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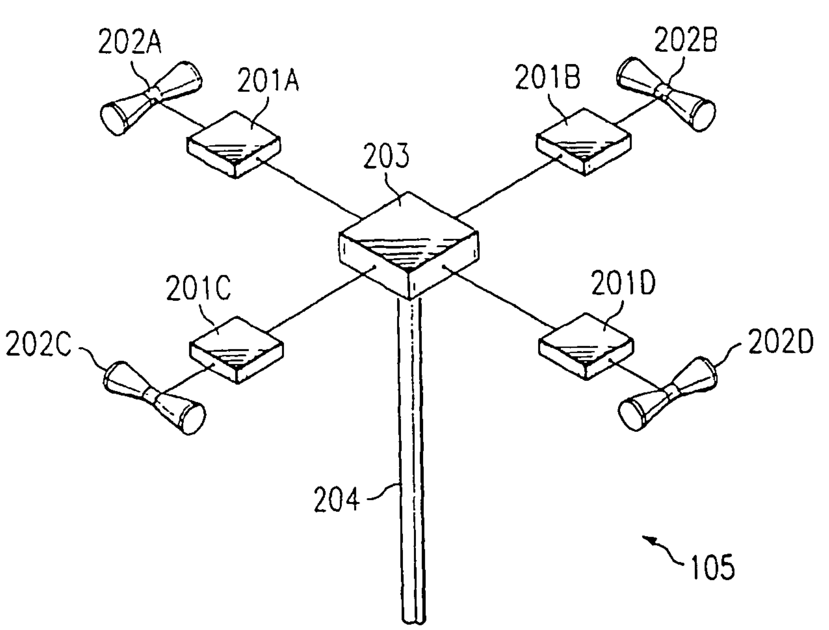
(54) Title: SYSTEM AND METHOD FOR FREQUENCY RE-USE IN A SECTORIZED CELL PATTERN IN A WIRELESS COMMUNICATION SYSTEM



(57) Abstract: The present invention relates to a system and method for frequency re-use in a wireless communication system. More particularly, the inventive system and method provides for maximum coverage of a service area with a pattern of cells (101, 102, 103 and 104) each having a sectorized (101A-101D) hub (105) antenna pattern (202A-202D) where only a limited number of communication channels are available.

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SYSTEM AND METHOD FOR FREQUENCY RE-USE IN A SECTORIZED CELL PATTERN IN A WIRELESS COMMUNICATION SYSTEM

RELATED APPLICATIONS

The present application is related to co-pending, commonly assigned U.S. patent application serial number 09/434,707, entitled "SYSTEM AND METHOD FOR BROADBAND MILLIMETER WAVE DATA COMMUNICATION," co-pending, commonly assigned U.S. patent application serial number 09/604,437, entitled "MAXIMIZING EFFICIENCY IN A MULTI-CARRIER TIME DIVISION DUPLEX SYSTEM EMPLOYING DYNAMIC ASYMMETRY," and co-pending, commonly assigned U.S. patent application serial number 09/607,456, entitled "FREQUENCY REUSE FOR TDD," which are incorporated herein by reference. The present application is also being filed simultaneously with a commonly assigned U.S. patent application entitled "SYSTEM AND METHOD FOR INBAND SIGNALING FOR SECTOR SYNCHRONIZATION IN A WIRELESS COMMUNICATION SYSTEM".

BACKGROUND OF THE INVENTION

The present invention relates to communication systems and methods and more particularly to a system and method for optimizing the bandwidth of a point to multipoint wireless system by synchronizing transmit and receive modes.

Wireless radio links have increasingly become important to provide data communication links for a variety of applications. For example, Internet Service Providers have begun to utilize wireless radio links within urban settings to avoid the installation expense of traditional wired connections or optical fiber. It may be advantageous to utilize wireless radio link systems to provide service to a plurality of users in a point to multipoint architecture. Point to multipoint systems typically consist of a plurality of hub units servicing a plurality of sub units (sometimes referred to as remote units, nodes, or subscriber units). The subs are typically associated with individual nodes on the system. For example, an individual sub unit may be connected to LAN to allow PC's on the LAN to bridge to other networks via the point to multipoint system. Each sub unit communicates via a wireless channel with a particular hub unit. In a point to multipoint system, the hub unit may control communication between a portion of the plurality of sub units associated with a particular coverage area. The hub units schedule transmit and receive bursts to and from sub units. The hub units may distribute data packets received from a particular sub unit to another sub unit within the same coverage area via such frames, to a traditional wired network backbone, or to another hub unit.

