiver. A photodiode 33 is adjacent to the end of the incoming optical fiber and is connected to an amplifier 34 which provides an incoming electrical signal to the RF transceivers.

The other end of the outgoing optical fiber 28 has a connector 36 which plugs into an antenna station 22 as illustrated in FIG. 4. An outgoing photodiode 37 is adjacent to the end of the outgoing optical fiber. The photodiode signal is amplified and applied by way of a coupler 40 to an RF antenna 38 from which the signal radiates to cellular devices within range of the antenna.

An incoming RF signal from a cellular device is picked up by the RF antenna, amplified and applied for modulating a semiconductor laser diode 39. The laser diode is adjacent to an angled physical contact (APC) connector 41 for an incoming optical fiber 31 which transmits the incoming optical signal to the fiber optic transceiver.

An important feature for making a low cost reliable fiber optic RF signal distribution system comprises the laser and optical fiber connection. At least one end, and preferably both ends, of each optical fiber in the star configuration includes a conventional APC connector. A typical APC connector has a metal body surrounding a cylindrical ceramic plug through which the end of the optical fiber passes. A threaded nut on the APC connector removably fastens it to a connector housing. The details of the APC connector are not illustrated herein since they are conventional and well known in the art. The ceramic plug of such a connector is illustrated schematically in FIG. 6.

In an APC connector, the end of the optical fiber is flush with the outermost end of the ceramic plug. In conventional use of an APC connector, good optical coupling is provided between the end of the optical fiber and an adjacent similar fiber by physical contact between the ends of the ceramic plugs and hence the ends of the optical fibers. By avoiding an air gap between the fibers, there is good optical coupling. To assure that there is good physical contact between the ends of the optical fibers, the ends of the ceramic plugs are made with a very slight curvature instead of being plane. The curvature has a very large radius so that the end of the fiber is nearly flat. Furthermore, the center of curvature is offset from the axis of the fiber so that there is an acute angle (about 8°) between the axis of the fiber and a radius to the center of curvature. All such connectors have a similar angle so that the contact between the ends of the optical fibers is angled relative to the fibers. This type of construction is the origin of the designation APC, "angled physical contact" connector.

An APC connector is one example of a connector useful in this invention. As will become apparent, other connectors with an angled end on the fiber may also be used. "Angled end" means an end plane which is not normal to the axis of the fiber.

Low cost in the fiber optic RF signal distribution system is achieved by employing a connector housing containing a laser and optical system for direct optical coupling between the laser and a connector with an angled end on the optical fiber that is plugged into the connector housing. Such a housing is illustrated in perspective in FIG. 5.

A typical connector housing for an APC connector has a metal body 41 with laterally extending flanges 42 for bolting the housing to the chassis of the RF signal distribution hub or an antenna station. The outer end of the body is threaded for receiving the nut on a standard APC connector. A slot 43 in the threaded end forms a key way for receiving a raised key on the body of an APC connector for correctly aligning the angled ceramic plug in the connector. A tight fitting split sleeve 44 in the body assures concentricity of the ceramic plug of the connector with the optical system in the connector housing. Such an arrangement for receiving a standard APC connector is conventional.



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The connector housing may have a significantly different exterior. For example, instead of flanges for bolting to a housing, the connector half may have male threads for receiving a nut for fastening to a housing in the same manner as conventional panel mounting connector halves.

As illustrated in FIG. 7, in the connector housing provided in practice of this invention, there is a hollow insert 46 inserted into the body and laser welded to the body. The insert has a passage from its hollow interior to an end referred to herein as an aperture plane 48. A stop surface 49 is immediately adjacent to the perimeter of the passage at the aperture plane. The stop surface engages the end of the ceramic plug (not shown in FIG. 7) of a standard APC connector when it is inserted into the housing. The stop surface assures that the end of the optical fiber in the plug is located very close to the aperture plane. The split sleeve 44 engages an external surface on the insert 46 as well as the ceramic plug to keep the plug concentric with the insert.

A base 51 includes an upstanding sleeve 52 which fits over the outside of the body insert and is secured thereto by a plurality of spot welds or circumferential laser weld 53. As explained hereinafter, this fit between the sleeve and insert are used for adjustment during assembly of the connector housing.

A header 54 is secured in the base 51, typically by press fitting. Four metal pins 56 extend through glass seals in the header for making electrical connections to components inside the connector housing.

A lid 57 is hermetically sealed on the header to form a laser subassembly. A rigid post 58 within the laser subassembly supports a semiconductor laser 59. In the embodiment illustrated in FIG. 7, a photodiode 61 is cantilevered from another post and is directly behind the laser. Other electrical components are formed on a substrate 62 on the rigid post.

Typical electrical connections are illustrated schematically in FIG. 6. The laser is connected to a DC bias by an inductor 63 and is also connected to ground. An RF modulating signal is also connected to the laser by a resistor 64 and capacitor 66. The inductor, capacitor and resistor tend to isolate the RF signal and the DC bias from each other. The DC bias, RF modulating signal and electrical ground use three of the four pins through the header.

The fourth pin may be used for either a photodiode 61 as illustrated in FIG. 7 or a thermistor 67 (FIG. 6). Either of these additional components may be used as desired for a particular application. When a photodiode is used, a portion of light through the back face of the laser illuminates the photodiode. The photodiode output may be used in an external feedback circuit for adjusting the DC bias current for controlling laser performance. Alternatively, a thermistor which is mounted on the bottom of the laser subassembly monitors the temperature of the connector housing. The thermistor signal may be used in an external feedback for controlling temperature or adjusting the DC bias for compensating changes in laser performance as a function of temperature.

The front of the electrical to optical converter module has at least a center portion that is transparent and includes a lens 68. The lens and laser are aligned for appropriately illuminating the aperture plane with light from the laser. The correct positions of the laser and lens are determined during assembly of the laser subassembly. The sequence of assembly of the laser module into the connector housing fixes the least critical positions first and the more critical positions last.

The laser module is assembled first. A laser 59 is mounted on the post 58 in its correct position off of the axis of the header 54. The cover 57 is then hermetically sealed onto the header with the lens coaxial with the header. The header is then pressed into the base 51. A subassembly of insert 46, sleeve 52 and base with laser module is then loosely assembled. The insert and sleeve are welded together at the appropriate telescoped spacing for placing the focus of the light from the laser near, but not in, the aperture plane for the desired illumination of the aperture plane. Finally, the base is positioned so that the lens is in an appropriate position off the axis of the insert and the base is welded to the sleeve.

This insert assembly is then inserted into the body of the connector housing and spot welded in place. This position is not critical since the optical fiber is positioned relative to the insert 46 by the stop surface 49 and split sleeve 44. The angular orientation of the insert subassembly and the body 41 also has a loose tolerance and the position of the pins 56 relative to the slot 43 is adequate for alignment.

Although this sequence of aligning and welding the parts together is preferred, a different sequence could be used. Parts of the connector can be assembled with epoxy bonding or the like instead of welding.

As can be seen by the schematic illustration of FIG. 6, the laser 59 and lens 68 are not aligned with the axis of an optical fiber 69 extending through the ceramic plug 71 of a standard APC connector (indicated schematically). Instead, the laser and lens are offset at an angle that assures that light enters the end of the fiber in an axial direction after refraction at the angled end. It is for this reason that the laser, lens and interconnecting structures are carefully oriented relative to the key way of the connector housing which positions the connector and hence ceramic plug in its correct orientation.

The semiconductor laser used for the low cost RF signal distribution system is preferably a distributed feedback (DFB) laser. DFB lasers are conventional semiconductor devices. Many semiconductor lasers use cleaved output and back facets to obtain the feed-



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back necessary for lasing. Feedback can also be obtained by periodic variations within the lasing cavity. Typically, this is produced by corrugating the interface between two adjacent cladding layers. The periodic ridges and grooves of the corrugated portion form a diffraction grating so that constructive interference due to the grating provides feedback distributed along at least a portion of the cavity length. As a result, the DFB laser has a single longitudinal mode output. The single output frequency (actually a narrow band of frequencies) is determined by the periodicity of the grating.

A DFB laser is preferred in the low cost transceiver system since it has the lowest noise of semiconductor lasers. A DFB laser, however, is more sensitive to external reflections than a Fabry-Perot laser. The optical system in the connector housing is therefore designed to minimize reflections. This design includes non-axial alignment of the laser and lens and "loose coupling" of the light from the laser to the optical fiber.

An angled end on the optical fiber such as provided in an APC connector is employed with the DFB laser so that illumination from the laser is not normal to the end of the ceramic plug and fiber. Thus, specular reflections from the end of the plug and fiber cannot reenter the laser.

The spacings of the laser, lens and aperture plane are fixed during assembly of the connector housing so that light from the laser is deliberately not focused on the aperture plane. The alignment is set so that about three to five percent of the light from the laser actually enters the core of the fiber. This is a result of two effects. One is that with the defocusing of the illumination at the aperture plane, the wave fronts encountering the end of the fiber are somewhat spherical instead of flat. Only the "flat" component of the spherical wavefront successfully traverses the fiber. Secondly, the area of the ceramic plug illuminated is larger than the area of the end of the fiber core and only light that illuminates the end of the fiber core can enter it.

Another way of loosely coupling light from the laser into the fiber would be to have the light from the laser illuminate the angled end of the optical fiber at an angle that is not optimum for refraction into the fiber in the axial direction. Flooding the end of the fiber with light that is not focused at the aperture plane, but which is at the correct angle for refraction into the fiber, is preferable since the proportion of light coupled into the fiber remains substantially unchanged if the fiber is displaced laterally within the illuminated area. Thus, manufacturing and positioning tolerances are significantly relaxed as compared with a device where the laser light is focused on the core of the fiber.

Since only about three to five percent of the light from the DFB laser enters the optical fiber, any reflections or backscattering from the fiber which could reenter the laser have extremely low power levels relative to the power level of the laser. Such loose coupling of the illumination thereby avoids reflections from the fiber that would destabilize the DFB laser.

As an alternative to loose coupling of the laser output and the optical fiber input, one may employ an optical isolator and couple a higher proportion of the laser light into the fiber. Very small dimension and low cost optical isolators are becoming available. Such an optical isolator can be placed in a passage 47 in the insert 46 between the lens and aperture plane of the connector.

Such an optical isolator is illustrated in FIG. 8 and comprises a sandwich of a plane polarizer 72, polarization rotator 73 and another polarizer 74, positioned within a rare earth magnet 76. Each polarizer comprises a thin sheet of glass including a surface layer containing silver dipoles tuned to the wavelength of the light from the laser and stretch oriented for high quality polarization of the light beam. Such a polarizing material is available from Corning as Polacor. The rotator is a garnet type crystal sandwiched between the polarizers. The polarizers are set at 45° with respect to each other in the optical isolator. Other polarizers may also be used.

A light beam from the laser is plane polarized by the first polarizer. The rotator then rotates the plane of polarization 45° so that it is aligned with the second polarizer and readily passes therethrough. Any light reflected back toward the optical isolator passes through the first polarizer and is again rotated 45° by the rotator. This places the plane of polarization of the reflected light 90° from the polarization of the original light beam. When this rotated reflected light beam encounters the second polarizer, its passage is prevented.

It is important to use an angled end on the optical fiber. such as in an APC connector, for the connectorized laser module. When two APC connector halves are connected together, there is essentially no air gap between the ends of the fibers and there is good optical coupling. In addition, there is very low reflection from the fiber connection. When there is an "open" connector where a fiber end has a glass-air interface, reflected light will be coupled back into the fiber if the fiber has an end that is normal to the axis of the fiber. In this case. light that is backscattered from within the fiber or reflected from the far end will be reflected from the near end and interfere with forward travelling light. That is avoided with an angled end on the fiber. The end of a fiber in the connector described herein has a glass-air interface and reflections within the fiber are inhibited by using an angled end face.

It is also desirable to employ an angled end face such as provided by an APC connector half at the output end of an optical fiber. In a low cost system it is also desirable to avoid having both halves of a con-



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nector in use at the output end of the fiber. Instead, one may use a fiber-air interface of an APC connector in combination with a connectorized photodiode. Such an arrangement is illustrated schematically in FIG. 9. Structurally the connector arrangement is similar to what has already been illustrated in FIGS. 5 and 7 and the details are omitted from FIG. 9.

At this output end of the fiber optic cable an optical fiber 169 extends through the ceramic plug 171 of a standard APC connector 81 indicated only as a dashed outline in the drawing. The APC connector is mated with a connectorized photodiode, the housing 82 of which is also indicated schematically in FIG. 9. This connector housing includes a lens 168 positioned close enough to an aperture plane 83 of the housing that light from the optical fiber encounters the lens despite being refracted at an angle from the axis of the fiber because of the angled end on the fiber. Preferably the lens is large enough or positioned close enough to the end of the fiber that the light is incident on a central portion of the lens where optical aberrations are minimized. The lens refocuses the light from the fiber toward the optical axis of the connector.

A photodiode 84 is located on the optical axis in or near the focal plane of the lens. Light from the fiber refracted by the lens is therefore directed onto the photodiode. Precise focusing on the photodiode or exact positioning on the optical axis are not critical. All that is required is that a maximum amount of the light from the fiber actually illuminates the photodiode.

This lack of criticality can be appreciated by recognizing that a connectorized photodiode may be employed without a focusing lens between the end of the fiber and the photodiode. All that would be needed is that the photodiode have a large enough area to receive most or all of the light from the fiber even though the light is off axis. It is preferred, however, to employ a lens instead of a large area photodiode since the capacitance of the photodiode increases with increasing area and such capacitance can limit the high frequency response of the photodiode.

It will be noticed that in a connector arrangement as illustrated in FIG. 9 it is not necessary to angularly orient the APC connector relative to the housing of the connectorized photodiode. A large enough lens can readily be provided on axis for illumination by the light from the fiber regardless of its angular orientation.

As an alternative arrangement. one may provide for angular orientation between the APC connector and the housing of the connectorized photodiode. In such an embodiment a small area photodiode may be placed off axis at a location where it will be illuminated by light from the fiber. Such an off axis photodiode can be a relatively small size for adequate high frequency response.

Thus, a suitable low cost fiber optic signal transmission system may comprise a connectorized laser module as illustrated in FIGS. 5 to 7, an optical fiber having an angled end at each end such as by having an APC connector at each end, and a connectorized photodiode as illustrated in FIG. 9. Thus, each end of the optical fiber has a fiber-air interface, but since both ends are angled relative to the axis of the fiber, reflections do not pose any problems. Such an arrangement is desirable for a number of reasons. Such a fiber optic cable is not "handed". In other words, either end of the cable can be the input or the output. Surplus connector halves can be avoided by reason of the connectorized laser module and connectorized photodiode. The system is low cost since low cost components are used. Installation is easy and does not require highly skilled labor.

Although described for particular utility in an RF signal distribution system, it will be apparent that a connector housing with built-in DFB laser is useful in a number of other applications where a modulated semiconductor laser illuminates an optical fiber. Previously, low reflection laser modules have been constructed which have an optical fiber output. This optical fiber is connected to another optical fiber for long transmission distances by means of an APC connector or the like. Regardless of the excellent transmission characteristics of APC connectors, there is the cost of a pair of such connectors. In effect, applicants have provided a laser module with an output for direct coupling to an optical fiber connector instead of an optical fiber output. This permits connecting the optical fiber directly to the module instead of requiring an additional connector half.

Although described as an RF signal distribution system for communications outside of a system, it will be apparent that a cellular telephone system is merely exemplary of the applications. Such an optical fiber wireless signal distribution system may be used in mobile radio systems for vehicles moving around a warehouse, for example. Because of the broad bandwidth available in a short range system of this sort, it is ideally suited for mobile personal communications. Such a system may also be used as a broadband wireless local area network with or without communication outside of the local area network. Such a system may simply be used as a wireless PBX which permits communication with anyone within range, regardless of their location. Other wireless digital terminal equipment systems will be apparent.

Although the connectors for a fiber optic data transmission system have been described as standard APC connectors. it will be apparent that these are merely exemplary of connectors that may have an angled end on the optical fiber. Thus, in a standard APC connector the end of the fiber is not only angled relative to the axis of the fiber, the ceramic plug and fiber end have a slight curvature so that the ends of adjacent fibers are sure to be in physical contact. Such curvature is not important in practice of this in-



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vention since the ends of the fiber have a fiber-air interface instead of a fiber-fiber interface. A connector with a simple flat diagonal end is equivalent for practice of this invention. A standard APC connector with curvature may, however, be useful so that cables may be standardized and used with conventional connectors as well.

## Claims

1. The fibre optic RF signal distribution system comprising:
   a plurality of distributed antenna stations, each antenna station including an RF antenna and means for converting between optical and electrical signals;
   an RF signal distribution hub for receiving and transmitting optical signals within the system; and
   a pair of optical fibres connecting each antenna station directly to the distribution hub for transmitting signals therebetween.

2. The fibre optic RF signal distribution system according to claim 1 further comprising means for coupling a semiconductor laser directly to a connector on the end of each optical fibre without an intervening connector.

3. The fibre optic RF signal distribution system according to claim 2 wherein the means for coupling a laser comprises:
   a fibre connector having an angled end on the optical fibre;
   a connector housing for receiving the fibre connector;
   means for positioning the angled end of the optical fibre in the fibre connector in an aperture plane in the housing;
   a laser mounted in the connector housing; and
   means for directing illumination from the laser onto the aperture plane at an acute angle to the axis of the optical fibre.

4. The fibre optic RF signal distribution system according to claim 1 further comprising:
   a fibre optic connector housing at the distribution hub for connection to one of the optical fibres for an antenna station, the connector housing comprising:
   a plurality of electrical input pins,
   a semiconductor laser mounted in the housing and connected to the input pins, and
   a socket for receiving an optical fibre connector with the end of an optical fibre in the connector being angled relative to the axis of the fibre and optically aligned with the laser.

5. The fibre optic RF signal distribution system according to claim 1 comprising a connector housing including a laser and a lens between the laser and an aperture plane positioned for receiving the end of the optical fibre of an APC connector, the optical axis of the lens and laser being at an acute angle to the axis of the housing and aligned for illuminating an area of the aperture plane larger than the area of the end of an optical fibre.

6. The fibre optic RF signal distribution system comprising:
   a plurality of antenna stations, each antenna station including an RF antenna;
   an RF signal distribution hub for receiving and transmitting signals within the system;
   a pair of optical fibres connecting each antenna station directly to the distribution hub;
   means at an end of each optical fibre for removably placing the end of the optical fibre in an aperture plane; and
   a semiconductor laser illuminating the aperture plane.

7. The fibre optic RF signal distribution system according to claim 11 wherein the means for placing the end of an optical fibre in an aperture plane comprises an APC connector, and further comprising a lens between the laser and aperture plane for illuminating the aperture plane at an acute angle to the axis of the optical fibre.

8. The fibre optic RF signal distribution system according to claim 11 further comprising:
   means at the opposite end of each optical fibre for removably placing the end of the optical fibre in an aperture plane; and
   a photodetector optically placed for illumination by light from the end of the optical fibre in the aperture plane.

9. The fibre optic RF signal distribution system according to claim 4 comprising an optical system aligned so that the laser is not focused on the aperture plane.

10. The fibre optic RF signal distribution system comprising:
    an RF signal distribution hub for receiving and transmitting signals within the system;
    a plurality of distributed feedback lasers connected to the distribution hub for converting each received electrical signal to an outgoing optical signal;
    a plurality of optical to electrical converters connected to the distribution hub for convert-



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ing an incoming optical signal to a transmitted electrical signal;

a plurality of antenna stations, each antenna station comprising:

an RF antenna,

a photodetector for sensing an outgoing optical signal,

means for connecting the photodetector to the antenna for broadcasting an outgoing RF signal,

a laser, and

means for connecting the antenna to the laser for converting an incoming RF signal to an incoming optical signal;

an outgoing optical fibre connecting each electrical to optical converter to the photodetector of one of the antenna stations; and

an incoming optical fibre connecting the laser of one of the antenna stations to each optical to electrical converter.

**11.** The fibre optic RF signal distribution system according to claim 15 further comprising means for minimizing reflections from the optical fibre back into the laser.

**12.** The fibre optic RF signal distribution system according to claim 16 wherein the means for minimizing reflections comprises means for defocusing the laser at the end of an optical fibre or means for aligning the laser at an acute angle to the axis of the optical fibre.

**13.** The fibre optic RF signal distribution system comprising:

a plurality of distributed antenna stations, each antenna station including an RF antenna and means for converting between optical and electrical signals;

an RF signal distribution hub for receiving and transmitting optical signals within the system; and

a pair of optical fibres connecting each antenna station directly to the distribution hub for transmitting signals therebetween, each optical fibre comprising a connector having an angled end on the optical fibre at each end;

a semiconductor laser adjacent to such a connector at one end of each optical fibre and optically coupled to the end of the fibre via an air-fibre interface; and

a photodiode adjacent a connector having an angled end on the optical fibre at the opposite end of each optical fibre and optically coupled to the end of the fibre via a fibre-air interface.

**14.** The fibre optic connector housing comprising:

a semiconductor laser in the housing;

a lens for directing light from the laser to an aperture plane in the housing, the laser and lens being offset from the axis of the housing so that light from the laser passes through the aperture plane at an acute angle relative to the axis of the housing, the laser and lens being spaced so that the area of the aperture plane illuminated by the laser is larger than the end of an optical fibre;

means for positioning a removable fibre connector in the housing with an end of an optical fibre in the aperture plane;

means in the housing for orientating an angled end of the optical fibre in the removable fibre connector so that illumination from the laser enters the fibre axially; and

means for applying an RF modulating signal to the laser in the housing.

**15.** The fibre optic connector housing according to claim 14 wherein the means for positioning the end of an optical fibre in the aperture plane comprises an axial passage in the housing and a stop surface adjacent the passage for engaging an end of an APC connector around the end of the optical fibre of the connector.

**16.** The fibre optic connector housing according to claim 14 comprising a hermetically sealed module containing the laser, the lens forming a window in the module; and a telescoping mounting between the module and the balance of the housing for adjusting the spacing between the lens and the aperture plane.

**17.** The fibre optic connector housing comprising:

a threaded body;

a key way for aligning a standard APC connector on the body;

a split sleeve centred in the body for receiving the plug of an APC connector;

a stop surface for aligning the end of the plug of a standard APC connector with an aperture plane in the body;

a semiconductor laser mounted in the housing; and

a lens for directing illumination from the laser onto the aperture plane at an acute angle to the axis of the split sleeve.

**18.** The fibre optic connector housing according to claim 17 wherein the laser and lens are spaced so that the area of the aperture plane illuminated by the laser is larger than the end of an optical fibre in an APC connector.

**19.** The fibre optic connector housing according to claim 18 comprising:



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a telescoping mounting for the lens for defocusing illumination from the laser at the aperture plane.

**20.** The fibre optic connector housing comprising:
a semiconductor laser in the housing;
a lens for directing light from the laser to an aperture plane in the housing;
an optical isolator in the optical path between the laser and the aperture plane;
means for positioning a fibre connector in the housing with an end of an optical fibre in the aperture plane; and
means for applying an RF modulating signal to the laser in the housing.

**21.** The fibre optic connector housing according to claim 20 wherein the laser and lens are offset from the axis of the housing so that light from the laser passes through the aperture plane at an acute angle relative to the axis of the housing, and further comprising means in the housing for orientating an angled end of an optical fibre in the fibre connector so that illumination from the laser enters the fibre axially, and stop means adjacent the aperture plane for engaging the fibre connector and locating the end of the optical fibre in the aperture plane.

**22.** The fibre optic invention according to any one of the preceding claims wherein each laser is a distributed feedback laser.

**23.** The fibre optic connector housing comprising:
means for positioning a removable connector with an angled end of an optical fibre in an aperture plane in the housing;
a photodiode axially mounted in the housing;
a lens between the aperture plane and the photodiode and sufficiently close to the aperture plane for directing substantially all of the light from the end of an optical fibre in the aperture plane to the photodiode.

**24.** The fibre optic connector housing comprising:
means for positioning an APC connector with an angled end of an optical fibre in a selected angular orientation in an aperture plane in the housing; and
a photodiode mounted off axis in the connector housing for illumination by light from the angled end of a fibre in the aperture plane.



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Fig. 1

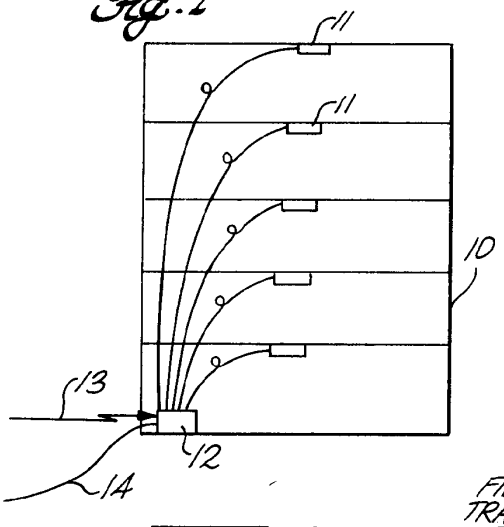



Fig. 3

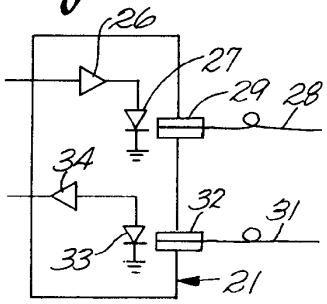



Fig. 2

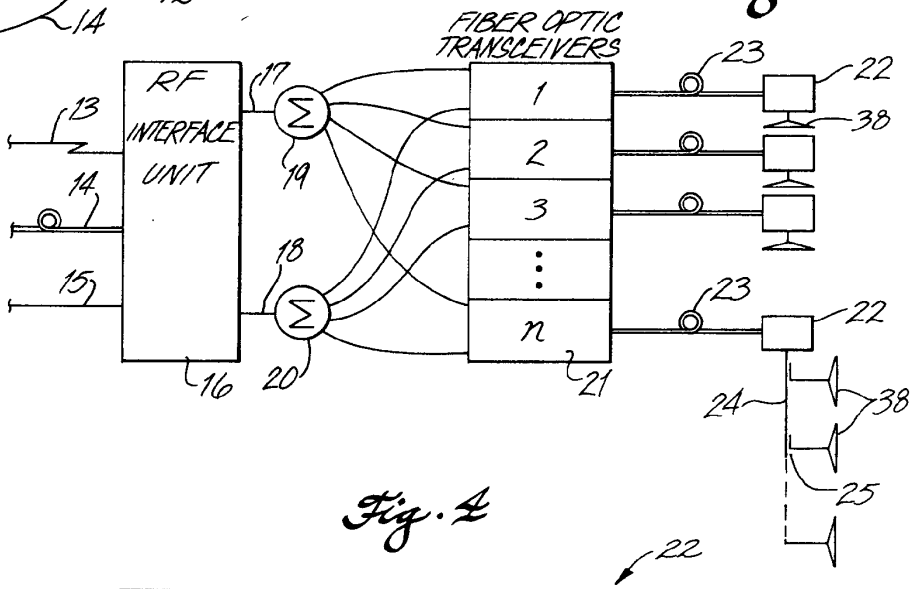
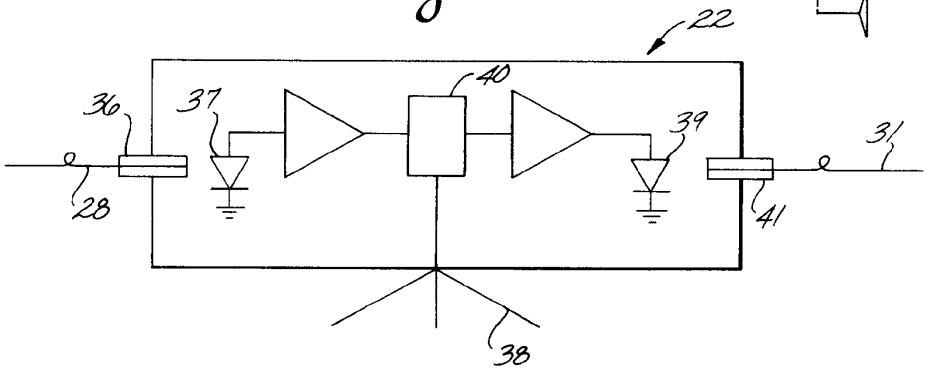


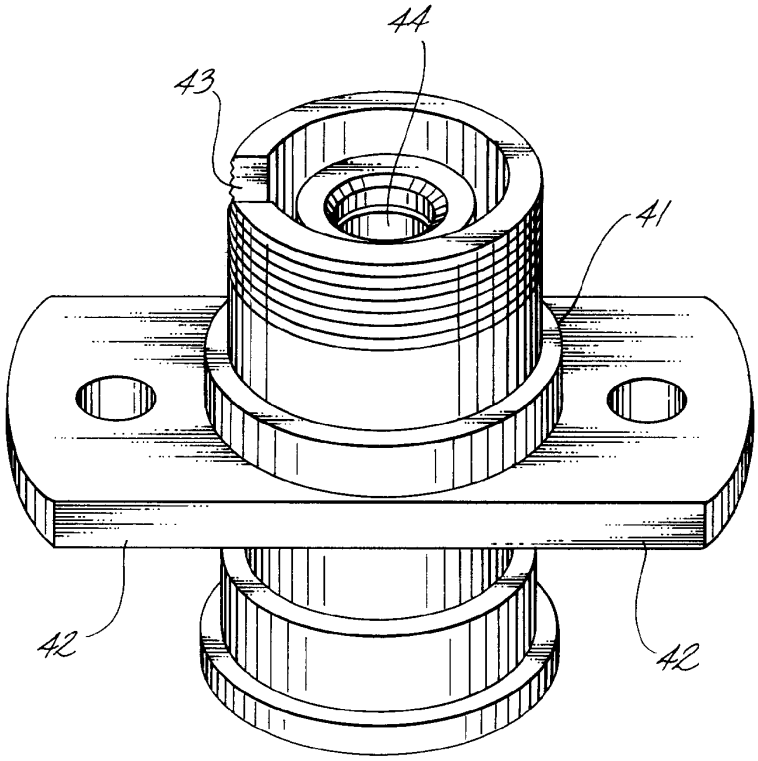

Fig. 4






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Fig. 5






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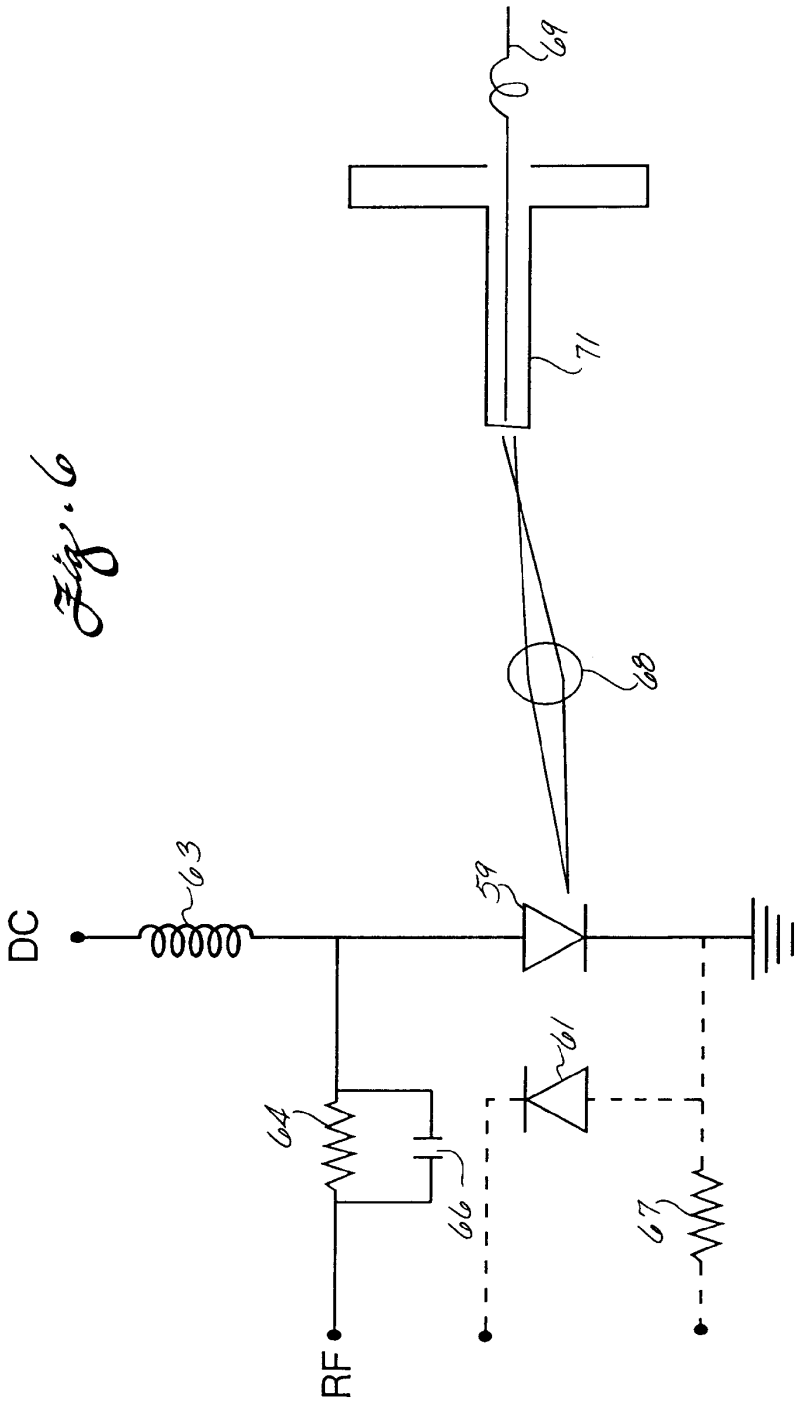
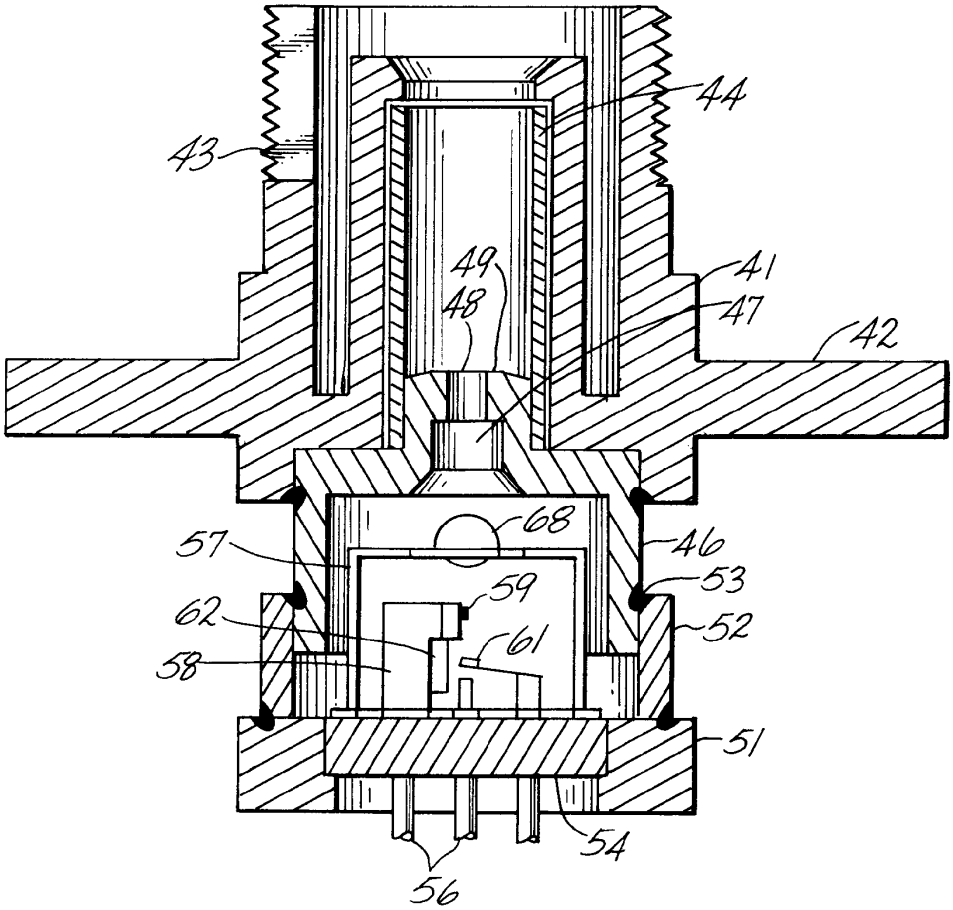



Fig. 6



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Fig.7






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Fig. 8

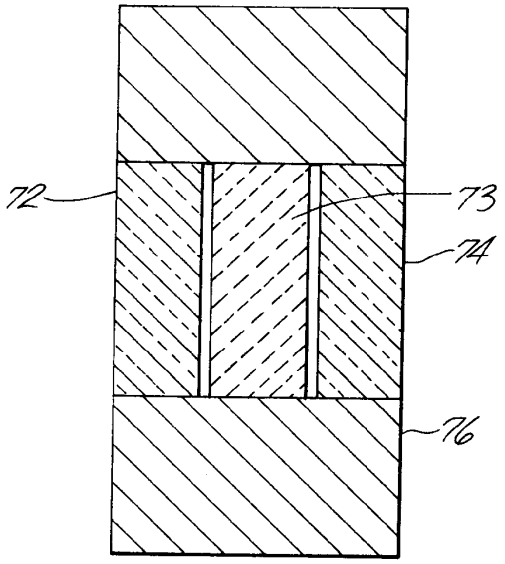
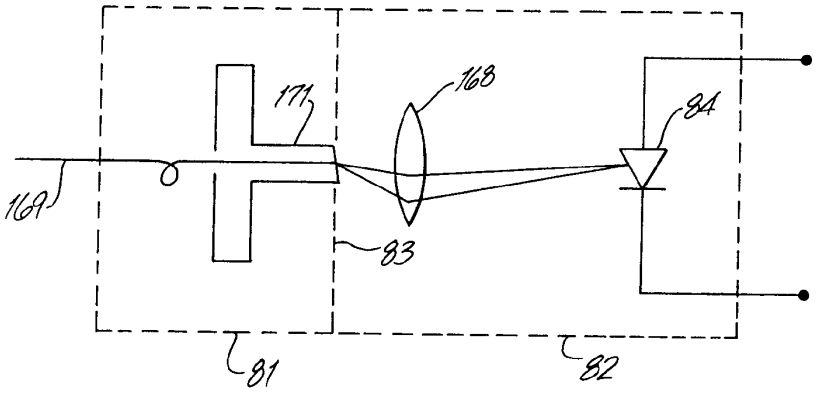



Fig. 9






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# EUROPEAN SEARCH REPORT

Application Number
EP 95 30 0366

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
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| Y | | 2-9, 12-15, 17,18 | TECHNICAL FIELDS SEARCHED (Int.Cl.6) |
| | --- | | H04B G02B |
| X | GB-A-2 184 289 (NEC) * page 2, line 34 - line 43 * * page 3, line 18 - line 34 * | 20 | |
| A | | 2-19, 21-24 | |
| | --- | | |
| Y | OPTICS COMMUNICATIONS, vol.68, no.3, 1 October 1988, NL pages 183 - 186 HILLERICH 'Trade-off between beam truncation and defocussing with taper lenses on single mode fibres' * figure 1 * | 9 | |
| A | | 12,14 | |
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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 13 April 1995 | Williams, M.I. |

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X : particularly relevant if taken alone
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# EUROPEAN SEARCH REPORT

Application Number
EP 95 30 0366

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
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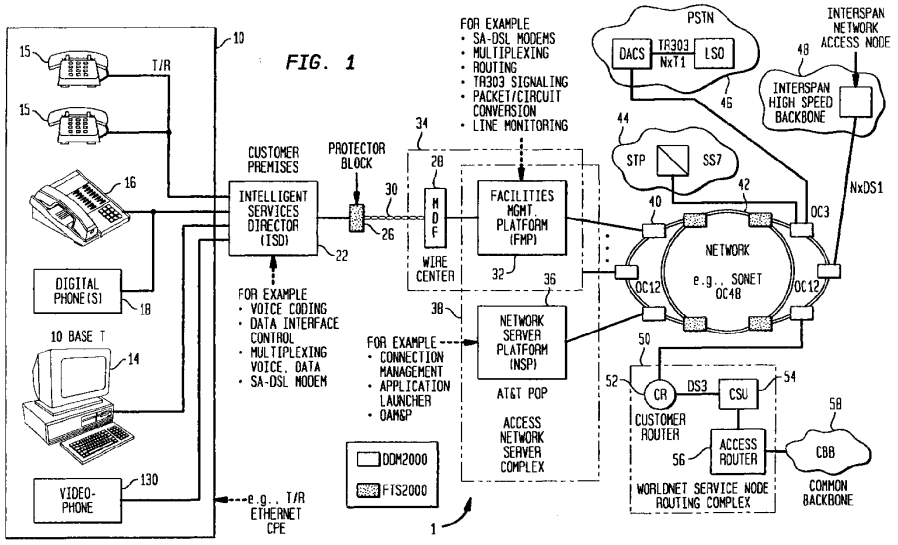
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## (54) Dual-mode telephone for cordless and cellular networks

(57) A cordless telephone network for wirelessly linking with a wireless phone. The cordless telephone network may include a plurality of wireless base stations, the base stations preferrably being disposed at customer premises such as private residences and/or businesses. A wireless phone linked to the cordless telephone network may roam between the wireless base stations and/or between the cordless telephone network and any other wireless network such as a conventional cellular phone network.




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EP 0 876 073 A2

## Description

### Field of the Invention

This invention discloses the a wireless capability for the intelligent services director to interface with a plurality of cordless telephones enabling the range of the cordless telephone to increase by using other user's intelligent services director to act as the base station.

### Background

There is a need for improved architectures, services and equipment utilized to distinguish interexchange companies' products and services. For instance, there exists a need for extending the range of cordless telephones beyond the relatively short distances supported by current cordless base stations. Currently, analog cordless phones typically have a range of up to several hundred feet, and digital cordless phones (e.g., those phones operating in the 900 MHz spectrum) typically have only a slightly longer range capability. Unfortunately, this range may be too short for even short trips away from a cordless base station. Thus, users who are waiting on calls from third parties are restricted to the limited range of the cordless telephone or must use an expensive cellular phone. Furthermore, users often need to provide several telephone numbers to a third party, for instance, one for a residence/office telephone and one for a cellular telephone.

Another problem is that conventional cellular base stations operated by cellular telephone service providers are becoming overloaded as more users purchase cellular phones. To accomodate additional users, either more cellular base stations must be built, or else the operating bandwidth of the cellular base stations must be increased or otherwise used more efficiently. Both of these options are expensive. Also, large cellular base stations may reduce the values of nearby residential properties.

### Summary of the Invention

In order to provide an improved network, it is desirable for the interexchange companies to have access to at least one of the twisted-pair lines or alternate wireless facility connecting each of the individual users to the local telephone network before the lines are routed through the conventional local telephone network equipment. It is preferable to have access to these lines prior to the splitter and modem technology offered by the local service providers. By having access to the twisted-pair wires entering the customer's premises, interexchange companies can differentiate their services by providing higher bandwidth, improving the capabilities of the customer premises equipment, and lowering overall system costs to the customer by providing competitive service alternatives.

The new architecture may utilize a video phone and/or other devices to provide new services to an end user; an intelligent services director (ISD) disposed near the customer's premises for multiplexing and coordinating many digital services onto a single twisted-pair line; a facilities management platform (FMP) disposed in the local telephone network's central office for routing data to an appropriate interexchange company network; and a network server platform (NSP) coupled to the FMP for providing new and innovative services to the customer and for distinguishing services provided by the interexchange companies from those services provided by the local telephone network.

As part of this system, one aspect of the invention provides a way to solve many of the problems associated with the current cordless telephone market. Wireless telephones are known that are capable of operating in both a first radiotelephone communication system including a first base station having a wide area of coverage and in a second radiotelephone communication system including a second base station having a localized area of coverage. See, for example, U.S. Patent No. 5,406,615 to Miller, II et al., entitled, "Multi-Band Wireless Radiotelephone Operative in a Plurality of Air Interface of Difference Wireless Communications Systems," which is hereby incorporated by reference. In the present invention, the intelligent services director may have a wireless interface. A plurality of intelligent services directors having wireless interfaces may define part of a cordless telephone network. Thus, a wireless telephone coupled with this cordless telephone network may roam within the range of the cordless telephone network, which may be considerably longer than a conventional cordless base station.

In further aspects of the invention, a wireless telephone may switch between the cordless telephone network and a conventional cellular network, between various cordless telephone networks, and/or between various conventional cellular networks.

### Brief Description of the Drawings

The foregoing summary of the invention, as well as the following detailed description of preferred embodiments, is better understood when read in conjunction with the accompanying drawings, which are included by way of example, and not by way of limitation with regard to the claimed invention.

Fig. 1 illustrates an embodiment of a hybrid fiber twisted pair local loop architecture.

Fig. 2 is a block diagram of an embodiment of an intelligent services director consistent with the architecture shown in Fig. 1.

Fig. 3A and 3B illustrate an embodiment of a video phone consistent with the architecture shown in Fig. 1.

Fig. 4A is a block diagram of an embodiment of a facilities management platform consistent with the architecture shown in Fig. 1.



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Fig. 4B illustrates a block diagram of an embodiment of a network server platform consistent with the architecture shown in Fig. 1.

Fig. 5 illustrates an embodiments of a wireless telephone capable of linking with a cordless telephone network.

Fig. 6 illustrates an embodiment of a wireless telephone consistent with Fig. 5 linking with a cordless telephone network.

## Detailed Description of Preferred Embodiments

Referring to Fig. 1, a first exemplary communication network architecture employing a hybrid fiber, twisted-pair (HFTP) local loop 1 architecture is shown. An intelligent services director (ISD) 22 may be coupled to a central office 34 via a twisted-pair wire, hybrid fiber interconnection, wireless and/or other customer connection 30, a connector block 26, and/or a main distribution frame (MDF) 28. The ISD 22 and the central or local office 34 may communicate with each other using, for example, framed, time division, frequency-division, synchronous, asynchronous and/or spread spectrum formats, but in exemplary embodiments uses DSL modem technology. The central office 34 preferably includes a facilities management platform (FMP) 32 for processing data exchanged across the customer connection 30. The FMP 32 may be configured to separate the plain old telephone service (POTS) from the remainder of the data on the customer connection 30 using, for example, a tethered virtual radio channel (TVRC) modem (shown in Fig. 4A). The remaining data may be output to a high speed backbone network (e.g., a fiber-optic network) such as an asynchronous transfer mode (ATM) switching network. The analog POTS data may be output directly to a public switch telephone network (PSTN) 46, and/or it may be digitized, routed through the high speed backbone network, and then output to the PSTN 46.

The FMP 32 may process data and/or analog/digitized voice between customer premise equipment (CPE) 10 and any number of networks. For example, the FMP 32 may be interconnected with a synchronous optical network (SONET) 42 for interconnection to any number of additional networks such as an InterSpan backbone 48, the PSTN 46, a public switch switching network (e.g. call setup SS7-type network 44), and/or a network server platform (NSP) 36. Alternatively, the FMP 32 may be directly connected to any of these networks. One or more FMPs 32 may be connected directly to the high speed backbone network (e.g., direct fiber connection with the SONET network 42) or they may be linked via a trunk line (e.g., trunks 40 or 42) to one or more additional networks.

The NSP 36 may provide a massive cache storage for various information that may be provided across the SONET net 42 to the FMP 32 and out to the ISD 22. The NSP 36 and the FMP 32 may collectively define an access network server complex 38. The NSP 36 may be interconnected with multiple FMPs 32. Furthermore, each FMP 32 may interconnect with one or more ISDs 22. The NSP 36 may be located anywhere but is preferably located in a point-of-presence (POP) facility. The NSP 36 may further act as a gateway to, for example, any number of additional services.

The ISD 22 may be interconnected to various devices such as a videophone 130, other digital phones 18, set-top devices, computers, and/or other devices comprising the customer premise equipment 10. The customer premise equipment may individually or collectively serve as a local network computer at the customer site. Application applets may be downloaded from the NSP 36 into some or all of the individual devices within the customer premise equipment 10. Where applets are provided by the NSP 36, the programming of the applets may be updated such that the applets are continually configured to the latest software version by the interexchange carrier. In this way, the CPE 10 may be kept up to date by simply re-loading updated applets. In addition, certain applets may be resident on any of the CPE 10. These resident applets may be periodically reinitialized by simply sending a request from, for example, a digital phone 18 and/or a videophone 130 to the FMP 32 and thereafter to the NSP 36 for reinitialization and downloading of new applets. To ensure widespread availability of the new features made possible by the present architecture, the customer premise equipment may be provided to end users either at a subsidized cost or given away for free, with the cost of the equipment being amortized over the services sold to the user through the equipment.

Referring to Fig. 2, the ISD 22 may connect with a variety of devices including analog and digital voice telephones 15, 18; digital videophones 130, devices for monitoring home security, meter reading devices (not shown), utilities devices/energy management facilities (not shown), facsimile devices 16, personal computers 14, and/or other digital or analog devices. Some or all of these devices may be connected with the ISD 22 via any suitable mechanism such as a single and/or multiple twisted-pair wires and/or a wireless connection. For example, a number of digital devices may be multi-dropped on a single twisted-pair connection. Similarly, analog phones and other analog devices may be multi-dropped using conventional techniques.

The ISD 22 may be located within the home/business or mounted exterior to the home/business. The ISD 22 may operate from electrical power supplied by the local or central office 34 and/or from the customer's power supplied by the customer's power company. Where the ISD 22 includes a modem, it may be desirable to power the ISD 22 with supplemental power from the home in order to provide sufficient power to enable the optimal operation of the modem.

As shown in Fig. 2, in some embodiments the ISD 22 may include a controller 100 which may have any of a variety of elements such as a central processing unit



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102, a DRAM 103, an SRAM 104, a ROM 105 and/or an internet protocol (IP) bridge router 106 connecting the controller 100 to a system bus 111. The system bus 111 may be connected with a variety of network interface devices 110. The network interface devices 110 may be variously configured to include an integrated services digital network (ISDN) interface 113, an Ethernet interface 119 (e.g., for 28.8 kbs data, 56 kbs data, or ISDN), an IEEE 1394 "fire wire" interface 112 (e.g., for a digital videodisc device (DVD)), a TVRC modem interface 114 (e.g., for a digital subscriber line (DSL) modem), a residential interface 114, (e.g., standard POTS phone systems such as tip ring), a business interface 116 (e.g., a T1 line and/or PABX interface), a radio frequency (RF) audio/video interface 120 (e.g., a cable television connection), and a cordless phone interface 123 (e.g., a 900 MHZ transceiver). Connected to one of the network interfaces and/or the system bus 111 may be any number of devices such as an audio interface 122 (e.g., for digital audio, digital telephones, digital audio tape (DAT) recorders/players, music for restaurants, MIDI interface, DVD, etc.), a digital phone 121, a videophone / user interface 130, a television set-top device 131 and/or other devices. Where the network interface is utilized, it may be desirable to use, for example, the IEEE 1394 interface 112 and/or the Ethernet interface 119.