A point to multipoint system, such as disclosed in the above referenced and commonly assigned patent application entitled "FREQUENCY REUSE FOR TDD," contains a plurality of adjacently located hub units providing an aggregate coverage area. Additionally, these hubs may have their individual coverage areas divided into particular sectors - such as 30 or 90 degree sectors. Additionally, the hubs may utilize frequency division or other techniques to provide a plurality of communication channels.

Channel reuse techniques have developed to allow reuse of channels within a network without introducing unacceptable levels of interference. The purpose of these channel reuse techniques is maximize channel availability while avoiding co-channel interference between neighboring hubs. Clearly, these channel reuse techniques are valuable tools to increasing the bandwidth of point to multipoint systems. However, according to the present invention it has been realized that point to multipoint systems contain architectural characteristics that may be exploited to allow optimization of channel availability greater than that available with traditional channel reuse techniques while avoiding co-channel interference.

For example, data traffic over a point to multipoint system may be bursty, rather than at a fixed or continuous data rate. Specifically, an Internet browser application executed on a sub unit would typically require significant down link bandwidth while downloading HTML code from a website, but would require little or no bandwidth while a user reads the display associated with the HTML code. Additionally, the bandwidth requirements of many applications such as browsers may be asymmetric. Specifically, Internet browsers often download a large amount of data, but upload proportionally very little. Accordingly, point to multipoint systems may implement dynamic bandwidth allocation (DBA) techniques to maximize the data throughput associated with asymmetric, bursty traffic.

Accordingly, it is an object of the present invention to provide a system and method to maximize the bandwidth of point to multipoint systems in accordance with the unique characteristics of point to multipoint systems as between particular portions of the network.

It is an additional object of the present invention to provide a system and method for synchronized dynamic allocation of bandwidth.

It is an additional object of the present invention to provide a system and method for synchronization of receive and transmit modes of sectors or other portions of an associated group of hub units to maximize the bandwidth of point to multipoint systems.

It is an additional object of the present invention to provide a system and method for sector to sector telemetry in point to multipoint systems.

It is an additional object of the present invention to provide an efficient communication channel for use with the invention systems and methods that allows synchronization of neighboring hubs while permitting rapid dynamic allocation of bandwidth in individual hubs.

It is still an additional object of the present invention to provide a pattern of frequency re-use in a wireless communication system.

It is another object of the present invention to provide a repeatable pattern of frequency re-use in a wireless communication system comprised of sixteen cells in a four-by-four grid using two polarizations per communication frequency.

It is yet another object of the present invention to provide a repeatable pattern of frequency re-use in a wireless communication system comprised of sixteen cells grouped in four sub-clusters of four cells in which facing sectors in the pattern are synchronized.

It is a further object of the present invention to provide a method of reducing co-channel and/or adjacent channel interference by a pattern of frequency re-use.

These and other objects, features and technical advantages are achieved by a system and method which operate in a point to multipoint system comprising a plurality of hubs and a plurality of subs distributed within coverage areas associated with the hubs. The point to multipoint system preferably divides its communication bandwidth into channels utilizing spectrum division techniques, such as frequency division, time division, or orthogonal code division. Also, the hubs communicate to the subs within their coverage areas via sector antennae. By utilizing spectrum division and sector antennas, preferred embodiments of the point to multipoint system coordinate channel allocation via a channel reuse plan. Additionally, preferred embodiments divide individual channels into transmit and receive modes via a Time Duplex Division (TDD) scheme via the same channel. In this TDD scheme, a hub transmits information to subs in the transmit mode and receives information from subs in the receive mode. Moreover, the hubs of the point to multipoint system preferably may dynamically allocate bandwidth between the transmit and receive modes to achieve asymmetric communication modes. Also, the preferred embodiment subs utilizing the present invention comprise directional antenna.

Co-channel interference such as in adjacent sectors of neighboring hubs is a significant concern. Specifically, hub to hub exposure is problematic, since hub antennas are typically directed toward other hubs of the network in order to provide composite coverage of a service area. For example, preferred embodiment hubs may utilize sector antennas covering between 30 to 90 degrees in azimuth, which are oriented to face similar sector antennas at neighboring hubs. Sub unit exposure is not as a significant issue for the preferred embodiments point to multipoint systems, because sub units of these point to multipoint systems utilize highly directional antenna. Accordingly, the subs units may not be exposed to significant co-channel interference from other sub units or other hub units.