A lifeline 126 may be provided for continuous telephone service in the event of a power failure at the CPE 10. The lifeline 126 may be utilized to connect the ISD 22 to the local telecommunications company's central office 34 and, in particular, to the FMP 32 located in the central office 34.

The ISD may be variously configured to provide any number of suitable services. For example, the ISD 22 may offer high fidelity radio channels by allowing the user to select a particular channel and obtaining a digitized radio channel from a remote location and outputting the digital audio, for example, on audio interface 122, video phone 130, and/or digital phones 121. A digital telephone may be connected to the audio interface 122 such that a user may select any one of a number of digital audio service channels by simply having the user push a digital audio service channel button on the telephone and have the speaker phone output particular channels. The telephone may be preprogramed to provide the digital audio channels at a particular time, such as a wake up call for bedroom mounted telephone, or elsewhere in the house. The user may select any number of services on the video phone and/or other user interface such as a cable set-top device. These services may include any number of suitable services such as weather, headlines in the news, stock quotes, neighborhood community services information, ticket information, restaurant information, service directories (e.g., yellow pages), call conferencing, billing systems, mailing systems, coupons, advertisements, maps, classes, Internet, pay-per-view (PPV), and/or other services using any suitable user interface such as the audio interface 122, the video phone / user interface 130, digital phones, 121 and/or another suitable device such as a settop device 131.

In further embodiments, the ISD 22 may be configured as an IP proxy server such that each of the devices connected to the server utilizes transmission control protocol / internet protocol (TCP/IP) protocol. This configuration allows any device associated with the ISD to access the Internet via an IP connection through the FMP 32. Where the ISD 22 is configured as an IP proxy server, it may accommodate additional devices that do not support the TCP/IP protocol. In this embodiment, the ISD 22 may have a proprietary or conventional interface connecting the ISD 22 to any associated device such as to the set top box 131, the personal computer 14, the video telephone 130, the digital telephone 18, and/or some other end user device.

In still further embodiments, the ISD 22 may be compatible with multicast broadcast services where multicast information is broadcast by a central location and/or other server on one of the networks connected to the FMP 32, e.g., an ATM-switched network. The ISD 22 may download the multicast information via the FMP 32 to any of the devices connected to the ISD 22. The ISD 22 and/or CPE 10 devices may selectively filter the information in accordance with a specific customer user's preferences. For example, one user may select all country music broadcasts on a particular day while another user may select financial information. The ISD 22 and/or any of the CPE 10 devices may also be programmed to store information representing users' preferences and/or the received uni-cast or multicast information in memory or other storage media for later replay. Thus, for example, video clips or movies may be multicast to all customers in the community with certain users being preconfigured to select the desired video clip/ movie in real time for immediate viewing and/or into storage for later viewing.

Referring to Fig. 3A, a videophone 130 may include a touch screen display 141 and soft keys 142 around the perimeter of the display 141. The display may be responsive to touch, pressure, and/or light input. Some or all of the soft keys 142 may be programmable and may vary in function depending upon, for example, the applet being run by the videophone 130. The function of each soft key may be displayed next to the key on the display 141. The functions of the soft keys 142 may also be manually changed by the user by pressing scroll buttons 143. The videophone 140 may also include a handset 144 (which may be connected via a cord or wireless connection to the rest of the videophone and/or directly to the ISD), a keypad 150, a video camera 145, a credit card reader 146, a smart card slot 147, a microphone 149, a motion and/or light detector 148, built-in speaker (s) 155, a printer/scanner/facsimile 152, and/or external speakers 154 (e.g., stereo speakers). A keyboard 153 and/or a postage scale 151 may also be connected to the videophone 130. Any or all of the above-mentioned



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items may be integrated with the videophone unit itself or may be physically separate from the videophone unit. A block diagram of the video phone unit is shown in Fig. 3B. Referring to Fig. 3B, in addition to the items above, the video phone 130 may also include a signal processor 171, high speed interface circuitry 172, memory 173, power supply 174, all interconnected via a controller 170.

When the videophone 130 is used as a video telephone, the display 141 may include one or more video window(s) 160 for viewing a person to whom a user is speaking and/or showing the picture seen by the person on the other end of the video phone. The display may also include a dialed-telephone-number window 161 for displaying the phone number dialed, a virtual keypad 162, virtual buttons 163 for performing various telephone functions, service directory icons 165, a mail icon 164, and/or various other service icons 166 which may be used, for example, for obtaining coupons or connecting with an operator. Any or all of these items may be displayed as virtual buttons and/or graphic icons and may be arranged in any combination. Additionally, any number of other display features may be shown on the video phone in accordance with one or more of the applications incorporated by reference below.

Referring to Fig. 4A, the FMP 32 may coordinate the flow of data packets, separate voice signals from other signals, perform line monitoring and switching functions, and/or convert between analog and digital signals. The FMP 32 may process data sent from the CPE 10 to the central or local office 34 by separating and reconstructing analog voice signals, data, and control frames. The FMP 32 may process data sent from the central or local office 34 to the CPE 10 by separating control messages from user information, and configure this information into segments that for transport across the digital subscriber loop. The FMP 32 may also terminate the link layer associated with the digital subscriber loop.

In some embodiments, the FMP 32 may include an access module 70 and a digital loop carrier 87. The access module 70 may include a line protector 71, a cross-connector 73, a plurality of TVRC modems 80, a plurality of digital filters 82, a controller multiplexer 84, and/or a router and facilities interface 86. The digital loop carrier 87 may include a plurality of line cards 96, a time domain multiplexing (TDM) multiplexor (MUX) 88, a TDM bus 90, a controller 92, and/or a facilities interface 94.

During normal operations, digital signals on the customer connection 30 (e.g., twisted-pair lines) containing both voice and data may be received by the TVRC modems 80 via the line protector 71 and the cross-connector 73. Preferably, the line protector 71 includes lightning blocks for grounding power surges due to lightning or other stray voltage surges. The TVRC modems 80 may send the digital voice and/or data signals to the controller multiplexor 84 and the digital filters 82. The digital filters 82 may separate the voice signals from the digital data signals, and the controller multiplexor 84 may then multiplex the voice signals and/or data signals received from the digital filters 82. The controller multiplexor 84 may then send multiplexed voice signals to the TDM MUX 88 and the data signals to the router and facilities interface 86 for transmission to one or more external networks. The TDM MUX 88 may multiplex the voice signals from the controller multiplexor 84 and/or send the voice signals to the TDM bus 90, which may then send the digital voice signals to the controller 92 and then to the facilities interface 94 for transmission to one or more external networks. Both the router and facilities interface 86 and the facilities interface 94 may convert between electrical signals and optical signals when a fiber optic link is utilized.

When there is a failure of the digital data link (e.g., if there is a failure of the TVRC modems 80 at the FMP 32 or the TVRC modem 114 at the ISD 22), only analog voice signals might be sent over the subscriber lines 30. In such a case, the analog voice signals may be directly routed to the line cards 96, bypassing the TVRC modems 80, the digital filters 82, the controller multiplexor 84, and the TDM MUX 88. Thus, voice communication is ensured despite a failure of the digital data link. The line cards 96 may convert the analog voice signals into digital format (e.g., TDM format) and send the digitized voice data onto the TDM bus 90 and eventually through the controller 92 and the facilities interface 94 for transmission to one or more external networks.

Referring to Fig. 4B, the NSP 36 may be variously configured to provide any number of services provided by a server such as information services, Internet services, pay-per-view movie services, data-base services, commercial services, and/or other suitable services. In the embodiment shown in Fig. 4B, the NSP 36 includes a router 185 having a backbone 180 (e.g., a fiber distributed data interface (FDDI) backbone) that interconnects a management server 182, an information/database server 183, and/or one or more application server clusters 184. The NSP 36 may be connected via the router 185 by a link 181 to one or more external networks, NSPs 36, and/or an FMPs 32. The information/data base server 183 may perform storage and/or database functions. The application server cluster 184 may maintain and control the downloading of applets to the ISD 22. The NSP 36 may also include a voice/call processor 186 configured to handle call and data routing functions, set-up functions, distributed operating system functions, voice recognition functions for spoken commands input from any of the ISD connected devices as well as other functions.

Referring to Fig. 5, a wireless phone 300 may be linked with an ISD 22 via the cordless interface 123 in the ISD 22. The wireless phone 300 may be used in conjunction with any of the features and/or functions described in any other type of communication device that may be connected to the ISD 22 as described in the applications incorporated herein by reference. The wire-



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less phone 300 may include a speaker 301, a microphone 302, a keypad 307, a display 303 or other similar indicator(s), a global positioning device 310 (or any other type of self-locating device) and/or an antenna 308 or other wireless linking device such as a microwave transmitter/receiver. The display 303 may serve several functions, including displaying a telephone number and/or other data such as signal strengths. Furthermore, the display 303 may show a signal strength meter 304 for indicating signal strength associated with a cordless phone network, a signal strength meter 305 for indicating signal strength associated with a conventional cellular network or other wireless network, and/or a network indicator 306 for indicating to which type of network the wireless phone 300 is linked. Any or all of the meters and/or indicators may be separate elements on the wireless phone 300 and/or part of the display 303. Furthermore, one or more of the meters and/or indicators may be combined. The wireless phone 300 may also include a switch 309 for allowing a user to manually switch between a cordless phone network and another system such as a conventional cellular network. The switch 309 may alternatively be a function accessible via a menu system in the display 303. The switch 309 may be toggled to one network or the other, and/or may be use to initiate a network search mode for finding the strongest network of a certain type or of any type.

Referring to Fig. 6, a cordless phone network 430 may include a plurality of network interface units (NIUs) 403 (e.g., the NIUs 403 located at Residences 1 and 2 in Fig. 6) and/or some or all of another network such as a public telephone network 402. An NUI 403 is preferrably located at a customer premise such as a private residence and/or a business. One or more of the NIUs 403 may include one or more ISDs 22. The ISDs 22 may be coupled to the public telephone network 402 and/or may function as wireless base stations for the cordless telephone network 430. The public telephone network 402 may include and/or be coupled with the FMP 32, the NSP 36, the network 42, and/or any other network devices and/or service providers. A conventional cellular system and/or other type of wireless communication system may be coupled with the public telephone network 402. In the embodiment of Fig. 6, a conventional cellular network is shown including a mobile switching center (MSC) 403 and a plurality of base stations 400 having associated cellular base antennas 401.

The wireless phone 300 may be associated with a home ISD 22, however, the wireless phone 300 may wirelessly link with and/or roam between one or more of a plurality of ISDs 22 (including the home ISD 22) and/or base station cellular antennas 401 in any combination using any set of frequencies. Thus, the wireless phone 300 may function as a universal wireless phone having the combined features of a conventional cellular phone and a conventional cordless phone, plus other advanced features as described hereinbelow. Preferably, the wireless phone 300 may link with an ISD 22 using frequencies that are different from those frequencies used to link with a base station cellular antenna 401. The wireless phone 300 may link with an ISD 22 using conventional cordless phone communications or any other communications standards. In preferred embodiments, the wireless phone 300 may link with an ISD 22 using fequencies around the 900 MHz range. However, the frequencies that may be used in the present invention are not limited to this or to any other range. Furthermore, the wireless phone 300, the ISDs 22, the public telephone network 402, the MSC 403, the base stations 400, and/or the cellular antennas 401 may monitor wireless signal strength between the wireless phone 300 and one or more of the ISDs 22 and/or cellular antennas 401. The signal strength of many possible wireless links with many cellular antennas 401 and/or ISDs 22 may be simultaneously monitored, even if the wireless phone 300 is not actually linked with them. Based on the relative signal strengths, the wireless phone 300 may switch between wireless links with various cellular antennas 401 and/or ISDs 22.

The wireless phone 300 may travel between various locations, roaming between communication systems, ISDs 22, and/or cellular antennas 401 as required. For instance, the wireless phone 300 may start at point A (shown in Fig. 6). In some embodiments, the wireless phone 300 at point A may be wirelessly linked with, for example, the ISD 22 at residence 2 (shown as wireless link 450). Upon moving to point B, the wireless phone may roam to a wireless link with the ISD 22 at residence 1 (shown as wireless link 451). In further embodiments, the wireless phone 300 at point A may be linked with the ISD 22 at residence 2, and at point B it may roam to a link with the cellular antenna 401 associated with base station #3 400 (shown as wireless link 453). In still further embodiments, the wireless phone 300 at point A may be linked with the cellular antenna 401 associated with base station #1 400 (shown as wireless link 452), and at point B it may roam to a link with the cellular antenna 401 associated with base station #3 400. In still further embodiments, the wireless phone 300 at point A may be linked with the cellular antenna 401 associated with base station #1 400, and at point B it may roam to a link with the ISD 22 at residence 1.

In some embodiments, the wireless phone 300 may be registered with the home ISD 22 and/or one or more other ISDs 22. When a wireless phone 300 is registered with an ISD 22, the wireless phone 300 may send an identification code identifying the wireless phone 300 and/or other data such as a personal identification number (PIN) for security, the date, and/or the time. This identification code and/or other data sent by the wireless phone 300 may be used by an ISD 22 to recognize and/or establish a wireless link with the wireless phone 300. In further embodiments, an ISD 22 linked with the wireless phone 300 but not having registration information associated with the wireless phone 300 may send messages to the FMP 32. The FMP 32 may then download



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call support information to other third party ISDs 22 supported by the FMP 32 and/or other FMPs 32. Thus, another ISD 22 that may have registration information associated with the wireless phone may feed the registration information to the ISD 22 linked with the wireless phone 300. In further embodiments, the wireless phone may be registered with the public telephone network 402, the MSC 403, and/or one or more base stations 400. In these further embodiments, the public telephone network 402, the MSC 403, and/or one or more base stations 400 may use the identification code and/or other data sent by the wireless phone 300 to recognize and/or establish a wireless link with the wireless phone 300.

In still further embodiments, the wireless phone 300 may communicate with an ISD 22 using encryption. This encryption may serve to hinder tampering with the ISD 22 for the purposes of intercepting communications between the wireless phone 300 and the ISD 22.

In operation, when the wireless telephone 300 handles a telephone call, a first ISD 22 (e.g., using the cordless interface 123) and/or the wireless phone 300 may sense the signal strength of the wireless link with the wireless phone 300. The wireless phone 300 may send a signal periodically for indicating and/or measuring signal strength. If that signal decreases below a predetermined quality level, a message may be sent to the FMP 32 When the signal strength decreases below a predetermined service quality level, the first ISD 22 may send a message to the FMP 32 to which it is connected. The FMP 32 and/or any other portion of the public telephone network 402 may determine channels that are available on the twisted pairs 30 between the FMP 32 and the various ISDs 22 connected to the FMP 32. If an available channel exists between the FMP 32 and a second ISD 22, a query message may be sent to that ISD 22 as to whether the wireless phone 300 is detected by that particular ISD 22. If that ISD 22 senses a signal strength greater than the signal strength associated with the link supporting on the current call, the call may be handed off to the second ISD 22. This process may also occur between FMPs 32 and/or between the public telephone network 402 and the MSC 403 (or any other telephone network). Thus, the wireless phone 300 may roam directly between ISDs 22 connected to different FMPs 32. Furthermore, this process may continue until the call is out of range of any ISD 22 and/or the call terminates. The same process may occur even when no call is being handled, in which case the wireless phone 300 may be in a standby mode, waiting to receive and/or transmit calls.

In further embodiments, the wireless phone may transmit its location using a position-locating system such as the global positioning system device 310. In such a case, the wireless phone 300 may transmit data, either automatically or in reponse to a query from an ISD 22 and/or the public telephone network 402, representing the geographic location of the wireless phone 300. The public telephone network 402 may use this data, in conjunction with a database containing locations of ISDs 22, to determine which ISD 22 is closest to the wireless phone 300. The wireless phone 300 may be caused to roam between various wireless links based upon which ISD 22 is found to be closest to the wireless phone 300.

The wireless phone 300 may also roam between a wireless link with an ISD 22 and a link with another communication system such as a conventional cellular network. This may be useful, for instance, when the wireless phone 300 moves out of wireless range from any ISD 22 (e.g., in a rural area), since ISDs 22 of the cordless telephone network 430 may individually have a smaller operating distance range than the cellular antennas of a conventional cellular network. In some embodiments, the wireless phone 300 may prefer a particular communication system. For example, the wireless phone 300 may automatically (or via manual control by the user of the switch 309) give priority to a link with the cordless phone network 430 over a link with a conventional cellular phone network. In further embodiments, the wireless phone 300 may give preference to the home ISD 22 over any other ISD 22.

In further embodiments, the wireless phone 300 may accept user identification data input by a user (e.g., via the keypad 307). This user identification data may identify a particular user who is using the wireless phone 300. The wireless phone 300 may pass this user identification data on to, for instance, the public telephone network 402. The public telephone network 402 may use the user identification data to bill a call by that user to that user's telephone account.

The following applications, filed concurrently herewith, are hereby incorporated by reference:

1. A Hybrid Fiber Twisted-pair Local Loop Network Service Architecture (Gerszberg 41-3-13);
2. Dynamic Bandwidth Allocation for use in the Hybrid Fiber Twisted-pair Local Loop Network Service Architecture (Gerszberg 42-4-14);
3. The VideoPhone (Gerszberg 43-9-2);
4. VideoPhone Privacy Activator (Gerszberg 44-10-3);
5. VideoPhone Form Factor (Gerszberg 45-11-4);
6. VideoPhone Centrally Controlled User Interface With User Selectable Options (Gerszberg 46-12-5);
7. VideoPhone User Interface Having Multiple Menu Hierarchies (Gerszberg 47-13-6);
8. VideoPhone Blocker (Gerszberg 79-38-26);
9. VideoPhone Inter-com For Extension Phones (Gerszberg 48-14-7);
10. Advertising Screen Saver (53-17);
11. VideoPhone FlexiView Advertising (Gerszberg 49-15-8);
12. VideoPhone Multimedia Announcement Answering Machine (Gerszberg 73-32-20);
13. VideoPhone Multimedia Announcement Message Toolkit (Gerszberg 74-33-21);



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14. VideoPhone Multimedia Video Message Reception (Gerszberg 75-34-22);
15. VideoPhone Multimedia Interactive Corporate Menu Answering Machine Announcement (Gerszberg 76-35-23);
16. VideoPhone Multimedia Interactive On-Hold Information Menus (Gerszberg 77-36-24);
17. VideoPhone Advertisement When Calling Video Non-enabled VideoPhone Users (Gerszberg 78-37-25);
18. Motion Detection Advertising (Gerszberg 54-18-10);
19. Interactive Commercials (Gerszberg 55-19);
20. VideoPhone Electronic Catalogue Service (Gerszberg 50-16-9);
21. A Facilities Management Platform For Hybrid Fiber Twisted-pair Local Loop Network, Service Architecture (Barzegar 18-56-17);
22. Multiple Service Access on Single Twisted-pair (Barzegar (16-51-15);
23. Life Line Support for Multiple Service Access on Single Twisted-pair (Barzegar 17-52-16);
24. A Network Server Platform (NSP) For a Hybrid Fiber Twisted-pair (HFTP) Local Loop Network Service Architecture (Gerszberg 57-4-2-2-4);
25. A Communication Server Apparatus For Interactive Commercial Service (Gerszberg 58-20-11);
26. NSP Multicast, PPV Server (Gerszberg 59-21-12);
27. NSP Internet, JAVA Server and VideoPhone Application Server (Gerszberg 60-5-3-22-18);
28. NSP WAN Interconnectivity Services for Corporate Telecommuters (Gerszberg 71-9-7-4-21-6);
29. NSP Telephone Directory White-Yellow Page Services (Gerszberg 61-6-4-23-19);
30. NSP Integrated Billing System For NSP services and Telephone services (Gerszberg 62-7-5-24-20);
31. Network Server Platform / Facility Management Platform Caching Server (Gerszberg 63-8-6-3-5);
32. An Integrated Services Director (ISD) For HFTP Local Loop Network Service Architecture (Gerszberg 72-36-22-12);
33. ISD and VideoPhone Customer Premise Network (Gerszberg 64-25-34-13-5);
34. ISD Wireless Network (Gerszberg 65-26-35-14-6);
35. ISD Controlled Set-Top Box (Gerszberg 66-27-15-7);
36. Integrated Remote Control and Phone (Gerszberg 67-28-16-8);
37. Integrated Remote Control and Phone User Interface (Gerszberg 68-29-17-9);
38. Integrated Remote Control and Phone Form Factor (Gerszberg 69-30-18-10) ;
39. VideoPhone Mail Machine (Attorney Docket No. 3493.73170);
40. Restaurant Ordering Via VideoPhone (Attorney Docket No. 3493.73171);
41. Ticket Ordering Via VideoPhone (Attorney Docket No. 3493.73712);
42. Multi-Channel Parallel/Serial Concatenated Convolutional Codes And Trellis Coded Modulation Encode/Decoder (Gelblum 4-3);
43. Spread Spectrum Bit Allocation Algorithm (Shively 19-2);
44. Digital Channelizer With Arbitrary Output Frequency (Helms 5-3);
45. Method And Apparatus For Allocating Data Via Discrete Multiple Tones (filed 12/22/97, Attorney Docket No. 3493.20096--Sankaranarayanan 1-1);
46. Method And Apparatus For Reducing Near-End Cross Talk In Discrete Multi-Tone Modulators/Demodulators (filed 12/22/97, Attorney Docket No. 3493.37219--Helms 4-32-18).

In addition, the following two patent applications are hereby incorporated by reference:

1. U.S. Patent Application 08/943,312 filed October 14, 1997 entitled Wideband Communication System for the Home, to Robert R. Miller, II and Jesse E. Russell, and
2. U.S. Patent Application No. 08/858,170, filed May 14, 1997, entitled Wide Band Transmission Through Wire, to Robert R. Miller, II, Jesse E. Russell and and Richard R. Shively.

**Claims**

1. A phone characterized in that the phone is configured to roam between a plurality customer premise base stations utilizing at a first set of frequencies and a plurality of cellular base stations utilizing a second set of frequencies different from the first set of frequencies.

2. The phone of claim 1 further characterized in that the first set of frequencies includes frequencies of about 900 MHZ.

3. The phone of claim 2 further characterized in that the phone includes a 900 MHZ signal strength meter.

4. The phone of any of the preceding claims further characterized in that the phone includes a locating device for determining a location of the phone.

5. The phone of any of the preceding claims further characterized in that the phone includes a switch for switching between the plurality of customer premise base stations and the plurality of cellular base stations.



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6. The phone of any of the preceding claims further characterized in that at least one of the customer premise base stations includes a network interface unit having a wireless interface, the network interface unit being located at a customer premise and being connected to a telephone network via a high speed modem.

7. The phone of any of the preceding claims further characterized in that the phone links with at least one of the plurality of customer premise base stations and the plurality of cellular base stations responsive to a signal strength between the phone and at least one of the plurality of customer premise base stations and the plurality of cellular base stations.

8. The phone of any of the preceding claims further characterized in that the phone links with at least one of the plurality of customer premise base stations and the plurality of cellular base stations responsive to a location of the phone.

9. A method for communicating using a phone, the method characterized by roaming between a plurality customer premise base stations utilizing at a first set of frequencies and a plurality of cellular base stations utilizing a second set of frequencies different from the first set of frequencies.

10. The method of claim 9 further characterized in that the first set of frequencies includes frequencies of about 900 MHZ.

11. The method of claim 10 further characterized in that the method includes displaying a 900 MHZ signal strength on a meter disposed on the phone.

12. The method of any of the preceding claims further characterized in that the method includes locating the phone using a locating device disposed in the phone.

13. The method of any of the preceding claims further characterized in that the method includes switching between the plurality of customer premise base stations and the plurality of cellular base stations using a switch disposed in the phone.

14. The phone of any of the preceding claims further characterized in that the method includes linking with at least one of the plurality of customer premise base stations and the plurality of cellular base stations responsive to a signal strength between the phone and at least one of the plurality of customer premise base stations and the plurality of cellular base stations.

15. The method of any of the preceding claims further characterized in that the method includes linking with at least one of the plurality of customer premise base stations and the plurality of cellular base stations responsive to a location of the phone.



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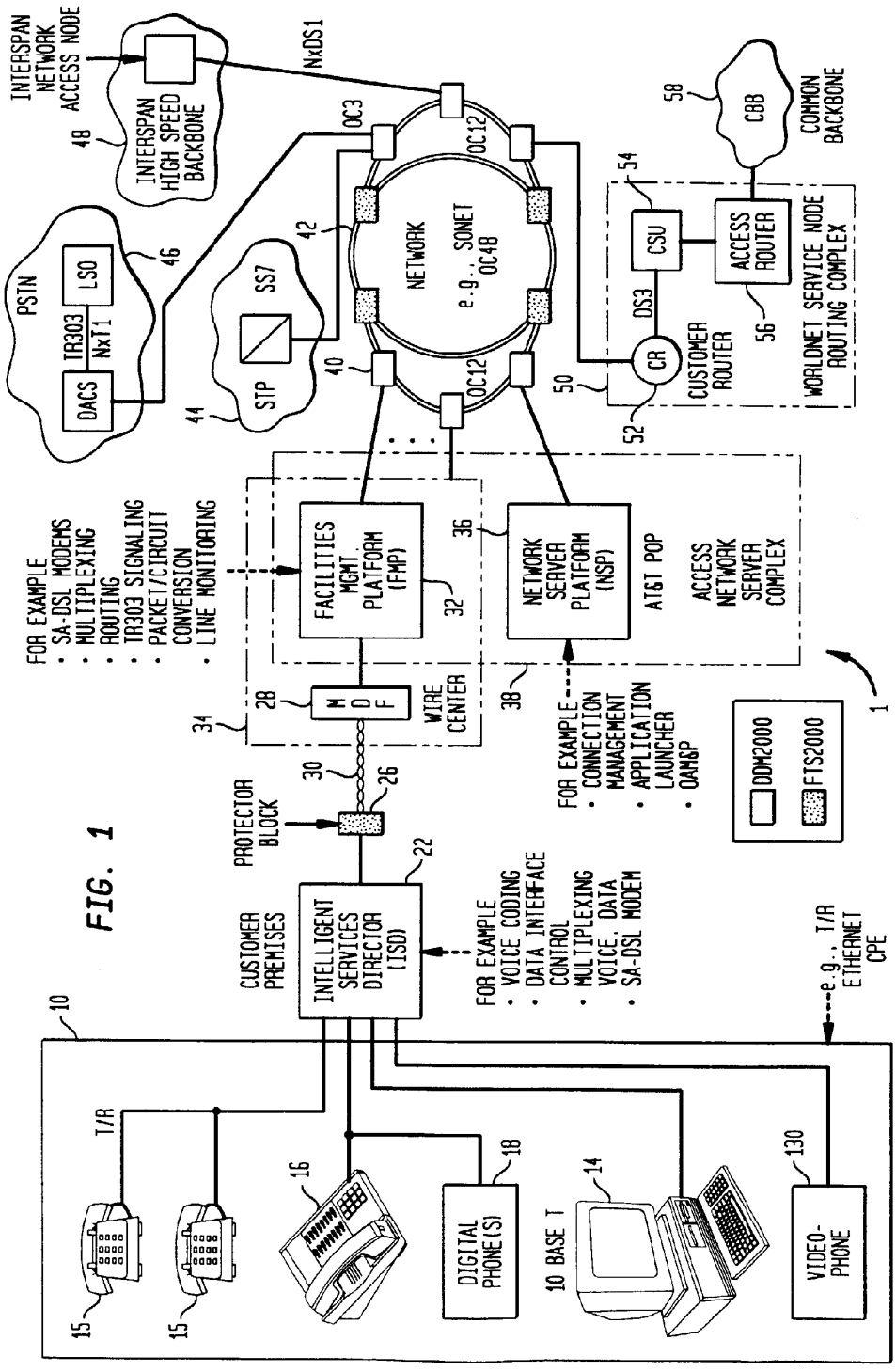



FIG. 1



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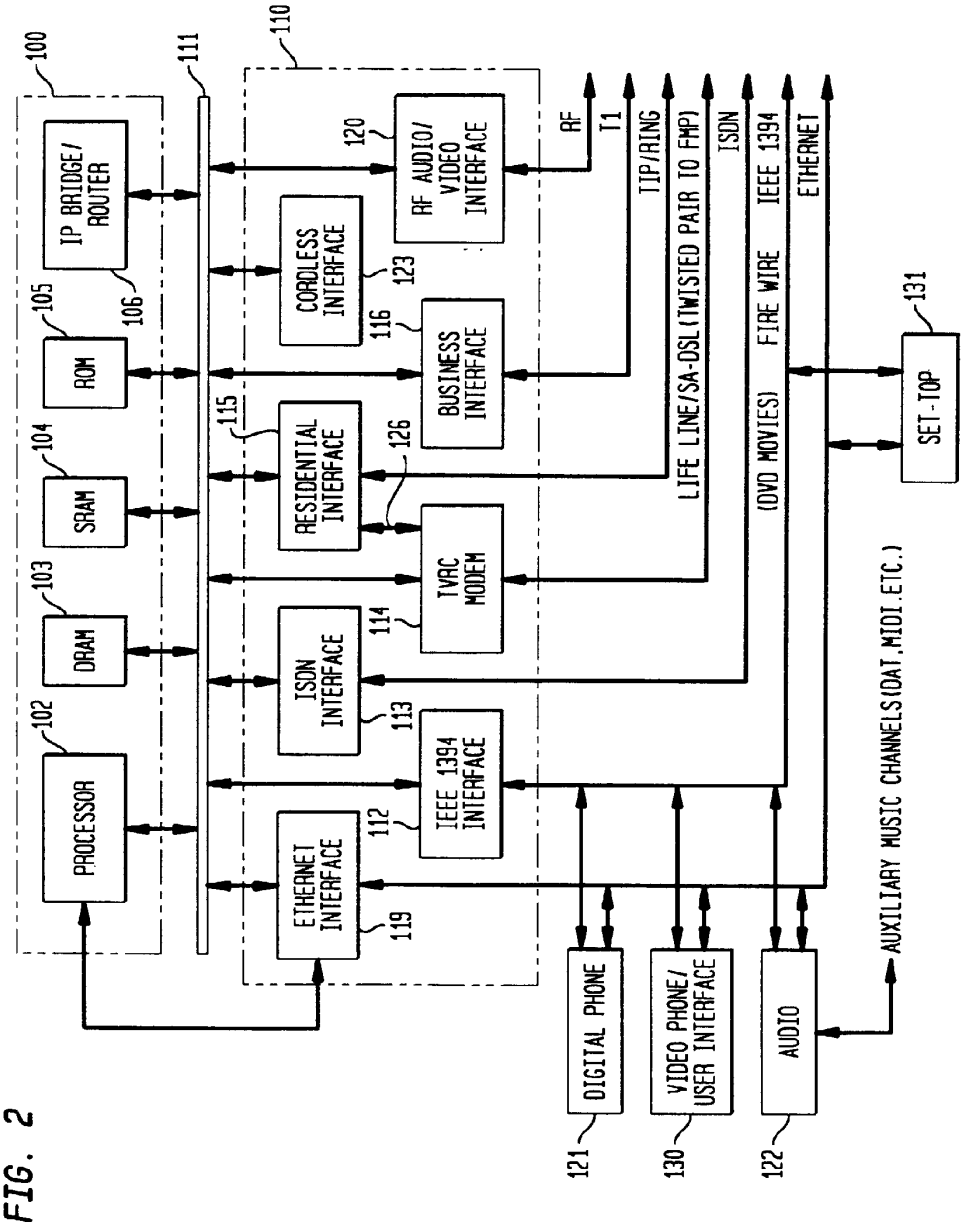



FIG. 2



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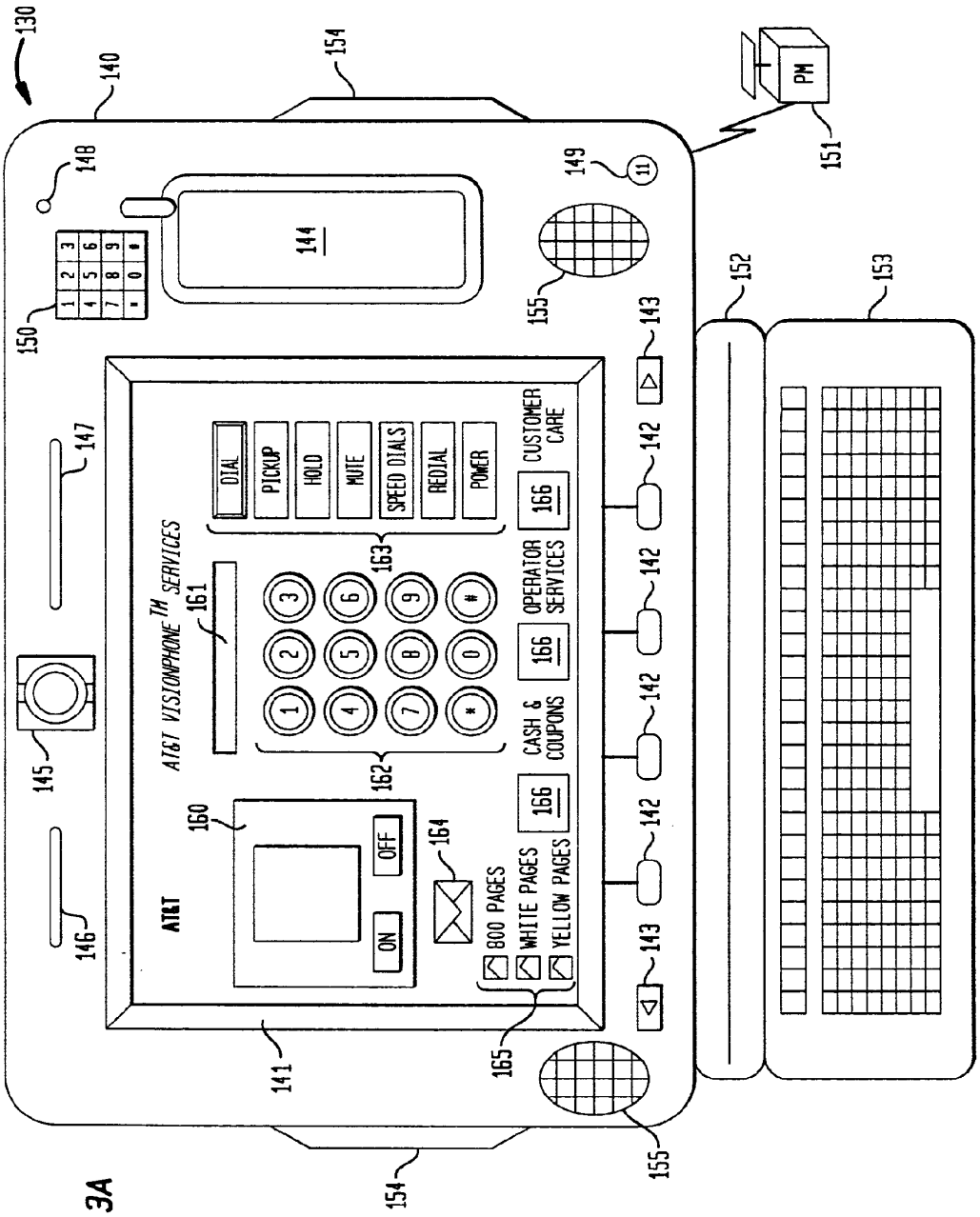
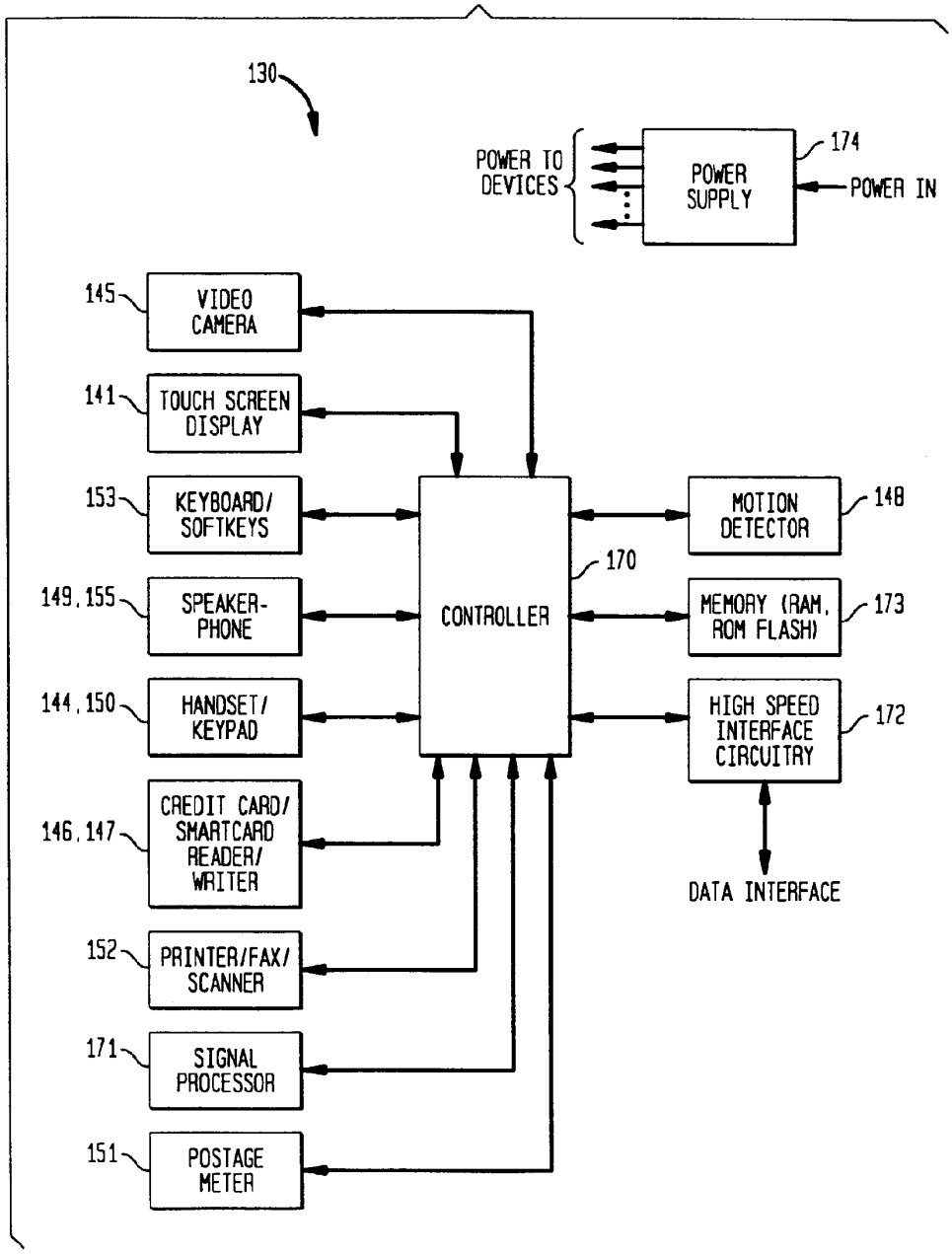



FIG. 3A



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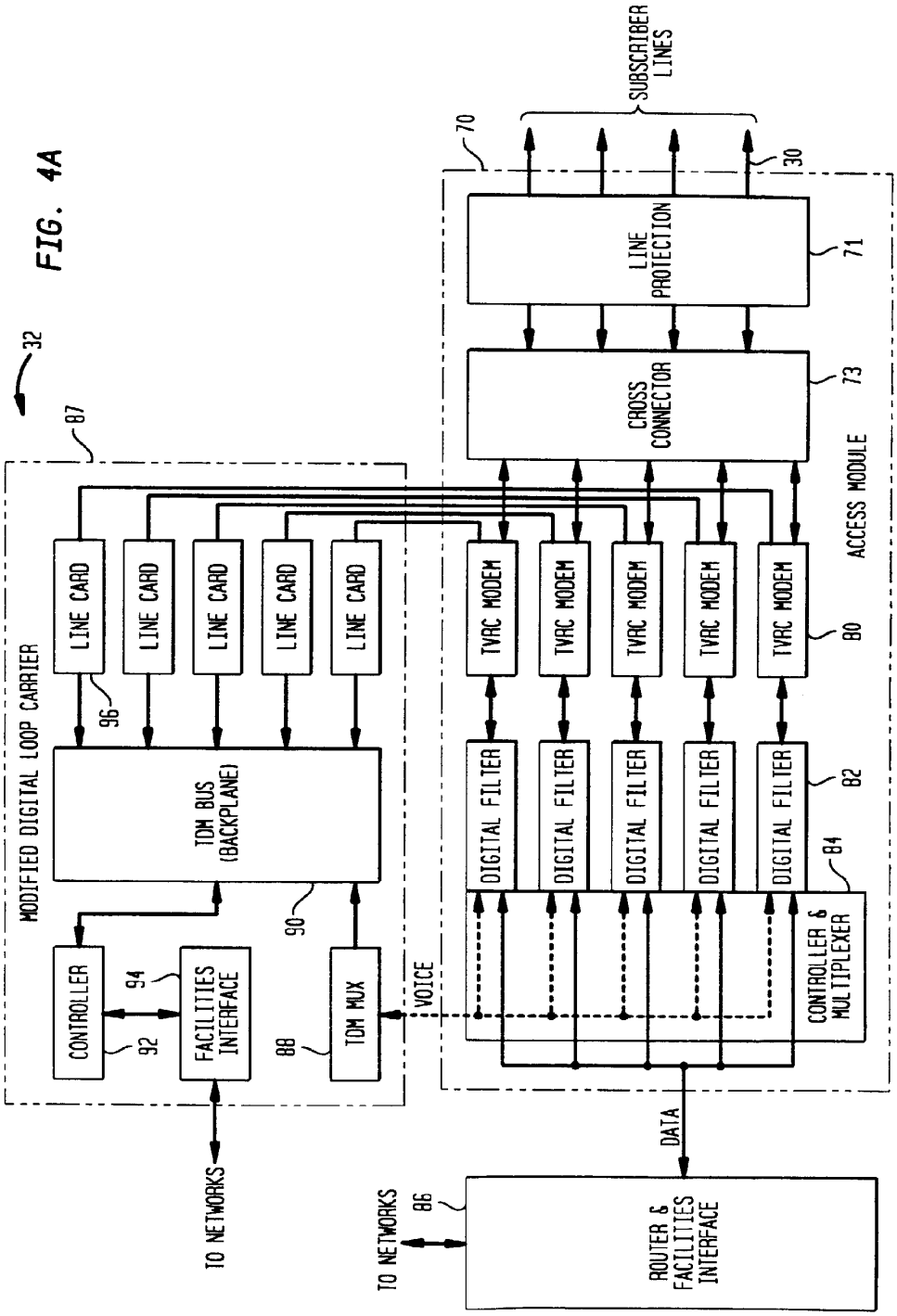
FIG. 3B






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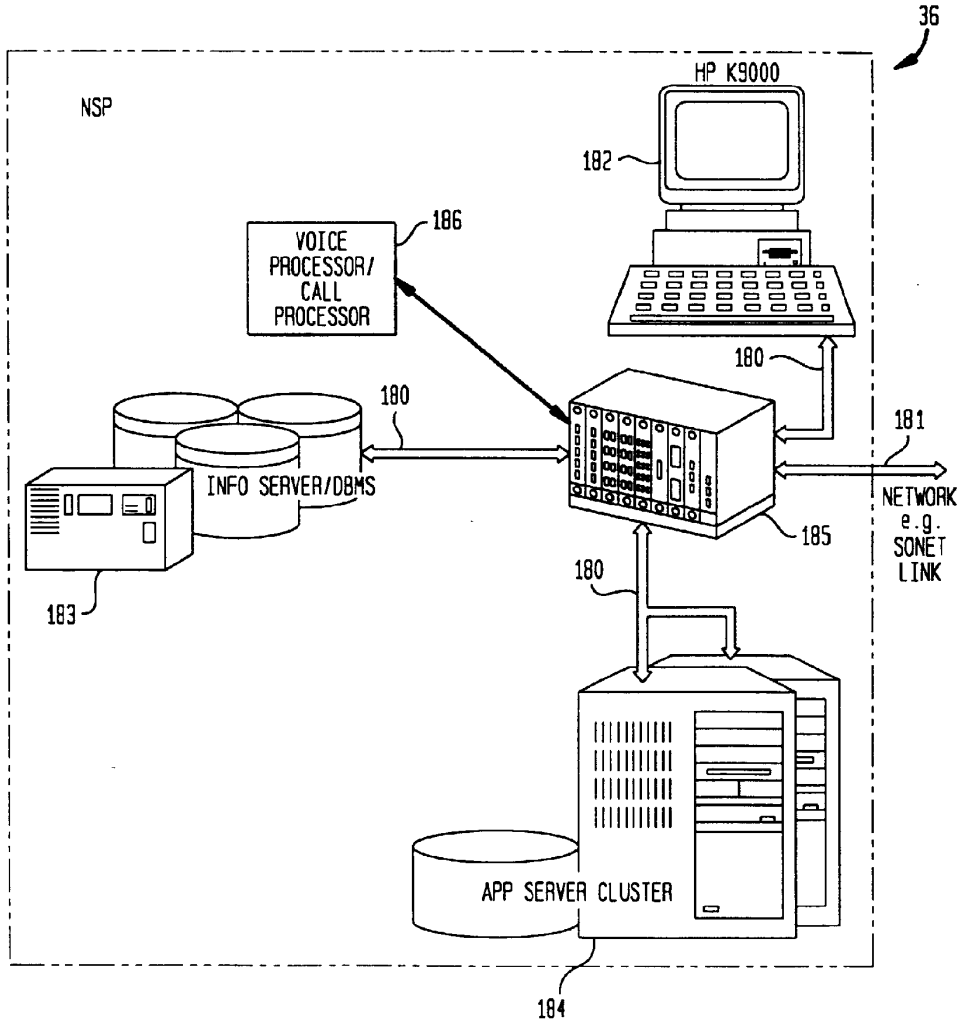
FIG. 4A






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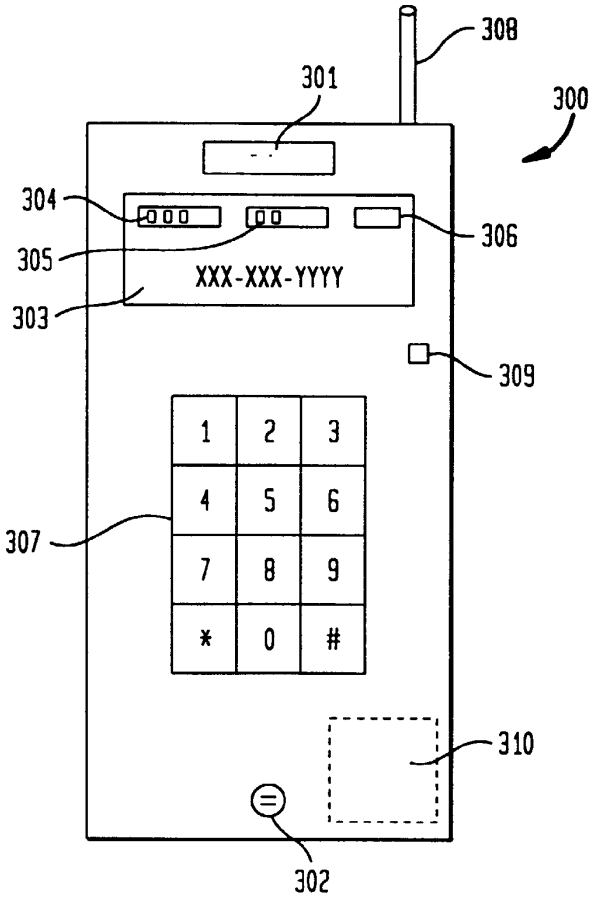
FIG. 4B






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FIG. 5






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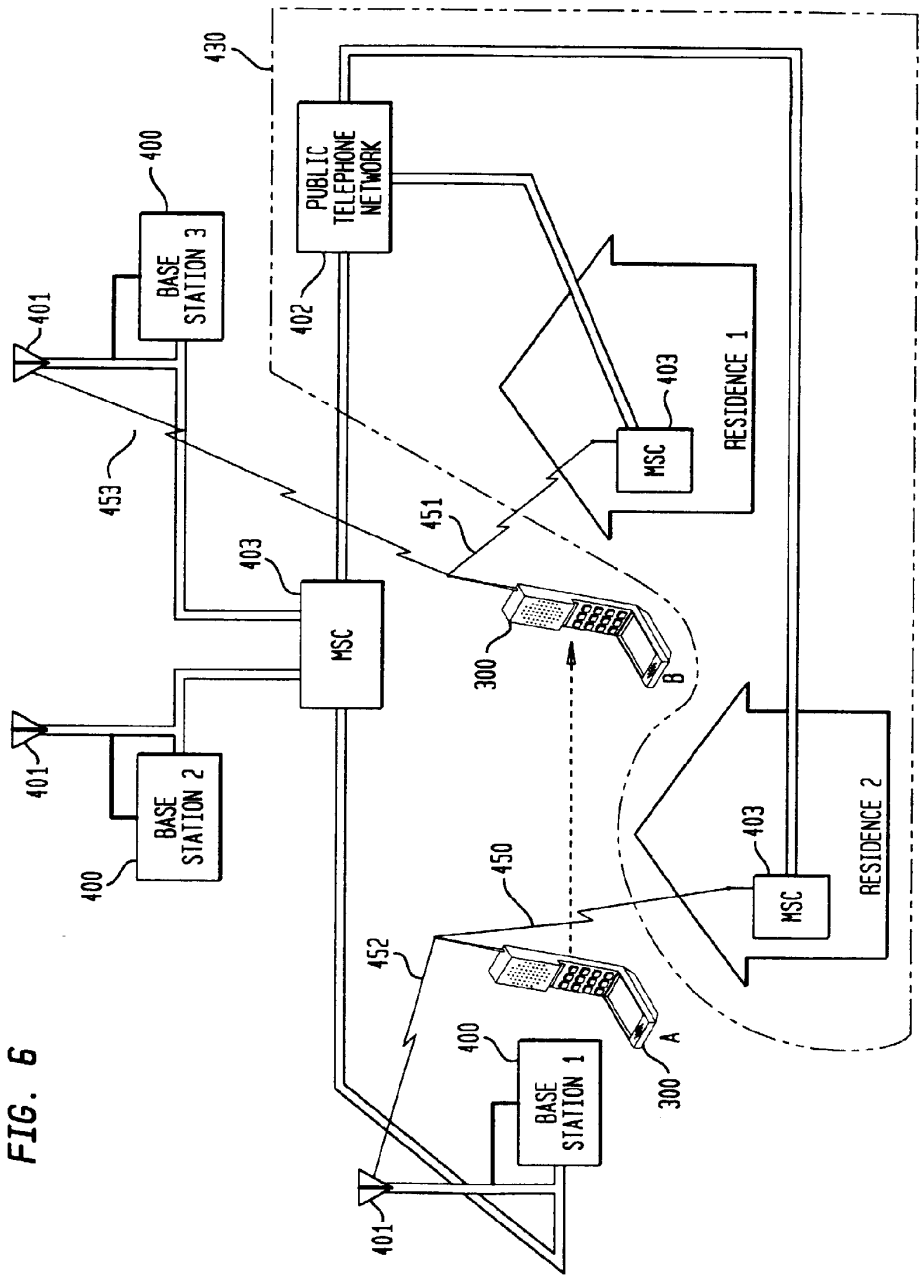



FIG. 6



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A1

# DEMANDE DE BREVET D'INVENTION

(21) **N° 77 08522**

(54) **Procédé et appareils pour les radiocommunications et/ou les radiosignalisations en milieux clos.**

(51) Classification internationale (Int. Cl.²). **H 04 B 7/26.**

(22) Date de dépôt ..... 22 mars 1977, à 15 h 27 mn.

(33) (32) (31) Priorité revendiquée : *Demande de brevet déposée en Italie le 22 mars 1976, n. 9.381 A/76 aux noms des demanderesses.*

(41) Date de la mise à la disposition du public de la demande ..... B.O.P.I. — «Listes» n. 42 du 21-10-1977.

(71) Déposant : Sociétés dites : S.I.N.A. S.P.A. et I.M.A.R.T. S.R.L., résidant en Italie.

(72) Invention de :

(73) Titulaire : *Idem* (71)

(74) Mandataire : Germain, Maureau et Millet, Conseils en brevets, 4, rue d'Amsterdam, 75009 Paris.

D Vente des fascicules à l'IMPRIMERIE NATIONALE, 27, rue de la Convention — 75732 PARIS *CEDEX 15*

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Il n'y a aucun doute que l'on a assisté, au cours de ces dernières années, à l'augmentation du nombre des services publics et privés assurés par des opérateurs et/ou des unités fixes et/ou mobiles constamment reliés entre eux et/ou à des centrales opérationnelles par signaux radio de fréquences déterminées, par exemple de fréquences radiophoniques.

A titre d'exemple, citons les services des forces de l'ordre, des corps de police et de surveillance publics et privés, les services d'assistance à la circulation et à la santé publique, les services de transports publics urbains, les services de mise en place et d'assistance pour les installations de production et de transport de l'énergie électrique et pour les installations industrielles en général, les services de surveillance de la circulation routière, autoroutière, par chemin de fer, etc...

On observe de même que de plus en plus les communications et les appareils radio remplacent des installations qui auparavant faisaient appel à différentes techniques et destinées par exemple à la gestion, au contrôle, à la réglementation et à la signalisation à distance des installations électriques, ferroviaires, routières, hydrauliques et permettent d'assurer à distance les opérations, les vérifications et les contrôles nécessaires par l'intermédiaire d'impulsions radio émises par les centres opérationnels et/ou les appareils récepteurs-émetteurs de ces mêmes unités sous contrôle, fixes et mobiles et l'affichage sur les tableaux de commande installés à la centrale opérationnelle non seulement de l'état des installations, mais également des opérations effectuées et de toute autre information nécessaire ; et ce, toujours par l'intermédiaire de signaux radio.

Dans les pays dont les caractéristiques orographiques sont assez complexes, comme en Italie, ou encore dans les villes, où se développe sans cesse le phénomène de l'urbanisation souterraine, avec des routes et des voies de chemin de fer construites dans le sous-sol, la "couverture" de ce que l'on appelle les "zones d'ombre" pose de nombreux problèmes car les liaisons radio sont empêchées par les difficultés auxquelles se heurte la propagation des ondes électromagnétiques, tout particulièrement dans les tunnels où, en général, les liaisons radio entre deux véhicules ou entre un poste fixe et un véhicule sont coupées lorsque le véhicule se trouve à l'intérieur du tunnel ; il s'agit là d'un inconvénient qui de manière générale se produit toujours dans des milieux fermés, se

développant essentiellement dans le sens de la longueur, même si ceux-ci débouchent sur l'extérieur.

On sait que cela arrive même si la liaison radio passe par l'intermédiaire d'une station relais normale, car en effet, les ondes électromagnétiques, qu'elles soient émises par la radio relais ou par le véhicule, ne sont pas en mesure de traverser les barrières ferromagnétiques ou conductrices d'une certaine densité, ni d'ailleurs les terrains de couverture et la structure même de l'ouvrage souterrain qui constituent de véritables obstacles à la propagation des ondes radio.

On connaît les procédés et les appareils mis au point à ce jour pour pallier ces inconvénients ; ils comportent néanmoins des limitations non négligeables à l'efficacité et à la fiabilité des services indiqués plus haut, qualités qui pourtant ne devraient pas faire défaut lorsque les objectifs à atteindre sont la sécurité et la continuité du service.

Les systèmes émetteurs-récepteurs en tunnel et en milieux souterrains, ou de toutes manières fermés, se développant essentiellement dans le sens de la longueur, débouchant aux extrémités sur l'extérieur, ont été, jusqu'à ce jour, réalisés suivant deux techniques principales : ceux de la première génération qui utilisent des antennes à rayonnement aux entrées des tunnels, ne sont applicables qu'en cas de développement longitudinal limité, compte tenu de l'atténuation considérable des signaux ; ceux de la deuxième génération, tels que le système AEG Telefunken, qui combinent les antennes directionnelles installées à l'extérieur du tunnel et les câbles coaxiaux "fendus", à rayonnement, installés tout le long de l'ouvrage souterrain, équipent actuellement un certain nombre de réseaux de métro et de lignes express, par exemple à Hambourg, Munich et Sao Paulo, ainsi que des tunnels automobiles dans de grandes villes, comme à Francfort, permettant les communications en semi-duplex entre les véhicules et les centres opérationnels avec des résultats satisfaisants.

Ce deuxième système ne comporte pas d'inconvénients rédhibitoires, si ce n'est le coût élevé et la vulnérabilité intrinsèque de l'élément essentiel, c'est-à-dire du câble coaxial "fendu" qui, monté tout le long du tunnel, risque d'être détruit en cas de sinistre (surtout en cas d'incendie) enlevant ainsi toute possibilité de communiquer avec l'extérieur dans des situations justement où il est plus que jamais nécessaire de pouvoir disposer d'un tel service.

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L'objet de la présente invention est constitué par une combinaison d'appareils et de techniques, déjà connus individuellement, mais utilisés selon une méthode et avec un équipement de conception originale permettant de dépasser les limites indiquées plus haut, le coût de la réalisation restant réduit.

On n'ignore pas en effet que le comportement des liaisons radio en milieu fermé est différent de celui en ambiance libre. Dans l'espace, les ondes ne s'atténuent pas, mais se dispersent en fonction du carré de la distance.

En milieu fermé, au contraire, la fréquence radio est en partie absorbée par les parois (placées à une distance déterminée de la source), et en partie réfléchie. La partie réfléchie agit à nouveau sur les parois, avec un résultat identique ; et ainsi de suite jusqu'à absorption totale de l'émission. Cet effet de réflexion-absorption entraîne l'atténuation rapide du phénomène électromagnétique, en fonction de la distance séparant les parois, de la nature et de la forme de celles-ci ainsi que de la fréquence des ondes radio utilisées.

Dans la suite, pour abréger, nous désignerons par le terme "tunnel" tout milieu fermé, se développant essentiellement dans le sens longitudinal, d'une longueur même importante, ouvert sur l'extérieur aux deux extrémités, dites "entrées".

Une observation s'impose ici : du point de vue géométrique, un tunnel peut être considéré comme un espace délimité par six surfaces opposées, dont quatre placées à des distances déterminées (les parois latérales, la voûte et le sol) et deux à une distance infinie (les entrées). Suivant une approche originale, les déposantes ont voulu étudier de manière concrète, en procédant à des expériences et à des essais, la possibilité d'assimiler le tunnel à une ligne de transmission de fréquence radio, sans rayonnement, c'est-à-dire à un "guide d'onde" par rapport à la propagation des ondes électromagnétiques. Elles sont ainsi arrivées au résultat surprenant que toutes les lois théoriques régissant la propagation d'ondes électromagnétiques dans les guides d'onde sont en partie applicables aux tunnels.

On n'ignore pas qu'il est possible d'irradier des fréquences radio à l'intérieur d'un conduit si l'on respecte les conditions suivantes :

1) la fréquence minimale pouvant être propagée est fonction des caractéristiques géométriques de la section du conduit ainsi que

du système d'excitation ;

2) le système d'excitation doit être choisi parmi les systèmes possibles en fonction du type du conduit ;

3) la surface interne du conduit doit être uniforme, exempte d'aspérités, se rapprochant le plus possible des caractéristiques d'un miroir, d'une conductibilité électrique élevée.

Ainsi, par exemple, dans le cas d'un tunnel d'autoroute standard, la première condition est respectée si la fréquence est supérieure à 60 MHz ; la deuxième peut être obtenue facilement ; la troisième, au contraire, n'est pas remplie pour des raisons évidentes ayant trait aux caractéristiques de construction de l'ouvrage, dont les parois sont en général de béton, à coefficients de rugosité élevés et à haut pouvoir absorbant ; on se heurte par conséquent au phénomène de l'atténuation. Néanmoins, des essais approfondis ont fait apparaître que l'atténuation, tout en étant importante, n'exclut pas l'utilisation du tunnel en tant que guide d'onde.

En prenant toujours l'exemple d'un tunnel d'autoroute standard, l'atténuation spécifique moyenne est d'environ 0,15 dB/m à 160 MHz assurant ainsi une "couverture" moyenne suffisante, sur environ 900 mètres, à partir du point d'excitation, en amont et en aval dudit système d'excitation.

Ces considérations et ces essais sont à la base de la présente invention qui est fondée sur l'idée d'utiliser des relais placés à l'intérieur du tunnel et permettant d'étendre, toujours à l'intérieur de celui-ci, la zone de couverture des relais extérieurs.

En ce qui concerne le procédé, celui-ci est fondé sur la combinaison des données ci-dessous :

1) un système d'excitation radioélectrique placé à l'intérieur d'un guide d'onde entraîne la propagation des ondes radio dans les deux directions opposées ; il en découle qu'un élément rayonnant placé à l'intérieur d'un tunnel fournit une couverture radio interne d'une longueur double par rapport à celle qu'il serait possible d'obtenir avec un élément rayonnant placé à l'entrée dudit tunnel.

2) Une information peut être transmise à un ou plusieurs relais intérieur par l'intermédiaire d'un câble téléphonique relié à un relais extérieur, ou, de manière plus générale, à la source de l'information.

3 - L'atténuation caractéristique du tunnel étant élevée, il y a

lieu d'utiliser un relais à deux voies et d'alimenter, à partir de ce même relais, un deuxième élément rayonnant placé sous l'arcade voisine dudit tunnel si l'ouvrage, ainsi que cela se produit souvent, est constitué de deux tunnels côte à côte (chemins de fer, routes, etc...)

La perte de répartition dans ce cas est de 3 dB (réduction de 20 mètres environ seulement de chaque côté de la zone de couverture de chaque élément dans le cas d'un tunnel d'autoroute standard à 160 MHz, mais en cas d'arcade double la zone couverte par un seul relais est doublée.

Il en résulte qu'un relais placé sous un tunnel d'autoroute standard à double arcade est en mesure de fournir une zone globale de couverture d'environ 900 x 4 = 3.600 m à 160 MHz.

4) L'atténuation plus importante des tunnels aux fréquences plus basses est compensée par l'atténuation caractéristique moindre d'un câble coaxial traditionnel par rapport au tunnel lui-même ; ainsi, en éloignant l'élément ou les éléments rayonnants du relais en utilisant un câble coaxial simple, il est possible d'étendre encore davantage la zone couverte par un relais.

5) Si la longueur d'un tunnel est nettement supérieure aux possibilités de couverture d'un relais unique, relié à un ou plusieurs éléments rayonnants par un simple câble coaxial, on peut utiliser deux ou plusieurs relais reliés entre eux par un simple câble téléphonique.

6) L'utilisation sur des fréquences toujours plus hautes (par exemple 400 - 470 MHz) assure une couverture bien supérieure à celle que l'on pourrait obtenir avec un seul relais à 160 MHz pour un tunnel d'autoroute standard.

Le procédé objet de la présente invention ainsi que l'équipement correspondant offrent de nombreux avantages par rapport à l'état actuel de la technique ; on peut les résumer ainsi :

a) utilisation du tunnel comme guide d'onde, avec excitation à l'intérieur du tunnel ;
b) liaison entre un relais extérieur et un ou plusieurs relais placés à l'intérieur du tunnel par simple câble téléphonique ;
c) exploitation de l'atténuation élevée du tunnel pour la réduction de la perte de répartition à deux voies et couvrir avec un relais unique, dans l'hypothèse de deux tunnels côte à côte, les deux arcades voisines ;

d) utilisation du taux nettement inférieur de perte du câble coaxial par rapport à celui du tunnel pour étendre la zone de couverture de chaque relais à l'intérieur du tunnel, plusieurs éléments rayonnants étant reliés entre eux et alimentés par câble coaxial par chaque relais ;

e) coût de l'installation nettement inférieur par rapport à celui d'une installation de liaison radio réalisée avec le système du câble "fendu" ;

f) vulnérabilité réduite en cas d'incendie, explosion, sabotage ou endommagement, car il est possible de concentrer en un seul endroit, que l'on choisira le plus à l'abri possible, tous les appareils ;

g) risque statistique de pannes réduit si les évènements ci-dessus venaient à se produire car l'élément rayonnant est placé en un ou plusieurs endroits du tunnel mais pas sur toute sa longueur ;

h) risque statistique de panne totale réduit dans le cas de plusieurs éléments rayonnants et/ou relais à l'intérieur du tunnel; l'endommagement éventuel d'un seul élément rayonnant et/ou relais ne ferait que réduire, pour ce qui a trait à la zone correspondante, la zone totale de couverture radio.

A titre d'exemple non limitatif, la figure 1 schématise l'une des dispositions possibles d'une installation fonctionnant suivant le procédé conforme à la présente invention.

Elle représente, en coupe horizontale, un tunnel (G - G') d'une longueur par hypothèse indéfinie, où la partie (L = 2I) représente la longueur de la zone de couverture radio que l'on peut obtenir avec un seul relais (la valeur (I) correspondant au rapport existant entre la puissance disponible du relais, exprimée en dB, et le facteur d'atténuation, exprimé en dB/m qui, pour une fréquence donnée, est fonction des caractéristiques de construction du tunnel). A l'intérieur de ce tunnel (G - G') sont installés deux relais (1, 2), à côté de leur élément rayonnant (1' - 2'), chacun permettant de recevoir et d'émettre des ondes radio respectivement dans les parties du tunnel comprises entre les sections (A - A') et (A' - A"). Les relais intérieurs (1 - 2) reçoivent l'information du ou des relais installés à l'extérieur du tunnel (qui, pour simplifier, ne sont pas représentés) par l'intermédiaire d'un câble téléphonique (3) qui assure également la liaison entre les relais intérieurs.

Bien évidemment, si la longueur du tunnel était inférieure

ou égale à (L) (1800 m environ dans le cas de tunnels d'autoroute avec revêtement de béton et de section standard, pour une fréquence de 160 MHz) un seul relais, installé à l'intérieur du tunnel, est suffisant pour assurer la réception et l'émission sur toute la longueur de l'ouvrage souterrain.

La figure 2, toujours à titre d'exemple non limitatif, montre comment, sans changer le nombre ni les prestations des relais devant être installés à l'intérieur du tunnel, la longueur de la zone de couverture radio pouvant être obtenue avec un seul relais (11) peut être étendue, dans une certaine mesure, en éloignant du relais (11) les éléments rayonnants (11' - 11") en utilisant un simple câble coaxial (4).

La longueur de la zone de couverture radio (L') pouvant ainsi être obtenue peut être égale à 4I' où (I'), à prestations égales du relais, est nettement inférieure à (I), en raison des atténuations dans le câble coaxial, mais presque toujours supérieure à 1/2 si l'on considère que le facteur d'atténuation du câble est faible par rapport à celui caractéristique du tunnel, surtout si le revêtement est en maçonnerie, ce qui est normalement le cas.

Ainsi, par exemple, pour les tunnels d'autoroutes de sections standard, dont la fréquence est de 160 MHz et le facteur d'atténuation caractéristique du tunnel de 0,15 dB/m, la longueur maximale pouvant être desservie par un seul relais, en utilisant un simple câble coaxial RG8/U (atténuation caractéristique à 160 MHz : 0,08 dB/m), peut dépasser les 1.800 m indiqués plus haut et atteindre 2.000 - 2.200 m.

Les figures 1 et 2 montrent également comment les relais radio doivent être installés à l'intérieur du tunnel, dans des niches (N1 - N2- N11) respectivement, séparés et à l'abri de la circulation, du public, etc...

La figure 3 montre, toujours à titre d'exemple non limitatif, un tronçon de tunnel à deux arcades $(G_1 - G'_1) - (G_2 - G'_2)$ d'une longueur 2L" et l'une des dispositions possibles d'une installation fonctionnant suivant la méthode conforme à la présente invention en cas de deux tunnels côte à côte dont la longueur serait supérieure à 2L' disposant bien entendu de passages de service ("by pass") permettant de passer d'une arcade à l'autre : les relais (21 - 22) sont convenablement placés dans les passages de service (P21 - P22) tet, grâce aux éléments rayonnants

(21' - 21" - 21"' - 21) (22' - 22" - 22"' - 22) alimentés par les câbles coaxiaux (4), ils permettent de recevoir et d'émettre dans les deux tronçons des arcades ($G_1$ - $G'_1$) et ($G_2$ - $G'_2$) du tunnel. l'information est fournie aux relais par un câble téléphonique (3) qui les relie entre eux et au ou aux relais extérieurs (non représentés). La longueur de la zone de couverture radio (L") ainsi obtenue, pour chaque arcade et pour chaque relais, est égale à 4 I", où I" - I' env.

Dans la pratique, les détails d'exécution peuvent de toutes manières varier dans la forme, les dimensions, la disposition des éléments, la nature des matériaux sans toutefois sortir du cadre des idées de solution adoptées.

REVENDICATIONS

1 - Procédé pour les radiocommunications et/ou les radiosignalisations en milieux fermés, se développant essentiellement en longueur et débouchant sur l'extérieur par les deux extrémités, même souterrains. en particulier tunnels, même de longueur importante, caractérisé par le fait qu'il consiste à assimiler lesdits milieux à un guide d'onde qui, correctement excité à l'intérieur, entraîne la propagation des ondes électromagnétiques grâce à l'utilisation d'un ou plusieurs relais et des éléments rayonnants correspondants et par le fait que ces relais sont reliés entre eux et à un ou plusieurs relais extérieurs par simple câble téléphonique.

2 - Procédé selon la Revendication précédente caractérisé par le fait que pour étendre la zone de couverture de chaque relais intérieur sont utilisés deux ou plusieurs éléments rayonnants, convenablement éloignés de chaque relais intérieur grâce à un câble coaxial dont le facteur d'atténuation caractéristique est nettement inférieur à celui du tunnel lui-même et par le fait qu'en cas de deux tunnels côte à côte les deux ou plusieurs éléments rayonnants sont placés un ou plusieurs par arcade de manière à couvrir, avec un seul relais, des tronçons d'égale longueur des deux tunnels côte à côte.

3 - Equipement pour les radiocommunications et/ou les radiosignalisations en milieux fermés se développant essentiellement en longueur et débouchant sur l'extérieur par les deux extrémités, même souterrain, en particulier tunnels, même de longueur importante, agencé pour la mise en oeuvre du procédé selon les Revendications ci-dessus, caractérisé par le fait qu'il comprend un ou plusieurs relais installés à des distances dépendant de la puissance disponible dudit ou desdits relais, de la fréquence adoptée ainsi que des caractéristiques géométriques et de construction du milieu ou tunnel, le ou les relais intérieurs étant reliés à un ou plusieurs relais extérieurs par simple câble téléphonique.

4 - Equipement selon la Revendication 3, caractérisé par le fait que les éléments rayonnants du ou des relais montés à l'intérieur du tunnel sont convenablement écartés du ou des relais grâce à un câble coaxial et par le fait que dans l'hypothèse de deux tunnels côte à côte les éléments rayonnants du ou des relais intérieurs sont convenablement éloignés desdits appareils grâce à des câbles coaxiaux, chaque câble coaxial pouvant porter même plusieurs

éléments, permettant ainsi, à chaque relais, de couvrir des tronçons des deux tunnels.

5 - Equipement selon l'une quelconque des Revendications 3 et 4, caractérisé par le fait que les relais intérieurs sont reliés entre eux au moyen d'un simple câble téléphonique.

6 - Equipement selon l'une quelconque des Revendications 3 à 5, caractérisé par le fait que les émetteurs-récepteurs intérieurs sont installés dans des niches et/ou logés dans les passages de service des tunnels.

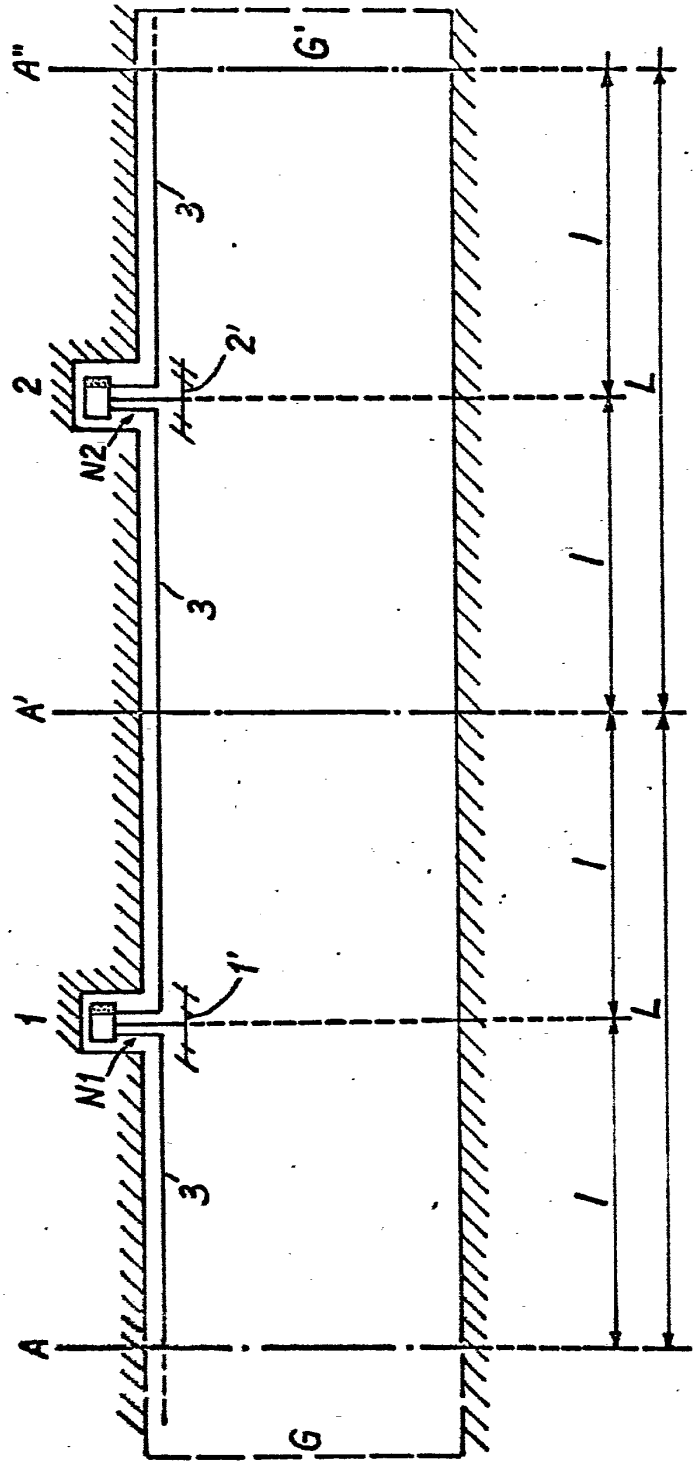



Fig:1

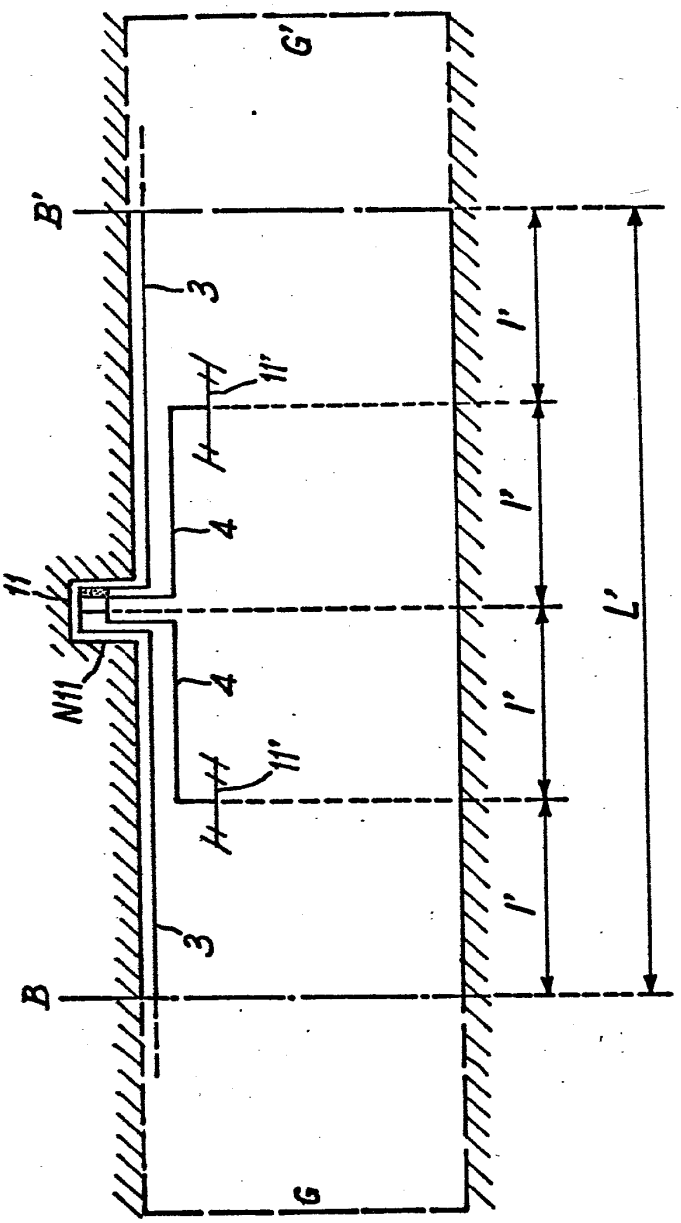



Fig. 2

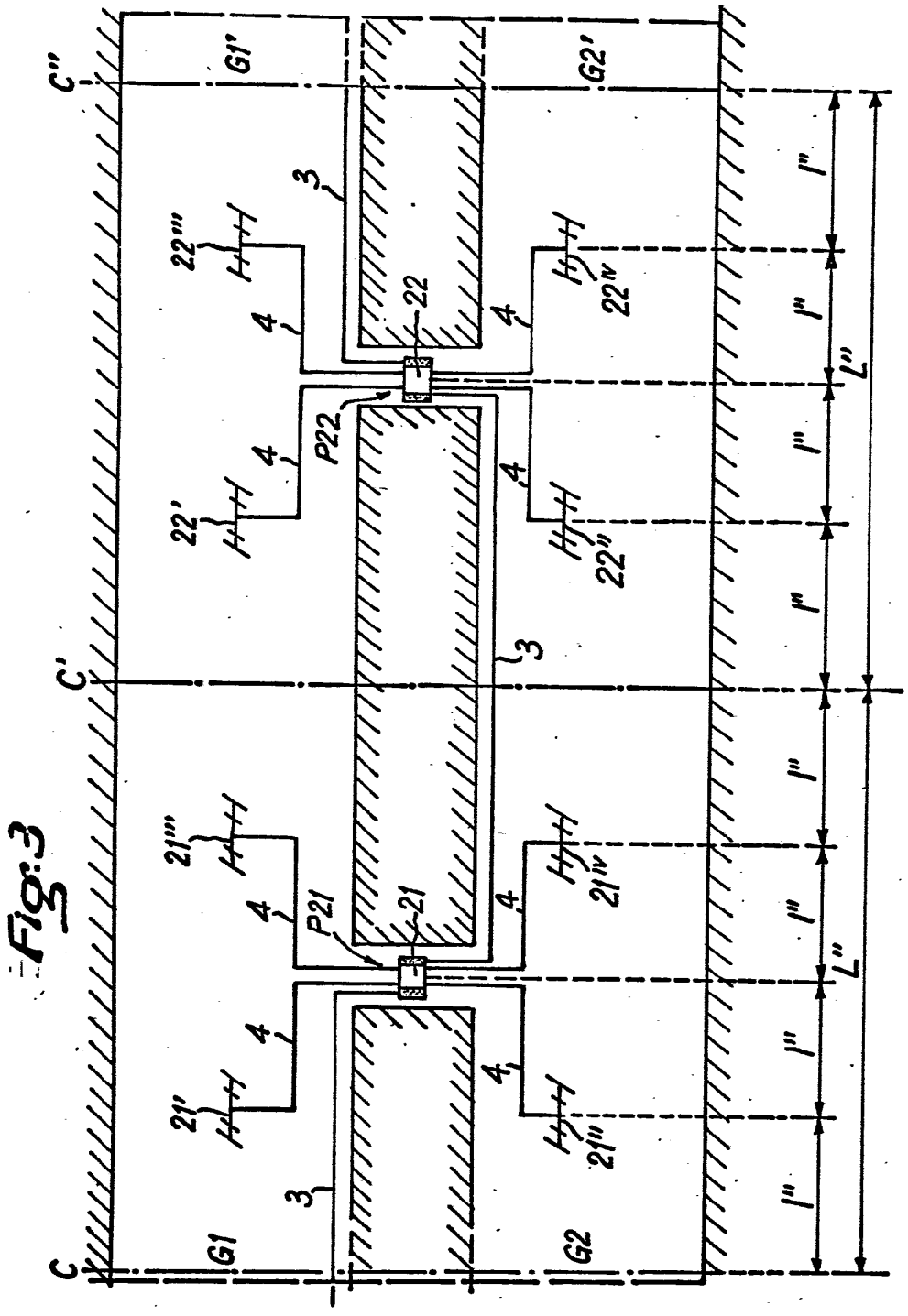



Fig. 3

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(43) Date of A publication 16.09.1992

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H4R RCC
U1S S2204 S2213

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US 4757496 A US 4644526 A

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Online databases : WPI, CLAIMS, INSPEC

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(54) **Multichannel radiotelephony system using bidirectional cable T.V. network**

(57) Two way cordless communications uses multichannel transceivers portable within a coverage area comprising cells, each associated with a base station and antennas, such as to permit channel frequency reuse in cells within the coverage area. For at least part of the coverage area, the locations of the antennas within the cells and the locations of the base stations are independently mapped, the antennas being associated with active antenna systems and the active antenna systems being connnected to the base stations utilizing broadband transmission by means of a fixed bidirectional cable television network. The network is connected to the base stations and the antenna systems through interfaces incorporating frequency translation so that available frequency bands in the cable television network, which will normally be shared with other services, may be utilised. Plural base stations may be co-located. The radio link to the transceivers may be FDM or TDM, but communication over the network will normally be frequency multiplexed, using separate bands for transmission and reception.

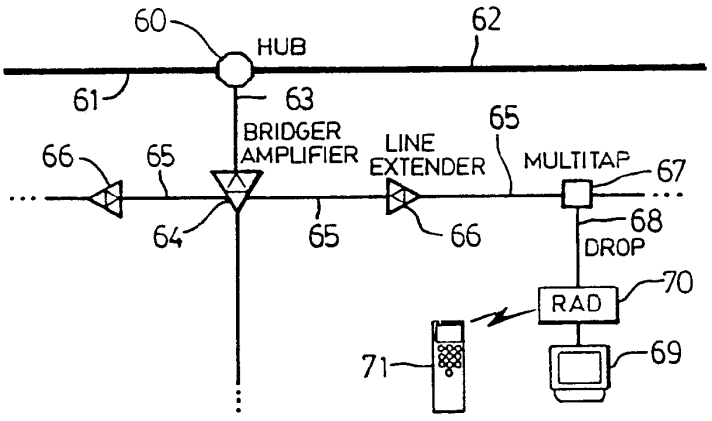



FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

GB 2 253 770 A

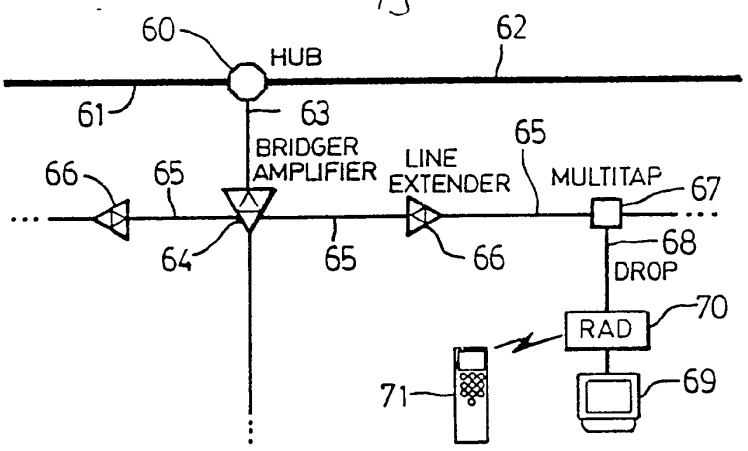

60
HUB
62
61
63
65
BRIDGER AMPLIFIER
LINE EXTENDER
MULTITAP
67
66
65
64
65
66
68
DROP
70
RAD
71
69

FIG. 1

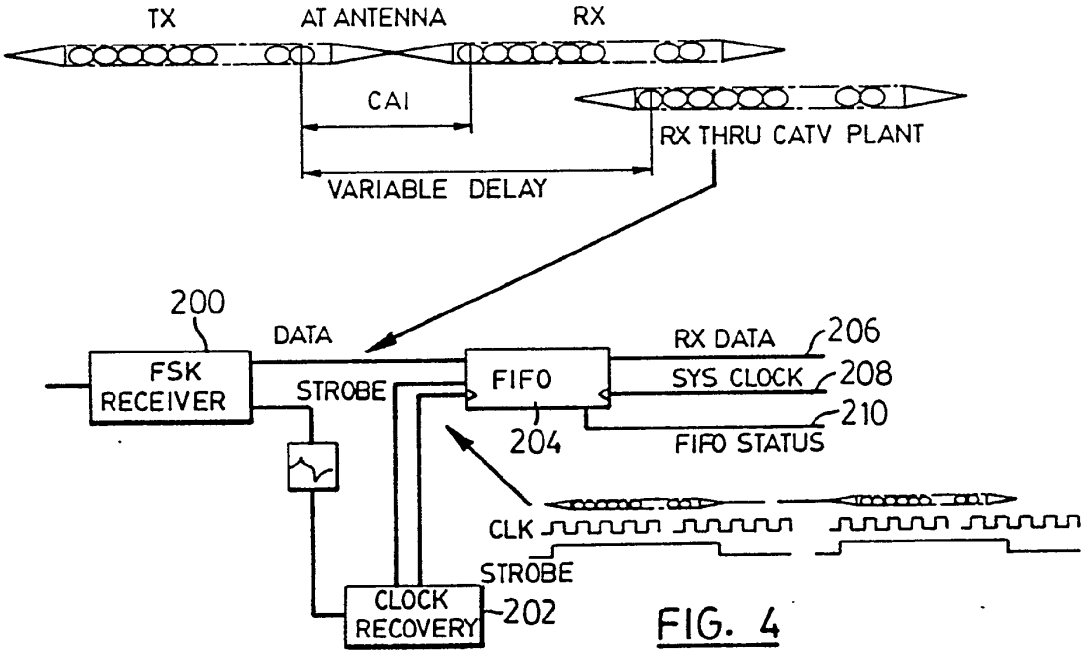

TX
AT ANTENNA
RX
CAI
RX THRU CATV PLANT
VARIABLE DELAY
200
DATA
RX DATA
206
FSK RECEIVER
STROBE
FIFO
SYS CLOCK
208
210
204
FIFO STATUS
CLK
STROBE
CLOCK RECOVERY
202

FIG. 4

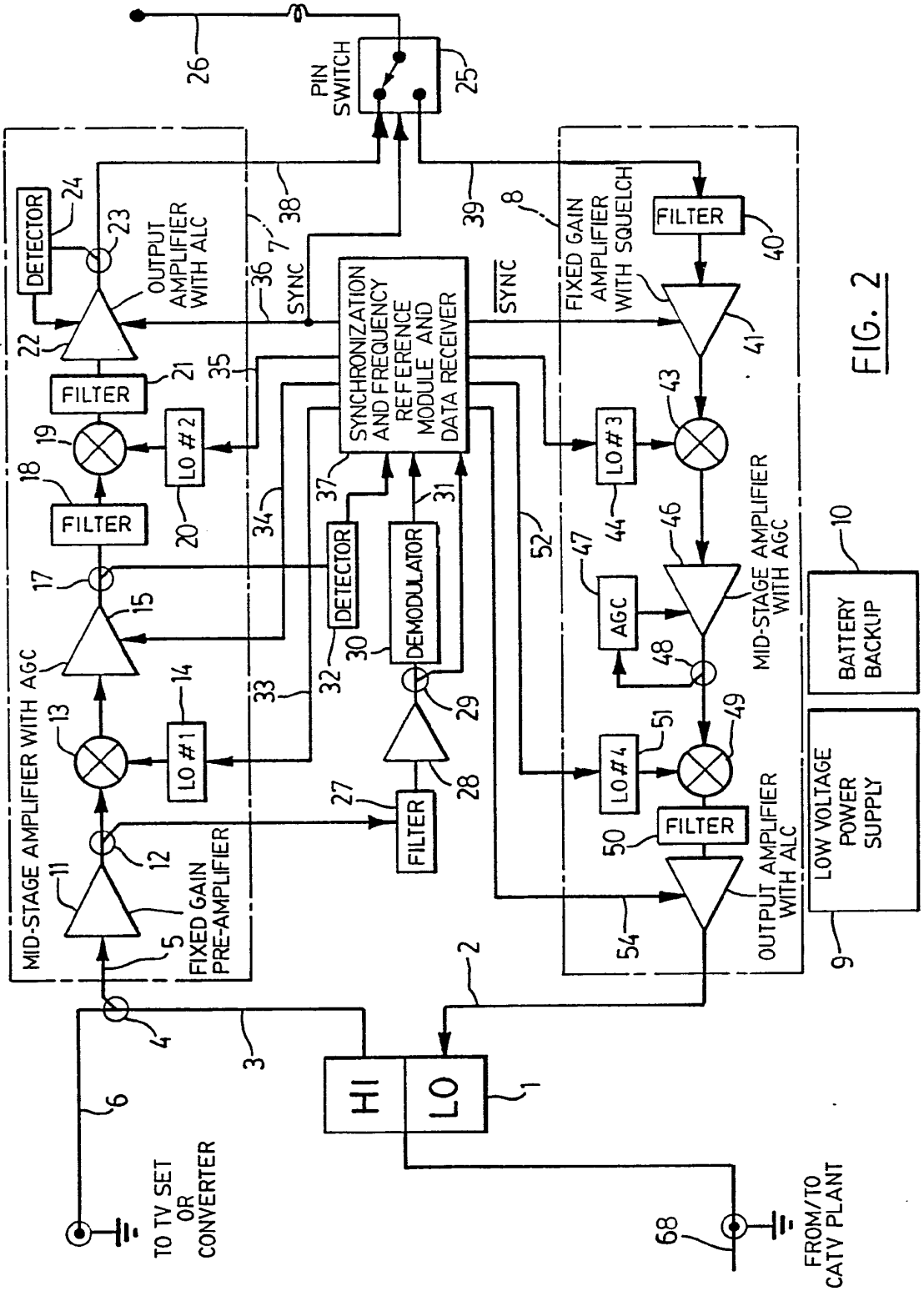

MID-STAGE AMPLIFIER WITH AGC
FIXED GAIN PRE-AMPLIFIER
OUTPUT AMPLIFIER WITH ALC
FIXED GAIN AMPLIFIER WITH SQUELCH
MID-STAGE AMPLIFIER WITH AGC
OUTPUT AMPLIFIER WITH ALC
SYNCHRONIZATION AND FREQUENCY REFERENCE MODULE AND DATA RECEIVER
DETECTOR
DEMODULATOR
FILTER
LO #1
LO #2
LO #3
LO #4
AGC
PIN SWITCH
BATTERY BACKUP
LOW VOLTAGE POWER SUPPLY
HI
LO
SYNC
TO TV SET OR CONVERTER
FROM/TO CATV PLANT

FIG. 2

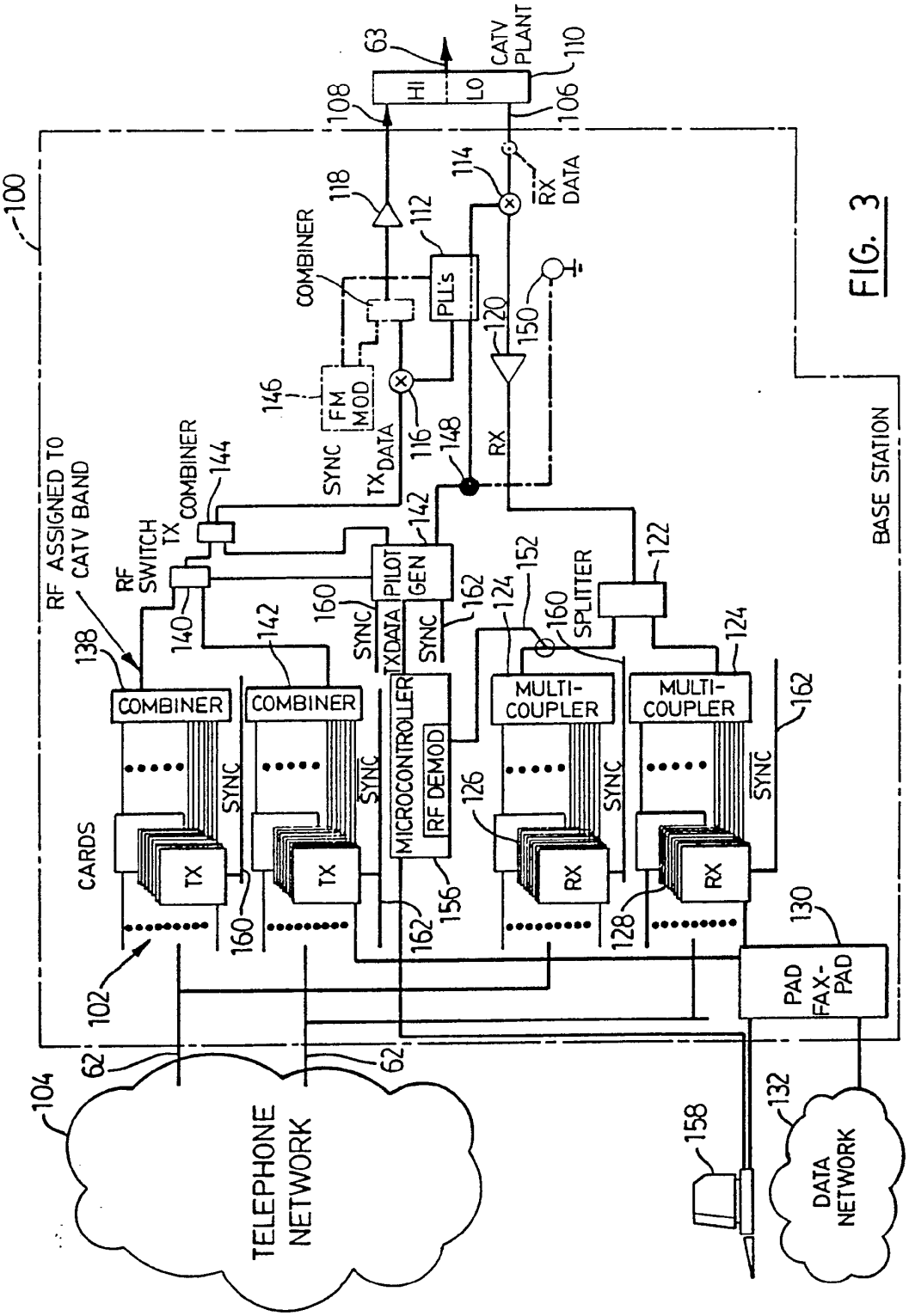

100
BASE STATION
RF ASSIGNED TO CATV BAND
CATV PLANT
HI
LO
63
110
108
106
114
RX DATA
118
112
COMBINER
PLL's
120
150
146
FM MOD
SYNC
TX DATA
116
148
RX
144
COMBINER
RF SWITCH TX
140
142
PILOT GEN
152
122
SPLITTER
160
124
162
138
COMBINER
COMBINER
MULTI-COUPLER
MULTI-COUPLER
MICROCONTROLLER
RF DEMOD
126
CARDS
TX
TX
RX
RX
SYNC
102
62
62
104
TELEPHONE NETWORK
156
128
130
PAD
FAX-PAD
158
132
DATA NETWORK

FIG. 3

# RADIOTELEPHONY SYSTEM

This invention relates to the interface between a telephone network and portable wireless telephone units in a radiotelephony system and more particularly to equipment for the implementation of a personal communications service utilizing cable television facilities.

The development and commercial success of both cellular telephone systems, primarily for mobile use, and cordless telephones, for use in the vicinity of fixed locations within the public switched telephone network (PSTN), has given rise to considerable interest in the provision of tetherless personal communications using small portable handsets within a system which combines some of the personal mobility afforded by a cellular system with the lower cost and greater system capacity afforded by cordless telephones. Proposals for several systems have been published and some cases have been the subject of public trials. Such systems are commonly referred to as second generation cordless telephony (CT2), third generation cordless telephony (CT3), and generically as personal communications services (PCS). Further information on such systems may be found for example in the following publications:

"Personal Communications - A Report on CT2 & PCN Wireless Communications Systems" by Matthew Dosch, published 1990 by Telecom Publishing Group.

"Generic Framework Criteria for Universal Digital Portable Communications Systems (PCS)" published March 1990 by Bellcore.

"MPT 1375 Common Air Interface Specification" published by Department of Trade & Industry, London, England,

1989.

"Second generation cordless (CT2) telephony in the U.K.: telepoint services and the common air-interface" by Professor J.G. Gardiner, Electronics & Communication Engineering Journal, April 1990.

"CT2 Plus - A proposal for a Canadian Common Radio Interface Standard", Issue 2.0, December 1990, Bell-Northern Research.

"CT3 - Common Radio Interface Specification for Canadian Cordless Communications" December 19, 1990, Novatel Communications Ltd and Ericsson Communications Inc.

A common objective of the above PCS systems is the provision of wireless telephony via small portable handsets to individuals, either stationary or pedestrian. This wireless service is intended to be available at low cost to the general public and operate within and about the home, shops, schools, offices and institutions where telephone usage is most likely to be required. Wireless telephony is made possible by way of a portable radio handset carried on the person and a complementary radio base station connected to the public switched telephone network (PSTN) within operating range of the handset. This operating range is likely to be in the vicinity of 1000 feet or less, being primarily limited by the transmitter power available in a small portable handset, with the result that a very large number of base station locations is required to provide substantial area coverage.

The interconnecting of many spatially distributed radio base stations with the PSTN and the associated intelligence

required to locate mobile handsets has been termed a personal communication network (PCN). The construction and operation of a PCN will be required in order for PCS to be achieved. A large number of complex radio base stations need to be deployed over a substantial area to support adequate radio access for the general public to purchase the service. Each radio base station transforms, in a duplex manner, voice signals in a format suitable for transmission on twisted pair or fiber optic facilities, into radio frequency (RF) signals suitable for exchange with the portable handset.

In all cases, a complex signal multiplexing arrangement is used to conserve scarce RF spectrum, available allotments being in the vicinity of 1000 MHz. Radio base station equipment must include circuitry to properly multiplex and de-multiplex the RF signals exchanged with the portable handset.

In the case where more than one handset is expected to be in radio contact with a base station, the circuitry necessary for one duplex conversation or voice channel needs to be duplicated for each handset. The number of users who can access a particular radio base station will therefore be limited to the number of channels it is equipped to support.

In all digital cordless telephone formats, the radio spectrum is divided into a number of discrete RF channels using Frequency Division Multiple Access (FDMA) Techniques. Additionally, some systems such as CT-3 employ Time Division Multiple Access (TDMA) to multiplex several traffic channels into each RF channel. In all cases, traffic channels are processed individually at the base station before interconnection to the PSTN occurs. Traffic

channels may be used to transport coded voice or data.

In general, each radio base station consists of a number of RF modulators and demodulators for radio communications with the handsets, multiplexers and demultiplexers for handling the transmission of digital information over the radio link, encoders and decoders for converting the voice messages into digitally-coded streams of data, and a control system for error correction, establishment of radio links, synchronization, and other functions related to digital radio transmission.

The PSTN interface to each radio base station requires sufficient capacity, using existing twisted copper pairs or new fiber based terminal equipment. Each channel of each base station represents a new telephone line which must be established to the PSTN switch network. In many cases, new transmission equipment is needed to serve the radio base stations.

Thus a major problem, common to both conventional cellular and PCS radiotelephony systems, is their requirement for numerous spatially distributed base stations in order to provide coverage over a substantial area. The low power and limited range of PCS base stations makes this problem more acute in the case of PCN networks, particularly if any substantial degree of user mobility is to be provided. This problem has two facets, the first being the cost and complexity of the base stations themselves, and the second the cost and complexity of the distribution network required to pass signals to and from the base stations.

It is known in the case of cellular radio systems to utilize fibre optic trunks associated with a CATV system

to provide signal distribution to the base stations of a cellular system, as described in an article "Rogers Fiber Architecture" by George Hart and Nick Hamilton-Piercy, CED Magazine, July 1989. Various other proposals have also been made for the provision of telephony services making use of the existing fixed plant of CATV systems, particularly those having two way capability. An article "Cellular Radio and Cable TV = Cellular Cable" also points out the capability of existing two-way CATV systems, particularly those using optical fiber technology, to replace conventional twisted pair plant in the transmission of telephone communications, the suggestion (no details are provided) being that a CATV system might in effect replace the transmitter of a cellular base station, with the signal being distributed by cable instead of broadcast, analogously to the distribution rather than broadcast of television and radio signals by the system, but making use of its two-way capability. A system operating generally on these principles is disclosed in U.S. Patent No. 4,757,496 (Bartholet), which discloses frequency-agile stations connected to a coaxial cable network in a manner such as to replace conventional twisted-pair local distribution of telephone signals. U.S. Patent No. 4,644,526 (Wu) discloses a device for connection of station to a network, which may be implemented by coaxial cable, by translating between a single frequency division duplex signal and separate signals carried on different sidebands of a common carrier.