Channel reuse plans may be utilized to mitigate hub to hub co-channel interference. For example, by carefully assigning channels for use by the hubs of a network, reuse performance of approximately 1 may be achieved. Moreover, through advanced channel planning techniques, such as shown and described in the above referenced patent application, entitled "FREQUENCY REUSE FOR

TDD", and as described below, higher channel reuse performance may be achieved.

Nonetheless, a method or system optimization that would permit greater channel reuse would allow greater bandwidth for the system as a whole. The present invention achieves this goal in one embodiment by synchronizing transmit and receive modes of hubs. One embodiment of the present invention synchronizes dynamic bandwidth allocation of facing sectors of a cluster of geographically adjacent hubs, while allowing other sectors of these hubs to independently allocate bandwidth through frequency reuse and facing sector synchronization. The hubs are adjacent in the sense that the hubs are the nearest neighbor hubs in a particular direction. In this embodiment, guard time between transmit and receive modes is minimized by preferably selecting a guard time to accommodate the synchronization distance of just over two hub coverage radii. For example, where a maximum reuse is 6R, a reuse schedule of 9, with 30 degree sectors, 4.5 km cells, the guard time is approximately 100μs or approximately 5 % of the embodiment's channel capacity to accommodate propagation from a maximum distance in the reuse cluster. However, as the present invention synchronizes facing sectors of adjacent hubs, the synchronization distance is greatly reduced. Accordingly, in this embodiment, the guard time only occupies .5 % of the channel capacity. Moreover, the computation requirements of the system are significantly reduced in this preferred embodiment, as a much smaller portion of the network is synchronized with respect to any particular synchronization determination. Also, the facing sector synchronization simplifies the implementation of synchronization telemetry.

In another embodiment of the present invention, a pattern of frequency re-use is described where a repeatable pattern of cells is employed to allow for re-use of a number of frequency assignments where there are two polarization modes available per frequency. Such a pattern of frequency re-use is especially useful when the number of frequency assignments, or communication channels, available for operation of a communication system is limited. In order to provide sufficient coverage for a particular operating area, a pattern of cells that re-use the available frequencies must be provided in order to avoid dead spots or to avoid interference between adjacent channels on the frequency spectrum used in the same area, known in the art as "adjacent channel interference" or interference between two cells using the same frequency with the same polarization in adjacent areas, known in the art as "co-channel interference".

Idealizing the shape of the cells in the pattern as circular and further idealizing each cell as having a similar radius, the shape of a repeatable pattern of such cells can be viewed as an overlay on a flat surface. Obviously, such idealizations such as a flat surface and substantially identical cells spaced at uniform distances rarely occur in the real world. However, it is to be understood that the present inventive system and method is not limited to such idealizations but rather is applicable to real world situations where the overall frequency re-use pattern can be used while taking into account minor variations to allow for obstructions, terrain features, dissimilar cell sizes, irregular spacing of cells, etc. While the disclosure of the invention below will discuss an idealized repeatable pattern composed of idealized cells, etc., such idealizations should not be construed as limitations of the invention.

For cells of substantially the same size and circular in shape, one arrangement of those cells in a multi-cell pattern may be seen as a square grid where the edge of two cells that are adjacent in the same rank or the same file are tangent at one point. In such an arrangement, cells that are diagonally adjacent are not tangent. In another multi-cell arrangement, a cell in the pattern is tangent to each of six adjacent cells. Such a pattern would appear as a honeycomb shape if the cells are idealized to be hexagonal in shape.

The inventors have determined empirically that for cells with 90° sectors, a minimum of eight frequency assignments and two polarizations are required for efficient frequency re-use for broadband wireless access systems. This is a reasonable requirement of frequency/polarization assignments for 90° sectorized cells in a time division duplex ("TDD") system considering the size of a typical license allocation of frequencies on a worldwide basis. For example, in Europe, the anticipated license allocation is 2 x 112 MHz or 224 MHz for the 28 GHz band and approximately 500 MHz for the 42 GHz band. Most of the North American broadband wireless access operators have allocations in excess of 200 MHz. An emerging popular channel size is 28 MHz in Europe and 25 MHz in North America. These channel sizes coupled with the anticipated license allocation of frequencies allows for eight or more available frequency channels.

While 90° sectors have some disadvantages over smaller sector sizes, such as 60°, 45°, and 30° sectors, 90° sector size is the baseline for planning for almost all broadband wireless access operators and standards groups. For example, RF performance is somewhat compromised for wide sectors relative to narrow sectors. Cell diameter is reduced thereby requiring a greater number of hubs/cells to cover a given area. Wider sectors also give rise to a greater possibility of co-channel and adjacent channel interference.