The architecture and technology of typical CATV systems is described further in "Cable Television System Overview-1987", published September 14, 1987 by American Television & Communications Corporation, Englewood, Colorado. Further discussion of two-way CATV systems is to be found in Chapter 12 of the book 'Cable Television', 2nd edition, by

John E. Cunningham, published 1980 by Howard W. Sams.

We have now found that we can effectively exploit the capabilities of a two-way CATV system in PCS and analogous radiotelephony systems by utilizing the CATV system to provide a base station or stations with a distributed radio transmission capability, thus enabling each base station to service a far larger area than would otherwise be possible.

In its broadest aspect, the present invention provides a radiotelephony interface in which the area coverage of base station equipment is increased by connecting it to a plurality of antenna drivers by frequency division duplex transmission of transmitted and received signals between the base station equipment and the antenna drivers over a bidirectional cable television system, in frequency bands reserved in that system for downstream and upstream communications respectively.

According to a further aspect of the invention, there is provided a radiotelephony interface for use in a multi-channel radio telephony system to establish wireless communication between multiple portable transceiver units and a telephone network, comprising at least a part of a CATV system including a headend or hub and a plurality of drops in two-way communication with the headend or hub, at least one means at the headend or hub for processing signals received from and for transmission in multiple channels to portable radio transceivers, utilizing blocks of channels occupying defined portions of the frequency spectrum for transmission and reception, and a plurality of remote antenna drivers connected to individual drops of the CATV system, the remote antenna drivers each comprising an antenna, first frequency conversion means for block

converting signals, received from said transceivers by said antenna in said defined portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to the associated drop as upstream signals, second frequency conversion means for block converting downstream signals, received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the portion of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna, and the signal processing means at the headend or hub comprising means for transmitting signals to the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for downstream communications, and means for receiving signals from the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for upstream communications.

The invention also extends to a remote antenna driver having the features set forth above.

The difficulties associated with the construction of a PCN may be significantly reduced by the use of the invention. The bidirectional transport of signals on two-way coaxial cable CATV facilities is well documented in the prior art. Conventionally, the conveyance of radio frequency (RF) signals at frequencies greater than 50 MHz from an originating location (headend) or relay points (hub) downstream to residences and businesses; upstream conveyance is at frequencies in the range 5 to 30 MHz from residences and businesses to the hub or headend. The signals are conveyed to and from homes and businesses via

single coaxial cable drops which are connected to a coaxial cable feeder line by way of signal couplers. The feeder line may be in turn connected to a coaxial trunk line or to opto-electronic transducers which are connected via optical fiber to a hub or headend.

By utilizing a CATV system to distribute the signals of a base station or group of base stations at the hub or headend to multiple antennas, the coverage of such stations can be greatly increased. If, as will usually be the case, multiple base stations are required to handle traffic demands, these may be co-sited at the hub or headend, except again for their shared distribution and remote antenna drivers. A remote handset exchanges RF signals with the CATV facility via a remote antenna driver (RAD). The number of handsets accessing the CATV facility at each RAD is only limited by the base station capacity at the hub or headend serving that RAD. The RADs plus the CATV facility are in effect a low loss transmission path between portable handsets and the main portion of the radio base stations at the hub or headend which allows a much greater distance between the handset and that main portion than would otherwise be possible. Calls are handled according to techniques already well known in cellular telephone networks, or as set forth in the publications set forth above.

A multiplicity of RADs may be connected to the CATV facility throughout a community, with widely scattered portable handsets able to communicate with the public switched telephone network (PSTN) through base station equipment located remotely from the RADs at a common hub or headend of the CATV system. The equipment required at the headend or hub may be provided by means of appropriate circuit modifications of a conventional radiotelephony base

station, to provide reception and transmission in appropriate frequency bands for interfacing with the CATV system, or an intermediate unit may be connected to radio base station antenna ports, the unit operating in a complementary manner to a RAD to provide the necessary frequency conversion and matching. The equipment must provide for the propagation delays inherent in a CATV system. A multiplicity of voice circuits interconnect the multiplicity of radio base stations to the PSTN in conventional manner.

In general, the RF frequencies allocated for PCS cannot be conveyed on CATV facilities and so the principal function of a RAD is to translate the PCS frequencies to frequencies suitable for CATV. Hence signals intended to be delivered to a portable handset by the radio interface of the invention are typically conveyed in a frequency band above 50 MHz on the CATV facility, and translated by a RAD in the vicinity of the portable handset to a frequency in the receiver frequency band of the portable handset. Signals transmitted by the portable handset are received by the RAD and translated to a frequency typically in the range 5 to 30 MHz for conveyance by the CATV system to the headend radio base station equipment serving that portable handset.

The range of frequencies which each RAD can accommodate is desirably sufficient to allow all channels available for PCS to be used without restriction. All RADs use functionally compatible translation systems to ensure any portable handset within communications range of any RAD can communicate with any free base station on any free channel, as established by the normal operation of the PCS system equipment as if the portable handset was in the vicinity of a conventional base station.

A presently preferred exemplary embodiment of the invention is described further below with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram showing part of a CATV system equipped to provide an interface according to the present invention;

Figure 2 is a more detailed schematic diagram of a remoted antenna driver incorporating the system of Figure 1; and

Figure 3 is a schematic diagram showing an interface to a PSTN incorporated in a hub of the CATV system of Figure 1.

Figure 4 is a schematic diagram of part of a base station receiver illustrating means compensating for propagation delays in the CATV system.

Figure 1 shows a segment of a CATV facility including a hub 60 connected to a headend via a supertrunk 61 as well as to the PSTN via voice circuits 62. Coaxial cable trunks 63 with bridger amplifiers 64 convey signals between the hub 60 and coaxial distribution feeders 65. Line extenders 66 amplify the signals to compensate for signal attenuation caused by cable and by couplers contained within multitaps 67. Coaxial drop cables 68 (of which only one is shown) provide cable television service to residences and businesses where television sets 69 are the usual terminal equipment. A remote antenna driver (RAD) 70 is connected to the drop 68 to allow portable telephone handsets 71 in the vicinity of the drop to communicate with the remaining equipment of a radio base station or stations contained in

the hub 60. This equipment will be referred to as the base station(s) although it should be understood that the entire system to be described, including the CATV system and RADs, together constitutes a form of distributed radio base station which acts collectively as the interface between the PSTN and the handsets 71. A multiplicity of RADs 70 may be connected to a multiplicity of drops 68 and multitaps 67 on a multiplicity of feeder lines 65 and line extenders 66 which in turn connect to a multiplicity of bridger amplifiers 64 on a multiplicity of trunks 63 connected to a common hub 60. Each bridger amplifier 64 is equipped with amplifiers and diplexing filters to support two-way operation in a manner conventional in the art of two-way CATV systems. Similarly each line extender 66 is equipped for two-way operation such that signals in the range of frequencies 5 to 30 MHz may pass with approximately 30dB attenuation from the RAD 70 to the hub 60. Signals above 50 MHz, up to the design limit of the amplifiers 64, line extenders 66 and multitaps 67, which limit is typically 400 to 550 MHz, are conveyed with approximately 50 dB attenuation from the hub 60 to RAD 70. These attenuation figures are exemplary only and may vary significantly with respect to individual drops 68.

Although Figure 1 shows connections being established to the PSTN through equipment located at the hub 60, such connections could also be established through similar equipment located at the headend, particularly in the case of a relatively smaller CATV system. Moreover, the coaxial trunk cables connecting bridging amplifiers 64 to the hub 60 may be replaced by optical fibers with appropriate transducers to support two-way signal conveyance in accordance with normal CATV system practice, without affecting the practicality or operation of the invention.

Referring now to Figure 2, the RAD 70 will be described in more detail. The drop cable 68 is connected to a diplexing filter 1 by means of which frequencies in the range 5 to 30 MHz present on a conductor 2 may be inserted onto the drop cable 68 with minimum attenuation. Signals above 50 MHz pass through the diplexing filter from the drop cable 68 to a conductor 3 from which they are available to a forward frequency translation subsystem 7 via a coupler 4 and a conductor 5. A low attenuation path through coupler 4 is made available via conductor 6 to a suitable connector on the RAD 70 for connection of a television 69, for the purpose of receiving television programming normally available on the CATV facility. The RAD 70 has no effect on normal CATV service other than a small attenuation of signals above 50 MHz.

PCS signals from the radio base station equipment in the hub and intended for a portable handset 71, are passed to the forward frequency translation subsystem 7. This acts to change low power signals from conductor 5, in any one of a block of channels in a pre-determined band of frequencies typically having a bandwidth equal to that allocated for PCS channels, but located between 50 and 550 MHz, into relatively higher power signals for transmission in the frequency band allocated for PCS channels receivable by the handset 71, typically in the range 900-1000 MHz. The transmission signals are delivered to an antenna 26 via an electronic switch 25. The band of frequencies to be so changed will typically be from 4 to 20 MHz wide, as determined by the portion of the RF spectrum allotted to the PCS. All RADs 70 will perform an identical translation of the complete PCS band of frequencies.

Within the subsystem 7, the low level downstream PCS signals from conductor 5 are amplified by a preamplifier

11 with fixed gain and connected via a coupler 12 to a mixer 13. A local oscillator 14 drives the mixer 13 at a suitable frequency in known manner to cause the PCS signals to be heterodyned to an intermediate frequency, typically in the vicinity of 45 MHz, and further amplified by a variable gain narrow band amplifier 15 whose output is connected to a band pass filter 18 via a coupler 17. The intermediate frequency, band limited, PCS signals are heterodyned a second time by a mixer 19 which is driven by a local oscillator 20 so as to be translated to the desired transmission frequency band. Band pass filter 21 prevents spurious mixer signals from reaching a power amplifier 22, which delivers the maximum allowable PCS signal power to the antenna 26 via a coupler 23 and the electronic switch 25. A sample of the power amplifier 22 output is diverted by the coupler 23 to a broadband detector 24 to provide an automatic level control signal which limits the gain of the power amplifier and so prevents excessive output power which might otherwise result in signal distortion and unlawful emissions.

A sample of the input signal is diverted by the coupler 12 to a filter 27 which extracts control and frequency reference signals, which signals are subsequently amplified by an amplifier 28 and demodulated by a demodulator 30 to provide control information to a controller 37 via conductor 31. A frequency reference is provided to the controller via coupler 29 to ensure that the various local oscillators in this and other RADs, which are frequency synthesizers, are operating coherently at predetermined frequencies.

The coupler 17 is used to divert a sample of the RF power at the output of the variable gain intermediate frequency (IF) amplifier 15. A power detector 32 delivers

a signal to the controller 37 used for controlling the gain of the amplifier 15 by a signal output on a conductor 34. The signal amplitudes in this subsystem also provide an indication of the input signal level to the RAD and thus the net RF path attenuation between the hub 60 and the RAD 70. The estimated path loss is used to provide a signal on conductor 54 which controls the gain of an amplifier 53 for optimum launching of PCS signals received from the portable handset 71 onto the CATV facility for conveyance to the hub 60. A frequency conversion subsystem 8 transforms low power emissions received by the antenna 26 from portable handsets 71 on channels allocated in the PCS frequency spectrum into higher power replicas displaced in frequency so as to be compatible with the upstream transport capabilities of conventional bidirectional CATV facilities, specifically an allotted band within the 5 to 30 MHz frequency band wide enough to accommodate the allocated block of reception channels.

The subsystem 8 is connected to the antenna 26 through the switch 25 by conductor 39, which passes signals through as an input filter 40 to a fixed gain amplifier 41 with conventional squelch capabilities. Provided the received PCS signals are of sufficient level to give reliable communication, the squelch of the input preamplifier 41 will be removed and the signals will be delivered to a mixer 43 which is driven by a local oscillator 44. The filter 40 ensures that unwanted signals outside the PCS frequency band are attenuated sufficiently to prevent interference likely to disrupt reliable communications. The output of the mixer 43 is at an intermediate frequency, typically 45 MHz, and is amplified by a band-limited variable gain amplifier 46 and delivered to a mixer 49 via a coupler 48. A local oscillator 51 drives the mixer 49 such that its output contains the PCS signals translated

to the desired band within the range of frequencies 5 to 30 MHz. A filter 50 prevents undesired mixer products from passing to the output amplifier 53. The coupler 48 diverts a sample of the PCS signal to an automatic gain control module 47 in order to provide optimum gain of the amplifier 46 relative to the PCS signal level received at antenna 26, which may vary over a very large range. More specifically the amplifier 46 operates at maximum gain for the lowest received signal power, its gain decreasing linearly with increasing received signal power until minimum gain is reached, whereafter it maintains minimum gain as receiver input power increases further.

The electronic switch 25 is controlled by the controller 37 such that it is synchronized with signal packets being exchanged between the RAD 70 and the portable handset 71. Suitable control information, extracted from the downstream signals, is delivered to the controller 37 via the demodulator 30 on conductor 31 to ensure that synchronization is achieved. Because of limitations on the isolation achievable in practical switches between the conductors 38 and 39, the amplifiers 22 and 41 are controlled by signals on conductors 36 and 42 so as to turn the amplifiers off when not connected to the antenna 26.

The RAD may be contained in an aesthetically pleasing container suitable for installation in homes or offices and is typically powered by commercial 120V AC via a wall mount power supply that delivers low voltage AC power to it. A low voltage power supply 9 uses this low voltage AC input to generate the direct current voltages necessary to power the RAD. A battery 10 is used to power the RAD during interruption of the commercial power source. Outdoor versions of the RAD may be powered by 60V square wave power conventionally available on the coaxial feeder cable 65,

the power supply being adapted in known manner to utilize this supply. As a further alternative, the RAD may be housed within a cable television converter unit, and share the power supply of that unit. This alternative has the advantage that it is more likely to provide a favourable location for the RAD antenna.

Most functions of the RAD described so far are substantially independent of the implementation of the PCS, since they are limited to block frequency conversion, power amplification and matching to the RAD antenna and to the CATV drop.

Several proposed radio Common Air Interfaces (CAI) for PCS radio communication employ Time Division Duplex (TDD) operation. As a result, the RAD must be designed for TDD operation on the radio side. A CATV plant will not support TDD operation, however, as it is frequency-divided into two bands: a high band which handles downstream transmission (head-end to hub to subscriber) and a low band which handles upstream transmission (subscriber to hub to headend).

To accommodate a CATV transport system from the remainder of the base station equipment, the latter is designed to provide Frequency Division Duplex (FDD) output. The duplex channels are divided into "transmit" and "receive" links which are transported on the CATV downstream and upstream bands, respectively.

As an example of bandwidth requirements, assume a PCS system using CT-2 plus. Such a system would occupy 8 MHz of bandwidth, with a nominal 80 channels spaced at 100 KHz between channels. In the simplest case, the transmit link would be carried downstream in an 8 MHz allocation (eg.500-

508 MHz) and the receive link would be carried upstream in an 8 MHz allocation (eg. 22-30 MHz). A conventional diplexing filter is used to couple the base station equipment to the CATV plant.

Conversion of FDD to TDD is performed in the RAD by the switch 25 under control of the controller 37 which performs the necessary time duplexing. An FDD radio link between the RAD and the handheld units can however also be accommodated by appropriate control or elimination of the switch. For the purposes of description, TDD operation of the link is assumed. The controller would regenerate the synchronization signals SYNC and SYNC on lines 36 and 42 from the downstream signal sample received from demodulator 30.

In a conventional PCS system, the handset communicates directly with the base station via a radio frequency link. The only time delay in the path is due to radio propagation delays between the base station and the handset. Due to the short radio range of these systems (typically less than 300 m for reliable radio coverage) these propagation delays are short. As a result, the digital transmission schemes developed for such systems do not incorporate elaborate equalization to compensate for time delays, and FDD operation is practicable without such equalization. The incorporation of CATV plant into the base station-to-handset transmission path does however introduce substantial time delays.

In a conventional PCN base station, the transmitter and receiver sections are synchronously coupled. A clock switches the transceiver between transmit and receive modes. The time frame employed depends on the Common Air Interface CT-2 and CT-2 Plus employ a 2 ms time frame (Tx

1 ms, Rx 1 ms) while CT-3 employs a 16 ms time frame (Tx 8ms, Rx 8 ms). This mode of operation requires that the base-to-handset data burst be closely followed by the handset-to-base data burst. A lengthy delay may cause the first few bits of a transmission to be lost resulting in no communications being established between base station and handset.

A CATV compatible PCS base station requires that the transmitter and receiver sections be asynchronous, i.e. the receiver must be allowed to 'slip' in time relative to the transmitter, so that received packets can be processed when received outside a time slot allocated for reception, and then delayed further so as to fall into such a time slot. Each transceiver within a multi-transceiver base station must employ an independent slip timing buffer so as to compensate for varying propagation delays in a system employing a multiplicity of distributed RADs. This is described further below with reference to Figure 4.

The handsets do not suffer from CATV induced delay because they are configured to slave their transmission to the data bursts or packets which they receive from the base station. The TDD to FDD translation at the RAD is also slaved to the data bursts received by the handset and since it occurs in close physical proximity to the handset, no propagation delays between the handset 71 and the RAD 70 are large enough to cause a problem. In other words neither the RAD nor the handsets need to make any provision for propagation delays within the CATV system since it is the responsibility of the base station equipment at the hub (or headend) to make such provision based on the timing of the upstream packets it receives from the RAD.

When the CAI between the RAD and the handset operates

in TDD mode and the proposed CATV transport system (Base Station-to-RAD) operates in an FDD mode, the CATV bandwidth is under-utilized because the transmit bandwidth is active only half the time and the receive bandwidth is active only half the time.

In order to utilize more fully the CATV transport capacity, a technique referred to as "Even/Odd" channel assignment can be utilized to increase the loading of the CATV plant and thus increase efficiency.

To take an example, each CT-2 Plus channel occupies a bandwidth of approximately 200 KHz. Therefore in an 8 MHz allocation, 40 channels may be transmitted simultaneously without adjacent channel interference. These 40 channels (the "even" channels) would be active during the transmit cycles of a first group of RADs designated "even". Also connected to the same CATV plant would be an approximately equal number of "odd" RADs, which would be in the receive mode while the even RADs are in the transmit mode. A total of 40 channels can thus be received simultaneously without adjacent channel interference. At any given time, therefore, there are up to 40 channels in the transmit mode and up to 40 channels in the receive mode for a total of 80 active channels in an 8 MHz allocation.

During a first phase of the synchronization signal used to operate the switch 25 in the RADs, the odd RADs would be transmitting on up to 40 channels and the even RADs would be receiving on the even channels, whilst during a second phase, the operation would be reversed. The only difference between 'odd' and 'even' RADs is the relative phase of the signals SYNC and $\overline{\text{SYNC}}$, which can be controlled by a signal from the equipment at the hub or headend. The RADs can be dynamically or manually assigned to operate in

one of the two phases by a signal from the hub or headend equipment.

A CATV system used for PCS systems must allow for the assignment of a block of channels in a contiguous frequency band to the service. If the radio CAI interface employs a 4 MHz spectrum allocation then an exclusive and contiguous 4 MHz of CATV spectrum must be assigned in each of the downstream and upstream paths. If this is not the case then the design of the RAD becomes prohibitively complex. Similarly, if the radio CAI is assigned an 8 MHz allocation, and the CATV transport is designed to handle the entire allocation, then an exclusive and contiguous 8 MHz of CATV spectrum is required in each of the downstream and upstream paths.

Except for this requirement, however, the actual frequency assigned is not restricted to any particular part of the CATV frequency spectrum. The actual assignment is determined by the CATV plant operator and is a function of the capabilities of the plant. An essential requirement, of course, is that the plant be capable of bi-directional operation.

The actual spectrum allocations are a function of traffic requirements, CATV system architecture, and utilization of the spectrum for applications other than PCS. If necessary, several blocks of spectrum can be assigned to the service to increase capacity. Different versions of the RAD would then be employed in the system to translate the CATV spectrum blocks into the radio common air spectrum.

Frequency re-use is a function of CATV system architecture. If a block of frequencies is employed at the

headend of a distribution system, then that block may not be re-used again in that system. On the other hand, if the block of frequencies is used at a hub, then the block of frequencies may be re-used at other hubs, in a technique analogous to a technique known as "cell-splitting" in the cellular telephone industry, used to increase frequency re-use as the density of cellular subscribers increases over time.

Pilot signals may be used for various functions in the proposed system. A downstream pilot signal may be used for base station-to-RAD signalling, and an upstream pilot signal may be used for RAD-to-base station signalling. The pilot signals may be located in the PCS transport band or an out-of-band allocation may be used. A number of modulation techniques are also possible. The actual allocation and modulation technique can be determined by the CATV operator to suit system requirements. At the least, a downstream pilot is desirable as a simple means to provide the synchronization signal for TDD switching, and a frequency reference for the frequency translators employed in the RAD.

The downstream pilot may also be modulated with data at the base station to control various functions at the RAD. These possible functions include:

a) "Even/Odd" channel block assignments
b) Spectrum block assignment
c) Output power control (RAD-handset interface)
d) Remote enable/disable of RADs
e) Input level control (RAD-CATV interface)
f) Output level control (RAD-CATV interface).

An upstream pilot generated by each RAD can provide functions such as acknowledgement of control messages and

power failure or device failure reporting.

In addition to these PCS-related functions, the two pilots can also be used for various other purposes. More specifically, they can carry data related to auxiliary services already proposed or implemented in two-way CATV systems such as special functions related to the CATV operation e.g. Pay TV, Pay-per-view TV and remote decoder enable/disable, and telemetry control of household utility services such as electricity and natural gas.

Referring now to Figure 3, there is shown exemplary base station equipment 100 provided at the hub 60 (or headend) for connection to multiple twisted pair circuits 102 forming the connection 62 to a PSTN 104. The base station equipment provides input and output signal lines 106 and 108 which are connected to the conventional CATV plant 110 at the hub (or headend) in which the signals are inserted into or extracted from the cables 63 extending out of the hub using conventional techniques. In the particular example being discussed, the downstream signals on line 108 are in a selected available frequency band, of a width corresponding to the band width allotted to the PCS service being implemented, somewhere within the 50-550 MHz frequency band allocated for downstream signals. The upstream signals are in a selected available frequency band in the 5 - 33 MHz frequency band allocated for upstream signals. It will be understood of course that, whilst these upstream and downstream allocations are typical of modern CATV installations, they may be varied in which case the frequencies utilized for upstream and downstream PCS signals will be selected accordingly.

If the signals on lines 106 and 108 are to be provided and processed using conventional base station equipment

intended for processing signals for direct transmission to and reception from PCS transceivers, then these signals must be translated to and from the frequencies utilized by the PCS air interface. In such a case, the upstream signals on line 106 are applied, together with a local oscillator signal from a phase locked loop synthesizer 112 to a mixer 114 to generate signals in the PCS air interface band. The channel frequencies so generated will be the same as those utilized for communication between the transceivers 71 and the RADs 70. Likewise, the base station signals to be transmitted on line 108 are translated, by a further mixer 116 receiving a local oscillator signal from the synthesizer 112, to the frequencies utilized for communication between the RADs 70 and the transceivers 71. The downstream signals are amplified by a bandpass amplifier 118 before application to the line 108, the pass band of the amplifier corresponding to the downstream CATV allocation for the signals, and the upstream signals are amplified by a bandpass amplifier 120 having a pass band corresponding to that of the base station receiver equipment. If the base station equipment is adapted to handle the allocated CATV frequencies directly, it will be understood that the mixers 114 and 116, and the synthesizer 112, may be omitted.

The upstream signals from the amplifier 120 are applied to a splitter 122, which forwards the signal to multicouplers 124 serving two groups 126 and 128 of receiver cards each providing an interface to a PSTN circuit 102. According to the nature of the PSTN circuit, the signals output by the cards may be analog signals or include an interface to provide pulse code modulated signals such as a standard T1 interface. The T1 interface may be an intelligent interface including a multiplexer with a packet assembler/disassembler (PAD) 130 for routing

data or facsimile signals to a data network 132.

Signals from a PSTN circuit 102 pass to a transmitter card in one of two groups 134 and 136, which cards may be interfaced to that circuit as described above in relation to the receiver cards. Outputs from the transmitter cards are passed to combiners 138 and thence to an RF switch 140 which selected the outputs of either group 134 or group 136 according to the phase of a synchronizing signal SYNC or $\overline{\text{SYNC}}$ received from a pilot signal generator 142. A pilot signal generated by the generator 142 and modulated with this synchronizing signal is also combined with the transmitter output by a combiner 144 to perform the functions of the downstream pilot signal already discussed above. If an out-of-band pilot signal is to be used, and the mixer 116 is utilized, a somewhat different arrangement is needed so that the pilot signal carrier is not modified by the mixer 116. In this case the synchronizing signal and other data to be carried by the pilot is supplied to a frequency modulator 146 together with a carrier frequency generated by the synthesizer 112, and the pilot signal is combined with the transmitter signals by a combiner 148 downstream of the mixer 116. The pilot generator 142 and the synthesizer 112 receive a common reference frequency from an internal frequency reference 148, or an external reference 150 if frequency coherence with other base stations is needed.

Upstream pilot signals, already discussed above, may be recovered if utilized from the received signal on a line 152, and applied through a demodulator 154 to a microcontroller 156, equipped with a terminal 158, which supervises the transmission and reception of data carried by the pilot signal and supplies data to be transmitted to the pilot generator.

The receiver and transmitter cards operate generally as is conventional in the cellular telephony and PCS art, with each card being capable of receiving or transmitting a signal on any channel of the block of channels comprised by the PCS band, and the control functions required for allocating channels and generally supervising communications are also conventional in this art. Since they form no part of the present invention they have not been described nor illustrated in detail. As however has been previously mentioned and will be described further below, provision must be made in the receiver cards to allow for the substantially larger and variable propagation delays which will occur in a CATV network as compared with conventional short range radio communication between base stations and portable or mobile transceivers.

In the example described, the base station equipment is grouped in such a way to allow 40 channels in the CT-2 Plus format to be combined together during the transmit phase of the Time Division Duplex (TDD). Although the nominal RF channel spacing in CT-2 and CT-2 Plus is 100 KHz, the actual bandwidth consumed by the modulation of this channel is actually 200 KHz. In formats such as CT-2 or CT-3, the number of channels would be adjusted accordingly (20 channels for CT-2).

To obtain the maximum number of channels over the plant it is necessary to synchronize all of the transmit portions of the CT-2 equipment, using the synchronization signals SYNC and $\overline{\text{SYNC}}$ on lines from the pilot generator 142. This prevent spill overs or dispersion effects on what would appear to be adjacent channels. This bandwidth requirement reduces the total number of available channels to half under worst case conditions. The CATV plant however

provides a bi-directional frequency duplex trunk system. When the TDD CT-2 system is mapped into the CATV plant system using frequency translation techniques it is found that during the receive portion of the TDD cycle the RF energy in the CATV plant is zero for the block of frequencies being utilized. This means that this block is available for use, and the odd/even interleaving technique outlined above can be implemented.

In describing Figure 3, it has already been noted that duplicate sets of receiver cards 126, 128 and transmitter cards 134 and 136 are provided. Each first set of cards is provided with the synchronization signal SYNC on line 160 and each second set of cards with the synchronization signal SYNC of reverse phase on line 162, such that only the first sets or the second sets are strobed to output receive or transmit signals at any one time. The operation of the switch 140 is also controlled by the pilot generator 142 so that only the active set of transmitter cards is connected to the CATV network at any one time.

A similar switching technique cannot be used in respect of the receiver cards since the propagation delays suffered by the received signals in different channels will be different according to the origin of the signal. Individual adjustment is therefore necessary at each receiver card, and one technique for achieving this is shown in Figure 4.

Referring to Figure 4, showing schematically a portion of one of the receiver cards in sets 126 and 128, a signal from one of the multicouplers 124 is applied to a frequency shift keying (FSK) receiver 200 to recover data from received data packets. In a typical CT-2 or CT-2 Plus PCS, signal packets are transferred in TDD to and from the

transceivers in alternate 1 ms intervals to provide a 2 ms cycle with transmit packets Tx from base station to transceiver and receive packets Rx from transceiver to base station following each other in immediate succeeding time slots at the transceiver, as shown at the top of Figure 4.

As a result of propagation delays in both downstream and upstream passage through the CATV system, there is likely to be a significant and highly variable delay between the end of the period allowed for transmission of a Tx packet at the base station, and the reception of the corresponding Rx packet. These delays will frequently be such that the Rx packet will not be received within the time slot allowed by the TDD synchronization signal SYNC or $\overline{\text{SYNC}}$ for its reception, resulting in loss of part of the Rx packet, as illustrated at the top of Figure 4.

To overcome this problem, provision is made to apply an additional delay to the Rx packets in the receiver so that each is delayed by a full TDD cycle period, in this case 2 ms, or a multiple of that period, so as to ensure that they are received in the proper phase relationship with the transmission of the associated Tx packets. The data recovered by receiver 200 is applied to a clock recovery circuit 202, which recovers from the data a data bit rate clock signal and a strobe signal marking the beginning and end of each packet. The clock signal is used to clock data from the receiver 200 into a first-in, first-out (FIFO) register 204, when enabled by the recovered strobe signal, as illustrated by the adjacent timing diagram. Data can be clocked out of the FIFO 204 on a line 206 by a base station system clock signal 208 when the receiver is enabled by the signal SYNC or $\overline{\text{SYNC}}$, as the case may be, provided that a FIFO status line 210 indicates that the FIFO contains a complete Rx packet, i.e. the strobe

signal is not active and the FIFO contains data. The received data packet can then be decoded and either converted to an analog signal, re-encoded as a PCM signal having an appropriate bit rate, or passed to a PAD 130 for further processing.

Whilst the foregoing description has related to an exemplary embodiment of the invention relating to a PCS, it should be appreciated that the invention could also advantageously be employed in a cellular radiotelephone system with suitable changes of parameters, and indeed in any application where the provision of wide area base station coverage is desired in a multi-channel radiotelephony system. Whilst the transceivers in the system described have commonly been referred to as handsets, it should be understood that the transceivers may be any of several forms, whether handheld, mobile, or even fixed where a conventional wired telephone circuit cannot conveniently be provided. Whilst an arrangement in which the CAI to the handsets uses a TDD format, the invention is also applicable to FDD formats, apart from those features specifically predicated upon the use of TDD. The nature of the telephone network to which the invention interfaces is significant only to the extent that the receivers and transmitters of the base station equipment must be provided with a suitable interface to the network.

CLAIMS:

1. A radiotelephony interface in which the area coverage of base station equipment is increased by connecting it to a plurality of antenna drivers by frequency division duplex transmission of transmitted and received signals between the base station equipment and the antenna drivers over a bidirectional cable television system, in frequency bands reserved in that system for downstream and upstream communications respectively.

2. An interface according to claim 1, wherein the radiotelephony system utilizes an air interface employing time division duplexing, and the antenna drivers perform conversions between frequency division multiplex and time division multiplex.

3. An interface according to claim 2, wherein the base station equipment comprises duplicated sets of transmitters and receivers, with each set of transmitters operating in successive frequency division multiplex time slots of the air interface whilst the other set of transmitters is inactive, and each receiver incorporating means to delay signals received from the air interface sufficiently to locate them in reception timeslots between the transmission timeslots of their associated transmitter.

4. A radiotelephony interface for use in a multi-channel radio telephony system to establish wireless communication between multiple portable transceiver units and a telephone network, comprising at least a part of a CATV system including a headend or hub and a plurality of drops in two-way communication with the headend or hub, at least one means at the headend or hub for processing

signals received from and for transmission in multiple channels to portable radiotelephone transceivers, utilizing blocks of channels occupying defined portions of the frequency spectrum for transmission and reception, and a plurality of remote antenna drivers connected to individual drops of the CATV system, the remote antenna drivers each comprising an antenna, first frequency conversion means for block converting signals received from said transceivers by said antenna in said defined portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to the associated drop as upstream signals, second frequency conversion means for block converting downstream signals received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the portion of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna, and the signal processing means at the headend or hub comprising means for transmitting signals to the drops in a block of channels within said portion of the frequency spectrum allotted in the CATV system for downstream communications, and means for receiving signals from the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for upstream communication.

5. A remote antenna driver for establishing a radiotelephony link between a CATV system and portable radiotelephone transceivers on any of a plurality of channels within a defined allocation of the radio frequency spectrum, comprising an antenna, first frequency conversion means for block converting signals received from a transceiver by said antenna in said allocation of the

frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to a drop of the CATV system as upstream signals, second frequency conversion means for block converting downstream signals, received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the allocation of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna.

6. A radiotelephony interface substantially as hereinbefore described with reference to the accompanying drawings.

7. A remote antenna driver substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

8. A radiotelephony interface, having 'odd-even' channel interleaving substantially as hereinbefore described with reference to the accompanying drawings.

9. A radiotelephony interface incorporating a cable based frequency division multiplex signal distribution system from base station equipment to remote antenna drivers which provide a time division multiplex air interface, the signal distribution system being substantially as hereinbefore described with reference to the accompanying drawings.

**atents Act 1977**
**aminer's report to the Comptroller under Section 17 (The Search Report)**

Application number 9100774.0

**Relevant Technical fields**

(i) UK Cl (Edition K ) H4R (RCSC,RCC,RCX)

(ii) Int Cl (Edition 5 ) H04H

Search Examiner

B.J. SPEAR

**Databases** (see over)

(i) UK Patent Office

(ii) Online databases: WPI, Claims, Inspec

Date of Search

24 June 1991

Documents considered relevant following a search in respect of claims

| Category (see over) | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| X | US 4757496 A (BARTHOLET) - Whole document, especially figure 1 | 1,4,5 |
| X | US 4644526 A (WU) - Whole document, especially figure 1 | 1,4,5 |

**SF2(p)**

| Category | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| | | |

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X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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H4R RCC
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(72) and (74) continued overleaf

## (54) Radiotelephony Interface

(57) A radiotelephony interface for communication with transceivers in a defined area, comprising base station equipment, a plurality of antenna drivers, antennas connected to said drivers, and a bidirectional cable television system. The antenna drivers each include a first frequency converter 7 for converting transmitted signals from frequencies in the band reserved for downstream signals to desired transmission frequencies for application to the antennas and a second frequency convertor 8 for converting received signals from frequencies received by the antennas to frequencies in the band reserved for upstream signals. The antenna drivers include means 27, 28, 29 to derive a common reference frequency and apply it as a reference to the frequency converters whereby to provide frequency coherency of the frequency converters of the plurality of antenna drivers.

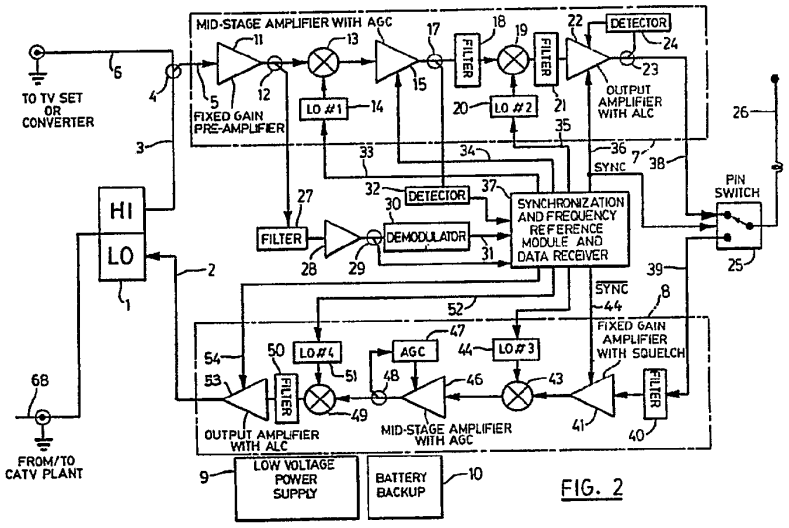



FIG. 2

GB 2 289 198 A

Amended claims have been filed in response to an objection under S.76(1).

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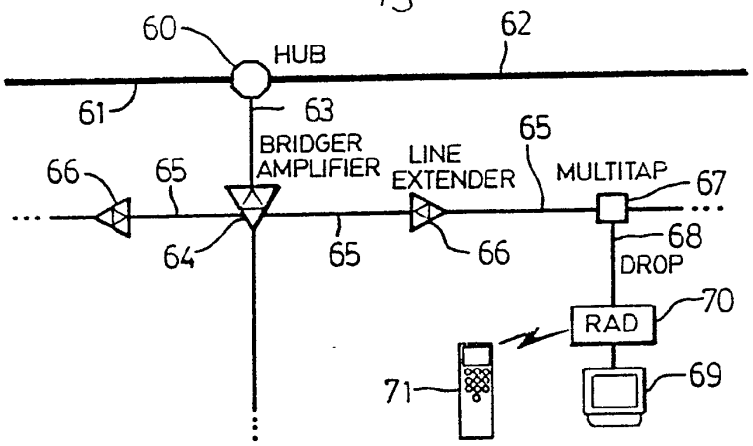

60
HUB
62
61
63
BRIDGER AMPLIFIER
LINE EXTENDER
65
MULTITAP
67
66
65
64
65
66
68
DROP
70
RAD
71
69

FIG. 1

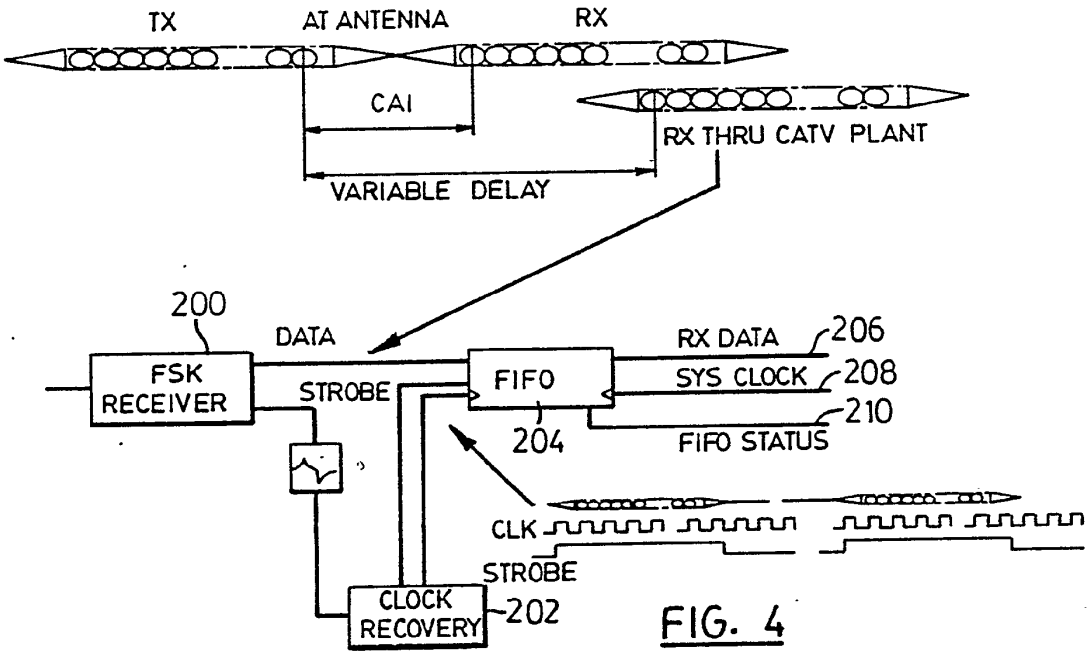

TX
AT ANTENNA
RX
CAI
RX THRU CATV PLANT
VARIABLE DELAY
200
DATA
RX DATA
206
FSK RECEIVER
STROBE
FIFO
SYS CLOCK
208
210
204
FIFO STATUS
CLK
STROBE
CLOCK RECOVERY
202

FIG. 4

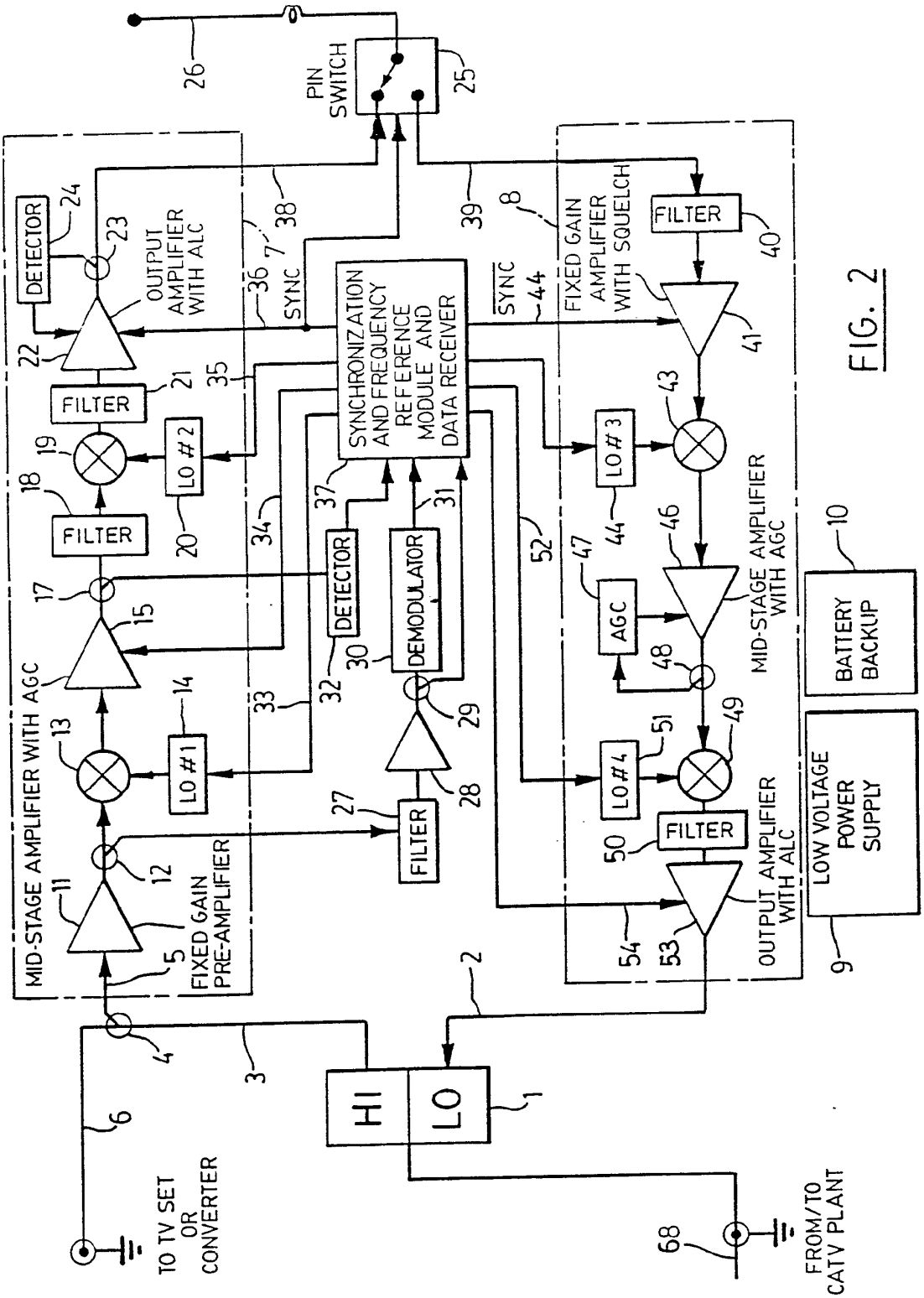

TO TV SET OR CONVERTER
FROM/TO CATV PLANT
HI
LO
MID-STAGE AMPLIFIER WITH AGC
FIXED GAIN PRE-AMPLIFIER
OUTPUT AMPLIFIER WITH ALC
FIXED GAIN AMPLIFIER WITH SQUELCH
MID-STAGE AMPLIFIER WITH AGC
OUTPUT AMPLIFIER WITH ALC
SYNCHRONIZATION AND FREQUENCY REFERENCE MODULE AND DATA RECEIVER
DETECTOR
DEMODULATOR
FILTER
AGC
LO #1
LO #2
LO #3
LO #4
PIN SWITCH
BATTERY BACKUP
LOW VOLTAGE POWER SUPPLY
SYNC
$\overline{\text{SYNC}}$

FIG. 2

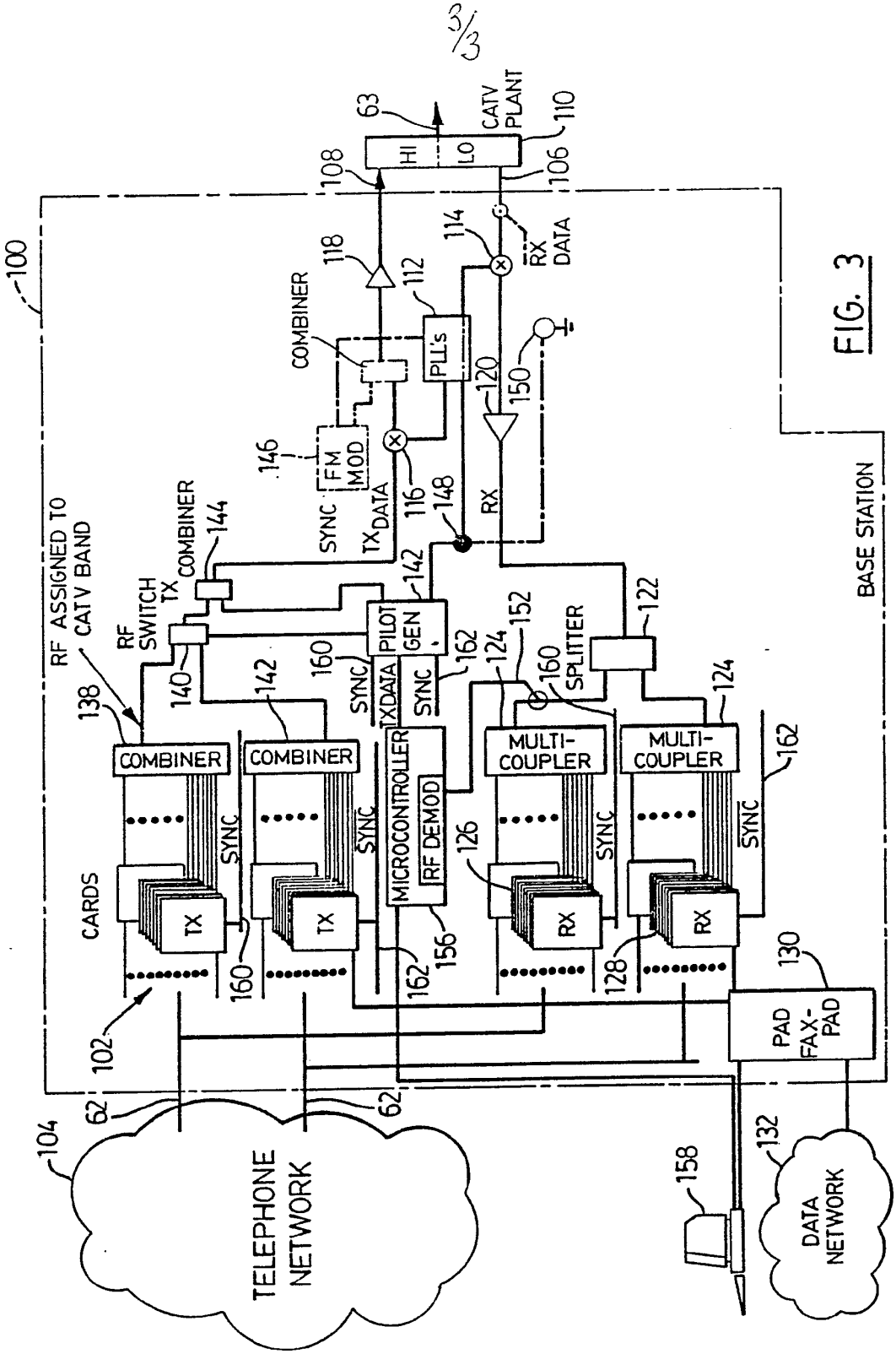

3/3
100
RF ASSIGNED TO CATV BAND
BASE STATION
63
HI
LO
CATV PLANT
110
108
106
114
RX DATA
118
112
COMBINER
PLL's
120
150
146
FM MOD
SYNC
TX DATA
116
148
RX
144
COMBINER
RF SWITCH TX
142
PILOT GEN
122
152
124
160
SPLITTER
162
138
140
142
COMBINER
COMBINER
MULTI-COUPLER
MULTI-COUPLER
MICROCONTROLLER
RF DEMOD
126
156
CARDS
TX
TX
RX
RX
SYNC
102
128
130
PAD
FAX-PAD
62
62
104
TELEPHONE NETWORK
158
132
DATA NETWORK

FIG. 3

This invention relates to the interface between a telephone network and portable wireless telephone units in a radiotelephony system and more particularly to equipment for the implementation of a personal communications service utilizing cable television facilities.

The development and commercial success of both cellular telephone systems, primarily for mobile use, and cordless telephones, for use in the vicinity of fixed locations within the public switched telephone network (PSTN), has given rise to considerable interest in the provision of tetherless personal communications using small portable handsets within a system which combines some of the personal mobility afforded by a cellular system with the lower cost and greater system capacity afforded by cordless telephones. Proposals for several systems have been published and some cases have been the subject of public trials. Such systems are commonly referred to as second generation cordless telephony (CT2), third generation cordless telephony (CT3), and generically as personal communications services (PCS). Further information on such systems may be found for example in the following publications:

"Personal Communications - A Report on CT2 & PCN Wireless Communications Systems" by Matthew Dosch, published 1990 by Telecom Publishing Group.

"Generic Framework Criteria for Universal Digital Portable Communications Systems (PCS)" published March 1990 by Bellcore.

"MPT 1375 Common Air Interface Specification" published by Department of Trade & Industry, London, England,

1989.

"Second generation cordless (CT2) telephony in the U.K.: telepoint services and the common air-interface" by Professor J.G. Gardiner, Electronics & Communication Engineering Journal, April 1990.

"CT2 Plus - A proposal for a Canadian Common Radio Interface Standard", Issue 2.0, December 1990, Bell-Northern Research.

"CT3 - Common Radio Interface Specification for Canadian Cordless Communications" December 19, 1990, Novatel Communications Ltd and Ericsson Communications Inc.

A common objective of the above PCS systems is the provision of wireless telephony via small portable handsets to individuals, either stationary or pedestrian. This wireless service is intended to be available at low cost to the general public and operate within and about the home, shops, schools, offices and institutions where telephone usage is most likely to be required. Wireless telephony is made possible by way of a portable radio handset carried on the person and a complementary radio base station connected to the public switched telephone network (PSTN) within operating range of the handset. This operating range is likely to be in the vicinity of 1000 feet or less, being primarily limited by the transmitter power available in a small portable handset, with the result that a very large number of base station locations is required to provide substantial area coverage.

The interconnecting of many spatially distributed radio base stations with the PSTN and the associated intelligence

required to locate mobile handsets has been termed a personal communication network (PCN). The construction and operation of a PCN will be required in order for PCS to be achieved. A large number of complex radio base stations need to be deployed over a substantial area to support adequate radio access for the general public to purchase the service. Each radio base station transforms, in a duplex manner, voice signals in a format suitable for transmission on twisted pair or fiber optic facilities, into radio frequency (RF) signals suitable for exchange with the portable handset.

In all cases, a complex signal multiplexing arrangement is used to conserve scarce RF spectrum, available allotments being in the vicinity of 1000 MHz. Radio base station equipment must include circuitry to properly multiplex and de-multiplex the RF signals exchanged with the portable handset.

In the case where more than one handset is expected to be in radio contact with a base station, the circuitry necessary for one duplex conversation or voice channel needs to be duplicated for each handset. The number of users who can access a particular radio base station will therefore be limited to the number of channels it is equipped to support.

In all digital cordless telephone formats, the radio spectrum is divided into a number of discrete RF channels using Frequency Division Multiple Access (FDMA) Techniques. Additionally, some systems such as CT-3 employ Time Division Multiple Access (TDMA) to multiplex several traffic channels into each RF channel. In all cases, traffic channels are processed individually at the base station before interconnection to the PSTN occurs. Traffic

channels may be used to transport coded voice or data.

In general, each radio base station consists of a number of RF modulators and demodulators for radio communications with the handsets, multiplexers and demultiplexers for handling the transmission of digital information over the radio link, encoders and decoders for converting the voice messages into digitally-coded streams of data, and a control system for error correction, establishment of radio links, synchronization, and other functions related to digital radio transmission.

The PSTN interface to each radio base station requires sufficient capacity, using existing twisted copper pairs or new fiber based terminal equipment. Each channel of each base station represents a new telephone line which must be established to the PSTN switch network. In many cases, new transmission equipment is needed to serve the radio base stations.

Thus a major problem, common to both conventional cellular and PCS radiotelephony systems, is their requirement for numerous spatially distributed base stations in order to provide coverage over a substantial area. The low power and limited range of PCS base stations makes this problem more acute in the case of PCN networks, particularly if any substantial degree of user mobility is to be provided. This problem has two facets, the first being the cost and complexity of the base stations themselves, and the second the cost and complexity of the distribution network required to pass signals to and from the base stations.

It is known in the case of cellular radio systems to utilize fibre optic trunks associated with a CATV system

to provide signal distribution to the base stations of a cellular system, as described in an article "Rogers Fiber Architecture" by George Hart and Nick Hamilton-Piercy, CED Magazine, July 1989. Various other proposals have also been made for the provision of telephony services making use of the existing fixed plant of CATV systems, particularly those having two way capability. An article "Cellular Radio and Cable TV = Cellular Cable" also points out the capability of existing two-way CATV systems, particularly those using optical fiber technology, to replace conventional twisted pair plant in the transmission of telephone communications, the suggestion (no details are provided) being that a CATV system might in effect replace the transmitter of a cellular base station, with the signal being distributed by cable instead of broadcast, analogously to the distribution rather than broadcast of television and radio signals by the system, but making use of its two-way capability. A system operating generally on these principles is disclosed in U.S. Patent No. 4,757,496 (Bartholet), which discloses frequency-agile stations connected to a coaxial cable network in a manner such as to replace conventional twisted-pair local distribution of telephone signals. U.S. Patent No. 4,644,526 (Wu) discloses a device for connection of station to a network, which may be implemented by coaxial cable, by translating between a single frequency division duplex signal and separate signals carried on different sidebands of a common carrier.

The architecture and technology of typical CATV systems is described further in "Cable Television System Overview-1987", published September 14, 1987 by American Television & Communications Corporation, Englewood, Colorado. Further discussion of two-way CATV systems is to be found in Chapter 12 of the book 'Cable Television', 2nd edition, by

John E. Cunningham, published 1980 by Howard W. Sams.

We have now found that we can effectively exploit the capabilities of a two-way CATV system in PCS and analogous radiotelephony systems by utilizing the CATV system to provide a base station or stations with a distributed radio transmission capability, thus enabling each base station to service a far larger area than would otherwise be possible.

In its broadest aspect, the present invention provides a radiotelephony interface in which the area coverage of base station equipment is increased by connecting it to a plurality of antenna drivers by frequency division duplex transmission of transmitted and received signals between the base station equipment and the antenna drivers over a bidirectional cable television system, in frequency bands reserved in that system for downstream and upstream communications respectively.

According to a further aspect of the invention, there is provided a radiotelephony interface for use in a multi-channel radio telephony system to establish wireless communication between multiple portable transceiver units and a telephone network, comprising at least a part of a CATV system including a headend or hub and a plurality of drops in two-way communication with the headend or hub, at least one means at the headend or hub for processing signals received from and for transmission in multiple channels to portable radio transceivers, utilizing blocks of channels occupying defined portions of the frequency spectrum for transmission and reception, and a plurality of remote antenna drivers connected to individual drops of the CATV system, the remote antenna drivers each comprising an antenna, first frequency conversion means for block

converting signals, received from said transceivers by said antenna in said defined portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to the associated drop as upstream signals, second frequency conversion means for block converting downstream signals, received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the portion of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna, and the signal processing means at the headend or hub comprising means for transmitting signals to the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for downstream communications, and means for receiving signals from the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for upstream communications.

The invention also extends to a remote antenna driver having the features set forth above.

The difficulties associated with the construction of a PCN may be significantly reduced by the use of the invention. The bidirectional transport of signals on two-way coaxial cable CATV facilities is well documented in the prior art. Conventionally, the conveyance of radio frequency (RF) signals at frequencies greater than 50 MHz from an originating location (headend) or relay points (hub) downstream to residences and businesses; upstream conveyance is at frequencies in the range 5 to 30 MHz from residences and businesses to the hub or headend. The signals are conveyed to and from homes and businesses via

single coaxial cable drops which are connected to a coaxial cable feeder line by way of signal couplers. The feeder line may be in turn connected to a coaxial trunk line or to opto-electronic transducers which are connected via optical fiber to a hub or headend.

By utilizing a CATV system to distribute the signals of a base station or group of base stations at the hub or headend to multiple antennas, the coverage of such stations can be greatly increased. If, as will usually be the case, multiple base stations are required to handle traffic demands, these may be co-sited at the hub or headend, except again for their shared distribution and remote antenna drivers. A remote handset exchanges RF signals with the CATV facility via a remote antenna driver (RAD). The number of handsets accessing the CATV facility at each RAD is only limited by the base station capacity at the hub or headend serving that RAD. The RADs plus the CATV facility are in effect a low loss transmission path between portable handsets and the main portion of the radio base stations at the hub or headend which allows a much greater distance between the handset and that main portion than would otherwise be possible. Calls are handled according to techniques already well known in cellular telephone networks, or as set forth in the publications set forth above.

A multiplicity of RADs may be connected to the CATV facility throughout a community, with widely scattered portable handsets able to communicate with the public switched telephone network (PSTN) through base station equipment located remotely from the RADs at a common hub or headend of the CATV system. The equipment required at the headend or hub may be provided by means of appropriate circuit modifications of a conventional radiotelephony base

station, to provide reception and transmission in appropriate frequency bands for interfacing with the CATV system, or an intermediate unit may be connected to radio base station antenna ports, the unit operating in a complementary manner to a RAD to provide the necessary frequency conversion and matching. The equipment must provide for the propagation delays inherent in a CATV system. A multiplicity of voice circuits interconnect the multiplicity of radio base stations to the PSTN in conventional manner.

In general, the RF frequencies allocated for PCS cannot be conveyed on CATV facilities and so the principal function of a RAD is to translate the PCS frequencies to frequencies suitable for CATV. Hence signals intended to be delivered to a portable handset by the radio interface of the invention are typically conveyed in a frequency band above 50 MHz on the CATV facility, and translated by a RAD in the vicinity of the portable handset to a frequency in the receiver frequency band of the portable handset. Signals transmitted by the portable handset are received by the RAD and translated to a frequency typically in the range 5 to 30 MHz for conveyance by the CATV system to the headend radio base station equipment serving that portable handset.

The range of frequencies which each RAD can accommodate is desirably sufficient to allow all channels available for PCS to be used without restriction. All RADs use functionally compatible translation systems to ensure any portable handset within communications range of any RAD can communicate with any free base station on any free channel, as established by the normal operation of the PCS system equipment as if the portable handset was in the vicinity of a conventional base station.

A presently preferred exemplary embodiment of the invention is described further below with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram showing part of a CATV system equipped to provide an interface according to the present invention;

Figure 2 is a more detailed schematic diagram of a remoted antenna driver incorporating the system of Figure 1; and

Figure 3 is a schematic diagram showing an interface to a PSTN incorporated in a hub of the CATV system of Figure 1.

Figure 4 is a schematic diagram of part of a base station receiver illustrating means compensating for propagation delays in the CATV system.

Figure 1 shows a segment of a CATV facility including a hub 60 connected to a headend via a supertrunk 61 as well as to the PSTN via voice circuits 62. Coaxial cable trunks 63 with bridger amplifiers 64 convey signals between the hub 60 and coaxial distribution feeders 65. Line extenders 66 amplify the signals to compensate for signal attenuation caused by cable and by couplers contained within multitaps 67. Coaxial drop cables 68 (of which only one is shown) provide cable television service to residences and businesses where television sets 69 are the usual terminal equipment. A remote antenna driver (RAD) 70 is connected to the drop 68 to allow portable telephone handsets 71 in the vicinity of the drop to communicate with the remaining equipment of a radio base station or stations contained in

the hub 60. This equipment will be referred to as the base station(s) although it should be understood that the entire system to be described, including the CATV system and RADs, together constitutes a form of distributed radio base station which acts collectively as the interface between the PSTN and the handsets 71. A multiplicity of RADs 70 may be connected to a multiplicity of drops 68 and multitaps 67 on a multiplicity of feeder lines 65 and line extenders 66 which in turn connect to a multiplicity of bridger amplifiers 64 on a multiplicity of trunks 63 connected to a common hub 60. Each bridger amplifier 64 is equipped with amplifiers and diplexing filters to support two-way operation in a manner conventional in the art of two-way CATV systems. Similarly each line extender 66 is equipped for two-way operation such that signals in the range of frequencies 5 to 30 MHz may pass with approximately 30dB attenuation from the RAD 70 to the hub 60. Signals above 50 MHz, up to the design limit of the amplifiers 64, line extenders 66 and multitaps 67, which limit is typically 400 to 550 MHz, are conveyed with approximately 50 dB attenuation from the hub 60 to RAD 70. These attenuation figures are exemplary only and may vary significantly with respect to individual drops 68.

Although Figure 1 shows connections being established to the PSTN through equipment located at the hub 60, such connections could also be established through similar equipment located at the headend, particularly in the case of a relatively smaller CATV system. Moreover, the coaxial trunk cables connecting bridging amplifiers 64 to the hub 60 may be replaced by optical fibers with appropriate transducers to support two-way signal conveyance in accordance with normal CATV system practice, without affecting the practicality or operation of the invention.

Referring now to Figure 2, the RAD 70 will be described in more detail. The drop cable 68 is connected to a diplexing filter 1 by means of which frequencies in the range 5 to 30 MHz present on a conductor 2 may be inserted onto the drop cable 68 with minimum attenuation. Signals above 50 MHz pass through the diplexing filter from the drop cable 68 to a conductor 3 from which they are available to a forward frequency translation subsystem 7 via a coupler 4 and a conductor 5. A low attenuation path through coupler 4 is made available via conductor 6 to a suitable connector on the RAD 70 for connection of a television 69, for the purpose of receiving television programming normally available on the CATV facility. The RAD 70 has no effect on normal CATV service other than a small attenuation of signals above 50 MHz.

PCS signals from the radio base station equipment in the hub and intended for a portable handset 71, are passed to the forward frequency translation subsystem 7. This acts to change low power signals from conductor 5, in any one of a block of channels in a pre-determined band of frequencies typically having a bandwidth equal to that allocated for PCS channels, but located between 50 and 550 MHz, into relatively higher power signals for transmission in the frequency band allocated for PCS channels receivable by the handset 71, typically in the range 900-1000 MHz. The transmission signals are delivered to an antenna 26 via an electronic switch 25. The band of frequencies to be so changed will typically be from 4 to 20 MHz wide, as determined by the portion of the RF spectrum allotted to the PCS. All RADs 70 will perform an identical translation of the complete PCS band of frequencies.

Within the subsystem 7, the low level downstream PCS signals from conductor 5 are amplified by a preamplifier

11 with fixed gain and connected via a coupler 12 to a mixer 13. A local oscillator 14 drives the mixer 13 at a suitable frequency in known manner to cause the PCS signals to be heterodyned to an intermediate frequency, typically in the vicinity of 45 MHz, and further amplified by a variable gain narrow band amplifier 15 whose output is connected to a band pass filter 18 via a coupler 17. The intermediate frequency, band limited, PCS signals are heterodyned a second time by a mixer 19 which is driven by a local oscillator 20 so as to be translated to the desired transmission frequency band. Band pass filter 21 prevents spurious mixer signals from reaching a power amplifier 22, which delivers the maximum allowable PCS signal power to the antenna 26 via a coupler 23 and the electronic switch 25. A sample of the power amplifier 22 output is diverted by the coupler 23 to a broadband detector 24 to provide an automatic level control signal which limits the gain of the power amplifier and so prevents excessive output power which might otherwise result in signal distortion and unlawful emissions.

A sample of the input signal is diverted by the coupler 12 to a filter 27 which extracts control and frequency reference signals, which signals are subsequently amplified by an amplifier 28 and demodulated by a demodulator 30 to provide control information to a controller 37 via conductor 31. A frequency reference is provided to the controller via coupler 29 to ensure that the various local oscillators in this and other RADs, which are frequency synthesizers, are operating coherently at predetermined frequencies.

The coupler 17 is used to divert a sample of the RF power at the output of the variable gain intermediate frequency (IF) amplifier 15. A power detector 32 delivers

a signal to the controller 37 used for controlling the gain of the amplifier 15 by a signal output on a conductor 34. The signal amplitudes in this subsystem also provide an indication of the input signal level to the RAD and thus the net RF path attenuation between the hub 60 and the RAD 70. The estimated path loss is used to provide a signal on conductor 54 which controls the gain of an amplifier 53 for optimum launching of PCS signals received from the portable handset 71 onto the CATV facility for conveyance to the hub 60. A frequency conversion subsystem 8 transforms low power emissions received by the antenna 26 from portable handsets 71 on channels allocated in the PCS frequency spectrum into higher power replicas displaced in frequency so as to be compatible with the upstream transport capabilities of conventional bidirectional CATV facilities, specifically an allotted band within the 5 to 30 MHz frequency band wide enough to accommodate the allocated block of reception channels.

The subsystem 8 is connected to the antenna 26 through the switch 25 by conductor 39, which passes signals through as an input filter 40 to a fixed gain amplifier 41 with conventional squelch capabilities. Provided the received PCS signals are of sufficient level to give reliable communication, the squelch of the input preamplifier 41 will be removed and the signals will be delivered to a mixer 43 which is driven by a local oscillator 44. The filter 40 ensures that unwanted signals outside the PCS frequency band are attenuated sufficiently to prevent interference likely to disrupt reliable communications. The output of the mixer 43 is at an intermediate frequency, typically 45 MHz, and is amplified by a band-limited variable gain amplifier 46 and delivered to a mixer 49 via a coupler 48. A local oscillator 51 drives the mixer 49 such that its output contains the PCS signals translated

to the desired band within the range of frequencies 5 to 30 MHz. A filter 50 prevents undesired mixer products from passing to the output amplifier 53. The coupler 48 diverts a sample of the PCS signal to an automatic gain control module 47 in order to provide optimum gain of the amplifier 46 relative to the PCS signal level received at antenna 26, which may vary over a very large range. More specifically the amplifier 46 operates at maximum gain for the lowest received signal power, its gain decreasing linearly with increasing received signal power until minimum gain is reached, whereafter it maintains minimum gain as receiver input power increases further.

The electronic switch 25 is controlled by the controller 37 such that it is synchronized with signal packets being exchanged between the RAD 70 and the portable handset 71. Suitable control information, extracted from the downstream signals, is delivered to the controller 37 via the demodulator 30 on conductor 31 to ensure that synchronization is achieved. Because of limitations on the isolation achievable in practical switches between the conductors 38 and 39, the amplifiers 22 and 41 are controlled by signals on conductors 36 and 42 so as to turn the amplifiers off when not connected to the antenna 26.

The RAD may be contained in an aesthetically pleasing container suitable for installation in homes or offices and is typically powered by commercial 120V AC via a wall mount power supply that delivers low voltage AC power to it. A low voltage power supply 9 uses this low voltage AC input to generate the direct current voltages necessary to power the RAD. A battery 10 is used to power the RAD during interruption of the commercial power source. Outdoor versions of the RAD may be powered by 60V square wave power conventionally available on the coaxial feeder cable 65,

the power supply being adapted in known manner to utilize this supply. As a further alternative, the RAD may be housed within a cable television converter unit, and share the power supply of that unit. This alternative has the advantage that it is more likely to provide a favourable location for the RAD antenna.

Most functions of the RAD described so far are substantially independent of the implementation of the PCS, since they are limited to block frequency conversion, power amplification and matching to the RAD antenna and to the CATV drop.

Several proposed radio Common Air Interfaces (CAI) for PCS radio communication employ Time Division Duplex (TDD) operation. As a result, the RAD must be designed for TDD operation on the radio side. A CATV plant will not support TDD operation, however, as it is frequency-divided into two bands: a high band which handles downstream transmission (head-end to hub to subscriber) and a low band which handles upstream transmission (subscriber to hub to headend).

To accommodate a CATV transport system from the remainder of the base station equipment, the latter is designed to provide Frequency Division Duplex (FDD) output. The duplex channels are divided into "transmit" and "receive" links which are transported on the CATV downstream and upstream bands, respectively.

As an example of bandwidth requirements, assume a PCS system using CT-2 plus. Such a system would occupy 8 MHz of bandwidth, with a nominal 80 channels spaced at 100 KHz between channels. In the simplest case, the transmit link would be carried downstream in an 8 MHz allocation (eg.500-

508 MHz) and the receive link would be carried upstream in an 8 MHz allocation (eg. 22-30 MHz). A conventional diplexing filter is used to couple the base station equipment to the CATV plant.

Conversion of FDD to TDD is performed in the RAD by the switch 25 under control of the controller 37 which performs the necessary time duplexing. An FDD radio link between the RAD and the handheld units can however also be accommodated by appropriate control or elimination of the switch. For the purposes of description, TDD operation of the link is assumed. The controller would regenerate the synchronization signals SYNC and SYNC on lines 36 and 42 from the downstream signal sample received from demodulator 30.

In a conventional PCS system, the handset communicates directly with the base station via a radio frequency link. The only time delay in the path is due to radio propagation delays between the base station and the handset. Due to the short radio range of these systems (typically less than 300 m for reliable radio coverage) these propagation delays are short. As a result, the digital transmission schemes developed for such systems do not incorporate elaborate equalization to compensate for time delays, and FDD operation is practicable without such equalization. The incorporation of CATV plant into the base station-to-handset transmission path does however introduce substantial time delays.

In a conventional PCN base station, the transmitter and receiver sections are synchronously coupled. A clock switches the transceiver between transmit and receive modes. The time frame employed depends on the Common Air Interface CT-2 and CT-2 Plus employ a 2 ms time frame (Tx

1 ms, Rx 1 ms) while CT-3 employs a 16 ms time frame (Tx 8ms, Rx 8 ms). This mode of operation requires that the base-to-handset data burst be closely followed by the handset-to-base data burst. A lengthy delay may cause the first few bits of a transmission to be lost resulting in no communications being established between base station and handset.

A CATV compatible PCS base station requires that the transmitter and receiver sections be asynchronous, i.e. the receiver must be allowed to 'slip' in time relative to the transmitter, so that received packets can be processed when received outside a time slot allocated for reception, and then delayed further so as to fall into such a time slot. Each transceiver within a multi-transceiver base station must employ an independent slip timing buffer so as to compensate for varying propagation delays in a system employing a multiplicity of distributed RADs. This is described further below with reference to Figure 4.

The handsets do not suffer from CATV induced delay because they are configured to slave their transmission to the data bursts or packets which they receive from the base station. The TDD to FDD translation at the RAD is also slaved to the data bursts received by the handset and since it occurs in close physical proximity to the handset, no propagation delays between the handset 71 and the RAD 70 are large enough to cause a problem. In other words neither the RAD nor the handsets need to make any provision for propagation delays within the CATV system since it is the responsibility of the base station equipment at the hub (or headend) to make such provision based on the timing of the upstream packets it receives from the RAD.

When the CAI between the RAD and the handset operates

in TDD mode and the proposed CATV transport system (Base Station-to-RAD) operates in an FDD mode, the CATV bandwidth is under-utilized because the transmit bandwidth is active only half the time and the receive bandwidth is active only half the time.

In order to utilize more fully the CATV transport capacity, a technique referred to as "Even/Odd" channel assignment can be utilized to increase the loading of the CATV plant and thus increase efficiency.

To take an example, each CT-2 Plus channel occupies a bandwidth of approximately 200 KHz. Therefore in an 8 MHz allocation, 40 channels may be transmitted simultaneously without adjacent channel interference. These 40 channels (the "even" channels) would be active during the transmit cycles of a first group of RADs designated "even". Also connected to the same CATV plant would be an approximately equal number of "odd" RADs, which would be in the receive mode while the even RADs are in the transmit mode. A total of 40 channels can thus be received simultaneously without adjacent channel interference. At any given time, therefore, there are up to 40 channels in the transmit mode and up to 40 channels in the receive mode for a total of 80 active channels in an 8 MHz allocation.

During a first phase of the synchronization signal used to operate the switch 25 in the RADs, the odd RADs would be transmitting on up to 40 channels and the even RADs would be receiving on the even channels, whilst during a second phase, the operation would be reversed. The only difference between 'odd' and 'even' RADs is the relative phase of the signals SYNC and $\overline{\text{SYNC}}$, which can be controlled by a signal from the equipment at the hub or headend. The RADs can be dynamically or manually assigned to operate in

one of the two phases by a signal from the hub or headend equipment.

A CATV system used for PCS systems must allow for the assignment of a block of channels in a contiguous frequency band to the service. If the radio CAI interface employs a 4 MHz spectrum allocation then an exclusive and contiguous 4 MHz of CATV spectrum must be assigned in each of the downstream and upstream paths. If this is not the case then the design of the RAD becomes prohibitively complex. Similarly, if the radio CAI is assigned an 8 MHz allocation, and the CATV transport is designed to handle the entire allocation, then an exclusive and contiguous 8 MHz of CATV spectrum is required in each of the downstream and upstream paths.

Except for this requirement, however, the actual frequency assigned is not restricted to any particular part of the CATV frequency spectrum. The actual assignment is determined by the CATV plant operator and is a function of the capabilities of the plant. An essential requirement, of course, is that the plant be capable of bi-directional operation.

The actual spectrum allocations are a function of traffic requirements, CATV system architecture, and utilization of the spectrum for applications other than PCS. If necessary, several blocks of spectrum can be assigned to the service to increase capacity. Different versions of the RAD would then be employed in the system to translate the CATV spectrum blocks into the radio common air spectrum.

Frequency re-use is a function of CATV system architecture. If a block of frequencies is employed at the

headend of a distribution system, then that block may not be re-used again in that system. On the other hand, if the block of frequencies is used at a hub, then the block of frequencies may be re-used at other hubs, in a technique analogous to a technique known as "cell-splitting" in the cellular telephone industry, used to increase frequency re-use as the density of cellular subscribers increases over time.

Pilot signals may be used for various functions in the proposed system. A downstream pilot signal may be used for base station-to-RAD signalling, and an upstream pilot signal may be used for RAD-to-base station signalling. The pilot signals may be located in the PCS transport band or an out-of-band allocation may be used. A number of modulation techniques are also possible. The actual allocation and modulation technique can be determined by the CATV operator to suit system requirements. At the least, a downstream pilot is desirable as a simple means to provide the synchronization signal for TDD switching, and a frequency reference for the frequency translators employed in the RAD.

The downstream pilot may also be modulated with data at the base station to control various functions at the RAD. These possible functions include:

a) "Even/Odd" channel block assignments
b) Spectrum block assignment
c) Output power control (RAD-handset interface)
d) Remote enable/disable of RADs
e) Input level control (RAD-CATV interface)
f) Output level control (RAD-CATV interface).

An upstream pilot generated by each RAD can provide functions such as acknowledgement of control messages and

power failure or device failure reporting.

In addition to these PCS-related functions, the two pilots can also be used for various other purposes. More specifically, they can carry data related to auxiliary services already proposed or implemented in two-way CATV systems such as special functions related to the CATV operation e.g. Pay TV, Pay-per-view TV and remote decoder enable/disable, and telemetry control of household utility services such as electricity and natural gas.

Referring now to Figure 3, there is shown exemplary base station equipment 100 provided at the hub 60 (or headend) for connection to multiple twisted pair circuits 102 forming the connection 62 to a PSTN 104. The base station equipment provides input and output signal lines 106 and 108 which are connected to the conventional CATV plant 110 at the hub (or headend) in which the signals are inserted into or extracted from the cables 63 extending out of the hub using conventional techniques. In the particular example being discussed, the downstream signals on line 108 are in a selected available frequency band, of a width corresponding to the band width allotted to the PCS service being implemented, somewhere within the 50-550 MHz frequency band allocated for downstream signals. The upstream signals are in a selected available frequency band in the 5 - 33 MHz frequency band allocated for upstream signals. It will be understood of course that, whilst these upstream and downstream allocations are typical of modern CATV installations, they may be varied in which case the frequencies utilized for upstream and downstream PCS signals will be selected accordingly.

If the signals on lines 106 and 108 are to be provided and processed using conventional base station equipment

intended for processing signals for direct transmission to and reception from PCS transceivers, then these signals must be translated to and from the frequencies utilized by the PCS air interface. In such a case, the upstream signals on line 106 are applied, together with a local oscillator signal from a phase locked loop synthesizer 112 to a mixer 114 to generate signals in the PCS air interface band. The channel frequencies so generated will be the same as those utilized for communication between the transceivers 71 and the RADs 70. Likewise, the base station signals to be transmitted on line 108 are translated, by a further mixer 116 receiving a local oscillator signal from the synthesizer 112, to the frequencies utilized for communication between the RADs 70 and the transceivers 71. The downstream signals are amplified by a bandpass amplifier 118 before application to the line 108, the pass band of the amplifier corresponding to the downstream CATV allocation for the signals, and the upstream signals are amplified by a bandpass amplifier 120 having a pass band corresponding to that of the base station receiver equipment. If the base station equipment is adapted to handle the allocated CATV frequencies directly, it will be understood that the mixers 114 and 116, and the synthesizer 112, may be omitted.

The upstream signals from the amplifier 120 are applied to a splitter 122, which forwards the signal to multicouplers 124 serving two groups 126 and 128 of receiver cards each providing an interface to a PSTN circuit 102. According to the nature of the PSTN circuit, the signals output by the cards may be analog signals or include an interface to provide pulse code modulated signals such as a standard T1 interface. The T1 interface may be an intelligent interface including a multiplexer with a packet assembler/disassembler (PAD) 130 for routing

data or facsimile signals to a data network 132.

Signals from a PSTN circuit 102 pass to a transmitter card in one of two groups 134 and 136, which cards may be interfaced to that circuit as described above in relation to the receiver cards. Outputs from the transmitter cards are passed to combiners 138 and thence to an RF switch 140 which selected the outputs of either group 134 or group 136 according to the phase of a synchronizing signal SYNC or $\overline{\text{SYNC}}$ received from a pilot signal generator 142. A pilot signal generated by the generator 142 and modulated with this synchronizing signal is also combined with the transmitter output by a combiner 144 to perform the functions of the downstream pilot signal already discussed above. If an out-of-band pilot signal is to be used, and the mixer 116 is utilized, a somewhat different arrangement is needed so that the pilot signal carrier is not modified by the mixer 116. In this case the synchronizing signal and other data to be carried by the pilot is supplied to a frequency modulator 146 together with a carrier frequency generated by the synthesizer 112, and the pilot signal is combined with the transmitter signals by a combiner 148 downstream of the mixer 116. The pilot generator 142 and the synthesizer 112 receive a common reference frequency from an internal frequency reference 148, or an external reference 150 if frequency coherence with other base stations is needed.

Upstream pilot signals, already discussed above, may be recovered if utilized from the received signal on a line 152, and applied through a demodulator 154 to a microcontroller 156, equipped with a terminal 158, which supervises the transmission and reception of data carried by the pilot signal and supplies data to be transmitted to the pilot generator.

The receiver and transmitter cards operate generally as is conventional in the cellular telephony and PCS art, with each card being capable of receiving or transmitting a signal on any channel of the block of channels comprised by the PCS band, and the control functions required for allocating channels and generally supervising communications are also conventional in this art. Since they form no part of the present invention they have not been described nor illustrated in detail. As however has been previously mentioned and will be described further below, provision must be made in the receiver cards to allow for the substantially larger and variable propagation delays which will occur in a CATV network as compared with conventional short range radio communication between base stations and portable or mobile transceivers.

In the example described, the base station equipment is grouped in such a way to allow 40 channels in the CT-2 Plus format to be combined together during the transmit phase of the Time Division Duplex (TDD). Although the nominal RF channel spacing in CT-2 and CT-2 Plus is 100 KHz, the actual bandwidth consumed by the modulation of this channel is actually 200 KHz. In formats such as CT-2 or CT-3, the number of channels would be adjusted accordingly (20 channels for CT-2).

To obtain the maximum number of channels over the plant it is necessary to synchronize all of the transmit portions of the CT-2 equipment, using the synchronization signals SYNC and $\overline{\text{SYNC}}$ on lines from the pilot generator 142. This prevent spill overs or dispersion effects on what would appear to be adjacent channels. This bandwidth requirement reduces the total number of available channels to half under worst case conditions. The CATV plant however

provides a bi-directional frequency duplex trunk system. When the TDD CT-2 system is mapped into the CATV plant system using frequency translation techniques it is found that during the receive portion of the TDD cycle the RF energy in the CATV plant is zero for the block of frequencies being utilized. This means that this block is available for use, and the odd/even interleaving technique outlined above can be implemented.

In describing Figure 3, it has already been noted that duplicate sets of receiver cards 126, 128 and transmitter cards 134 and 136 are provided. Each first set of cards is provided with the synchronization signal SYNC on line 160 and each second set of cards with the synchronization signal SYNC of reverse phase on line 162, such that only the first sets or the second sets are strobed to output receive or transmit signals at any one time. The operation of the switch 140 is also controlled by the pilot generator 142 so that only the active set of transmitter cards is connected to the CATV network at any one time.

A similar switching technique cannot be used in respect of the receiver cards since the propagation delays suffered by the received signals in different channels will be different according to the origin of the signal. Individual adjustment is therefore necessary at each receiver card, and one technique for achieving this is shown in Figure 4.

Referring to Figure 4, showing schematically a portion of one of the receiver cards in sets 126 and 128, a signal from one of the multicouplers 124 is applied to a frequency shift keying (FSK) receiver 200 to recover data from received data packets. In a typical CT-2 or CT-2 Plus PCS, signal packets are transferred in TDD to and from the

transceivers in alternate 1 ms intervals to provide a 2 ms cycle with transmit packets Tx from base station to transceiver and receive packets Rx from transceiver to base station following each other in immediate succeeding time slots at the transceiver, as shown at the top of Figure 4.

As a result of propagation delays in both downstream and upstream passage through the CATV system, there is likely to be a significant and highly variable delay between the end of the period allowed for transmission of a Tx packet at the base station, and the reception of the corresponding Rx packet. These delays will frequently be such that the Rx packet will not be received within the time slot allowed by the TDD synchronization signal SYNC or $\overline{\text{SYNC}}$ for its reception, resulting in loss of part of the Rx packet, as illustrated at the top of Figure 4.

To overcome this problem, provision is made to apply an additional delay to the Rx packets in the receiver so that each is delayed by a full TDD cycle period, in this case 2 ms, or a multiple of that period, so as to ensure that they are received in the proper phase relationship with the transmission of the associated Tx packets. The data recovered by receiver 200 is applied to a clock recovery circuit 202, which recovers from the data a data bit rate clock signal and a strobe signal marking the beginning and end of each packet. The clock signal is used to clock data from the receiver 200 into a first-in, first-out (FIFO) register 204, when enabled by the recovered strobe signal, as illustrated by the adjacent timing diagram. Data can be clocked out of the FIFO 204 on a line 206 by a base station system clock signal 208 when the receiver is enabled by the signal SYNC or $\overline{\text{SYNC}}$, as the case may be, provided that a FIFO status line 210 indicates that the FIFO contains a complete Rx packet, i.e. the strobe

signal is not active and the FIFO contains data. The received data packet can then be decoded and either converted to an analog signal, re-encoded as a PCM signal having an appropriate bit rate, or passed to a PAD 130 for further processing.

Whilst the foregoing description has related to an exemplary embodiment of the invention relating to a PCS, it should be appreciated that the invention could also advantageously be employed in a cellular radiotelephone system with suitable changes of parameters, and indeed in any application where the provision of wide area base station coverage is desired in a multi-channel radiotelephony system. Whilst the transceivers in the system described have commonly been referred to as handsets, it should be understood that the transceivers may be any of several forms, whether handheld, mobile, or even fixed where a conventional wired telephone circuit cannot conveniently be provided. Whilst an arrangement in which the CAI to the handsets uses a TDD format, the invention is also applicable to FDD formats, apart from those features specifically predicated upon the use of TDD. The nature of the telephone network to which the invention interfaces is significant only to the extent that the receivers and transmitters of the base station equipment must be provided with a suitable interface to the network.

CLAIMS

1. A radiotelephony interface for communication with transceivers in a defined area, comprising base station equipment, a plurality of antenna drivers, antennas connected to said drivers, and a bidirectional cable television system, the area coverage of the base station equipment being remapped to the defined area by connecting it to the plurality of antenna drivers by frequency division multiplex transmission of transmitted and received signals between the base station equipment and the antenna driver over the bidirectional cable television system, in frequency bands reserved in that system for downstream and operation communications respectively, the antenna drivers including frequency converters for converting transmitted signals from frequencies in the band reserved for downstream signals to desired transmission frequencies for application to the antennas and converting received signals from frequencies received by the antennas to frequencies in the band reserved for upstream signals, the antenna drivers including means to derive a common reference frequency and apply it as a reference to the frequency converters whereby to provide frequency coherency of the frequency converters of the plurality of antenna drivers.

2. A radiotelephony interface according to claim 1, wherein the base station equipment includes a pilot signal generator providing a pilot signal which is transmitted over the cable television system by the base station equipment, the pilot signal providing the reference frequency derived by the antenna drivers.

3. A radiotelephony interface according to claim 2, wherein the frequency converters in the antenna drivers include local oscillators which are frequency synthesizers controlled by the reference frequency derived from the pilot signal.

4. A radiotelephony interface according to claim 3,

further including further frequency converters between the base station equipment and the bidirectional cable television system, said frequency converters including local oscillators which are frequency synthesizers controlled by a reference frequency provided to the further converters and to the pilot signal generator.

5. A radiotelephony interface according to claim 2, wherein the antenna drivers include switching means to transmit and receive signals through said antennas in a time division multiplexed mode, said switching means being controlled by a synchronizing signal included in said pilot signal.

6. A radiotelephony interface according to claim 5, including means at the base station equipment to compare the phase of synchronizing signal components recovered from signals received by the base station equipment from said bidirectional cable television system with that of the synchronizing signal included in the pilot signal at the base station, and delay means at the base station equipment to delay said received signals such that each such received signal is delayed by an integral number of cycles of the synchronizing signal.

7. A radiotelephony interface according to claim 6, wherein the delay means comprise first-in-first-out buffers receiving said received signals, said signals being read from the buffers under control of said synchronizing signals.

8. A radiotelephony interface according to claim 2, wherein the pilot signal establishes a reference signal level, wherein the antenna drivers include gain control circuits, and the gain control circuits are controlled in accordance with the level of said pilot signal to compensate for attenuation in the cable television system.

9. A radiotelephony interface according to any of

the preceding claims, wherein the bidirectional cable television system is a portion of a cable television network having a head end and multiple hubs, the portion extending downstream from the hub of the network, other hubs of the network also being used to provide radiotelephony interfaces in different areas of the network, frequencies used in one hub also being reused for independent signals in interfaces associated with other hubs.

10. A radiotelephony interface according to any of the preceding claims, wherein the base station equipment and the antenna drivers are adapted to handle multiple communication channels allotted different air interface frequencies within a frequency band, wherein at least a section of the antenna driver which processes received signals comprises several similar processing sections, the sections being connected in parallel and each operating on a subsection of the frequency band.

11. A radiotelephony interface according to any of the preceding claims, wherein at least some of the antenna drivers have power supplies receiving power from the cable television system through a coaxial feeder cable.

12. A radiotelephony interface according to any of the preceding claims, wherein the transceivers within the defined area include fixed transceivers.

13. A radiotelephony interface according to claim 2, wherein the antenna drivers include a pilot signal receiver to receive the pilot signal and extract from it a frequency reference and control signals for the antenna driver.

14. A radiotelephony interface according to claim 13, wherein the antenna drivers include an upstream pilot signal generator to send upstream pilot signals carrying data from the antenna drivers to the base station equipment together with signals received by the antenna driver from the antennas.

15. A radiotelephony interface according to any of claims 1 to 9, wherein the base station equipment and the antenna drivers are adapted to handle multiple communication channels, and the cable television system carries channels of frequencies more closely spaced within a frequency band than the minimum channel spacing that can be accommodated by the antenna drivers, adjacent channels on the cable television system being directed to different sets of antenna drivers.

16. A remote antenna driver for establishing a radiotelephony link between a bi-directional CATV system connected to a base station and a portable radiotelephone transceiver using at least one channel within a portion of radio frequency spectrum, comprising at least one antenna, a receiver having first frequency conversion means, including a local oscillator, for converting signals received from a transceiver by said antenna in said portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, an interface for applying said converted signals to the CATV system as upstream signals, a transmitter having second frequency conversion means, including a local oscillator, for converting downstream signals, received from said CATV system for transmission in a portion of the frequency spectrum allocated in the distribution system for downstream communications, to said portion of the radio frequency spectrum, said transmitter applying said converted downstream signals to said at least one antenna, a circuit for extracting a frequency reference from a pilot signal received by said remote antenna driver, and a controller for maintaining the frequency of the local oscillators coherent with respect to said frequency reference.

17. A remote antenna driver according to claim 16, wherein the controller also derives a synchronizing signal from the pilot signal, and further including a multiplexing switch driven by said synchronizing signal to connect said

at least one antenna alternately to said receiver and said transmitter.

18. A remote antenna driver according to claim 16 or 17, wherein said receiver includes a squelch circuit.

19. A remote antenna driver according to claim 16, wherein the controller receives a sample of the signal input to the transmitter from the CATV system, determines its level to determine path losses across the CATV system, and controls output levels of the transmitter and receiver accordingly.

20. A remote antenna driver according to any of claims 16 to 19, including a circuit to extract control signals from the signal input to the transmitter from the CATV system and apply said control signals to the controller.

21. A radiotelephony interface in which the area coverage of base station equipment is increased by connecting it to a plurality of antenna drivers by frequency division duplex transmission of transmitted and received signals between the base station equipment and the antenna drivers over a bidirectional cable television system, in frequency bands reserved in that system for downstream and upstream communications respectively.

22. An interface according to claim 21, wherein the radiotelephony system utilizes an air interface employing time division duplexing, and the antenna drivers perform conversions between frequency division multiplex and time division multiplex.

23. An interface according to claim 22, wherein the base station equipment comprises duplicated sets of transmitters and receivers, with each set of transmitters operating in successive frequency division multiplex time slots of the air interface whilst the other set of

transmitters is inactive, and each receiver incorporating means to delay signals received from the air interface sufficiently to locate them in reception timeslots between the transmission timeslots of their associated transmitter.

24. A radiotelephony interface for use in a multichannel radio telephony system to establish wireless communication between multiple portable transceiver units and a telephone network, comprising at least a part of a CATV system including a headend or hub and a plurality of drops in two-way communication with the headend or hub, at least one means at the headend or hub for processing signals received from and for transmission in multiple channels to portable radiotelephone transceivers, utilising blocks of channels occupying defined portions of the frequency spectrum for transmission and reception, and a plurality of remote antenna drivers connected to individual drops of the CATV system, the remote antenna drivers each comprising an antenna, first frequency conversion means for block converting signals received from said transceivers by said antenna in said defined portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to the associated drop as upstream signals, second frequency conversion means for block converting downstream signals received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the portion of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna, and the signal processing means at the headend or hub comprising means for transmitting signals to the drops in a block of channels within said portion of the frequency spectrum allotted in the CATV system for downstream communications, and means for receiving signals from the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for upstream communication.

25. A remote antenna driver for establishing a radiotelephony link between a CATV system and portable radiotelephone transceivers on any of a plurality of channels within a defined allocation of the radio frequency spectrum, comprising an antenna, first frequency conversion means for block converting signals received from a transceiver by said antenna in said allocation of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to a drop of the CATV system as upstream signals, second frequency conversion means for block converting downstream signals, received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the allocation of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna.

26. A radiotelephony interface substantially as hereinbefore described with reference to the accompanying drawings.

27. A remote antenna driver substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

28. A radiotelephony interface, having 'odd-even' channel interleaving substantially as hereinbefore described with reference to the accompanying drawings.

29. A radiotelephony interface incorporating a cable based frequency division multiplex signal distribution system from base station equipment to remote antenna drivers which provide a time division multiplex air interface, the signal distribution system being substantially as hereinbefore described with reference to the accompanying drawings.

**Amendments to the claims have been filed as follows**

1. A remote antenna driver for establishing a radiotelephony link between a bi-directional CATV system connected to a base station and a portable radiotelephone transceiver, using any of a plurality of channels within a portion of the radio frequency spectrum, comprising at least one antenna, first frequency conversion means for converting signals, received from a transceiver by said antenna in said portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to the CATV system as upstream signals, second frequency conversion means for converting downstream signals, received from said CATV system for transmission in a portion of the frequency spectrum allocated in the distribution system for downstream communications, to said portion of the radio frequency spectrum, and means for applying said converted downstream signals to said at least one antenna.

2. A remote antenna driver according to claim 1, including means to establish time division multiplex transmission and reception over the radiotelephony link.

3. A remote antenna driver according to claim 1, including means to receive and transmit pilot signals used for control purposes from and to the base station over the CATV system.

4. A remote antenna driver for establishing a radiotelephony link between a bi-directional CATV system connected to a base station and a portable radiotelephone transceiver using at least one channel within a portion of radio frequency spectrum, comprising at least one antenna, a receiver having first frequency conversion means, including a local oscillator, for converting signals received from a transceiver by said antenna in said portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream

communications, an interface for applying said converted signals to the CATV system as upstream signals, a transmitter having second frequency conversion means, including a local oscillator, for converting downstream signals, received from said CATV system for transmission in a portion of the frequency spectrum allocated in the distribution system for downstream communications, to said portion of the radio frequency spectrum, said transmitter applying said converted downstream signals to said at least one antenna, a circuit for extracting a frequency reference from a pilot signal received by said remote antenna driver, and a controller for maintaining the frequency of the local oscillators coherent with respect to said frequency reference.

5. A remote antenna driver according to claim 4, wherein the controller also derives a synchronizing signal from the pilot signal, and further including a multiplexing switch driven by said synchronizing signal to connect said at least one antenna alternately to said receiver and said transmitter.

6. A remote antenna driver for establishing a radiotelephony link between a bi-directional CATV system connected to a base station and a portable radiotelephone transceiver using at least one channel within a portion of the radio frequency spectrum, the remote antenna driver comprising an antenna; a receiver having first frequency conversion means including a first local oscillator for converting signals received from the portable transceiver by said antenna in said portion of the radio frequency spectrum to first intermediate frequency signals, and a second local oscillator for converting said first intermediate frequency signals to signals in a portion of the frequency spectrum allocated in the CATV system for upstream communications; an interface for applying said converted first intermediate frequency signals to the CATV system as upstream signals; a transmitter having second frequency conversion means including a third local oscillator for converting downstream

signals received from said CATV system for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications to second intermediate frequency signals, and a fourth local oscillator for converting said second intermediate frequency signals to signals in said portion of the radio frequency spectrum, said transmitter applying said converted second intermediate frequency signals to said antenna; a circuit for extracting a reference frequency from a signal applied to said circuit; and a controller for maintaining the frequency of the first, second, third and fourth local oscillators coherent with respect to the reference frequency.

7. A remote antenna driver according to claim 4, 5 or 6, wherein said receiver includes a squelch circuit.

8. A remote antenna driver according to claim 4 or 6, wherein the controller receives a sample of the signal input to the transmitter from the CATV system, determines its level to determine path losses across the CATV system, and controls output levels of the transmitter and receiver accordingly.

9. A remote antenna driver according to any of claims 4 to 8, including a circuit to extract control signals from the signal input to the transmitter from the CATV system and to apply said control signals to the controller.

10. A remote antenna driver substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

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| Patents Act 1977<br>Examiner's report to the Comptroller under Section 17<br>(The Search report) | Application number<br>GB 9511174.6 |
|---|---|
| **Relevant Technical Fields**<br>(i) UK Cl (Ed.N) H4R: RCC; RCSC; RCX<br>(ii) Int Cl (Ed.6) H04H, H04N | Search Examiner<br>AL STRAYTON<br>Date of completion of Search<br>30 JUNE 1995 |
| **Databases** (see below)<br>(i) UK Patent Office collections of GB, EP, WO and US patent specifications.<br>(ii) | Documents considered relevant following a search in respect of Claims :-<br>1-20 |

**Categories of documents**

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| **X:** | Document indicating lack of novelty or of inventive step. | **P:** | Document published on or after the declared priority date but before the filing date of the present application. |
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| Category | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| A | WO 93/06669 A1 (BARAN) | |

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EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00782

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| **Application No:** | GB 9511174.6 | **Examiner:** | Mr.S.SATKURUNATH |
| **Claims searched:** | 1 to 3 | **Date of search:** | 8 August 1995 |

## Patents Act 1977
## Further Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): H4R: RCC, RCSC, RCX

Int Cl (Ed.6): H04H, H04N

Other: Online: WPI, JAPIO, INSPEC

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | Relevant to claims |
|---|---|---|
| | NONE | |

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| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
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H04Q 7/30

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INT CL$^6$ H04B 7/155 7/185 7/195 7/204, H04Q 7/30
On-Line - WPI

# (54) Communications network node with switched channelizer architecture

(57) A communications network (10, fig.1) includes nodes (18) in which switched channelizers 32 decompose wideband signals into narrowband signals and route the narrowband signals to specified demodulators 34. The switched channelizers 32 serve as building blocks which may be coupled together in parallel and in series. Switch portions 28 of switched channelizers 32 may be coupled together so that the switched channelizers 32 form interconnected switched channelizer groups (54, fig.5). Within an interconnected switched channelizer group (54), any channel from any wideband signal may be routed to any demodulator 34. Nodes may include space-based satellite relays or land-based base stations.