Despite the operational drawbacks of 90° sectors, there are significant economical advantages to 90° sector plans. One advantage is the lower cost of outdoor gear. With 90° sectors, fewer sectors and hence fewer radios, antennas, and associated equipment, both primary and redundant, are required when compared with smaller-sized sectors. Additionally, a significant cost to operators are roof rights. Landlords tend to charge for the right to place equipment of the roof of their building based on the number of antennas so 90° sectors translates into lower cost for roof rights. Also, wider sectors provide greater RF coverage which is an important benefit in the early deployment of a system.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawing, in which:

FIGURE 1 depicts an illustrative example of a point to multipoint system arranged in a cluster architecture.

FIGURE 2A depicts an illustrative sector configuration for the point to multipoint system set forth in FIGURE 1.

FIGURE 2B illustrates a sectorized antenna arrangement for a hub for one of the cells in FIGURE 2A.

FIGURE 3 illustrates particular sectors and the propagation of transmissions from hubs to a plurality of subs within the particular sectors.

FIGURES 4A to 4D each illustrate a timing diagram for a series of RX and TX frames associated with opposing sectors of adjacent hubs.

FIGURE 5 illustrates an exemplary power density spectrum for a QAM carrier signal and an associated Adaptation carrier.

FIGURE 6A illustrates a set of eight frequency channels with two polarizations per frequency channel for use in a frequency re-use pattern.

FIGURE 6B illustrates eight unique cell types using the set of eight frequency channels with two polarizations per frequency channel illustrated in FIGURE 6A.

FIGURE 7 illustrates a repeatable pattern of sixteen cells in a four-by-four rectilinear grid where each cell is divided into four 90° sectors where opposing sectors operate on the same frequency channel with the same polarization.

FIGURE 8 illustrates one group of four cells from the repeatable pattern of sixteen cells in FIGURE 7.

FIGURE 9 illustrates a repeatable pattern of sixteen cells in a four-by-four grid forming a parallelogram where each cell is divided into four 90° sectors where opposing sectors operate on the same frequency channel with the same polarization.

FIGURE 10 illustrates a repeatable pattern of FIGURE 7 where facing sectors operate on the same frequency channel and polarization to allow for transmit and receive synchronization between hub antennas of facing sectors.

FIGURE 11A illustrates the set of eight frequency channels with two polarizations per frequency channel shown in FIGURE 6A indicating those frequency channels and polarizations used in the pattern in FIGURE 10 and those frequency channels and polarizations not used in the pattern of FIGURE 10 that are held in reserve.

FIGURE 11B illustrates eight unique cell types using the set of four frequency channels with two polarizations per frequency channel illustrated in FIGURE 11A as being used in the frequency re-use pattern of FIGURE 10.

FIGURE 12 illustrates one group of four cells from the repeatable pattern of sixteen cells in FIGURE 10.

FIGURE 13 illustrates the repeatable pattern FIGURE 10 with an overlay of additional frequency channel sectors to accommodate an increase in the capacity demands of the users of the system.

DETAILED DESCRIPTION

FIGURE 1 illustrates an exemplary point to multipoint system utilizing the present invention. The system is preferably deployed in a cluster configuration. The illustrative cluster consists of a plurality of hubs (105, 106, 107, 108), although clusters in numbers different than the illustrated configuration may be employed according to the present invention. It shall be appreciated that communication networks utilizing the present invention may include additional clusters, either remotely located or adjacently located, with the clusters utilizing the present invention.

Hubs 105, 106, 107, and 108 provide coverage to cells 101, 102, 103, and 104. A plurality of subs (109 - 119) are deployed in cells 101, 102, 103, and 104, respectively. In addition, processor systems (120 - 131) are respectively associated with individual sub units. It shall be appreciated that sub units of a point to multipoint system may be alternatively associated with a LAN network of processors system. Alternatively, the sub units of point to multipoint system may be connected to an intermediate network. For example, a sub unit may be connected to an intermediate ATM switch. It shall further be appreciated that a system employing the present invention may contain an arbitrarily large number of hubs, cells, and sub units. For simplicity of describing the present invention, the exemplary embodiment has been described in terms of four cells.