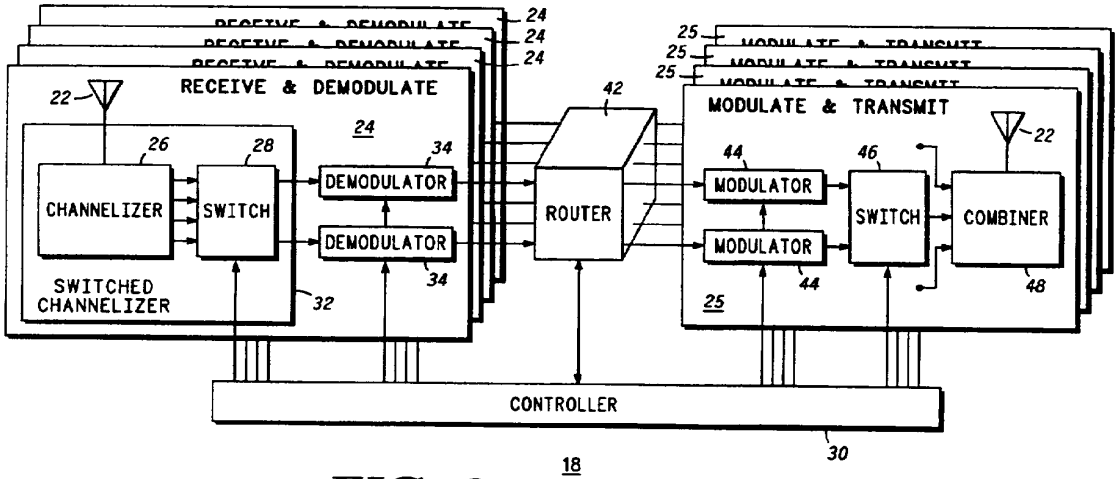



FIG. 2

GB 2 315 959 A

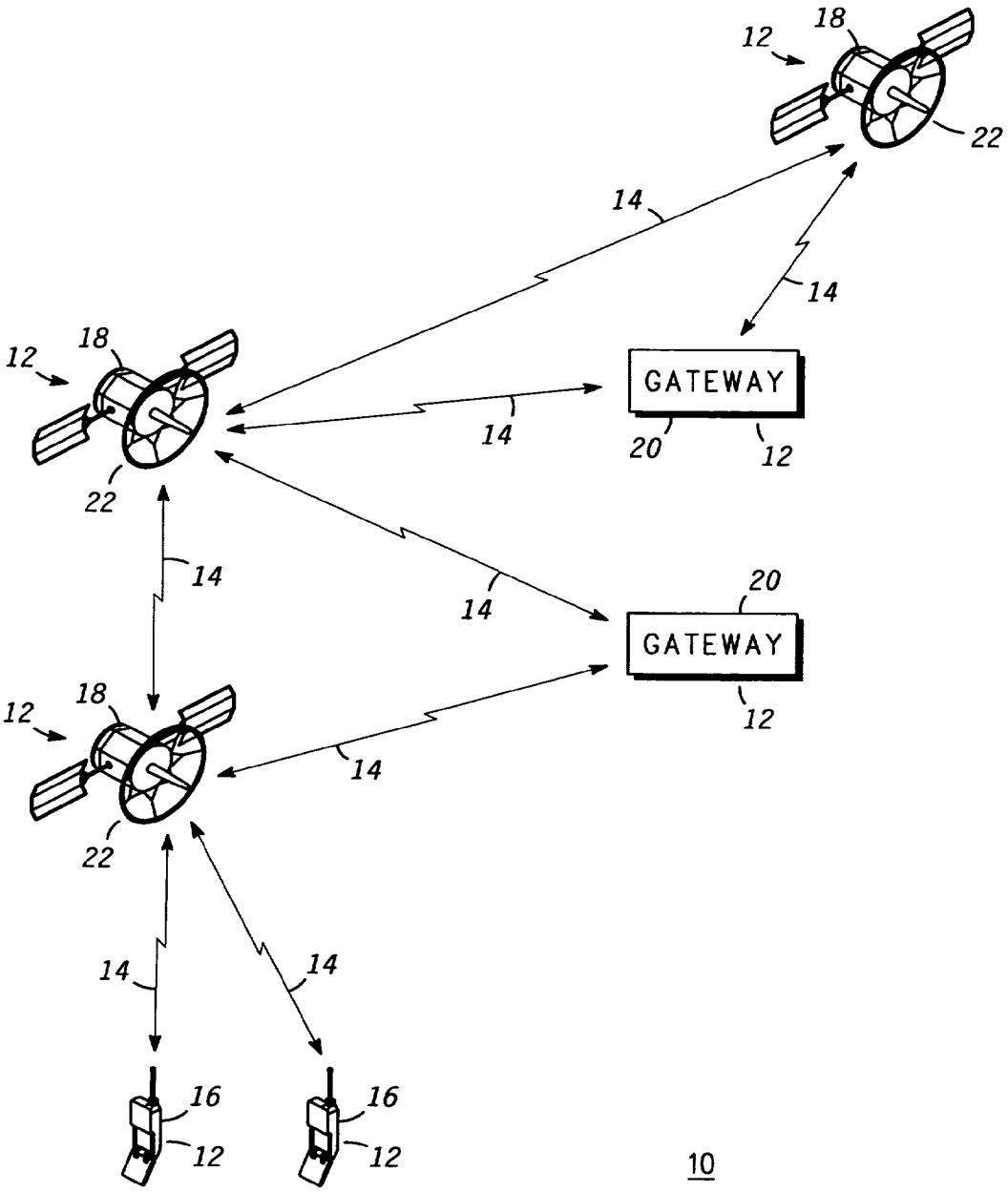



FIG. 1

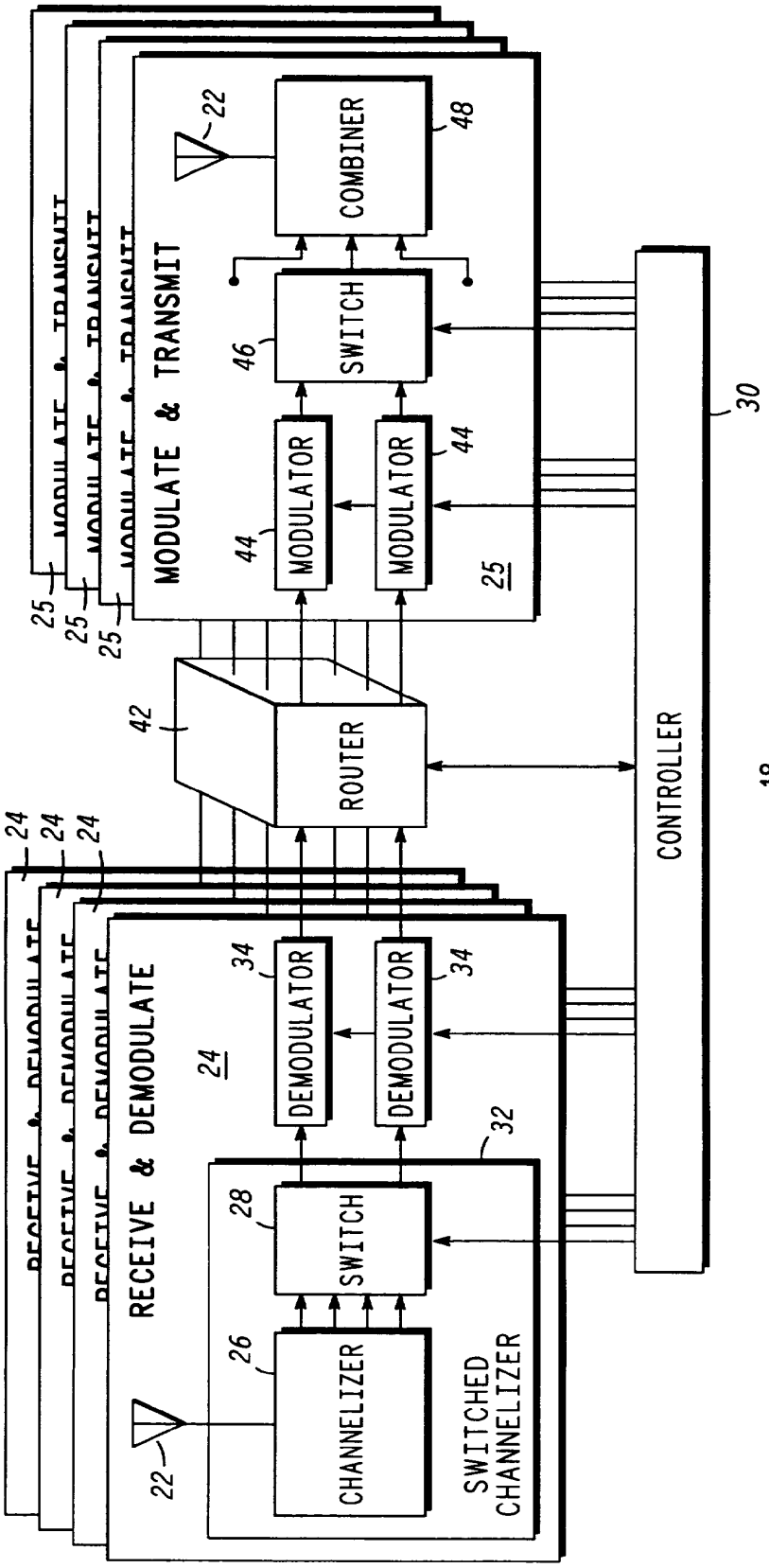

RECEIVE & DEMODULATE
MODULATE & TRANSMIT
SWITCHED CHANNELIZER
CHANNELIZER
SWITCH
DEMODULATOR
MODULATOR
COMBINER
ROUTER
CONTROLLER
22
24
25
26
28
30
32
34
42
44
46
48
18

FIG. 2

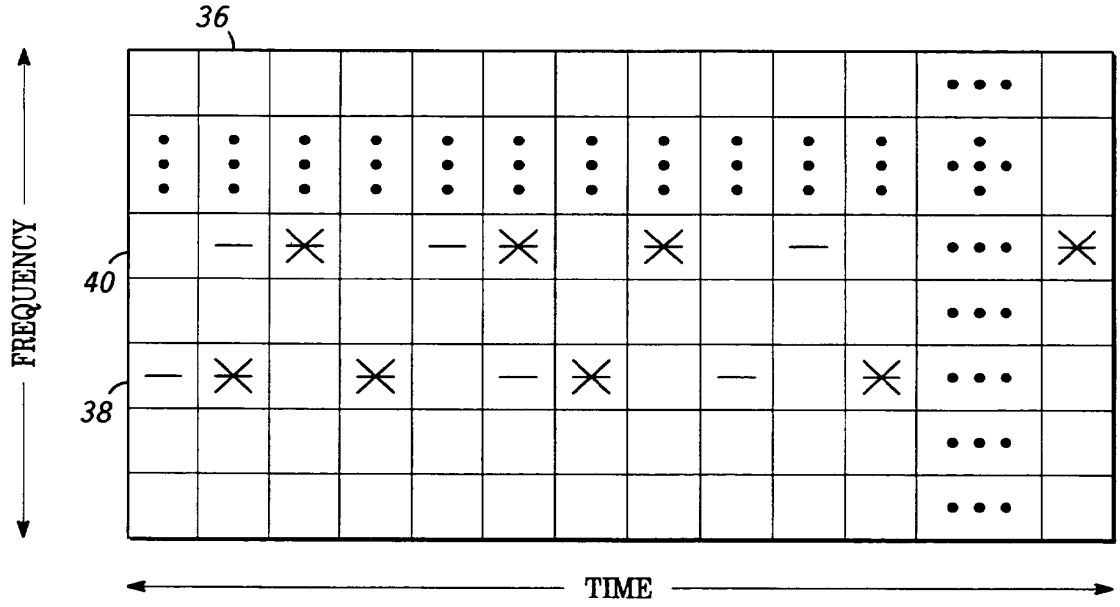
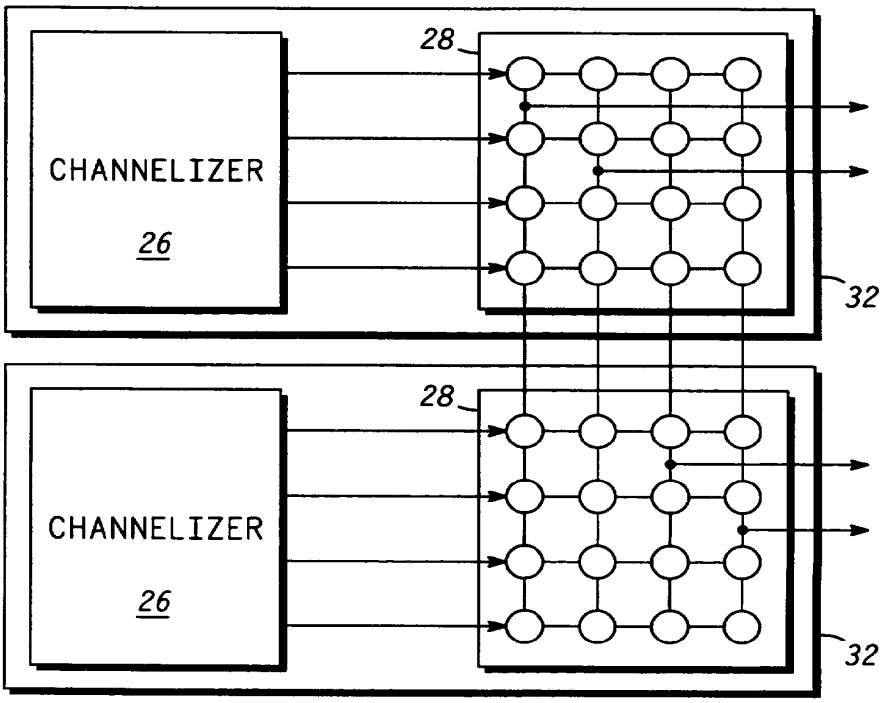

36
FREQUENCY
40
38
TIME

FIG. 3

54 FIG. 5


28
CHANNELIZER
26
32
28
CHANNELIZER
26
32

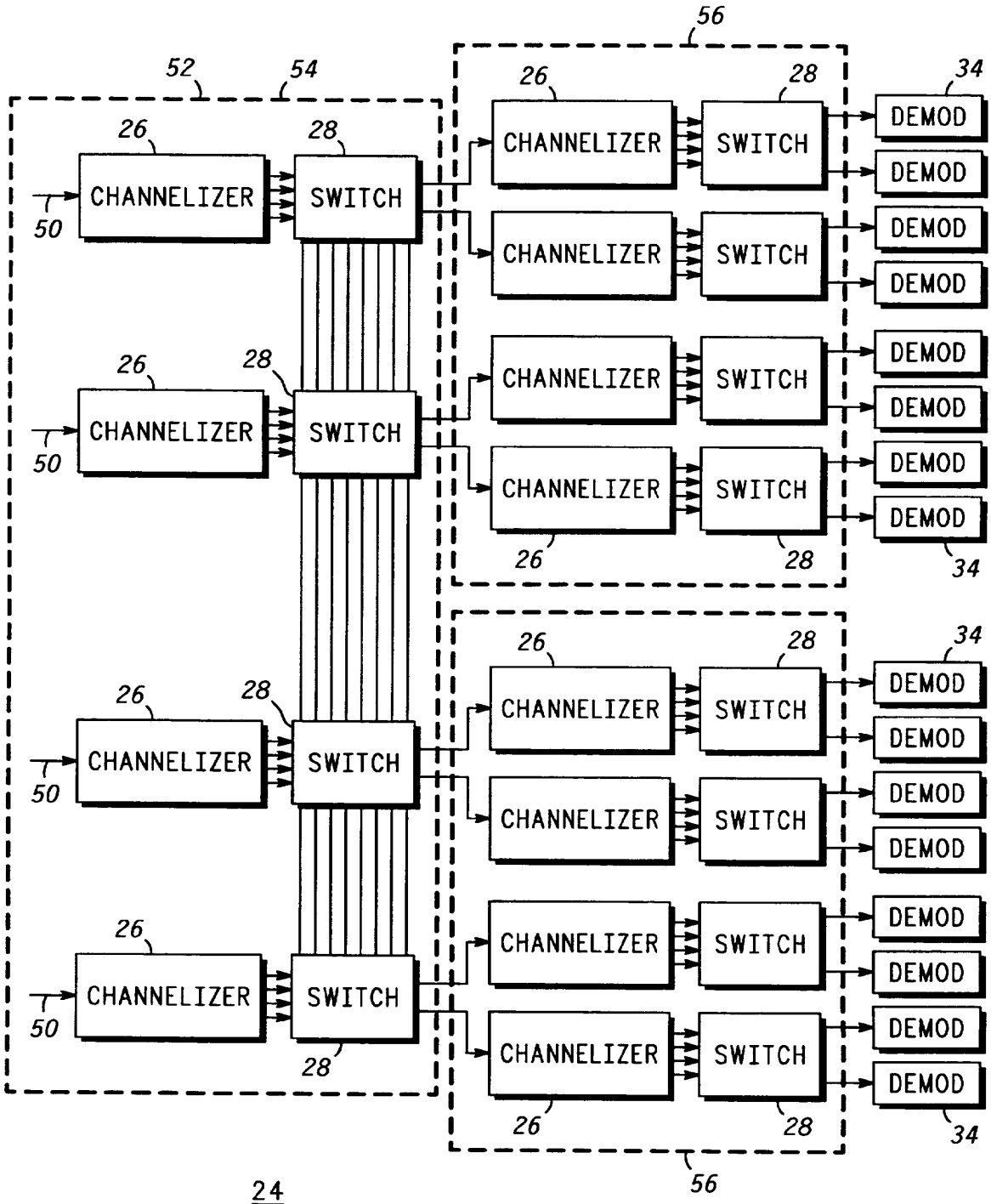



FIG. 4

# COMMUNICATIONS NETWORK NODE WITH SWITCHED CHANNELIZER ARCHITECTURE

## Field of the Invention

The present invention relates generally to communication networks. More specifically, the present invention relates to networks in which nodes receive numerous individual communication channels conveyed by one or more wideband signals and decompose the wideband signals into constituent channels.

## Background Of The Invention

In communication networks, and particularly cellular radio telephony networks, any single network node, such as a cellular base station, is often required to process only a fraction of the total channels available to the network. A channel is typically processed by receiving a wideband signal, decomposing the wideband signal into many narrowband signals, demodulating the narrowband signal which conveys a channel of interest, picking the channel of interest out of a specific time slot if TDMA communication schemes are employed, and performing any repackaging, modulation, combination, or other function needed to pass the information obtained from the channel of interest toward its ultimate destination.

Different nodes process different channels from the total network allocation. All channels get used, but the usage is spread over many different nodes. From time to time, the mix of channels processed at the nodes changes. When nodes reside in satellites orbiting the earth in moving orbits, the mix of channels processed at the nodes can change on a minute by minute basis. Accordingly, network nodes are typically configured to process a greater number of channels than they actually need to process at any given instant. This type of configuration



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leads to inefficiencies which have particularly serious consequences when the nodes are located in earth-orbiting satellites.

Conventional communication network nodes may be arranged in either of two different configurations. When the mix of channels processed at each node changes slowly, such as on a month by month basis, and when the nodes are located where they may be accessed by service personnel, the minimum hardware needed to meet the maximum instantaneous demand may be allocated to the node. This minimum hardware is usually manually tuned to process those channels which might possibly be used at each node. This technique is undesirable because it causes different hardware configurations to be located at different nodes, is labor intensive, and provides little excess capacity in case of failures.

When the mix of channels processed at each node changes quickly, or when the nodes are located where they cannot be easily accessed by service personnel, the nodes are typically provisioned with significantly more hardware than is required to process all channels being by the node used at any given instant. This is a conventional technique for nodes located in moving-orbit satellites. Unfortunately, the inclusion of more hardware than is absolutely necessary is highly undesirable in satellites. Excess hardware causes increased weight, increased power consumption, and reduced reliability, all of which can lead to tremendous increases in expenses. While power management schemes may be employed to de-energize hardware not being used at any given instant, such schemes are typically applied at system levels rather than assembly levels to prevent the power management hardware from causing more problems than it solves.

Accordingly, a need exists for a communications network node which can process any channel that may be allocated to the network using a hardware-efficient architecture.



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## Brief Description of the Drawings

A more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in connection with the Figures, wherein like reference numbers refer to similar items throughout the Figures, and:

FIG. 1 shows a layout diagram of a communications network environment in which a preferred embodiment of the present invention may be used;

FIG. 2 shows a block diagram of a network node;

FIG. 3 shows a table of an exemplary FDMA/TDMA communication scheme;

FIG. 4 shows a block diagram of a receive and demodulate section of the network node; and

FIG. 5 shows a block diagram of an interconnecting switching arrangement.

## Detailed Description of the Drawings

FIG. 1 shows a layout diagram of an environment within which a communications network 10 may be implemented. Network 10 includes numerous nodes 12 which couple together through RF communication links 14. FIG. 1 depicts nodes 12 as being configured as handsets 16, satellites 18, and gateways 20. Through RF communication links 14, subscriber units 16 satellites 18 may communicate with other satellites 18, handsets 16, and gateways 20. The below-discussed features of a preferred embodiment of the present invention may be practiced at any node 12 of network 10 or of other communications networks. However, such features may be particularly beneficial if incorporated in satellites 18.

Satellites 18 may reside in low earth orbits. In such orbits, satellites 18 move at high speed relative to any given point on the surface of the earth. Subscriber



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units 16 and gateways 20 may reside proximate the surface of the earth where they are virtually stationary relative to satellites 18.

Satellites 18 are desirably configured as cellular telecommunications base stations and are referred to as base station nodes 18 and simply nodes 18 below. Base station nodes 18 project cells (not shown) toward the surface of the earth. Communications with subscriber units 16 are conducted in accordance with channels assigned for use in the cells at any given instant. Due to the high speed movement of nodes 18, the channel assignments may change from minute to minute. Communications conducted with subscriber units 16 and other communications, such as signaling and trunked communications, are received at nodes 18 via communication links 14 and passed onward within network 10 toward the ultimate destinations for the communications. Such communications may be received from subscriber units 16, other nodes 18, or gateways 20, at any of various antennas 22 of nodes 18.

Generally, antennas 22 provide wideband signals each of which can convey numerous channels of information. In the preferred embodiment, the information is conveyed digitally using data packets. The channels of information are combined together in the wideband signals using FDMA/TDMA techniques. However, the use of digital communication or any specific multiple access technique is not a requirement of the present invention. While the wideband signals may convey numerous channels of information, it would be an extremely rare circumstance for all channels combined together in a wideband signal to be active and convey information at any given instant.

Nodes 18 receive these wideband signals at an incoming portion of a link 14. Nodes 18 then decompose the wideband signals into narrowband signals which convey individual channels. Those individual channels which are active at any given instant are demodulated to obtain



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communicated information, and the communicated information is routed to appropriate outgoing portions of links 14. Appropriate outgoing links 14 are the ones which further movement of the information toward the information's ultimate destinations. Node 18 then re-modulates the information for each outgoing link 14 and combines the re-modulated information with other modulated packets flowing outward over the outgoing link to form a wideband signal. The wideband signal is then transmitted over the outgoing link.

In accordance with the preferred embodiments of the present invention, node 18 provides extensive receiving and decomposing functions to accommodate the numerous diverse channels and the various received wideband signals which network 10 uses. Node 18 also incorporates switching functions along with limited demodulation and modulation (i.e. modem) functions. The switching functions provide extensive interconnectivity between decomposing functions and modem functions. Consequently, each node 18 need not incorporate modem functionality sufficient to accommodate all channels used in network 10 when only a fraction of the channels are active for any single node 18 at any given instant.

FIG. 2 shows a simplified block diagram of a communications network node, such as node 18. Node 18 includes any number of receive and demodulate sections 24 and any number of modulate and transmit sections 25. Each receive and demodulate section 24 is driven by one or more antennas 22. An antenna 22 provides a wideband signal which is fed to a channelizer 26.

Channelizer 26 is a conventional circuit known to those skilled in the art. Channelizer 26 decomposes the wideband signal into its constituent channels. Channelizer 26 may operate on RF or baseband, analog or digital signals. The wideband signal carries different channels using different frequency bands, different time slots, different spread spectrum coding, or a combination



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of any two or more of these techniques. Accordingly, channelizer 26 translates the wideband signal into a plurality of narrowband signals, where each narrowband signal conveys one of the channels conveyed by the wideband signal.

A switch 28 has an input port for each narrowband signal. In the preferred embodiments of the present invention, switch 28 has fewer output ports than it has input ports. Switch 28 is configured so that a selected one of the narrowband signals appearing at the input ports is provided for each of the output ports. In the preferred embodiments, the selected signals are specified by a controller 30 which couples to a selection input of switch 28.

A wide range of switching architectures known to those skilled in the art may be used to implement switch 28. The precise structure of switch 28 will depend in part upon the nature of the narrowband signals supplied at the input ports to switch 28. FIG. 2 illustrates the narrowband signals using four separate connectors extending from outputs of channelizer 26 to corresponding input ports of switch 28. Those skilled in the art will appreciate that a space switching fabric may be useful in this architecture. However, nothing prevents the narrowband signals from being provided in series over a common communication path between channelizer 26 and switch 28. In this situation, a time switching fabric may be useful for switch 28. In other embodiments, channelizer 26 may be implemented, at least in part, using a digital signal processor. In this embodiment, switch 28 and channelizer 26 may simply share a common buffer memory. FIG. 2 shows only four narrowband signals for convenience. Typical channelizers often produce many more narrowband signals than this number, but the present invention applies to any number of narrowband signals, whether that number is greater or less than four.



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Channelizer 26 and switch 28 together form a switched channelizer 32. Switched channelizer 32 represents a building block or module which may be used in numerous instances within node 18. The use of switched channelizer 32 as a building block is discussed below in connection with FIG. 4.

The output ports of switch 28 and of switched channelizer 32 couple to inputs of demodulators 34. Demodulators 34 desirably incorporate conventional designs to extract communicated information from the narrowband signals. Demodulators 34 may also couple to controller 30 so that controller 30 may provide power management for demodulators 34. In the preferred embodiment, fewer demodulators 34 are included in a receive and demodulate section 24 than the receive and demodulate section 24 has of narrowband signals.

FIG. 3 shows a table 36 depicting an exemplary FDMA/TDMA communication scheme. Rows in FIG. 3 indicate frequency bands for individual channels, columns indicate time slots for individual channels, and the cells where rows and columns intersect represent the individual channels. An entire frequency spectrum allocated to network 10 (see FIG. 1) may be divided into many frequency bands and time slots to yield a vast number of individual channels. Only a portion of this vast number of individual channels is allocated to any single node 18, but this portion changes over time. For convenience, FIG. 3 depicts channels allocated to a node 18 with a "-" mark. The allocated channels represents the maximum capacity of the node 18, and this maximum capacity is determined in response to a network-wide analysis of channel resources to be allocated to node 18 and other nodes 18. Referring back to FIG. 2, the number of demodulators 34 included in node 18 is based upon this maximum capacity for any future instant. This number is significantly less than the total number of frequency bands or individual channels allocated to network 10.



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At any given instant, the actual number of active channels in use at a node 18 is usually less than the maximum capacity. FIG. 3 depicts active channels, which are in use, with an "X" mark. Referring to FIGs. 2 and 3, a single demodulator 34 may be used efficiently by being quickly switched between frequency bands 38 and 40 during different time slots. In other words, a greater number of demodulators 34 need not remain idle when frequency bands to which they may be assigned experience inactive time slots. Rather, a lesser number of demodulators 34 may get switched between frequency bands in different time slots to process active channels. By switching a demodulator 34 between different frequency bands, channelizer 26 may maintain constant tuning rather than suffer settling time delays associated with re-tuning. Moreover, channelizer 26 may be constructed using a simple constantly tuned architecture rather than a complex tunable architecture.

Accordingly, the ability to switch demodulators 34 to track changes in channel allocations to node 18 allows node 18 to incorporate fewer demodulators 34 than it otherwise would. Moreover, the ability to quickly switch demodulators 34 between time slots allows node 18 to incorporate even fewer demodulators 34 than it otherwise would. Furthermore, when allocated channels are inactive, power management processes provided by controller 30 may selectively energize and de-energize demodulators 34 so that only a minimum number of demodulators 34 are energized at any given instant. Entire demodulator systems may remain de-energized for longer periods of time to further reduce power consumption.

Referring back to FIG. 2, outputs from demodulators 34 couple to a node router section 42. Router section 42 routes packets as required to ensure re-transmission away from node 18 over a link 14 (see FIG. 1) which will cause the communicated information to move closer to its intended destination. Other paths into and out of the router may be included to allow the information to be



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provided to other equipment. Modulate and transmit section 25 provides reverse or complementary functions to those provided by receive and demodulate section 24. Modulators 44 of modulate and transmit section 25 couple to router section 42 to accept and modulate routed packets. Each modulated packet forms a narrowband signal, and these narrowband signals are provided to input ports of a switch 46. An output port of switch 46 couples to an input of a channelizer or combiner 48, and an output of combiner 48 provides a wideband signal that drives an antenna 22. Combiner 48 may include a plurality of inputs some of which are driven by other modulate and transmit sections 25. Controller 30 may couple to router 42 to control routing, modulators 44 to manage power consumption, and switch 46 to specify the channels which are to be combined in combiner 48. In a preferred embodiment of the present invention, switch 46 and combiner 48 comprise a transmit switched channelizer that performs substantially the opposite function of switched channelizer 32 of demodulate section 24.

While FIG. 2 shows separate antennas 22 associated with receive and demodulate section 24 and with modulate and transmit section 25, a common antenna 22 may also be used. Likewise modulators 44 and demodulators 34 need not be entirely separate items but may be combined into common modems. Further, while FIG. 2 depicts controller 30 as performing power management functions only for demodulators 34 and modulators 44, power management may be extended to switches 28 and 46 and to channelizers 26 and combiners 48.

FIG. 2 illustrates a simplified block diagram of a node 18 to show certain features of the preferred embodiment of the present invention. FIG. 4 shows a more detailed block diagram of a more practical and complex receive and demodulate section 24 to show other features of the preferred embodiment. For clarity, FIG. 4 omits signal communication paths between controller 30 and



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switches 28 and between controller 30 and demodulators 34. However, switches 28 and demodulators 34 in FIG. 4 nevertheless desirably couple to controller 30, as illustrated in FIG. 2, to specify channels selected at switches 28 and to selectively energize demodulators 34.

Referring to FIG. 4, receive and demodulate section 24 includes numerous switched channelizer 32 building blocks coupled together in a serial/parallel architecture. Different wideband signals are provided at inputs 50 to a wideband tier 52 of switched channelizers 32. The different wideband signals may be provided from different antennas 22 (see FIGs. 1-2). Switches 28 in wideband tier 52 couple together so that any narrowband signal provided by any channelizer 26 in wideband tier 52 may be routed to any output port of any switch 28 in tier 52. Due to the interconnections between switches 28 in wideband tier 52, tier 52 forms a single interconnected switched channelizer group 54.

FIG. 5 shows a block diagram of an interconnected switched channelizer group 54 which incorporates two switched channelizers 32. FIG. 5 illustrates a space switch arrangement for switches 28, where rows correspond to input ports, columns correspond to output ports, and the intersections between rows and columns represent individual switch elements. As illustrated in FIG. 5, an interconnection is provided between switches 28 for each output port. Any input of either switch 28 can be routed to the output of the other switch 28.

Referring back to FIG. 4, wideband tier 52 of switched channelizers 32 drives a narrowband tier 56 of switched channelizers 32 to form a two stage switch. In other words, output ports of switches 28 in wideband tier 52 couple to inputs of channelizers 26 in narrowband tier 56. Desirably, the number of switched channelizers 32 in narrowband tier 56 is less than the number of narrowband signals provided by channelizers 26 in wideband tier 52.



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Each switched channelizer 26 in narrowband tier 56 drives one or more demodulators 34.

Those skilled in the art will appreciate that the terms wideband and narrowband are relative terms. Accordingly, the narrowband signals produced by wideband tier 52 serve as wideband signals for narrowband tier 56 and have a wider bandwidth than the narrowband signals produced by narrowband tier 56. The narrowband signals produced by wideband tier 52 may be viewed as intermediate bandwidth signals, or the wideband signals received at inputs 50 of channelizers 26 may be viewed as super-wideband signals. In a digital implementation, wideband tier 52 may be implemented using high speed components which provide FFT processes to decompose the wideband signals received at inputs 50 into intermediate bandwidth frequency bins. Narrowband tier 56 may be implemented using lower speed components which consume less power and which provide FFT processes to further decompose the intermediate bandwidth frequency bins into narrowband signals which convey one channel at a time.

FIG. 4 depicts narrowband tier 56 as being arranged into two interconnected switched channelizer groups 54. No coupling is provided between switches 28 in the two groups 54 within narrowband tier 56 to reduce switch complexity. Nevertheless, any channel conveyed by any super-wideband signal received at an input 50 may still be routed to any demodulator 34 using, as a minimum, switching in wideband tier 52.

Although not shown, modulate and transmit section 25 (see FIG. 2), may have a complementary architecture to that depicted in FIG. 4 for receive and demodulate section 24.

In summary, the present invention provides an improved communications network node with a switched channelizer architecture. The communications network node incorporates a switched channelizer that can be combined in parallel and/or in series with other similar switched



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channelizers to process any number of channels obtained from any number of received wideband signals. The communications network node provides modem functions in proportion to cell traffic rather than spectrum capacity. The flexibility which results from the switched channelizers allows modem resources to be allocated to received channels as needed from instant to instant. Accordingly, modem resources are reduced. Power consumption management is improved since active channels can be routed so that entire modulator systems may be de-energized.

The present invention has been described above with reference to preferred embodiments. However, those skilled in the art will recognize that changes and modifications may be made in these preferred embodiments without departing from the scope of the present invention. For example, the communications node described need not be located in a satellite but may be included in a terrestrial base station, switching office, or the like. Such changes and modifications which are obvious to those skilled in the art are intended to be included within the scope of the present invention.



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CLAIMS

What is claimed is:

1. A communications network node comprising:

a channelizer configured to decompose a wideband signal into a plurality of narrowband signals;

a switch having at least one input port coupled to said channelizer and having an output port, said switch being configured to provide a selected one of said narrowband signals at said output port;

a second switch having a plurality of input ports and an output port;

a combiner having a plurality of inputs wherein one of said inputs couples to said second switch output port; and

means, coupled to said switch and said second switch for specifying channels selected at said switch and said second switch.

2. A communications network node as claimed in claim 1 additionally comprising a demodulator coupled to said switch output port, wherein said channelizer is a first channelizer which decomposes a first wideband signal into a first plurality of narrowband signals, said switch is a first switch which provides a selected one of said first narrowband signals at said first switch output, and said network node additionally comprises:

a second channelizer configured to decompose a second wideband signal into a second plurality of narrowband signals;

a second switch having at least one input port coupled to said second channelizer and having an output port, said second switch being configured to provide a selected one of said second narrowband signals at said output port thereof; and



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means, coupled to said first and second switches, for selecting ones of said first and second pluralities of narrowband signals to route to said first and second switch outputs, respectively.

3. A communications network node as claimed in claim 2 wherein said first switch couples to said second switch so that a selected one of said first narrowband signals can be routed to said second switch output.

4. A communications network node as claimed in claim 3 wherein said first switch has a third plurality of outputs, said second switch has a fourth plurality of outputs, and said communications network node additionally comprises:

a third plurality of demodulators coupled to said third plurality of first switch outputs;

a fourth plurality of demodulators coupled to said second switch outputs; and

power control means, coupled to each of said fourth plurality of demodulators, for selectively energizing said fourth plurality of demodulators.

5. A communications network node as claimed in claim 4 wherein:

said first channelizer and said first switch together form a first switched channelizer;

said second channelizer and said second switch together form a second switched channelizer;

said first and second switched channelizers form a first interconnected switched channelizer group; and

said method additionally comprises a second interconnected switched channelizer group coupled to said selecting means.



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6. A communications network node as claimed in claim 1 wherein said channelizer is a first channelizer which decomposes a first wideband signal into a first plurality of narrowband signals, said switch is a first switch which provides a selected one of said first narrowband signals at said first switch output, and said network node additionally comprises:

a second channelizer configured to decompose said selected one of said first narrowband signals into a second plurality of narrowband signals, wherein each of said second plurality of narrowband signals has a narrower bandwidth than said selected one of said first narrowband signals;

a second switch having at least one input port coupled to said second channelizer and having an output port, said second switch being configured to provide a selected one of said second narrowband signals at said output port thereof;

a third channelizer configured to decompose a third wideband signal into a third plurality of narrowband signals;

a third switch having at least one input port coupled to said third channelizer and having an output port, said third switch being configured to provide a selected one of said third narrowband signals at said output port thereof; and

means, coupled to said first and third switches, for selecting ones of said first and third pluralities of narrowband signals to route to said first and third switch outputs, respectively.



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7. A method of routing communication signals within a communications network node comprising the steps of:

a) decomposing a wideband signal into a plurality of narrowband signals; and

b) switching a selected one of said plurality of narrowband signals to an input of a demodulator,

wherein said step a) decomposes said first wideband signal into a first plurality of narrowband signals, said step b) switches said selected one of said first narrowband signals to a first demodulator, and said method additionally comprises the steps of:

c) decomposing a second wideband signal into a second plurality of narrowband signals; and

d) switching a selected one of said second plurality of narrowband signals to a second demodulator.

8. A method as claimed in claim 7 additionally comprising the steps of:

switching said selected one of said first plurality of narrowband signals to said second demodulator; and

selectively energizing said first and second demodulators.



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9. A communications network node comprising:

a first channelizer configured to decompose a wideband signal into a plurality of intermediate bandwidth signals;

a first switch having an input port adapted to receive said plurality of intermediate bandwidth signals and having first and second output ports, said first switch being configured to provide first and second selected ones of said intermediate bandwidth signals at said first and second output ports, respectively, of said first switch;

a second channelizer having an input adapted to decompose said first selected one of said intermediate bandwidth signals into a plurality of first narrowband signals;

a second switch having an input port adapted to receive said plurality of first narrowband signals and having first and second output ports, said second switch being configured to provide first and second selected ones of said first narrowband signals at said first and second output ports, respectively, of said second switch;

a third channelizer having an input adapted to decompose said second selected one of said intermediate bandwidth signals into a plurality of second narrowband signals;

a third switch having an input port adapted to receive said plurality of second narrowband signals and having first and second output ports, said third switch being configured to provide first and second selected ones of said second narrowband signals at said first and second output ports, respectively, of said third switch;

first and second demodulators coupled to said first and second outputs, respectively, of said second switch; and

third and fourth demodulators coupled to said first and second outputs, respectively, of said third switch.



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10. A communications network node as claimed in claim 9 wherein said second switch couples to said third switch so that a selected one of said first narrowband signals can be routed to said third switch outputs.



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The Patent Office

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**Application No:** GB 9715978.4 **Examiner:** Jared Stokes
**Claims searched:** 1 to 10 **Date of search:** 29 September 1997

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4K (KOT)
H4L (LDM, LDRSX, LECX, LERX)
H4M (MFB)

Int Cl (Ed.6): H04B (7/155, 7/185, 7/195, 7/204)
H04Q (7/30)

Other: On-Line - WPI

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | Relevant to claims |
|---|---|---|
| A | WO 96/28946 A1 (Airnet) See abstract | - |

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|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |



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H04Q 7/38

(52) UK CL (Edition P )
H4L LDSC L1H10

(56) Documents Cited
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ONLINE: WPI

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# (54) Mobile Communications Network Using Alternative Protocols

(57) A mobile communications network is adapted to service mobile terminals having different operating protocols. The network includes multimode base stations each capable of operating selectively in at least some of said operating protocols and each having means for interrogating a mobile terminal so as to determine that terminal's operating protocol. A store contains sets of operating instructions, one for each protocol, which are downloaded to a base station controller so as to operate the base station serving that mobile terminal in a mode consistent with the terminal's operating protocol.

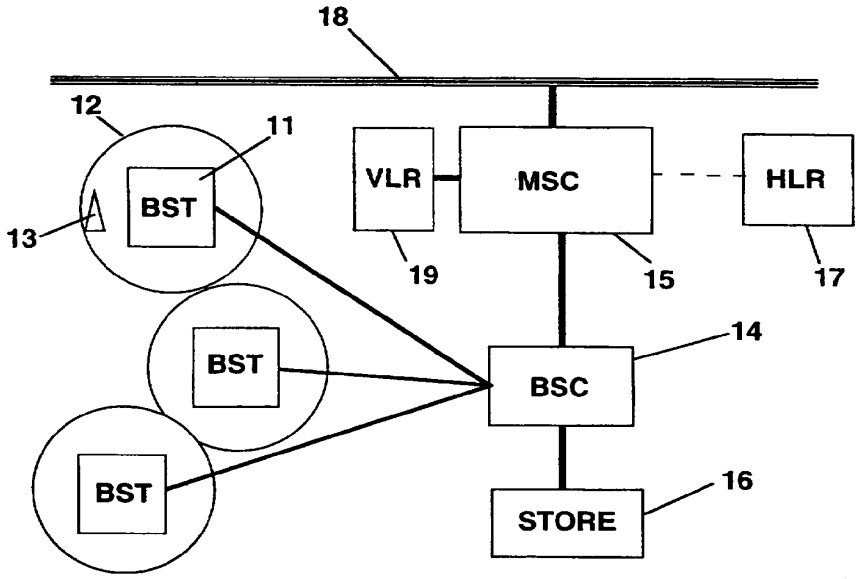



Fig.1

GB 2 320 653 A

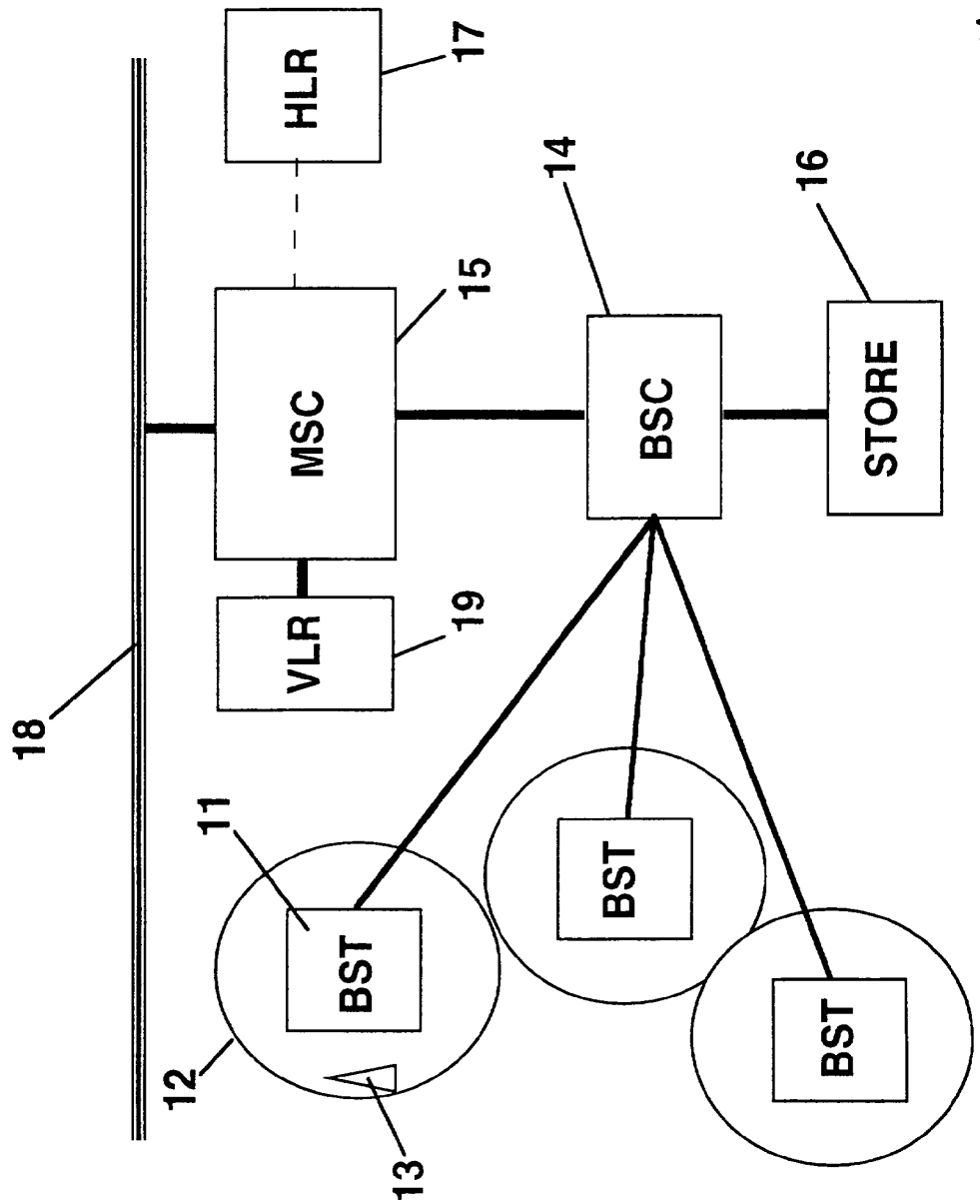



Fig.1

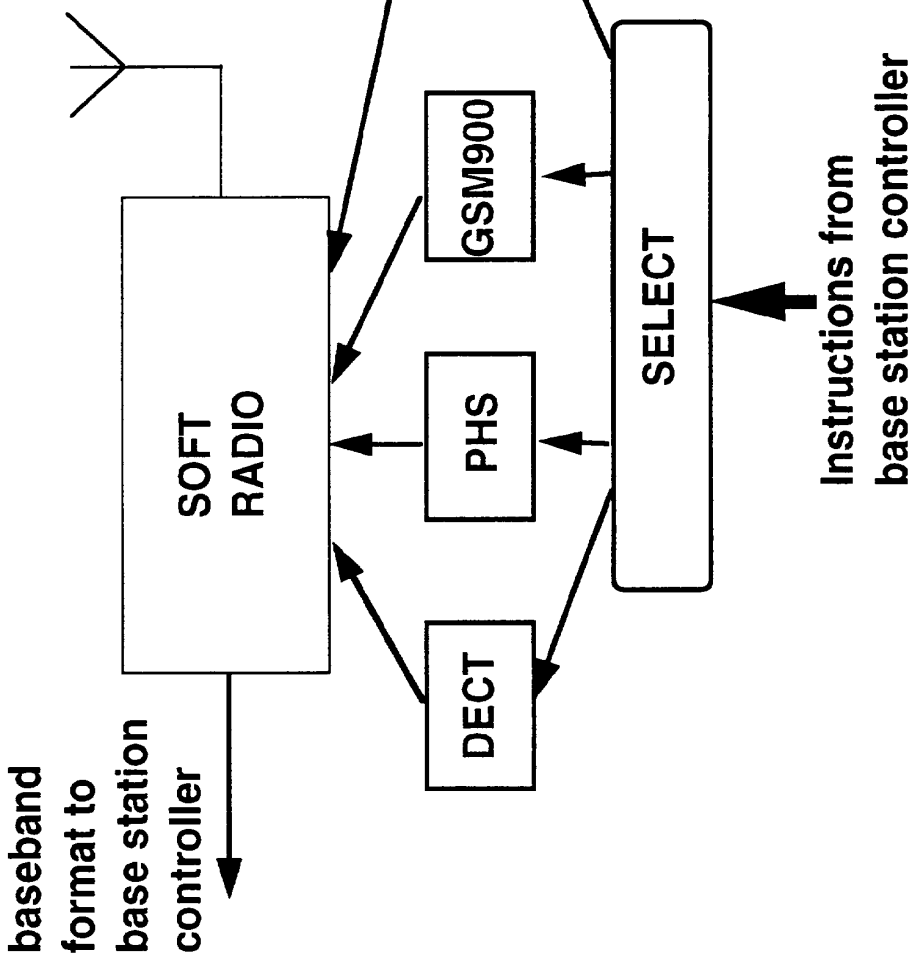

DCS1800
GSM900
PHS
DECT
SOFT
RADIO
SELECT
Instructions from
base station controller
baseband
format to
base station
controller

Fig.2

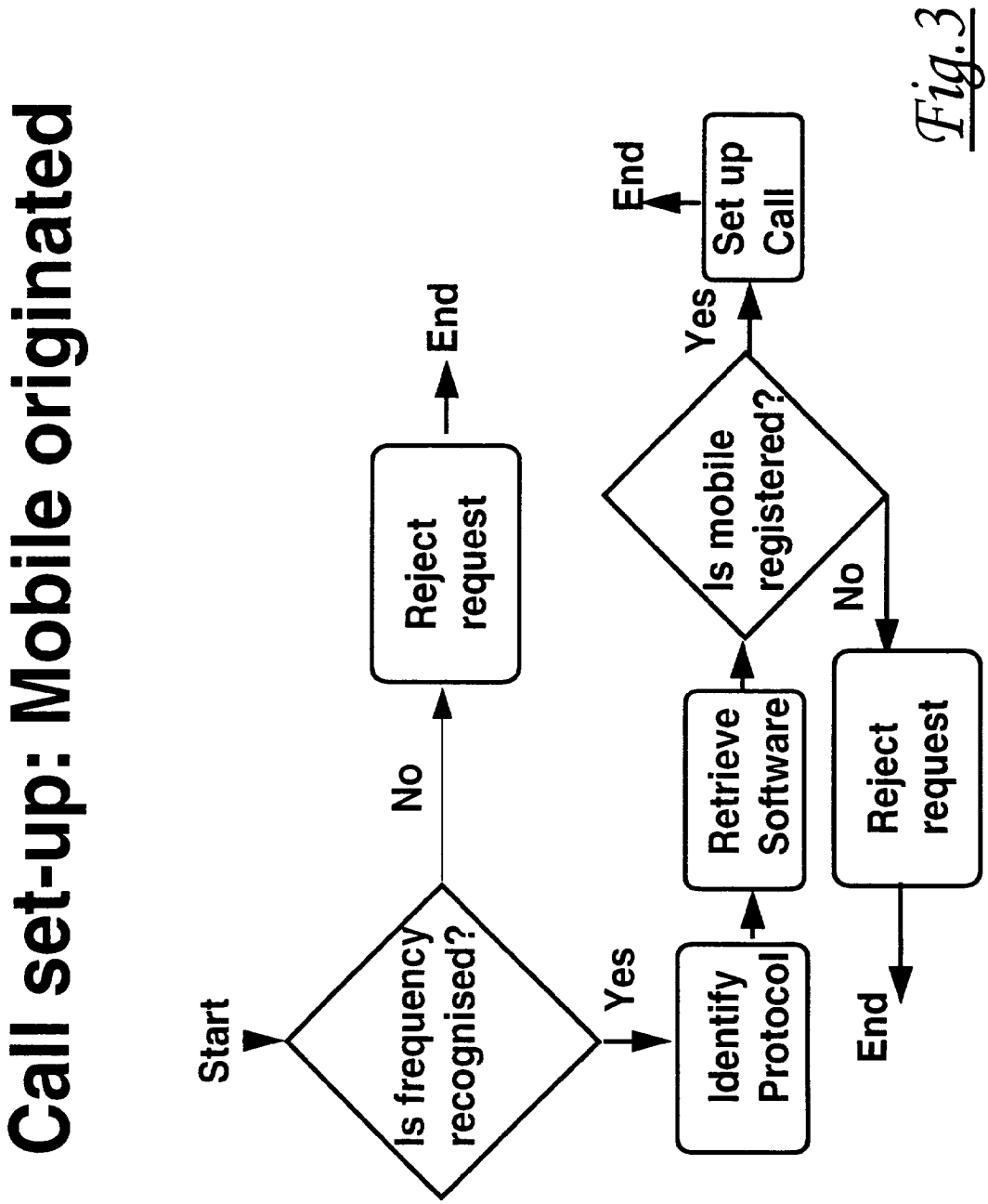

Call set-up: Mobile originated
Start
Is frequency recognised?
No
Reject request
End
Yes
Identify Protocol
Retrieve Software
Is mobile registered?
Yes
Set up Call
End
No
Reject request
End

Fig.3

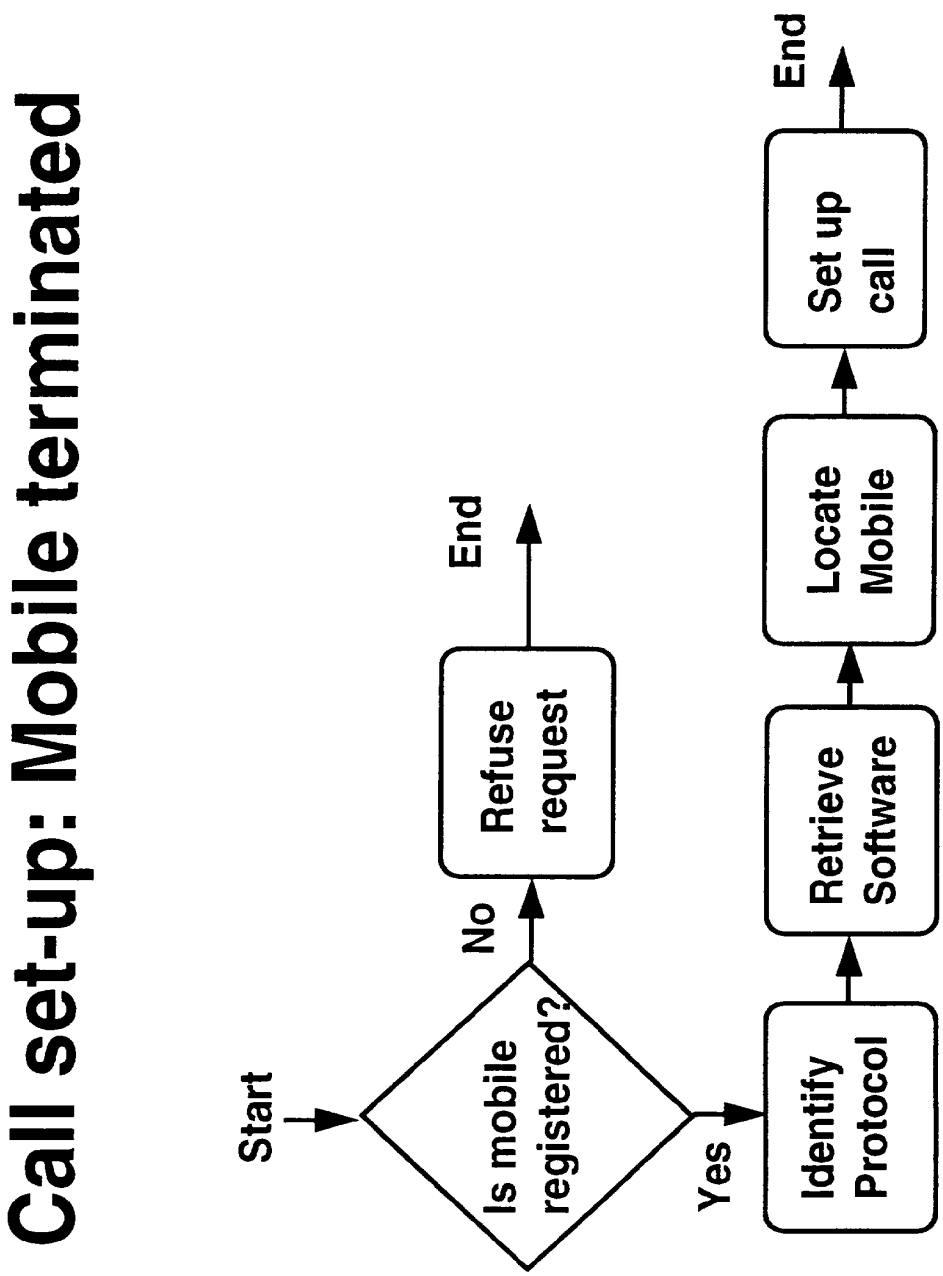

Call set-up: Mobile terminated
Start
Is mobile registered?
No
Refuse request
End
Yes
Identify Protocol
Retrieve Software
Locate Mobile
Set up call
End

Fig.4

# MOBILE COMMUNICATIONS NETWORK

This invention relates to mobile communications networks and in particular to arrangements and methods for controlling communication between mobile terminals and a base station in such networks.

A number of standard mobile communications systems are currently under development. For example, in Europe the GSM900 system operating at 900 MHz is gaining wide acceptance while in North America the near equivalent PCS1900 system is a current standard operating at 1900MHz. Within each of these systems a set of standard operating procedures has evolved, and all equipment supplied for use in such a system must conform to the corresponding standard. This provides a significant advantage to the system operator as he can obtain equipment from a number of suppliers and be confident that it will be fully compatible. For example, the operator may purchase handsets from one manufacturer, base stations from another and mobile switching centres from a third. Although this provides the operator in that he can force down the costs of the purchased equipment, there are attendant disadvantages.

Firstly, the key protocols defining the standard must be conceived at the original installation of the system. If these protocols have not been chosen with sufficient care and forethought, adherence to the standard can preclude the adoption of more advantageous techniques that may subsequently become available. Secondly, although the key protocols may be defined, there is often considerable scope for the provision of proprietary services that can provide added value to a particular manufacturer's product. This provides the operator with the problem of supporting different equipment designs. In practice a particular operator supports only one service mix and users of equipment, e.g. handsets, capable of providing other services may well find that those services are not supported. Thirdly, there is increasing concern about the

proliferation of base station installations that are required to service a variety of mobile communications systems that are operating in the same geographical region and there is thus a need to minimise the number of such installations.

The object of the invention is to minimise or to overcome these disadvantages.

It is a further object of the invention to provide an improved mobile communications system.

It is a further object of the invention to provide a mobile communications system that can service mobile terminals having different operating protocols.

According to one aspect of the invention there is provided a mobile communications network for serving a plurality of mobile terminals each capable of being coupled to the network, wherein the network incorporates means for determining for each mobile terminal accessing the network an operating protocol employed by that terminal, and means for retrieving from a store a corresponding a corresponding operating protocol whereby to provide control instructions for the network so as to enable communication with that terminal.

According to another aspect of the invention there is provided a mobile communications network adapted to service mobile terminals having different operating protocols, the network including a plurality of multimode base stations each capable of operating selectively in at least some of said operating protocols and each having means for interrogating a said mobile terminal so as to determine that terminal's operating protocol, a store containing sets of operating instructions one for each said protocol, base station control means for controlling the operation of each said base station, and means responsive to the determination of the operating protocol of a said mobile terminal for downloading the corresponding set of operating instructions from the store to the control means whereby to operate the base station serving that mobile terminal in a mode consistent with that operating protocol.

According to a further aspect of the invention there is provided a method of operating a mobile communications network so as to service a plurality of terminals each capable of being coupled to the network, wherein the method includes storing a plurality of operating protocols for said terminals, determining for each terminal accessing the network an operating protocol employed by that terminal, and retrieving from the stored protocols a corresponding operating protocol whereby to provide control instructions for that terminal.

By providing access to software packages appropriate to the terminals communicating with the system, a variety of terminal operating protocols can be accommodated. this is of particular advantage in a large international system as terminals that have been constructed to comply with individual country requirements and/or with a particular service mix can roam throughout the system and can receive a full or substantially full range of services in all parts of the system. This also facilitates the development and introduction of new terminals which can operate in parallel with existing devices.

In a development of the network, the operating packages provided in the system may be updated to take account of developments in mobile terminal construction and the introduction of enhanced protocols and services.

In another development, the mobile terminals may be adapted to download operating software from the network over the air interface to provide those terminals with particular operating characteristics.

In a further development of the network, both the network and the terminals may be provided with software packages which allow the particular operating protocol to be negotiated between the network and the terminal at the commencement of communication therebetween.

An embodiment of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a mobile communications system;

Figure 2 illustrates the provision of software to a multimode base station in the system of figure 1;

Figure 3 is a flow chart illustrating the set-up of a mobile terminal originated call in the network of figure 1; and

Figure 4 is a flow chart illustrating the set-up of a mobile terminal terminated call in the network of figure 1.

Referring to figure 1, the mobile communications system includes a plurality of multimode base stations 11 each of which defines a respective cell 12 within which communications may be established with mobile terminals 13 currently located within that cell. Groups of base stations 11 are controlled via a base station controller 14 from a mobile switching centre 15. The mobile switching centre has access to a home location register 17 and, via a communications path 18, to one or more other mobile switching centres (not shown) and to one or more fixed networks (not shown). Advantageously, traffic on the path 18 may be carried in a broad band format such as asynchronous transfer mode (ATM) and at a rate appropriate to the particular protocol to which that traffic relates.

Information on the mobile terminals is stored in the home location register 17 which may be disposed at a location remote from the mobile switching centre. Information relating to those mobile terminals currently in the service area of the mobile switching centre is retrieved from the home location register and stored together with current location information in a visitors location register 19. Advantageously, the visitors location register forms part of the mobile switching centre.

In the network of figure 1, the base stations operate at appropriate frequencies to provide a communications service and also provide a beacon function for those mobile communications protocols that require such a function. For example, the system may provide access to mobile terminals using the GSM 900, DECT, and DCS 1800 protocols. It will be understood that this group of protocols is by no means exclusive and that other existing or future protocols can be accommodated.

Figure 2 shows the general construction of a base station for use in the system of figure 1. The station comprises a soft radio unit 21 coupled to an antenna 22 and which functions as a slave in both transmit and receive modes under the control of a selected one of a number of protocol dedicated control units 23.

For a mobile terminal initiated call, the terminal will emit a request for service on its frequency band according to its built-in operating protocol. This request is used by the network to determine the terminal's protocol, the general procedure being illustrated in figure 3.

When a base station receives a request for service from a mobile terminal in its service area, it relays the request to the base station controller which determines, from the frequency band and the format of the request signal, which protocol is being employed by the requesting mobile terminal. This determination may be effected by the use of a soft radio receiver that is programmed to recognise the presence of radio frequency transmissions from a mobile terminal within a frequency band extending over all the supported protocols. Measurement of the particular frequency employed by the mobile terminal establishes the required protocol for communication with that terminal. If a number of protocols are permitted within a given frequency band, then a further test will be required to identify the protocol uniquely. If the frequency is not recognised, then the call request is aborted.

When the protocol has been identified, the corresponding software package is retrieved from the store and downloaded into the base station controller so as to operate the base station controller according to the desired protocol. At the same time, the appropriate dedicated control unit in the base station is enabled under control from the base station controller. The details of the mobile terminal are then checked to ensure that the terminal is registered and the call is set up according to the desired protocol.

Figure 4 shows the process sequence for setting up a call to a mobile terminal. The details of that terminal's operating protocol and last reported location are retrieved from the home location register. If the

terminal is registered, the appropriate mobile switching centre then interrogates its visitors location register to determine a paging pattern for the mobile terminal so as to determine which base station controller(s) need to be provided with the appropriate software package to service the mobile terminal via a base station. If the terminal is not registered then the call attempt is refused.

Messaging within the wired portion of the mobile network to accommodate the various message and signalling protocols appropriate to each operating protocol is effected by encapsulating the traffic in packets each containing a payload and a header whereby routing and handling of the packet can be determined. In an alternative embodiment, this traffic can be converted into a common transmission format at interfaces (not shown) provided at appropriate ingress and egress points to the mobile network. This common format may be employed to provide e.g. Internet services to mobile terminals served by the network.

In a further embodiment, some or all of the mobile terminals may be programmable via software downloaded over the air interface from the mobile network via the base station in response to a request from a terminal. The downloading can be performed at call set-up or during the call. This technique can be used to provide a terminal with functionality that conforms to one of a set of preferred protocols. Further, the terminal can perform a negotiation with the network to establish which protocol is to be employed, which functions are to be handled by the network, and which functions are to be handled by the terminal in the setting up and processing of calls.

**CLAIMS:-**

1. A mobile communications network for serving a plurality of mobile terminals each capable of being coupled to the network, wherein the network incorporates means for determining for each mobile terminal accessing the network an operating protocol employed by that terminal, and means for retrieving from a store a corresponding operating protocol whereby to provide control instructions for the network so as to enable communication with that terminal.

2. A mobile communications network adapted to service mobile terminals having different operating protocols, the network including a plurality of multimode base stations each capable of operating selectively in at least some of said operating protocols and each having means for interrogating a said mobile terminal so as to determine that terminal's operating protocol, a store containing sets of operating instructions one for each said protocol, base station control means for controlling the operation of each said base station, and means responsive to the determination of the operating protocol of a said mobile terminal for downloading the corresponding set of operating instructions from the store to the control means whereby to operate the base station serving that mobile terminal in a mode consistent with that operating protocol.

3. A network as claimed in claim 2, wherein each said base station comprises a soft radio unit for providing radio communication to said terminals, operating means, one for each said operating protocol, and means for selectively enabling a said one of said operating means so as to operate the base station in conformity with that operating protocol.

3. A network as claimed in claim 2 or 3, wherein at least some of said mobile terminals have means for downloading of operating instructions from the network.

5. A mobile communications network substantially as described herein with reference to and as shown in the accompanying drawings.

6. A method of operating a mobile communications network so as to service a plurality of terminals each capable of being coupled to the network, wherein the method includes storing a plurality of operating protocols for said terminals, determining for each terminal accessing the network an operating protocol employed by that terminal, and retrieving from the stored protocols a corresponding operating protocol whereby to provide control instructions for that terminal

7. A method as claimed in claim 6, wherein the operating protocol employed by a mobile terminal requesting service is determined from the frequency of radio transmissions from that terminal.

8. A method as claimed in claim 6 or 7, and including downloading of operating software from the network to a said terminal.

9. A method as claimed in claim 8, wherein a said operating protocol is determined by negotiation between the network and a said mobile terminal.

10. A method of operating a mobile communications network substantially as described herein with reference to and as shown in the accompanying drawings.

The Patent Office

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**Application No:** GB 9626772.9 **Examiner:** Nigel Hall
**Claims searched:** all **Date of search:** 13 October 1997

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4L ( LDLX, LECX, LDSC)

Int Cl (Ed.6): H04Q 7/30, 7/20, 7/22, 7/38

Other: Online: WPI

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| Y,E | GB 2307622 A | (NEC) See whole document | 1,2,6 at least |
| X,Y | EP 0449471 A2 | (CLIFFORD) See whole document | 1,2,6 at least |
| X,Y | WO 96/21999 A2 | (NOKIA) See whole document | 1,2,6 at least |

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|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |



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審査請求　未請求　請求項の数 1　(全6頁)

⑤4発明の名称　中継方式及び中継装置

⑳特　願　平1−160212
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明細書

1．発明の名称

中継方式及び中継装置

2．特許請求の範囲

(1)地上無線局と地下無線局とを中継する中継方式において、前記地上無線局と地下無線局との間にある地面のシールド性を利用して前記地上無線局の周波数と地下無線局の周波数とを同一にすることを特徴とする中継方式。

3．発明の詳細な説明

(産業上の利用分野)

本発明は地上無線局と地下無線局とを中継する中継方式及び中継装置に関する。

(従来の技術)

地上側の無線局と、地下側の無線局との間で通信を行なう方法として、従来から第3図に示すシステムが知られている。

このシステムは地上側に設置される基地局101と、地下側に設置される漏洩同軸ケーブル102と、この漏洩同軸ケーブル102と前記基地局101とを接続する分配器103とを備えている。

基地局101は基地局アンテナ104と、この基地局アンテナ104に接続される第1基地局送受信機105と、前記分配器103に接続される第2基地局送受信機106と、前記第1基地局送受信機105の受信部107と第2基地局送受信機106の送信部108とを接続するとともに前記第1基地局送受信機105の送信部109と第2基地局送受信機106の受信部110とを接続する接続部111とを備えている。

地上無線局115から周波数f1の無線信号が送信されたとき、基地局アンテナ104はこの地上無線局115からの無線信号を受信してこれを第1基地局送受信機105の受信部107に供給する。

受信部107はこの信号を復調して音声信号及び受信信号を生成してこれを接続部111を介して第2基地局送受信機106の送信部108に送る。



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送信部１０８はこれら音声信号及び受信信号を変調信号として周波数ｆ２の高周波信号を生成するとともに、この高周波信号を分配器１０３を介してこの分配器１０３に接続されている漏洩同軸ケーブル１０２から地下空洞内に放射し地下無線局１１６に伝える。

また、地下無線局１１６から周波数ｆ２の無線信号が送信されたとき、漏洩同軸ケーブル１０２はこの地下無線局１１６からの無線信号を受信するとともにこれを分配器１０３を介して第２基地局送受信機１０６の受信部１１０に供給する。

送受信部１１０はこの信号を復調して音声信号及び受信信号を生成してこれを接続部１１１を介して第１基地局送受信機１０５の送信部１０９に伝達する。

送信部１０９はこれら音声信号及び受信信号を変調信号として周波数ｆ１の信号を生成するとともに、この信号を基地局アンテナ１０４から出射して地上無線局１１５に伝える。

このようにこのシステムでは、地上側で周波数ｆ１の無線信号を使用し、地下側で周波数ｆ２の無線信号を使用して電波干渉による発振現象等の発生を防止しながら地上無線局１１５と地下無線局１１６との通信を中継している。

しかしながらこのような従来の中継方式においては、２つの周波数を必要とするため、電波資源の有効利用という要請に反する結果を招来していた。

また、地上と、地下とで異なる周波数を使用するために、地上無線局１１５及び地下無線局１１６として、地上側の周波数と地下側の周波数とを併有する２周波切換式の無線機を用意しなければならず、設備投資が大きくなるとともに、無線機の運用管理等も煩雑になるという問題があった。

（発明の目的）

本発明は上記の如き従来の欠点を除去するためになされたものであって、１つの周波数によって地上無線局と地下無線局とを中継することができ、これによって電波資源の有効利用を促進することができるとともに、設備コストを低減することができる中継方式を提供することを目的としている。

（発明の概要）

上記の問題点を解決するために本発明による中継方式においては、前記地上無線局と地下無線局との間にある地面のシールド性を利用して前記地上無線局の周波数と地下無線局の周波数とを同一にすることを特徴としている。

（実施例）

以下、本発明を図面示した実施例に基づいて詳細に説明する。

第１図は本発明の一実施例を示すブロック図である。

この図に示す中継装置は地上側に設置される地上基地局１と、地下空洞５内に敷設される漏洩同軸ケーブル２と、この漏洩同軸ケーブル２に接続される地下基地局３と、この地下基地局３と前記地上基地局１とを接続する基地局間ケーブル４とを備えている。

地面１４が持っているシールド効果によって地上６側と、地下空洞５側とを電磁的に完全に分離して地上側６と、地下空洞５側との間で電波干渉が生じないようにしている。

地上基地局１は第２図に示すように基地局アンテナ７と、受信部８と送信部９とを有する地上局送受信機１０と、前記アンテナ７を前記受信部８と送信部９とのいずれかに接続する切換スイッチ１１とを備えている。

前記地上局送受信１０の受信部８は、通常の受信機と同様にアンテナ７に接続される高周波バンドパスフィルタ１５と、その出力信号を増幅する高周波アンプ１８と、該アンプの出力と後述する地下基地局から送致されローパスフィルタ２０及びローカルアンプ１９を介して得るローカル信号とを混合するミキシング回路２１と、このミキシング回路２１の出力のうちから両信号の差の中間周波数信号を抽出するＩＦバンドパスフィルタ１６と、その出力を増幅するＩＦアンプ２２と、該アンプによる高周波を除去し、地下基地局に至るケーブルに接続された第２のＩＦバンドパスフィ



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ルタ１７とを備え、前記基地局アンテナ７によって地上無線局１２（第１図参照）からの信号（ｆ１）が受信されたとき、所要レベルに増幅した後この信号と、基地局間ケーブル４を介して地下基地局から供給される局部発振信号（ｆ２）とに基づいて周波数（ｆ１－ｆＬ）なる中間周波数信号を生成し、高周波を除去しつつ所要レベルに増幅してこれを基地局間ケーブル４を介して前記地下基地局３に送出する。

また、前記地上局送受信機１０の送信部９は地下基地局から送致された中間周波信号（ｆ１）を増幅するＩＦアンプ２５と、その出力から歪成分を除去するＩＦバンドパスフィルタ２３と、該フィルタ出力信号を一方の入力とし、又局部発振器２８の出力（ｆＬ）をローカルアンプ２７にて増幅した信号を他方の入力とするミキシング回路２９と、このミキシング回路出力を所要レベルに増幅する高周波アンプ３０と、その出力からｆ１＋ｆＬなる信号を抽出する高周波バンドパスフィルタ２４及び前記局部発振器２８の出力を増幅した後地下基地局に送出するローカルアンプ２６とを備え、前記基地局間ケーブル４を介して周波数（ｆ１－ｆＬ）の中間周波数信号（ｆ１）が供給されたとき、これを所要レベルに増幅し歪を除去した後、発振回路２８によって得られた局部発振信号と混合して周波数ｆ１の信号を生成するとともに、歪を除去しつつ所要レベルに増幅し、これを切換スイッチ１１を介して基地局アンテナ７から出射して前記地上無線局１２に伝える。

また、前記地下基地局３は受信部３２と送信部３３とを有する地下局送受信機３４と、前記漏洩同軸ケーブル２に接続される分配器３５と、この分配器３５と前記地下局送受信機３４とを接続する切換スイッチ３６とを備えている。

前記地下局送受信機３４の送信部３３は上記地上基地局の送信部とほぼ同様の構成で、２つのバンドパスフィルタ３７、３８と、３つのアンプ３９～４１と、発振回路４２と、ミキシング回路４３と、パワーアンプ４４とを備え、前記基地局間ケーブル４を介して前記受信部８から周波数（ｆ１－ｆＬ）の中間周波数信号が供給されたとき、この中間周波数信号と、発振回路４２によって得られた局部発振信号とに基づいて周波数ｆ１の信号を生成するとともに、これを切換スイッチ３６と、分配器３５とを介して漏洩同軸ケーブル２から出射させ地下無線局１３（第１図参照）に伝える。

また、前記地下局送受信機３４の受信部３２は上記地上基地局のそれと同様の構成で、３つのバンドパスフィルタ４５～４７と、２つのアンプ４８、４９と、ローパスフィルタ５０と、ミキシング回路５１と、ＩＦアンプ５２とを備え、前記漏洩同軸ケーブル２によって地下無線局１３からの信号が受信されたとき、分配器３５、切換スイッチ３６を介してこの信号を受けるとともに、この信号と、基地局間ケーブル４を介して供給される局部発振信号とに基づいて周波数（ｆ１－ｆＬ）の中間周波数信号を生成しこれを基地局間ケーブル４を介して前記送信部９に送出する。

この実施例においては、中継装置の地上局及び地下局夫々の送信部に局部発振器を備え、その出力と各々対応して接続された受信部から送致された信号とを混合して両者の和の信号を作出するとともに、互いに接続された受信部においては前記対応して接続された送信機の局部発振器出力をケーブルを介して導出し、この信号と受信信号とを混合して両者の差を抽出して中間周波数信号としている。

従って、一方のアンテナを介して受信機に入力する信号と、これに対応する送信機にて作出され他方のアンテナから出力する信号との周波数は全く同一となり、仮に局部発振器の周波数が変動したとしても両者の信号周波数に変化は全く無いことが特徴的である。

これは、一方の受信機において引き算する局部発振周波数信号と、他方の送信機において加算する局部発振周波数とが同一発振器から供給されていることに起因する。

更に、この例のように地上、地下基地局間にて受渡しを行う信号の周波数が送受信周波数と異な



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り、しかも中間周波数に変換され低い周波数となっているが、このことによって、各送信部における増幅度を大きくしても入出力の回り込みによるトラブルを防止するとともに、比較的低い周波数にすることによって、地上、地下両基地局間の距離が長くなった場合でも、この間のケーブルによる高周波信号損失を軽減し、S／N低下を防止する上でも都合が良い。

また、上記2つの局部発振器の周波数を互いに異ならせれば、夫々の中間周波数が異なるので、互いの干渉によるトラブルを防ぐことができる。

次に、第1図を参照しながらこの実施例の動作を説明する。

今、地上無線局12から周波数f1で送信すると、基地局アンテナ7はこの地上無線局12からの無線信号を受信してこれを地上局送受信機10の受信部8に供給する。

受信部8はこの信号を中間周波数信号に変換してこれを基地局間ケーブル4を介して地下基地局送受信機34の送信部33に伝達する。

送信部33はこの中間周波数信号から周波数f1の信号を生成するとともに、この信号を漏洩同軸ケーブル2から地下空洞5内に放射し地下無線局13に伝達する。

また、地下無線局13から周波数f1で送信すると、漏洩同軸ケーブル2はこの地下無線局13からの無線信号を受信してこれを地下局送受信機34の受信部32に供給する。

受信部32はこの信号を中間周波数信号に変換するとともにこれを基地局間ケーブル4を介して地上局送受信機10の送信部9に伝達する。

送信部9はこの中間周波数信号から周波数f1の信号を生成するとともに、この信号を基地局アンテナ7から出射して地上無線局12に伝達する。

このようにこの実施例では、地上6と地下空洞5の間にある地面14の導電性を利用してこの地面14をシールド部材として使用するようにしたので、電波干渉による発振現象等の発生を防止しながら1つの周波数f1で地上無線局12と地下無線局13との通信を中継することができる。

これによって、電波資源の有効利用を促進することができるとともに、設備コストを低減することができる。

なお、本発明の実施に当っては、上記実施例に限定される理由はなく、例えば夫々の局部発振器を一つで共用すること、又は、中間周波数に変換することなく、所要の増幅を施してそのまま他方の送信機へ送致し、該送信機を単なる高周波増幅器としたもの、或は一方の受信機にて受信信号を復調し、他方の送信機に該復調信号と、受信信号の周波数（或は周波数と位相）情報とを送致するとともに、これを受けた他方送信部ではこれらの情報をもとにVCXO等を制御して、受信周波数と全く同一の電波を作出しても良い。この方法によれば、、両基地局を結ぶ信号線は低周波（オーディオ）用でよく、安価になる上S／Nの劣化も伴わない。

（発明の効果）

以上説明したように本発明によれば、1つの周波数によって地上無線局と地下無線局とを中継することができ、これによって電波資源の有効利用を促進することができるとともに、設備コストを低減することができる。

4．図面の簡単な説明

第1図は本発明による中継方式の一実施例を示すブロック図、第2図は同実施例の詳細なブロック図、第3図は従来からある中継方式の一例を示すブロック図である。

1…地上基地局、2…漏洩同軸ケーブル、3…地下基地局、7…基地局アンテナ、12…地上無線局、13…地下無線局。

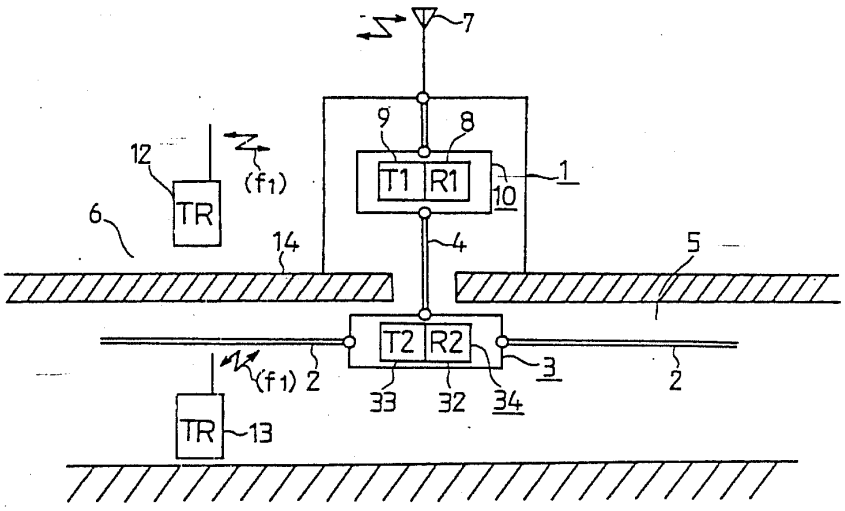
特許出願人　東洋通信機株式会社

代理人　弁理士　鈴木　均

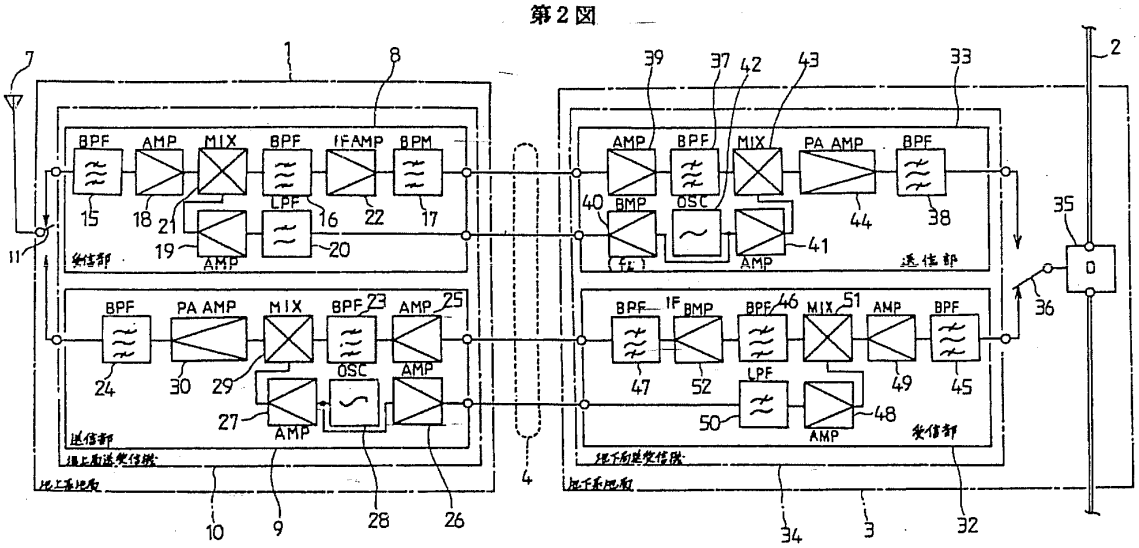


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第1図



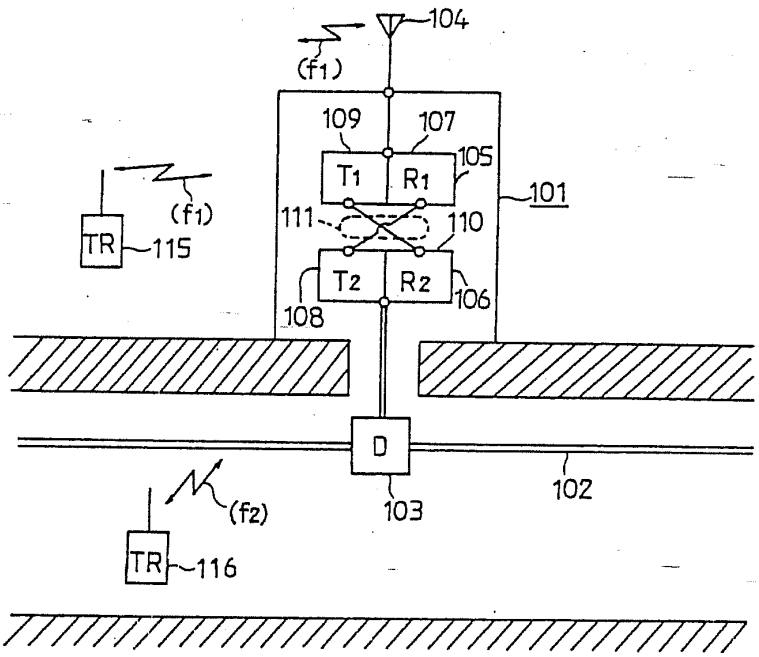

第2図






EX-1002
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00826

第3図






EX-1002
Ericsson Inc. and Verizon Wireless v. Procomm International PTE Ltd.
00827

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審査請求　未請求　請求項の数１(全　9　頁)

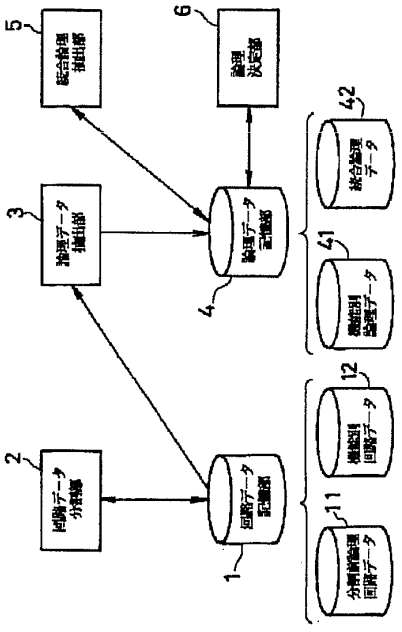
(21)出願番号　特願平3－160212

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(54)【発明の名称】　論理回路設計装置

(57)【要約】
【目的】　回路規模が小さく高性能な論理回路を短時間で設計することを目的としている。
【構成】　論理回路を複数の機能に分割する回路データ分割部２と、分割された各機能毎に既に論理が決定している確定論理データを抽出する論理データ抽出部３と、抽出された確定論理データの和集合である統合論理データを抽出する統合論理抽出部５と、抽出された統合論理データを用いてまだ論理の確定していない機能の論理データを決定する論理決定部６とから構成されている。
【効果】　短時間で論理回路の設計が行え、回路規模の小さい高性能な論理回路が設計できる。



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【特許請求の範囲】

【請求項１】　電子回路の機能及び動作に関する情報を記憶する回路データ記憶手段と、この回路データ記憶手段に記憶されている機能及び動作に関する情報を機能別に分割する回路データ分割手段と、この回路データ分割手段によって分割され機能別回路データの各々に対して確定論理データを抽出する論理データ抽出手段と、この論理データ抽出手段によって抽出された確定論理データを記憶する論理データ記憶手段と、この論理データ記憶手段に記憶されている確定論理データを統合して統合論理データを抽出する統合論理抽出手段と、この統合論理抽出手段によって抽出された統合論理データから不確定論理機能の論理データを決定する論理決定手段とを有することを特徴とする論理回路設計装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は論理回路の設計装置に関する。

【０００２】

【従来の技術】順序回路には、演算などの様々な動作を意味する複数の内部状態を有し、フリップフロップが出力するコードあるいは外部入力信号によって現在の内部状態を識別する順序回路がある。このような順序回路には、設計仕様から抽出できる論理回路の機能及び動作を実現する確定論理回路部分と、このフリッププロップが出力するコードを実現する、未だ論理の確定していない不確定論理回路部分とがある。

【０００３】従来、この順序回路を設計する際には、これらの論理回路を別途生成するという手法が採られてきた。即ち、予め複数の内部状態を識別するコードを設計仕様に基づいてそれぞれ決定し、決定された識別コードを出力する不確定論理回路部分を確定論理回路部分とは別途設計し、各々論理が確定した後に双方の論理回路を統合するという手法がとられてきた。

【０００４】

【発明が解決しようとする課題】上述したように、従来の方法においては、識別コードを出力する未だ論理の確定していない不確定論理回路部分と、電子回路の仕様上の機能及び動作を実現する既に論理の確定した確定論理回路部分とを別途設計している。このため、設計者が自由に設計できる不確定論理回路部分の設計の如何により、最終的に生成される電子回路の品質が大きく左右される。

【０００５】例えば、確定論理回路部分で用いられている論理データと同じ論理データを用いて不確定論理回路部分を生成すると、双方の論理回路を統合した後の論理回路の回路規模が大きくなってしまい、高品質の電子回路を得ることができないという問題があった。また、確定論理回路部分と不確定論理回路部分との論理データがどの程度共用させれるかを知るには、実際に一つの論理

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回路として統合した後でなくては知ることができないという問題もあった。

【０００６】このため、一つの論理回路として統合しても回路規模が大きいために、再設計や修正を余儀なくされることがあった。

【０００７】本発明は上記のような事情に鑑みてなされたもので、その目的とするところは、論理回路の設計仕様から自動的に、論理が確定していない不確定論理回路部分を既に確定している確定論理回路部分の論理データを用いて生成することにより、回路規模が小さく高性能な論理回路を効率的に設計できる論理回路設計装置を提供することにある。

【０００８】

【課題を解決するための手段】上記目的を達成するため、本発明の論理回路設計装置は、電子回路の機能及び動作に関する情報を記憶する回路データ記憶手段と、この回路データ記憶手段に記憶されている機能及び動作に関する情報を機能別に分割する回路データ分割手段と、この回路データ分割手段によって分割され機能別回路データの各々に対して確定論理データを抽出する論理データ抽出手段と、この論理データ抽出手段によって抽出された確定論理データを記憶する論理データ記憶手段と、この論理データ記憶手段に記憶されている確定論理データを統合して統合論理データを抽出する統合論理抽出手段と、この統合論理抽出手段によって抽出された統合論理データから不確定論理機能の論理データを決定する論理決定手段とから構成されている。

【０００９】

【作用】上記構成によって本発明は、自動的に論理回路を機能別にいくつかの論理回路に分割し、分割した各々の部分論理回路の確定論理データを求める。さらに、それらの確定論理データの和集合を求めることによって統合し、この統合論理データを用いて論理が確定していない部分回路の論理を実現している。

【００１０】

【実施例】以下、図面を用いて本発明の一実施例を説明する。

【００１１】図１は、本発明の一実施例に関わる論理回路設計装置の構成を示す回路ブロック図である。

【００１２】同図に示す論理回路設計装置は、回路データ記憶部１、回路データ分割部２、論理データ抽出部３、論理データ記憶部４、統合論理抽出部５、及び論理決定部６から構成されている。

【００１３】回路データ記憶部１は、設計仕様に基づく論理回路の動作及び機能に関する情報（以下、分割前回路データ１１と呼ぶ）を記憶するところである。

【００１４】回路データ分割部２は、回路データ記憶部１に記憶されている分割前回路データ１１を機能別に複数回路データとして分割し、機能別回路データ１２として回路データ記憶部１に書き込むものである。

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【００１５】論理データ抽出部３は、回路データ記憶部１に記憶されている機能別回路データ１２の機能毎の各回路データに対する設計仕様上確定している確定論理データを抽出する機能を有している。

【００１６】論理データ記憶部４は、機能別回路データ１２の各々に関し、論理データ抽出部３で抽出された確定論理データを機能別論理データ４１として記憶することである。

【００１７】統合論理抽出部５は、論理データ記憶部４に記憶されている確定論理データの和集合を求め、統合論理データ４２を抽出する役目を有している。

【００１８】論理決定部６は、論理データ記憶部４に記憶されている機能別論理データ４１のうちまだ論理が決定していない論理データを統合論理データ４２から求める役割をしている。

【００１９】以上のように、本発明の論理回路設計装置は構成されており、次に本発明の作用を説明する。ここでは、例えば図２に示すような論理回路の機能及び動作に関する情報を有する回路データを一例として説明する。

【００２０】この回路データは回路データ記憶部１に分割前回路データ１１として記憶されている。ここで、ＳＴＴＥＳは回路名、Ａ，Ｂ，ＣＬＫは外部入力信号名、Ｘ，Ｙは外部出力端子名、ＳＴ１，ＳＴ２，ＳＴ３は状態名を示す。

【００２１】まず、この分割前回路データ１１は、回路データ分割部２によって図３に示すような機能ブロックである状態遷移条件部、ＤＡＴＡ生成部、状態コード生成部の３つの機能別回路データ１２に分割される。

【００２２】この回路データ分割部２は、分割前回路データ１１を構文解析によって各文の接続関係を樹状構造で現し、状態の遷移関係を示す文である分割前回路データ１１中の「ＮＥＸＴ」文に関する文を各状態ＳＴ１，ＳＴ２，ＳＴ３毎に抽出する。さらに、これを機能別回路データ１２における状態遷移条件部とし、分割前回路データ１１が示す論理回路データ「ＳＴＴＥＳ」の出力信号である「Ｘ」「Ｙ」が含まれる文を各状態ＳＴ１，ＳＴ２，ＳＴ３毎に抽出する。そして、これを機能別回路データ１２におけるＤＡＴＡ生成部とすることで実現する。

【００２３】ここで、状態コード生成部における機能別回路データ１２は、論理が不確定なため分割前回路データ１１から得ることができない。そのため、図３に示す機能別回路データ１２のように空となる。

【００２４】次に、回路データ記憶部１に記憶されている機能別回路データ１２における各機能ブロック毎の確定論理データを論理データ抽出部３によって抽出し、論理データ記憶部４に機能別論理データ４１として、例えば図４，５のように書き込んでいく。

【００２５】これは、回路データ分割部２で回路データ

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記憶部１に記憶されている分割前回路データ１１に対して構文解析を行った結果得た、文の接続関係を現す樹状構造を用いて、分割前回路データ１１が示す論理回路データ「ＳＴＴＥＳ」の入力信号である「Ａ」「Ｂ」「ＣＬＫ」の信号ビットパタン毎の各機能ブロック毎の動作、即ち状態遷移条件部の状態遷移関係とＤＡＴＡ生成部の内部及び出力信号パタンとを抽出することによって得ることができる。

【００２６】以上のようにして得た機能別論理データ４１に対して、統合論理抽出部５が全ての確定論理データを用いて和集合を求め、例えば図６に示す統合論理データ４２を抽出する。この統合論理抽出部５では、論理データ記憶部４に記憶されている機能別論理データ４１に対し、各現状態及び各入力信号パタン毎の次状態名、出力信号パタンＸ，Ｙ及び内部信号パタン「Ａ＠Ｂ」「Ａ！Ｂ」「＾Ａ！Ｂ」を求め、その結果を図５に示す形式で論理データ記憶部４に記憶する。ここで、「＠」は排他的論理和を、「！」は論理和を、「＾」は論理否定を示す。

【００２７】最後に、このようにして抽出された統合論理データ４２を用い、図５の機能別論理データ４１の例における状態コード生成部のように未だ論理が確定していない論理データを論理決定部６によって決定していく。

【００２８】この状態コード生成部は、状態を識別する２進コードを生成するものであり、統合論理抽出部５で抽出した統合論理データ４２における２進コードのうちから適当なコードを選んで全ての状態の各々に割り当てることで、論理決定部６を実現する。

【００２９】具体的には、まず統合論理データ４２から現状態と次状態が等しいものを抽出し、その入力コード及び出力コードを求める。図６に示す統合論理データの例では、（Ａ，Ｂ，Ｘ，Ｙ）＝（０，０，１，０）の場合のみ現状態と次状態がＳＴ２で一致するため、ＳＴ２の状態コードを入力信号と等しい「００」とする。そして、論理データ記憶部４の機能別論理データ４１に状態コード生成部を、例えば図７のような形式で記憶する。

【００３０】ここで割り当てた状態コードのコード長は回路データ全体の状態数の２を基底とする対数の値以上の最小の整数とし、本実施例の回路データでは状態数が３であるため、コード長は２ビットとなった。次に既に状態コードが決定したＳＴ２からなんらかの条件により遷移する次状態のコードを割り当てる。ここでは、（Ａ，Ｂ，Ｘ，Ｙ）＝（１）（０，１，１，０），（２）（１，０，１，１），（３）（１，１，１，１，）の３通りの場合で等しく状態ＳＴ１に遷移するので、状態ＳＴ１のコードを決定することとなる。

【００３１】（１）～（３）のコードから任意の２ビットのコードを生成すると（００，０１，１０，１１）が生成可能であるが、未使用でかつ「１」の少ないコード

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を選択すると（０１，１０）であり、その２つのコードのうちの一方（０１）を選択し、状態ＳＴ１のコードとして図７に示す機能別論理データ４１として論理データ記憶部４に記憶する。

【００３２】図７の機能別論理データ４１において入力信号Ａ，Ｂの「－」はＤｏｎ´ｔｃａｒｅな状態を示し、全ての入力信号パタンを意味する。仮にここで、（Ａ，Ｂ，Ｘ，Ｙ）＝（０，０，０，０）のみが状態ＳＴ１に遷移する条件であった場合、生成できるコードは「００」のみであり、これは既にＳＴ２の状態コードとして論理データ記憶部４に記憶されているため割り付けることができない。

【００３３】よって他にコードを割り当てる状態が存在しない場合には直前にコードを割り当てた状態ＳＴ２のコードをキャンセルし、別候補を探して再度同じ処理を繰り返す。

【００３４】なお、本実施例では論理データを回路データより抽出したが、この発明はこれに限るものではなく、予め真理値表や論理式のような形で各機能毎に示された論理を回路データ記憶部１の機能別論理回路データ１２として取り込み、処理することもできる。

【００３５】また、回路データを分割する際の機能ブロックとしては、上述した状態遷移条件部、ＤＡＴＡ生成部、状態コード生成部の３種に限られるものではなく、例えば、機能ブロックの分割をマイクロプロセッサなどにおけるＤＡＴＡ処理部と制御部とを既知の論理とすることにより、命令コード生成部の論理を自動生成することも可能である。

【００３６】また、状態コード生成部においても全ての状態のコードを自動生成するだけではなく、予め特定の状態に対してはコードを割り当てておき、他のまだコードが割り当てられてない状態についてのみコードを割り当てることも可能である。また、論理データ記憶部４中に機能別論理データ４１と統合論理データ４２とを共通のデータベースとしたが、別個のデータベースに記憶することもでき、同様に機能別論理データ４１の各機能の論理データもまた、別個のデータベースに記憶することもできる。

【００３７】更に、本実施例では状態コード長を状態数の２を基底とする対数の値以上の整数値としたが、ユーザの指定や回路の要求仕様により、生成回路の遅延時間や面積に関する制限を考慮して自由に変えることで、設計者の要求に見合った回路を生成することができる。

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【００３８】

【発明の効果】以上説明したように、本発明の論理回路設計装置によれば、論理回路の機能毎の確定論理データを抽出し、抽出された確定論理データを用いて未だ論理の決定していない機能回路の論理データを決定している。

【００３９】このため、確定論理回路部分と不確定論理回路部分とで共通な論理回路を使用できることから、よりコンパクトで高性能な論理回路の設計を高速かつ正確に実行することができる。

【図面の簡単な説明】

【図１】本発明の論理回路設計装置の構成を示すブロック図である。

【図２】図１で示した分割前論理回路データ１１の一例である。

【図３】図１で示した機能別回路データ１２の一例である。

【図４】図１で示した機能別論理データ４１の一例である。

【図５】図４と同様な機能別論理データ４１の一例である。

【図６】図１で示した統合論理データ４２の一例である。

【図７】論理決定された機能別論理データ４１の一例である。

【符号の説明】

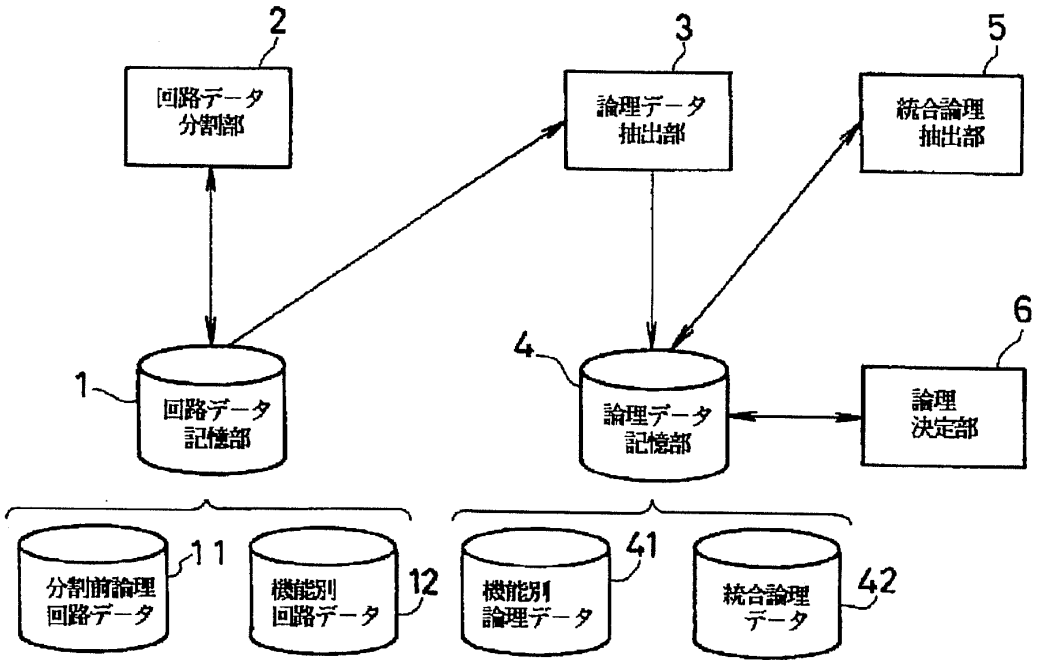
１　回路データ記憶部
２　回路データ分割部
３　論理データ抽出部
４　論理データ記憶部
５　統合論理抽出部
６　論理決定部
１１　分割前回路データ
１２　機能別回路データ
４１　機能別論理データ
４２　統合論理データ

【図7】

| 現状態 | CLK | A | B | 状態コード |
|---|---|---|---|---|
| ST1 | 1 | - | - | 01 |
| ST2 | 1 | - | - | 00 |
| ST3 | 1 | - | - | 10 |

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【図１】


2
回路データ
分割部
3
論理データ
抽出部
5
統合論理
抽出部
6
1
回路データ
記憶部
4
論理データ
記憶部
論理
決定部
分割前論理
回路データ
11
機能別
回路データ
12
機能別
論理データ
41
統合論理
データ
42

【図2】

```
<INTS> STTES;
<IN>   A, B, CLK;
<OUT>  X, Y;
<STT>  CLK;
      ST1 : IF A@B THEN X = A;
                        Y = 1B0;
                        NEXT ST2;
                  ELSE Y = A;
                        X = 1B1;
                        NEXT ST3;
            ENDIF;
      ST2 : IF A|B THEN X = 1B1;
                        Y = A;
                        NEXT ST1;
                  ELSE X = 1B1;
                        Y = B;
                        NEXT ST2;
            ENDIF;
      ST3 : IF ^A|B THEN X = A&B;
                         Y = A|B;
                   ELSE X = 1B1;
                        Y = 1B0;
            ENDIF;
            NEXT ST2;
<ENDSTATE>;
<ENDINTS>;
```

【図5】

［状態コード生成部］

| 現状態 | CLK | A | B | 状態コード |
|---|---|---|---|---|
| ST1 | 1 | 0 | 0 | |
| ST1 | 1 | 0 | 1 | |
| ST1 | 1 | 1 | 0 | |
| ST1 | 1 | 1 | 1 | |
| ST2 | 1 | 0 | 0 | |
| ST2 | 1 | 0 | 1 | |
| ST2 | 1 | 1 | 0 | |
| ST2 | 1 | 1 | 1 | |
| ST3 | 1 | 0 | 0 | |
| ST3 | 1 | 0 | 1 | |
| ST3 | 1 | 1 | 0 | |
| ST3 | 1 | 1 | 1 | |

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【図3】

```
[状態遷移条件部]    状態名    機能記述部
                  ST1 : IF A@B THEN NEXT ST2;
                                ELSE NEXT ST3;
                        ENDIF;
                  ST2 : IF A!B THEN NEXT ST1;
                                ELSE NEXT ST2;
                        ENDIF;
                  ST3 : NEXT ST2;
[ＤＡＴＡ生成部]    状態名    機能記述部
                  ST1 : IF A@B  THEN X = A; Y = 1B0;
                                ELSE X = B; Y = 1B0;
                        ENDIF;
                  ST2 : IF A!B  THEN X = 1B1; Y = A;
                                ELSE X = 1B1; Y = B;
                        ENDIF;
                  ST3 : IF ^A!B THEN X = A&B; Y = A!B;
                                ELSE X = 1B1; Y = 1B0;
                        ENDIF;
[状態コード生成部]  状態名    機能記述部
                  ST1 :
                  ST2 :
                  ST3 :
```

【図4】

［状態遷移条件部］

| 現状態 | CLK | A | B | 次状態 |
|---|---|---|---|---|
| | | A⊙B | | |
| ST1 | 1 | 0 | 0 | ST3 |
| ST1 | 1 | 0 | 1 | ST2 |
| ST1 | 1 | 1 | 0 | ST2 |
| ST1 | 1 | 1 | 1 | ST3 |
| | | A⊕B | | |
| ST2 | 1 | 0 | 0 | ST2 |
| ST2 | 1 | 0 | 1 | ST1 |
| ST2 | 1 | 1 | 0 | ST1 |
| ST2 | 1 | 1 | 1 | ST1 |
| | | ^A⊕B | | |
| ST3 | 1 | 0 | 0 | ST2 |
| ST3 | 1 | 0 | 1 | ST2 |
| ST3 | 1 | 1 | 0 | ST2 |
| ST3 | 1 | 1 | 1 | ST2 |

［ＤＡＴＡ生成部］

| 現状態 | CLK | A | B | X | Y |
|---|---|---|---|---|---|
| | | (A⊙B) | | | |
| ST1 | 1 | 0 | 0 | 0 | 0 |
| ST1 | 1 | 0 | 1 | 0 | 0 |
| ST1 | 1 | 1 | 0 | 1 | 0 |
| ST1 | 1 | 1 | 1 | 1 | 0 |
| | | (A⊕B) | | | |
| ST2 | 1 | 0 | 0 | 1 | 0 |
| ST2 | 1 | 0 | 1 | 1 | 0 |
| ST2 | 1 | 1 | 0 | 1 | 1 |
| ST2 | 1 | 1 | 1 | 1 | 1 |
| | | (^A⊕B) | | | |
| ST3 | 1 | 0 | 0 | 0 | 0 |
| ST3 | 1 | 0 | 1 | 0 | 1 |
| ST3 | 1 | 1 | 0 | 1 | 0 |
| ST3 | 1 | 1 | 1 | 1 | 1 |