FIGURE 2A illustrates an exemplary sector configuration of the point to multipoint system set forth in FIGURE 1. As previously noted, the system is divided into coverage areas associated with cells 101, 102, 103, and 104. Moreover, cells 101, 102, 103, 104, of the illustrated embodiment are sectorized into 90 degree sectors (101A-101D, 102A-102D, 103A-103D, and 104A-104D), although other sector sizes may be synchronized according to the present invention. Hubs 105, 106, 107, and 108 transmit and receive signals to/from the sectors via sector antennas, such as illustrated in FIGURE 2B for the hub 105. The sector antennas 202A through 202D may utilize a discrete antenna element for each sector. Alternatively, the sector antennas may utilize a plurality of narrow beam antenna elements to synthesize sector coverage. In this configuration, energy from RF signals transmitted from a sector antenna associated with any of sectors 101D, 102C, 103B, and 104A may be detected in the other sector antennas of this group.

The spectrum allocated to the point to multipoint system as a whole is preferably subdivided into channels. Numerous methods of channel division may be utilized with the present invention, such as time division, frequency division channels, frequency hopping channels, and orthogonal code channels. The channels are divided into discrete sets. Additionally, the sets of channels are allocated among the sectors of the point to multipoint system in accordance with a reuse schedule. In this exemplary system, RF signals 302-307 are being transmitted upon the same channel for the purpose of illustrating the present invention. It shall be appreciated that other signaling may occur on other channels concurrently with the exemplary transmit and receive signals.

According to a preferred embodiment, at least adjacent sectors of a particular cell are provided different channel sets according to the channel reuse plan. For example, the channels assigned for use by sectors 104B and 104C are different from the channels assigned for use by sector 104A. However, depending upon the front and back isolation of the sector antenna, side lobe characteristics, and the like, channel sets may be reused in a cell, such as within sector 104B and 104C and/or 104A and 104D.

FIGURE 3 illustrates a series of RF transmit signals (301-306) broadcast from hubs 105 and 106, respectively. Hub 105 transmits a series of RF time burst or time slot signals (302, 303, and 304) with the signals propagating in direction 301 within sector 101D. Since hub 105 utilizes a sector antenna, the energy associated with RF signals 302, 303, and 304 propagates through out sector 101D. RF signal 302 comprises information for sub 109. RF signal 303 comprises information for sub 110. RF signal 304 comprises information for sub 111. Similarly, hub 108 transmits a series of RF time burst or time slot signals (305, 306, and 307) with the signals propagating in direction 308 within sector 104A. Since hub 104 utilizes a sector antenna, the energy associated with RF signals 305, 306, and 307 propagates through out sector 104A. RF signal 305 may comprise information for sub 117. RF signal 306 may comprise information for sub 118. RF signal 307 may comprise information for sub 119.

Eventually, RF signals 302, 303, and 304 will propagate beyond the confines of cell 104 into cells 101, 102, and 103. Accordingly, RF signals 302, 303, and 304 could cause co-channel interference in cells 101, 102, and 103. In the preferred embodiment point to multipoint system, the sub units utilize highly directional antennas directed toward an associated hub and therefore generally away from the remaining hubs of a cluster. Accordingly, the subs generally will not experience co-channel interference from RF signals 302, 303, and 304.

However, hubs 105, 106, and 107 will experience co-channel interference if the hubs are in receive mode with respect to the particular channels associated with RF signals 302, 303, and 304 when the RF signals arrive at the particular hub. According to a preferred embodiment, hub 108 utilizes the same set of channels for sector 104A as hub 105 utilizes for sector 101D, hub 106 uses for sector 102c, and as hub 107 uses for sector 103b. Accordingly, RF signals 302, 303, and 304 could cause co-channel interference depending upon their arrival time at hubs 106, 107, and 108. It shall be appreciated that RF signals 302, 303, and 304 will have negligible effect if RF signals 302, 303, 304 arrive when hubs 106, 107, and 108 are in transmit mode. Similarly, RF signals 305, 306, and 307 may cause co-channel interference in hubs 105, 106, and 107, if the hubs are in receive mode with respect to the channels associated with the signals upon their arrival.

Additionally, the subs in sectors 101D and 104A broadcast RF signals 309-314. As previously noted, the sub units of the preferred embodiment of this system utilize highly directional antennas. The architecture of the system is such that the highly directional antennas focus the radiated RF energy within a very narrow beam centered upon the respective hubs. Accordingly, it is unlikely that the subs could couple with another antenna in the system to cause co-channel interference. It shall be appreciated that this exemplary system contemplates that RF signals 302-307 and RF signals 309-314 are being transmitted via the same frequency channel. Accordingly, the exemplary system illustrating the present invention controls the timing of RF signal transmissions in TDMA burst periods.

The preferred embodiment of the present invention and method synchronizes particular transmissions within a point to multipoint system to prevent hub transmission from causing co-channel interference. Of course, reception windows may also be synchronized in addition to or in the alternative to transmission window synchronization in accordance with the present invention. Depending upon the amount of isolation between channels, it may be possible to independently synchronize individual channels in adjacent sectors. By synchronizing individual channels, an adaptive time division duplex scheme may maximize throughput on a per channel basis. However, this approach requires greater processing capacity, and hence greater equipment costs and complexity, to calculate optimal receive and transmit asymmetries. Accordingly, the preferred embodiment synchronizes transmission and reception for all channels utilized within adjacent sectors. In this manner, the present system and method allows greater performance of the asymmetric time division duplex algorithms while maintaining costs and complexity at preferred levels.

FIGURES 4A through 4D set forth exemplary timing diagrams for transmit and receive frames for sectors 101D, 102C, 103B, and 104A of hubs 105, 106, 107, and 108. Each hub is preferably synchronized to begin its transmit mode at time t_0. Hub 105 transmits TX bursts 401-403, comprising information for subs 109-111, respectively. Hub 106 transmits TX burst 404 comprising information for sub 114. Hub 107 transmits bursts 405 and 406, comprising information for subs 115 and 116, respectively. Hub 108 transmits bursts 407-409, comprising information for subs 117-119, respectively. Also, each hub is preferably synchronized to end its transmit mode at time t_6.

Additionally, hubs 105-108 are further synchronized such that hubs 105-108 do not transmit from time t_6 to time t_7. Also, hubs 105-108 do not receive bursts from subs from time t_6 to time t_7. During this period, the delay in transmission and reception creates guard 316. The duration of guard 316 is preferably selected so that the RF signals associated with the respective bursts will propagate beyond any hub that may experience co-channel interference before the hub will enter receive mode. Adjacent sector synchronization causes the synchronization distance for this embodiment to be slightly more than two hub radii (the distance between hubs 105 and 108). Adjacent sector synchronization with proper reuse planning is sufficient, because non-synchronized sectors utilizing the channels will be sufficiently separately spatially or facing different directions to avoid co-channel interference.

An exemplary discussion of such frequency reuse planning is contained in the above reference patent application, entitled "FREQUENCY REUSE FOR TDD." In an environment utilizing frequency use, channels may be assigned to hubs and their respective sectors by storing assigned channels in non-volatile memory at a hub which is utilized to physically configure the hub during a configuration start-up operation. Alternatively, channels may be assigned upon a dynamic basis in accordance with dynamic channel assignment algorithms. In this case, a channel controller may implement a particular dynamic assignment algorithm and periodically communicate assigned channels to the hubs for use in the respective sectors.

After time t_7, hubs 105-108 are synchronized to enter the receive mode. At this point, hubs 105-108 may receive transmissions from their respective subs without detecting RF signals transmitted from the other hub. During the receive mode, hub 105 receives RX bursts 410-412 from subs 109-111, respectively. Hub 106 receives RX bursts 413 from sub 114. Likewise, hub 107 receives RX bursts 414 and 415 from subs 115 and 116, respectively. Hub 108 receives RX bursts 416-418 from subs 117-119, respectively. Hubs 105-108 are preferably synchronized to end their receive modes at time t_{13}.

Additionally, this embodiment provides other advantages. First, adjacent hubs are capable of direct communication and therefore may coordinate frame timing and/or channel allocation without the use of separate telemetry lines. Secondly, the telemetry bandwidth necessary to coordinate channel allocation in a synchronous manner is significantly reduced in the adjacent hub configuration.

Moreover, adjacent sector synchronization requires much less computation capacity than cluster-wide synchronization.

It shall be appreciated that the present invention allows greater system utilization and performance through other considerations in addition to greater channel reuse. By synchronizing adjacent sectors or adjacent antenna beams, the present invention does not place any other arbitrary restrictions upon the transmit and receive asymmetries associated with other sectors or antenna beams. For example, it is possible that sub units in adjacent sectors aggregately require significant transmit bandwidth but little receive bandwidth at a particular moment in time. Concurrently, it is possible that sub-units of non-adjacent sectors may aggregately require inverse bandwidth requirements. If the entire group of sectors were synchronized, a portion of the bandwidth would be wasted in both the adjacent and non-adjacent sectors. Accordingly, the present invention operates the transmit and receive asymmetries of adjacent sectors independently of other asymmetries. By severing the asymmetries relationship, the system may adapt to bandwidth requirements that inherently vary throughout the system at various points in time.