【図6】

| 現状態 | CLK | A | B | X | Y | 次状態 |
|---|---|---|---|---|---|---|
| | | | (A⊕B) | | | |
| ST1 | 1 | 0 | 0 | 0 | 0 | ST3 |
| ST1 | 1 | 0 | 1 | 1 | 0 | ST2 |
| ST1 | 1 | 1 | 0 | 1 | 1 | ST2 |
| ST1 | 1 | 1 | 1 | 0 | 1 | ST3 |
| | | | (A!B) | | | |
| ST2 | 1 | 0 | 0 | 0 | 1 | ST2 |
| ST2 | 1 | 0 | 1 | 1 | 1 | ST1 |
| ST2 | 1 | 1 | 0 | 1 | 1 | ST1 |
| ST2 | 1 | 1 | 1 | 1 | 1 | ST1 |
| | | | (^A!B) | | | |
| ST3 | 1 | 0 | 0 | 1 | 0 | ST2 |
| ST3 | 1 | 0 | 1 | 1 | 0 | ST2 |
| ST3 | 1 | 1 | 0 | 0 | 1 | ST2 |
| ST3 | 1 | 1 | 1 | 1 | 1 | ST2 |

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発明の数　1
審査請求　未請求

（全11頁）

# ⑤4信号の符号化記憶再生装置

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明　　細　　書

1.発明の名称

信号の符号化記憶再生装置

2.特許請求の範囲

原信号の時間軸上における変化の状態に応じて標本化周期が可変となされる如き符号化により、原信号の振幅値を示す標本値と、その標本値を得るための標本化周期を示すデータとが組となされているデジタルデータを復号化する信号の符号化記憶再生装置であって、前記したデジタルデータにおける振幅値と標本化周期を表わす値との比を割算によって求める手段と、前記の割算手段で求めた結果を積分する手段とを備えて、折線近似された再生信号が得られるようにした信号の符号化記憶再生装置

3.発明の詳細な説明

音声信号を符号化し、デジタル信号として伝送あるいは記録再生する場合に、データ量をなるべく少なくするための手段としては、従来、信号振幅を対数圧縮したり、あるいは差分をとったり、もしくはデルタ変調をするなどの諸方式が採用されて来ていることは周知のとおりであるが、これらの従来の諸方式ではデータ量の減少を振幅方向に求めていたために、量子化歪により再生信号の品質が劣化したものになるという問題があった。

そして、本出願人会社では、データ量の減少を大巾なものとする場合に、ビットの減少を振幅方向に求めることをせず、それをむしろ時間軸方向に求めて、大巾なデータ量の減少が達成できるようにした標本化周期の可変な符号化装置、すなわち、原信号の時間軸上における変化の状態に応じて標本化周期が可変となされる如き符号化により、原信号の振幅値を示す標本値と、その標本値を得るための標本化周期を示すデータとが組となされているデジタルデータが得られるような各種の標本化周期の可変な符号化装置についての提案を行なって来た。

本発明は、既提案の標本化周期の可変な符号化装置によって符号化されているデジタルデータのように、原信号の振幅値を示す標本値と、その標



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本値を得るための標本化周期を示すデータとが組となされているデジタルデータを復号して再生信号を得る場合に、デジタルデータにおける振幅値と標本化周期を表わす値とを用いて簡単に折線近似された再生信号を得ることができるようにした信号の符号化記憶再生装置を提供することを目的としてなされたものであり、以下、添付図面を参照して本発明の信号の符号化記憶再生装置の具体的な内容について説明する。

第1図及び第7図は、それぞれ本発明の信号の符号化記憶再生装置の各異なる実施態様のブロック図であって、第1図及び第7図において、MICはマイクロホン、LPFr，LPFpは低域濾波器、ADCはAD変換器、CCTは例えばマイクロコンピュータを含んで構成されている制御回路、$M_1$は第1の記憶装置（第1のメモリ、バッファメモリ）、$M_2$は第2の記憶装置（第2のメモリ）、DACはDA変換器、CPは補間回路、SPはスピーカであり、また、OPは操作部であって、操作部OPには記録釦Br，再生釦Bp，停止釦Bsが設けられている。なお、第7図中におけるCGはクロックパルスの発生器である。

第1図及び第7図によってそれぞれ示されている装置は、ともに、制御回路CCTの制御の下に、入力のアナログ信号の時間軸上における変化の状態に応じて標本化周期が可変となされる如き符号化を行なって、原信号の振幅値を示す標本値と、その標本値を得るための標本化周期を示すデータとが組となされているデジタルデータを作り、それを第2のメモリ$M_2$に記憶し、再生に際しては、制御回路CCTの制御の下に、第2のメモリ$M_2$から順次に読出されたデジタルデータにおける振幅値と標本化周期を表わす値との比を割算によって求め、前期の振幅値と標本化周期を表わす値との比の値を積分して折線近似された再生信号が得られるように構成されているが、第1図示の装置と第7図示の装置とにおいては符号化の具体的な内容において差異があるから、まず、第1図示の装置について説明する。

第2図は、第1図示の装置によって信号が符号



化される際に、信号の時間軸上での変化の状態と対応してどのように標本化周期が変化しているものとなされるものであるのかを図示説明するための波形図であって、この第2図においてSaは符号化の対象とされている交流信号であり、また、図中の0－0線は交流軸線を示している。

第2図において、$t_1$，$t_2$，$t_3$…は、交流信号Saが次々に交流軸線0－0を切る時間位置、すなわち、交流信号Saにおける次々のゼロ点の時間位置であり、また、$T_{12}$，$T_{23}$，$T_{34}$…などは、前記した交流信号Saにおける相次ぐゼロ点の時間位置$t_1$，$t_2$ …における相隣るものの時間々隔（以下、ゼロ点間隔と記載されることもある）を示している。

さて、交流信号Saにおける次々のゼロ点間隔$T_{12}$，$T_{23}$，$T_{34}$…は、交流信号が一定の周波数を有する正弦波信号の場合には、その交流信号の周期の1/2と対応する一定の時間値を示すが、音声信号の場合には信号内容と対応して第2図中の$T_{12}$，$T_{23}$，$T_{34}$…のように時間値が変化しているものとなっている。



ところで、従来、アナログ信号を標本化量子化してデジタル信号とする際には、第2図中の交流軸線0－0線上に示した一定の時間々隔Tpを有するサンプリングパルスPsによって交流信号Saがサンプリングされていることは周知のとおりであって、従来法によると第2図中の交流信号Saを例とした場合でも、明らかなように、次々のゼロ点間隔において標本抽出される標本値の個数は、ゼロ点間隔が長いところ程多くなっているが、第1図示の装置では、交流信号における次々のゼロ点間隔の長短に拘わらずに、各ゼロ点間隔においてそれぞれ略々一定個数の標本が抽出された状態のものとして交流信号が符号化されるようにし、データ量の減少が達成されるようにしたのである。

すなわち、交流信号Saにおける次々のゼロ点間隔について、それぞれのものを予め定められた数$\alpha$（ただし、$\alpha$は2以上の整数で、予め定められた数）で等分したときにそれぞれ得られる時間値が、それぞれのゼロ点間隔と対応する信号部分からの標本値を得るための標本化周期となるように



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して、データ量を減少させることのできる交流信号のデジタル符号化装置が構成できるようにしたのであり、各ゼロ点間隔をα等分するのに、αを2とするのか、あるいは3とするのか、もしくは4以上とするのかは再生信号に求められる忠実度の程度、符号化装置のコストなどを勘案して適当に定められるべきことはいうまでもない。

第1図示の装置では、交流信号のデジタル符号化装置においては、デジタル符号化の対象とされる交流信号における時間軸上で相次ぐゼロ点を検出し、また、時間軸上で相隣るゼロ点の時間々隔、すなわちゼロ点間隔を計測し、前記の計測されたゼロ点間隔をα等分（ただし、αは2以上の整数で予め定められた数）した時間値を標本化周期としてそのゼロ点間隔と対応する信号部分から（α－1）個の標本値が得られるようにするものであるから、装置の構成は前記の各動作が良好に行なわれるものでありさえすれば、大部分の動作がアナログ信号処理によって行なわれるように構成されても、あるいは、略々全動作がデジタル信号処理によって行なわれるように構成されていてもよいが、装置の略々全動作がデジタル信号処理によって行なわれるように構成された方が装置の構成が簡単化できるので、第1図に示す装置中のデイジタル信号符号化装置部分は、それの動作の略々全動作がデジタル信号処理によって行なわれるような構成例のものとして示されている。

次に、第1図示の装置の構成や動作などについて説明する。

第1図におけるマイクロホンMICは音波を電気信号（音声信号）に変換して低域濾波器LPFrに与える。第1図示の例では信号源がマイクロホンMICであるとなされているが、信号源が他の音声信号の発生器であってもよいことは当然である。前記した低域濾波器LPFrは、以下の実施例の説明ではそれの遮断周波数が4KHzであるとされている。

低域濾波器LPFrによって4KHz以下の周波数帯域となされた音声信号は、AD変換器ADCによって所定のビット数（以下の説明では8ビット）の



デジタル信号に変換される。以下の説明において、AD変換器ADCは、それの標本化周波数（サンプリング周波数）が8KHzであるとされており、AD変換器ADCでは、それに入力された音声信号を、常に1/8000秒の標本化周期で標本化し、それぞれの標本の振幅値を量子化して、それぞれ8ビットのデジタル信号に変換する。

AD変換器ADCから出力されたデジタル信号は、マイクロコンピュータを含んで構成されている制御回路CCTの制御の下に所定の信号処理が施こされることによりデータ量が減少されたデジタル信号となされるが、その信号処理動作は第1図示の構成の装置では、制御回路CCT、第1の記憶装置$M_1$（第1のメモリ$M_1$）、第2の記憶装置$M_2$（第2のメモリ$M_2$）などによって行なわれる。以下の説明において、前記の第1のメモリ$M_1$は256バイトのメモリであるとされ、また、第2のメモリ$M_2$は64Kバイトのメモリであるとされている。

次に、第3図に示すフローチャートを参照して、第1図示の装置における操作部OPの記録釦Brが操



作されることによって順次に行なわれる信号の符号化について説明する。

操作部OPの記録釦Brが操作されることによって、プログラムがスタート（第3図中の「はじめ」）すると、ステップ(1)で制御回路CCTに設けられているゼロ点間隔の計測のための8ビットのカウンタがリセットされる。ステップ(2)でAD変換器ADCからの次々の8ビット（1バイト）のデジタル信号を256バイトの第1のメモリ$M_1$に記憶し、また、第1のメモリ$M_1$に前記の1バイトのデジタル信号が記憶される度毎に、ゼロ点間隔の計測のための8ビットのカウンタを1づつカウントアップする。

ステップ(3)で、第1のメモリ$M_1$に記憶した1バイトのデジタル信号が示すもとの交流信号の振幅値がゼロか否かを判定し、ゼロでないと判定された場合はステップ(2)に戻り、また、ゼロと判定された場合はステップ(4)に進む。

ステップ(4)では、ゼロ点間隔の計測のための8ビットのカウンタの計数値によって示されているゼロ点間隔をα個に等分（ただし、αは2以上の



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整数の内から予め定められた数）させうるような（α－1）個の分割点にそれぞれ対応しているような数値を得る（例えば、ゼロ点間隔を示す計数値がAであったとしたときに、αが2，αが3，αが4の場合に、ステップ(4)で得る数値は、αが2の場合には$\frac{A}{2}$、αが3の場合には$\frac{A}{3}$，$\frac{2A}{3}$、αが4の場合には$\frac{A}{4}$，$\frac{2A}{4}$，$\frac{3A}{4}$である。一般に、ゼロ点間隔がAである時に、ステップ(4)で得る数値は、$\frac{A}{\alpha}$，$\frac{2A}{\alpha}$…$\frac{(\alpha-1)A}{\alpha}$で示されるような（α－1）個のものとなる）。以下の説明では簡単のために、αが2の場合を例にとって記載されている。

ステップ(5)で、ゼロ点間隔の計測のための8ビットのカウンタの計数値の1/2と対応する第1のメモリ$M_1$のアドレス位置における第1のメモリ$M_1$の振幅値のデータを読み出し、その振幅値のデータと前記したゼロ点間隔の計測のための8ビットのカウンタの計数値の1/2の数値とを組にして、64Kバイトの第2のメモリ$M_2$へ記憶する（前記した第1のメモリ$M_1$から読出した振幅値のデータと、ゼロ点間隔の時間値を示しているゼロ点間隔の計

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モリ$M_2$がフルカウントになった状態、または停止釦Bsが押されている状態を検出したときはプログラムが終了し、そうでなければステップ(2)に戻る。

上記した説明では、説明の簡単化のために、信号のゼロ点の判別について単に第1のメモリ$M_1$に記憶した振幅値が0か否かによって行なうとだけ記載したが、第1のメモリ$M_1$に順次に記憶される振幅値は、AD変換器ADCにおける標本化周期毎に得られた離散的なものであるから、常に必らずしも交流信号のゼロ点が標本化されているとは限らないから、第1のメモリ$M_1$に順次に記憶される振幅値を示す情報においてそれの極性が反転した場合にそれが交流のゼロ点を示すものとするなどの判定手段が用いられる。

また、ステップ(3)で、もとの交流信号の振幅値がゼロであるとの判定が行なわれた場合に、ステップ(4)でゼロ点間隔の計測のための8ビットのカウンタの計数値から得る（α－1）個の数値の個数が2以上、すなわち、αが3以上の場合には、ステップ(5)において第1のメモリ$M_1$から読出され

測のための8ビットのカウンタの計数値とを組にして、64Kバイトの第2のメモリ$M_2$から読出した振幅値のデータと組にして用いられるべき前記のカウンタの計数値は、それが小さな数値である程、所要ビット数が少なくて済むという利点があるから、以下の説明では、第1のメモリ$M_1$から読出した振幅値のデータと組にして用いるべき数値が、ゼロ点間隔の計測のための8ビットのカウンタの計数値の1/2の数値の場合について記載されている）。

ステップ(6)で、ゼロ点間隔の計測のための8ビットのカウンタをリセットして計数値を0とし、また、第2のメモリ$M_2$に記憶されるデータ組の個数を計数するために設けられている15ビットのカウンタを、第2のメモリ$M_2$に対して新らたなデータ組が記憶される度毎に1づつカウントアップしてステップ(7)に進む。

ステップ(7)では、第2のメモリ$M_2$がフルカウントになったか否か、あるいは操作部OPにおける停止釦Bsが押されているか否かを判定し、第2のメ

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るべき振幅値のデータは、ゼロ点間隔の計測のための8ビットのカウンタの計数値によって示されているゼロ間隔をα個に等分させうるような（α－1）個の分割点にそれぞれ対応しているような数値の個々のものと対応する第1のメモリ$M_1$の各アドレス位置について順次に読出されるものであり、前記のようにして読出されたそれらの振幅値のデータは、それらの個別のもの毎にそれぞれゼロ点間隔と関連する数値とが組となされて第2のメモリ$M_2$に記憶されるようになされるのである。

これまでの説明から明らかなように、第1図示の装置による符号化は交流信号におけるゼロ点間隔を予め定められた数α（ただし、αは2以上の整数で、予め定められた数）で等分したときにそれぞれ得られる時間値が、それぞれのゼロ点間隔と対応する信号部分からの（α－1）個の標本値を得るための標本化周期となるようにして、データ量を減少させることができるようにしたものであり、また、前記の（α－1）個の標本値のそれぞれのものに対し、その標本値が得られたゼロ点



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間隔の情報と関連する情報を加えて、標本値とゼロ点間隔の情報とを組にしたものとし、それにより復号化が容易に行なわれ得るようになされているのである。

次に、第1図示のブロック図と、第4図示のフローチャートとを用いて、復号化について説明する。まず、装置における操作部OPの再生釦Bpを操作して第4図のフローチャートに示すプログラムがスタートすると、ステップ(1P)で第2のメモリ$M_2$へ記憶させるデータ組の個数を計数するために設けられている15ビットのカウンタをリセットしてステップ(2P)に進む。前記の15ビットのカウンタは第2のメモリ$M_2$から1つのデータ組が読出される度毎に1づつカウントアップする。

ステップ(2P)では、第2のメモリ$M_2$に記憶された順序で、振幅値とゼロ点間隔に関連する情報(ゼロ点間隔の計測のための8ビットのカウンタの計数値を$\alpha$等分して得た数値…既述した説明例では前記した8ビットのカウンタの計数値の1/2の数値)との組からなるデータ組を読出してDA変

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割算器DIVからの出力信号Xiは積分器INTによって積分されて信号Yiとして出力される。

$$Yi = \int Xi\,dt \cdots\cdots(2)$$

補間回路CPによる信号の補間は、補間の傾斜$\theta$が、第6図の$\ell i/\tau i$に等しくなるようになされるのである。そして補間の行なわれた信号は、折線近似によってもとの交流信号に近似した波形のものとなされうるのである。

第5図及び第6図を参照して説明した補間動作による信号の補間を行なう時間、すなわち、ゼロ点間隔の時間を$\alpha$等分した時間を設けるために、ステップ(4P)ではステップ(2P)、ステップ(3P)、ステップ(4P)を経過する時間が、前記したゼロ点間隔の時間を$\alpha$等分した時間と等しくなるようにプログラムデレイを作る。そして、ステップ(4P)におけるプログラムデレイは次のように示される。

{(ゼロ点間隔を$\alpha$等分したものの1つと対応するゼロ点間隔の計測のための8ビットのカウンタの計数値)÷(AD変換器ADCにおける標本化周期)

換器DACに与え、ステップ(3P)でDA変換器DACでは、前記した振幅値をアナログ量の振幅値$\ell i$に変換すると共に、前記したゼロ点間隔に関連する情報をアナログ量の電気量$\tau i$に変換してそれらを補間回路CPに与えるようにする。

第5図は補間回路CPの1例構成及び関連部分の構成を示すブロック図であって、この第5図においてDIVは割算器、INTは積分器であり、また、DA変換器DACにおいて、D/A1は第2のメモリ$M_2$から読出された振幅値をDA変換してアナログ量の振幅値$\ell i$を出力するDA変換器、D/A2は第2のメモリから読出されたゼロ点間隔に関連する情報をアナログ量の電気量$\tau i$に変換して出力するDA変換器である。

補間回路CPは、それの割算器DIVに対してDA変換器D/A1の出力信号$\ell i$とDA変換器D/A2の出力信号$\tau i$とが与えられて、

$$Xi = \frac{\ell i}{\tau i} \cdots\cdots(1)$$

(1)式のような演算を行なって、信号Xiを出力する。

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=(デレイ時間)×(ゼロ点間隔を$\alpha$等分したものの1つと対応するゼロ点間隔の計測のための8ビットのカウンタの計数値)−1}+{ステップ(2P)とステップ(3P)の時間}+{ステップ(4P)中における固定した時間}……(3)

ステップ(5P)で振幅値を符号反転して出力し、ステップ(6P)では既述したステップ(4P)の場合と同様にして、今度はステップ(5P)、ステップ(6P)、ステップ(7P)の経過時間が前記した(3)式と対応するような態様でプログラムデレイを作る。

ステップ(7P)では、第2のメモリ$M_2$から読出されるデータ組の個数を計数する15ビットのカウンタがフルカウントとなったか否か、あるいは停止釦Bsが押されたか否かをみて、15ビットのカウンタがフルカウントの場合あるいは停止釦Bsが操業されている場合には終了し、否であればステップ(2P)へ戻り、次のデータ組を読み出す。

第1図示の装置において、AD変換器ADCにおける標本化周期が既述の例のように1/8000の場合



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に例えば、ゼロ点間隔の平均が計数値4であったとすると、ゼロ点間隔の平均は0.5msとなるから、振幅値と、ゼロ点間隔に関連する情報とについてそれぞれ1バイトを割当てて記憶を行なうようにした場合には、第2のメモリ$M_2$として64Kバイトのメモリ$M_2$を用いれば約16秒間分の音声信号が記憶され、再生されることになる。なお、第1図示の装置において、補間回路CPによって折線近似された再生信号は、低域濾波器LPFpを通してスピーカSPに与えられて再生音が得られる。

次に、第7図に示す装置について説明する。この第7図に示す装置においては、符号化の対象とされる信号を一定の時間長毎の信号（1フレームの信号）とし、その1フレームの信号毎に標本化周期Tc（標本化間隔Tc）を設定するのである。

第8図は、符号化前の信号Saの波形例図であって、第8図中の0－0線は参考のために示した交流軸線であり、第8図中において、Tfは信号Saを時間軸上で一定の時間長毎に区切った信号部分の時間長（1フレームの信号の時間長）である。

信号Saにおいて、予め定められた時間長Tfを有する各1フレームの信号は、時間長Tf内において交流軸線0－0線に対して複数回交叉している状態、すなわち、時間長Tf内に複数個のゼロ点を有しているものとなっているが、各1フレームの信号におけるゼロ点の個数は、各1フレーム中の信号の周波数成分がどうであるのかに応じて異なっており、例えば、第8図に示す信号Saについて説明すると、時刻$t_1$から$t_2$までの1フレームの信号ではゼロ点が8個であり、時刻$t_2$から$t_3$までの1フレームの信号ではゼロ点が4個であり、以下、時間軸上で相次ぐ次々の1フレームの信号について、ゼロ点の個数は6個、3個、4個となっている。

第7図に示す装置では、前記のように信号Saにおける予め定められた一定の時間長Tfの信号部分すなわち、各1フレームの信号毎に、1フレームの信号中に存在するゼロ点の個数と関連する数で時間長が等分されるような標本化周期Tcにより、その1フレームの信号についての標本値列が得ら



れるような符号化を行なって、データ量の減少の達成を図かっているのであり、この点について前記した第8図示の信号Saを例にとって説明すると次のとおりである。

すなわち、第8図示の信号Saのように時間軸上で相次ぐ1フレームの信号のゼロ点の個数が既述のように、8個、4個、6個、3個、4個である場合には、例えばゼロ点の個数が8個である1フレームの信号については、時間長Tfが（8×K）等分されるような標本化周期で、その1フレームの信号からの標本値列が得られるように、また、例えば、ゼロ点の個数が4個の1フレームの信号については、時間長Tfが（4×K）等分されるような標本化周期で、その1フレームの信号からの標本値列が得られるように、以下同様に、ゼロ点の個数が6個あるいは3個であるような各1フレームの信号については、時間長Tfが（6×K）等分あるいは（3×K）等分されるような標本化周期で、各1フレームの信号からの標本値列が得られるようにするのであり、一般に、1フレームの



信号中のゼロ点の個数がZ個の場合には、その1フレームの信号については、時間長Tfが（Z×K）等分されるような標本化周期で、標本値列が得られるようにされるのであり、前述のような符号化手段を用いれば、データ量を減少させた状態での記録再生動作が容易に実現できるのである。

前記のような符号化手段によって得られるデータ、すなわち、予め定められた時間長Tfを有する各1フレームの信号からの標本値列が、1フレームの信号中におけるゼロ点の個数Zと特定な関係を有する数（Z×K）によって、時間長Tfを等分して得た標本化周期により標本抽出が行なわれることによって得られるデータは、そのデータと、標本化周期~~毎に~~Tc、1フレームの信号における標本値の個数N、フレームの番号などの情報とを組にして伝送あるいは記録に用いられる。

次に、第7図示の装置の構成や動作などについて説明する。第7図に示すマイクロホンMICは音波を電気信号（音声信号）に変換して低域濾波器LPFrに与える。第7図示の装置では、信号源と



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してマイクロホンMICが用いられているが、信号源が他の形態の音声信号の発生器、あるいは他の信号の発生器であってもよい。

低域濾波器LPFrは、以下の実施例の説明では、それの遮断周波数が3KHzであるとされている。低域濾波器LPFrによって3KHz以下の周波数帯域の信号になされた音声信号は、AD変換器ADCによって所要のビット数（以下の説明では8ビット）のデジタル信号となされて、マイクロコンピュータを含んで構成されている制御回路CCTへ与えられるが、前記したAD変換器ADCは、クロックパルスの発生器CGからの8KHzの繰返し周波数のパルスによってAD変換を行なっている。

AD変換器ADCから出力されたデジタル信号は、入力された音声信号が常に一定の標本化周期（説明例においては1/8000秒）で標本化され、それが量子化された8ビットのデジタル信号であり、それは制御回路CCTの制御の下に第1の記憶装置$M_1$（第1のメモリ$M_1$、あるいはバッファメモリ$M_1$）へ順次に記憶される。前記したバッファメモリ$M_1$は以下の説明例では512バイトの記憶容量を有しているものとされており、それは記憶容量の半分づつの2つの部分に分けられて、その2つの部分が交互にデータの書込みとデータの読出しに使用される。

さて、第7図示の装置の記録動作は、操作部OPにおける記録釦Brが操作されることによって、第9図に示すフローチャートに示すようなプログラムに従って行なわれるのであり、操作部OPにおける記録釦Brが操作されると、プログラムがスタート（第9図中の「はじめ」）すると、ステップ（1r）で制御回路CCTに設けられている9ビットの標本カウンタ、8ビットのゼロ点カウンタ、16ビットのフレームカウンタなどがリセットされる。

記録釦Brが操作される以前、すなわち、第9図示のフローチャートにおける「はじめ」の前においても、記録再生装置の制御回路CCTは、クロックパルスの発生器CGからのパルスを受けることにより、ステップ（10r）の割込み動作を実行な



っていて、AD変換器ADCからのデジタル信号出力をバッファメモリ$M_1$に順次に記憶させ、また、9ビットの標本カウンタをカウントアップしている。

また、「はじめ」の以前において、9ビットの標本カウンタは、それがフルカウントに達する度毎にリセットを繰返えすようになされている。

ステップ（2r）でバッファメモリ$M_1$から記憶されていた標本値を読出すと共に、9ビットの標本カウンタを1だけカウントアップする。

ステップ（3r）では、前記のステップ（2r）で読出した標本値の符号が、その直前の標本値の符号と同一かどうかをみて、符号の変化がなかった時はゼロ点ではないとしてステップ（2r）へ戻り、また、符号の変化があった時にはステップ（2r）で読出した標本値がゼロ点であるとしてステップ（4r）に進みステップ（4r）で8ビットのゼロ点カウンタを1だけカウントアップする。

ステップ（5r）で、バッファメモリ$M_1$から順次に読出した標本値の個数が256（または512）



に達したかどうかを9ビットの標本カウンタの計数値で調べて、バッファメモリ$M_1$から読出した標本値の個数が256に達したら｛つまり、ステップ（2r）～（4r）を256回繰返したら｝、ステップ（6r）に進み、また、バッファメモリ$M_1$から読出した標本値の個数が256に達していなかったら、ステップ（2r）に戻る。

ここで、前記のようにバッファメモリ$M_1$から読出された標本値の個数256は、第8図に示す信号Saの時間長Tfの1フレームの信号について、AD変換器ADCが一定の標本化周期（1/8000秒）で標本抽出を行なって得た標本値の個数であって、その個数256は1フレームの信号の時間長Tfと対応しているものである。

ステップ（6r）で、8ビットのゼロ点カウンタの計数値Zcと、予め定められた数Kと、1フレームの信号の時間長Tfを表わす数256とを用いて、その1フレームの信号における標本値列を得るのに必要とされる標本化周期Tcを計算すると共に、標本数Nを計算する。



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標本化周期 $Tc = 256/Zc \cdot K$

バッファメモリ$M_1$として、既述のように記憶容量が512バイトのものを、記憶容量が1/2の2部分に分けて、前記の2部分を書込みと読出しとに順次交互に用いて、1フレームの信号の時間長が32ミリ秒で、1フレーム中に256の標本がある信号の記憶と読出しが行なわれているものとし、今、例えば既述した数Kを2に定めた場合に、1フレームの信号中のゼロ点の個数Zcが32であったとすると、標本化周期Tcは、

$Tc = 256/32 \times 2 = 4$

すなわち、4/8000 = 0.5（ミリ秒）となる。

上記の例の場合に、標本数Nは64となり、256の標本からなり、時間長が32ミリ秒の1フレームの信号は標本数Nが、標本数 $N = 256/Tc = \frac{256}{4} = 64$ となる。

次いで、ステップ（7r）では、バッファメモリ$M_1$から、前記した標本化周期Tcが適用されて標本値列が取り出されるべき1フレームの信号について、前記した標本化周期Tc毎の標本値を順次に読出すために、9ビットの標本カウンタ（アドレスカウンタ）の、Tcおきの計数値をアドレス信号としてバッファメモリ$M_1$から順次にN個の標本値を読出し、また、16ビットのフレームカウンタの計数値Fcのフレーム番号と標本数N、標本化周期Tcと、前記したN個の標本値とを組にしたデータを作り、それを第2の記憶装置$M_2$（第2のメモリ$M_2$）に記憶させてステップ（8r）に進む。

ステップ（8r）では、16ビットのフレームカウンタを1だけカウントアップする。

ステップ（9r）では、16ビットのフレームカウンタがフルカウントになっているか、あるいは停止釦Bsが操作されているかをみて、フレームカウンタがフルカウントになっていたり、あるいは停止釦Bsが操作されている状態であればおわりとなり、そうでなければステップ（2r）に戻って、上記の各ステップを繰返えす。

フレームカウンタのカウント数Fcに対応して2バイト、標本数Nに対応して1バイト、標本化周期Tcと対応して1バイト、64バイトの標本値列

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とによって、1フレームの信号に対して68バイトの記憶容量の第2のメモリ$M_2$が必要とされるから、今、第2のメモリ$M_2$として64Kバイトのメモリを使用すれば、第2のメモリ$M_2$には963フレーム、すなわち、約30秒強の信号が記憶されることになる。

これまでの説明より明らかなように、第2のメモリ$M_2$には各1フレームの信号について、標本化周期Tcのデータと、標本値列と、標本数Nのデータと、フレーム番号Fc（フレームカウンタの計数値Fc）などが組となったデジタル信号が記憶されるが、これは第1のメモリ$M_1$（バッファメモリ$M_1$）に記憶されていたもとのデジタル信号に比べて大巾にデータ量が減少されているものとなっているのであり、記録時に行なわれた前述のような符号化によりデータ量が減少され、小容量のメモリによって、長時間の音声信号の記録再生を可能とする。

第7図示の装置によって、より一層忠実度の高い記録再生が行なわれるようにするために、次の

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ように信号のスペクトル分析の結果に基づいた符号化が行なわれるようにすることは有意義である。

すなわち、AD変換器ADCから制御回路CCTの制御の下にバッファメモリ$M_1$に記憶された1フレームの信号について、スペクトル計算を行ない、その計算結果から、その1フレームの信号における、あるしきい値レベル（例えば最高の信号レベルの1/64の信号レベル）以上の信号成分中の最高の周波数値を求め、その最高の周波数値の略々2倍の数値の逆数を計算して、その計算値をその1フレームの信号に対する新たな標本化周期Tcとし、その標本化周期Tcによってバッファメモリ$M_1$から、その1フレームの信号と対応する標本値列を得るようにするのであり、このような符号化を行なった場合には、既述したゼロ点間隔、あるいはゼロ点の個数などと関連して標本化周期が設定された場合に比べてより一層忠実度の高い再生信号が得られるのである。

そして、この場合においても、前記のようにして求めた新たな標本化周期Tcによってバッファメ



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モリ$M_1$から選択的に読出した標本値列と、標本化周期Tcに関連するデータとを組にしたデータが伝送または記録再生のために用いられるのである。

第7図示の装置における復号化の動作は、装置の操作部OPの再生釦Bpを操作することによって開始されるが、それは第1図及び第4図を参照して述べた第1図示の装置における復号化の動作と同様であって、第2のメモリ$M_2$から順次に読出された次のデータ組がDA変換器DACによって振幅値のアナログ量$\ell i$と標本化周期Tcと関連するアナログ量$\tau i$に変換されて補間回路CPに与えられることにより補間が行なわれ、折線近似によって原信号波形に近似した波形の再生信号となされるのであり、それが低域濾波器LPFpを通ってスピーカSPに与えられる。

以上、詳細に説明したところから明らかなように、本発明の信号の符号化記憶再生装置では、データ量を減少させるために、原信号の時間軸上における変化の状態に応じて標本化周期が可変となされるような符号化が行なわれて、原信号の振幅

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CP…補間回路、

特許出願人　日本ビクター株式会社

代理人　弁理士　今　間　孝　生



値を示す標本値と、その標本値を得るための標本化周期を示すデータとが組となされているデジタルデータを復号化する際に、デジタルデータにおける振幅値と標本化周期を表わす値との比を積分して信号の補間を行なって、折線近似された再生信号を容易に得ることができるのであり、本発明装置によれば、簡単な構成の復号化手段により良質な再生信号を容易に得ることができる。

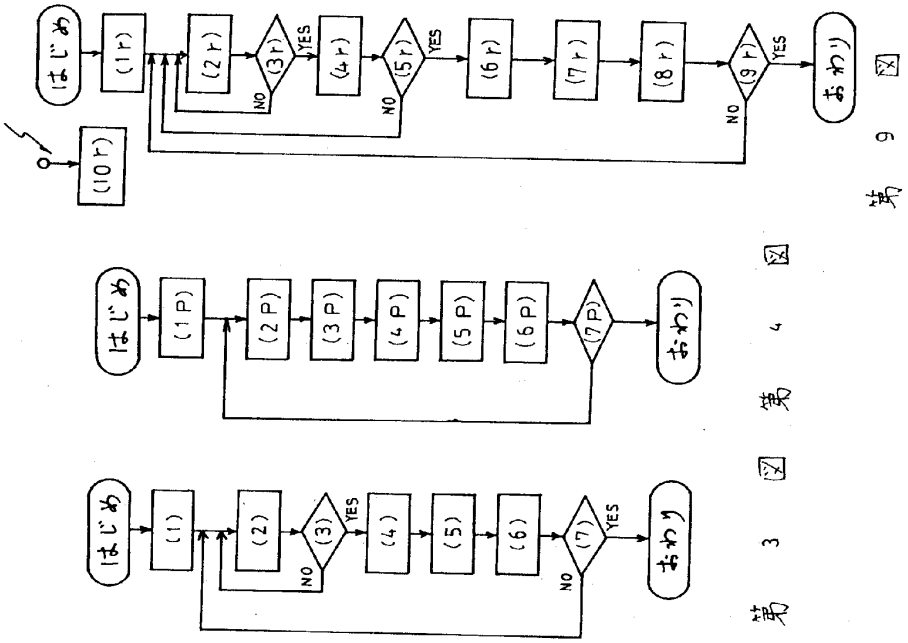
4.図面の簡単な説明

第1図及び第7図は本発明装置の各異なる実施態様のブロック図、第2図及び第8図は説明用の波形例図、第3図，第4図及び第9図はフローチャート、第5図は補間回路の一例構成のブロック図、第6図は特性例図である。

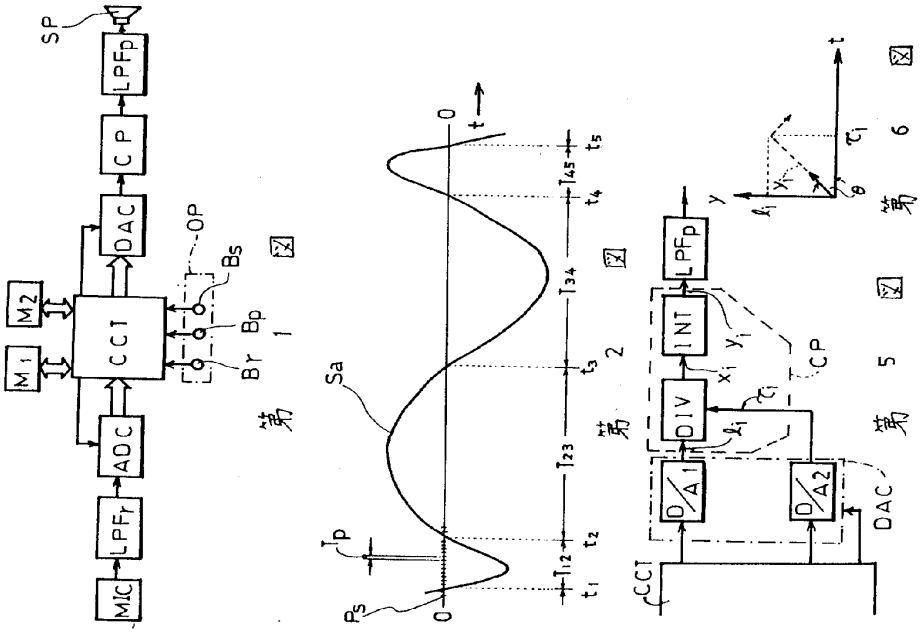
MIC…マイクロホン、LPFr，LPFp…低域濾波器、ADC…AD変換器、CG…クロックパルスの発生器、CCT…マイクロコンピュータを含んで構成された制御回路、OP…操作部、DAC…DA変換器、$M_1$…第1の記憶装置（第1のメモリ、バッファメモリ）、$M_2$…第2の記憶装置（第2のメモリ）、



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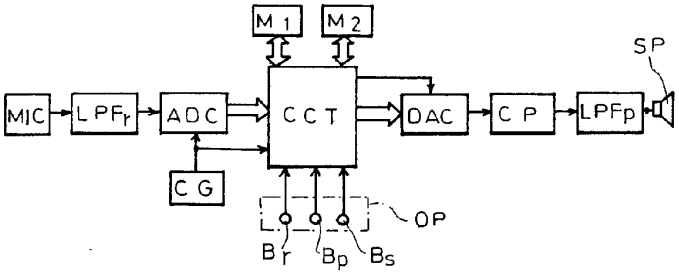

第9図 第4図 第3図



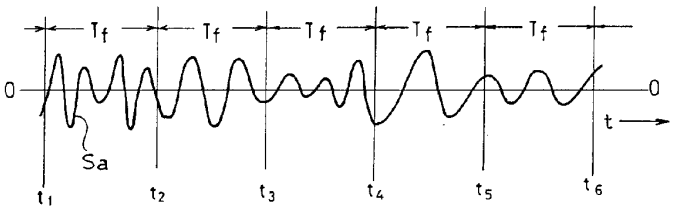

第1図 第2図 第5図 第6図



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第 7 図




第 8 図



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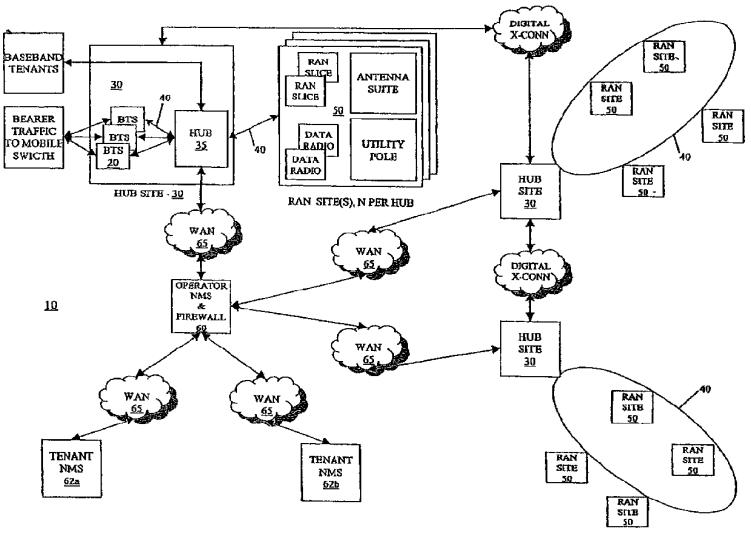
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(54) Title: OPERATIONS AND MAINTENANCE ARCHITECTURE FOR MULTIPROTOCOL DISTRIBUTED SYSTEM




(57) Abstract: An architecture for providing operations and maintenance functionality in an open access wireless signal distribution system. The open access system makes use of a common, shared, distributed radio frequency distribution network and associated network entities that enable a system operator to offer access to wireless infrastructure that may be shared among multiple wireless service providers (WSPs). The WSPs, or tenants of the operators, may obtain access in a tenant lease-space model. The open access system provides the ability for multiple tenants in a given community to share wireless equipment such as remotely located antenna sites, regardless of their specific requirements for radio frequency (RF) air interface signal protocols and/or management messaging formats. The present invention is directed to an open access Network Management System (NMS) that provides multiple tenants with an appropriate level of access and control over the system elements that carry their signaling. For example, in addition to forwarding messages from tenant-controlled NMSs to the open access system elements, the open access NMS preferably acts as a caching firewall to ensure that the tenant NMS are permitted privileges to access only those system elements to which they are properly assigned. A database function included with the open access NMS may be used to build and maintain a database of operations and maintenance information from autonomously initiated poll and status functions. This then permits queries from tenant NMSs to be answered without the need to duplicate open system network traffic.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# OPERATIONS AND MAINTENACE ARCHITECTURE FOR MULTIPROTOCOL DISTRIBUTED SYSTEM

## 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. 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 where it may be allowed by local zoning and the work with the new service providers to use the already existing towers. The speculative build spawned by the recently adopted zoning by-law is actually encouraged by communities to mitigate the "unsightly ugliness" of cellular phone towers. Towns adopted the by-laws to control tower placement since Federal laws prohibit 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 may employ a high speed 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 microcellularsites without degradation in RF signal 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 Management System (NMS) 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 access to the infrastructure regardless of the specific RF air interface or other signal formatting and/or managing messaging formats that such operators choose to deploy.

More particularly, the present invention is concerned with a technique for implementing an open access Network Management System (NMS) that acts a common control message interface for respective network management systems operated by multiple wireless service providers in a given community. This open network management system consists of a software element that communicates control messages with open access system elements, such as radio hubs and Remote Access Nodes (RANs). In the preferred embodiment, the control messages consist of Simple Network Management Protocol (SNMP) messages and other similar messages using, for example, Transmission Control Protocol-Internet Protocol (TCP/IP) packets.

The open access NMS architecture enables different tenants to have access to the control and status information they need in a familiar form while preventing access to information that they do not need to have or have their privilege is to see. For example, the open access Network Management System preferably includes a statefull firewall for SNMP traffic. The statefull firewall looks like an SNMP agent for the tenant interfaces, but looks like an SNMP client to the open access system elements such as the radio hubs and RANs. The statefull firewall software system contains configuration information that defines which SNMP privileges a particular tenant client may use, such as based on the IP address of the client.

The open access NMS thus provides each respective wireless operator with a set of alarms, operation and maintenance signaling, built-in testing and other remote control messaging privileges for their own respective wireless access systems. They can thus perform SNMP functions for the open access system elements using their own tenant-specific Network Management System (tenant NMS). However, a hierarchy is employed between the tenant NMSs and the open access system NMS, to minimize the signaling across multiple wireless operators, and to, perhaps more importantly, create a firewall to prevent one tenant from obtaining information from or even sending control messages to open system elements that are under the control of other tenants.

The open network management system also provides a facility whereby information to which common access is needed maybe cached or accessed through database queries. In particular, the open access NMS can autonomously initiate queries to the open access system elements to determine status information, and then place this information in its own database. This serves two purposes. First, when an SNMP request message is received from a tenant NMS, the local database can be queried for the information rather than sending request messages out to the system elements. This prevents unnecessary network traffic when a different tenant NMS's are making queries for common information such as, for example, fault states, temperature information and the like which should be sharable among the various system operators. A second benefit is provided in that relatively large amounts of data can be passed to the tenant NMS without crating correspondingly large amounts of traffic on the internal open access system communication network.

## 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 is a more detailed view of a cross connect providing for the ability to connect multiple base stations for different Wireless Service Providers (WSPs) or tenants of the open system to a network of Radio Access Nodes.

Fig. 6 is a diagram illustrating how RAN slices may be allocated to different tenants and sectors in simulcast.

Fig. 7 is a message flow diagram illustrating how the open access system may provide for shared or open access Network Management System (NMS) functionality.

Fig. 8 is an illustration of a messaging scenario where a one tenant sends an SNMP message that the open access NMS may determine violates a privilege.

Fig. 9 illustrates a messaging scheme where a caching firewall is used to reduce SNMP message traffic to the open system components.

Fig. 10 is an illustration of how tenants may gatherblocks of data from an operator NMS without incurring overhead of SNMP.

## 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 herein also 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 transceiver stations (BTSs) 20, located at hub sites 30. The base stations 20 are connected via high speed data links 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 50, 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.

An operator controlled, common or open access Network Management System 60 provides remote monitoring and control of the open access network 10 by the network operator. The open access 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. The present invention relates in particular to the manner in which the open access NMS 60 communicates with tenant NMSs 62a, 62b. By "tenant" herein, 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 using the open access system 10.

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 and/or WCS/ISM/MMDS/U-NII wireless service providers, and wireless data providers who require last mile access to their targeted customers, all at the same time.

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 tenants 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 from the operator of the open access system 10, so that the operators can install corresponding, appropriate individual radio elements in a RAN slice 52. Each HUB 35 can scale to support one to three sectors each for multiple 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 provide a wide area distribution network that is logically a "horizontal radio 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 slices may be stacked to serve additional tenants, as needed.

Open access network elements such as the HUBs 35 and RANs 50 incorporate a System Network Management Protocol (SNMP) communication scheme to facilitate integration with the host operator's open access network management system (NMS) 60. The open access NMS is in turn connected to tenant-specific NMSs 62a, 62b through convenient data networking equipment such as wide area data networks (WANs) 65. This architecture allows easy and complete communication across the open access system 10 with a high level of control and visibility. The preferred manner in which the open access NMS 60 coordinates requests from tenant NMSs 62a, 62b to communicate SNMP messages with the open access system elements is described below.

But before discussing the NMS messaging hierarchy, it is instructive to understand the basic functionality of the open access system elements. 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 (but 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 bit-wide data

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. These control bits can be used for a link layer to support SNMP messaging between the open access system elements over the fiber 40, or for other purposes. The 16 bit wide 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 RF feed network 117 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 back now 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 (embodiments greater than 8 are also possible) 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, 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. For more details concerning link budget allocation, refer to our co-pending U.S. Patent Application serial number... filed March 27, 2001 and assigned to Transcept OpenCell, Inc., the same assignee as the present invention.

Turning attention now to Fig. 5, 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. 5 and 6, the system described by this invention selects a different simulcast scheme for each individual sector of each wireless tenant 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. 5 and 6, WSP or tenant 1 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. 6 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. 5 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. The open access product allows a tenant 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 62 via the wide area network 65..

What is important to note here in the context of the present invention is that any given WSP or tenant may require access to only certain ones of the RAN slices at particular RANs 50, depending upon the simulcast configuration presently in place, and depending upon the types and amount of access that the individual tenant has requested from the operator of the open access system.

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 RANs 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, ATM cells, and other traffic as need for open access signal transmission and system management and control.

The data link 40 connects a Hub 35 and multiple RANs 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.

With continuing reference to Fig. 1, it can now be better understood how operations and maintenance works for the open access system 10. Recall that the

open access system 10 provides wireless signal distribution service for a number of different tenants or Wireless Service Providers (WSP) who ultimately provide service to the end users. The open access system tenants may typically lease RF bandwidth services and network management services from the operator of the open access system 10.

Such tenants are likely to require and benefit from having certain levels of operations, maintenance and control information concerning the open access system elements over which their own customers signals and information travel. For example, even a tenant is extremely concerned when system elements are not functional; however, such tenant have often devised their own management schemes for detecting, reporting, and acting upon such system events. The operator of the open access system 10 therefore implements the open access network management system (NMS) 60 and provides operational procedures that permit the tenants to perform certain system management functions in a coordinated manner.

The open access NMS 60 consists of a software system that is typically the sole or at least primary path for communication of control messages with the open access system elements such as the Hubs 35 and RANs 50. The communication consists of SNMP (Simple Network Management Protocol) messages and other messages using TCP/IP packets. The NMS 60 performs the functions of discovery, poll, status, control, forward, filter-SNMP, database, query and filter-query. For example, the discovery function polls the range of IP addresses to identify new Hubs 35 or RANs 50. The poll function polls specific Hubs 35 or RANs 50 to monitor health of network communication. The status function exchanges messages with specific services at Hub 35 or RAN 50 to monitor status. The control function sends messages from operator to Hub 35 or RAN 50. The forward function forwards messages from tenant NMSs 15 to Hub 35 or RAN 50. The filter-SNMP function filters forwarded messages to limit access by tenants 15 to status and control. The database function builds a database of information from the poll and status functions. The query function responds to database access queries from tenant

NMSs 15. The filter-query function filters database queries to limit access by tenants 15 to status and control functions only.

Tenants need to monitor and control their leased portion of the open access network. 10 including certain aspects of the Hubs 35 and RANs 50. Tenants expect to have access to the information needed in a familiar form (compatible with industry NMS), and therefore expect to be able to use their own tenant NMS facilities 62a, 62b to accomplish this. The operator of the open access system 10 thus desires to provide these services to his tenants, however, while preventing access to information that individual tenants do not need or should not have the privileges to see. For example, one tenant should not have access to certain proprietary information concerning the slices installed for that tenant in a RAN, even when the RAN is shared among multiple tenants.

The tenant NMS 62 can use two forms of access to gather information, SNMP and database queries made to a local database maintained by the open access NMS 60. The open access NMS 60 can then either allow access or prevent access to the requested based upon privileges granted to specific tenants and for specific types of queries.

Fig. 7 depicts a first scenario for communication of operations, maintenance and control messages. The open access NMS can in one manner of thinking be described as a Statefull Firewall for SNMP traffic traveling between the tenant NMS 62 and the open access system elements 35, 50. The statefull firewall looks like an SNMP agent for the whole open access network 10 but looks like an SNMP client (or NMS) to the Hubs 35 and RAN's 50.

The statefull firewall software system in the open access NMS 60 contains a configuration file that defines the SNMP privileges (get, set, etc) that each SNMP client (e.g., the tenant NMS 62) can use, based upon, for example, the IP address of the client. Another portion of the TCP/IP protocol stack ensures that IP addresses actually come from an authorized client (to prevent IP address spoofing).

The scenario depicted in Fig. 7 in particular relates to a situation where a tenant originates a valid SNMP message and the open access NMS 60 forwards the message to one of the open access system elements 35, 50, which in turn responds with the requested information, that is then relayed back to the requesting tenant NMS. In a preferred embodiment, a sequence of events occurs as follows.

1. Tenant NMS has a Management Information Block (MIB) 61 that defines valid types and formats for SNMP GETs and SETs messages to be sent to the open access system elements 35, 50;
2. Tenant NMS creates an SNMP message that fits one of the MIB 61 entries;
3. Tenant NMS send an SNMP message to the open access statefull firewall NMS 60 over an wide area network 65;
4. The open access statefull firewall 60 then receives SNMP message with its SNMP agent software;
5. The incoming message is identified with the IP address of originating authorized tenant NMS 62;
6. The SNMP agent in the open access NMS 60 uses the Tenant identification information and SNMP address to look up the validity of message in a local MIB copy 63 of the MIB 61 in the originating tenant NMS 62;
7. The Message is determined to be valid, so the SNMP agent in the open access statefull firewall NMS forwards the message to open access Hub 35/RAN 50 network;
8. The addressed Hub 35 or RAN 50 receives the SNMP message and responds with a message back to the open access statefull firewall NMS 60;
9. The open access statefull firewall NMS 60 receives response and verifies its association with an SNMP message; it may also verifies the origin and destination IP addresses and perform other client to agent verification needed; and
10. The open access statefull firewall NMS 60 forwards the response on to the Tenant NMS 62 that originated the transaction.