It shall be further appreciated that the present invention does not requires that hubs 105-108 begin or end their transmit modes or receive modes at the exact times. However, more accurate synchronization reduces the guard time and thereby maximizes the system throughput. Moreover, the present invention does not require any particular allocation of channel bandwidth to subs. It shall be appreciated that any number of channel division techniques may be utilized. All of the bandwidth during a single transmit/receive cycle may be allocated to a particular sub. Alternatively, each sub in the sector may receive a designated portion of the available bandwidth per transmit/receive cycle in a TDM / TDMA scheme. Alternatively, the subs may be allocated bandwidth according to a polling scheme. The hubs may implement any number of algorithms to schedule bandwidth to particular sub units. The receive and transmit modes may be divided through other techniques. For example, the subs may employ a CSMA/CD technique to send bursts to the hubs. Alternatively, the system may employ a contention period and a contention free period for sub access to the communication channel.

It shall be appreciated that numerous other signaling may occur between the hubs and subs on the selected channel in conjunction with the present invention. For example, the hubs may transmit broadcast bursts intended for all sub units. The hubs may transmit control channel bursts. Additionally, the hubs may transmit a beacon signal containing timing information or a network allocation vector to allow sub units to synchronize with the hub. The signaling may include requests to transmit, permission to transmit, or acknowledgment of data bursts.

It shall be appreciated that present invention does not require rigid definition of the transmit and receive modes. For example, TDM / TDMA telephony systems rigidly define the timing and duration of receive and transmit modes to optimize the systems to carry voice traffic. In contrast, the present invention may operate within a system that has asymmetric transmit and receive modes. Also, the present invention may be employed in a system that dynamically changes the duration of the transmit and receive modes. Exemplary dynamic bandwidth allocation systems and methods that may be employed in conjunction with the present invention are described in the above referenced patent application, entitled "SYSTEM AND METHOD FOR BROADBAND MILLIMETER WAVE DATA COMMUNICATION." To facilitate dynamic variation of bandwidth allocated to transmit and receive modes according to a preferred embodiment, hubs possessing synchronized sectors of the preferred embodiment communicate the variations to corresponding hubs and/or a common control system. Accordingly, a further aspect of the present invention provides a telemetry communication channel for synchronizing transmit and receive modes of hubs subject to co-channel coupling.

Several approaches may be taken to provide this communication channel. Leased connections from a ILEC (incumbent local exchange carrier) may be utilized for the synchronizing telemetry. However, it is preferred to utilize communication resources associated with the point to multipoint system, rather than ILEC connections. Accordingly, sector synchronization telemetry may utilize a backhaul associated with the point to multipoint network. A backhaul may be implemented in any form of communication means, such as a broadband fiber-optic gateway or other broadband data grade connection, T1 communications lines, a cable communication system, or the like. However, a connection to the backhaul or other system connected to the backhaul is required for each hub of a cluster that implements sector synchronization utilizing such a control channel. Although this may be sufficient in many systems, it is not an optimal solution as particular systems may have hubs that are not connected to the backhaul.

FIGURE 5 illustrates a preferred option for synchronization telemetry involving a narrow carrier band adjacent to the primary carrier band. In a preferred embodiment of the present invention, the spectrum of the point to multipoint system is divided into discrete 50 MHz channels. The primary data communication occurs via a Quadrature Amplitude Modulation (QAM) carrier 501 that occupies approximately 46 MHz. Additionally, narrow band adaptation carrier 502, preferably having a bandwidth of 130 kHz, is established in the guard space of the 50 MHz channel to provide the synchronization telemetry. The hubs preferably utilize 2-level FSK modulation to signal information via adaptation carrier 502. In a preferred embodiment, adaptation carrier 502 comprises a 100 kbps signaling rate, 10 dB C/N for 10^{-12} BER, 1/2 concatenated coding, and transmit power 10 dB below the QAM power level. By utilizing this type of channel, the control channel may be transmitted and/or received via the adjacent sector antenna beams of a particular cluster of hubs.

It shall be appreciated that narrow band adaptation carrier 502 provides a preferred signaling channel optimized for the 50 MHz system. However, it shall be appreciated that the telemetry control channel is not required to be implemented as a narrow band carrier. If the present invention is utilized in a broadband point to multipoint system, the telemetry control channel may be spread spectrum processed across a larger spectrum. Additionally, it is not required to located adaptation carrier 502 in guard space associated within a predefined channel. The adaptation carrier may be implemented utilizing distinctly allocated spectrum.

In a preferred embodiment, adjacent hubs utilizing the present invention may receive bandwidth requests from their respective sub units. The hubs may perform calculations based upon the bandwidth calculations. In this type of a system, a bandwidth controller may be located in one hub to receive the results of the bandwidth calculations via adaptation carrier 502. Alternatively, the bandwidth controller may by implemented as a separate system link to the respective hubs.

The bandwidth controller utilizes the received calculations to determine optimal transmit and receive mode durations for synchronized sectors. The controller hub utilizes the adaptation carrier to signal the determined transmit and receive mode durations to the hubs. At this point, the hubs utilize the durations to allocate transmit and receive resources to their respective subs within the adjacent sectors. It shall be appreciated that the controller may receive the bandwidth requests and perform the calculations directly. However, performing the calculations at the hubs is preferred, since it distributes the processing requirements more efficiently. Also, it shall be appreciated that the hubs may contain logic to control receive and transmit modes in the event that the adaptations carrier link is interrupted. For example, the hubs may temporarily revert to a predefined lengths for transmit and receive modes. Alternatively, the hubs may temporarily define receive and transmit modes of equal lengths.

For example, a bandwidth controller of the present invention may monitor the instantaneous traffic demands on both forward and reverse links to thereby determine the appropriate amount of ATDD and/or asymmetry at which to operate the carrier channels. The bandwidth controller of the preferred embodiment of the present invention is operable upon a processor (CPU) and associated memory (RAM) of a hub of the present invention. The controller may contain a record of adjacent antenna beams and respective channels in a non-volatile memory in order to effect the desired synchronization. Alternatively, the bandwidth controller may operate in an environment that dynamically varies sectors and/or dynamically assigns channel to various sectors. In this environment, the bandwidth controller may communicate with the portions of the system that effects the sector configuration and/or channel assignment algorithms to obtain information concerning adjacent antenna beams and their channels. Of course, additional and/or other apparatus, such as a general purpose processor based computer system having an appropriate algorithm controlling operation thereof, may be utilized for operation of the bandwidth controller of the present invention.

With reference now to FIGURE 6A, the set 600 is a notional depiction of eight available frequency channels, also referred to herein as "frequencies", for a communication system with two polarizations available per frequency channel. The set 601 of frequencies are at one polarization and the set 602 of frequencies is at another polarization. Preferably, the polarizations of the frequency set 601 and the frequency set 602 are mutually orthogonal to minimize the possibility of interference between antennas operating at the same frequency but different polarizations as discussed further below. The polarizations can be, but are not limited to, horizontal and vertical alignments or slant left and slant right alignments.

It should be understood that although the discussion below develops frequency re-use patterns for eight frequencies and two polarizations, the present inventive system and method is not limited to eight frequencies and two polarizations. The principles on which the frequency re-use patterns herein disclosed are applicable likewise apply in situations where more than eight frequencies are available for the communication system deploying a frequency re-use pattern of the present inventive system and method.

FIGURE 6B depicts eight cells, such as the cells illustrated in FIGURE 2A, where each cell is divided into four 90° substantially non-overlapping sectors. The hub of each cell has at least one antenna per sector, for example the hub 105 shown in FIGURE 2B. As shown in FIGURE 6B, opposing sectors of a cell operate with the same frequency/polarization assignment. Taking cell 610 as an example, sectors 610A and 610D operate at frequency/polarization 601A while sectors 610B and 610C operate at frequency/polarization 602T. Although the sector designations are only shown for the cell 610, is it to be understood that the sector designations apply to every cell and are used throughout the specification and drawings. With eight frequencies and two polarizations per frequency available as shown in FIGURE 6A, there are 16 unique frequency/polarization sector assignments, or "degrees of freedom", available. It is important for minimizing adjacent channel and co-channel interference in a frequency re-use plan to maximize the "distance" between the frequency/polarization sector assignments in a cell, i.e., the largest frequency separation and orthogonal polarization assignment is preferred. Additionally, for adaptive time division duplex systems ("ATDD") maximizing frequency separation minimizes coupling problems associated with independent dynamic asymmetric frame usage within a cell. The pattern of assignment of the 16 degrees of freedom as shown in FIGURE 6A is preferred since that pattern results in the maximum "distance" between sector assignments for a cell. The present inventive system and method contemplates the use of other patterns of assignment of the 16 degrees of freedom.

Using the pattern of sector assignments discussed above, there are eight unique "cell types" available if each of the 16 sector assignments, or degrees of freedom, is used once. Each of the cells in FIGURE 6B is of a unique cell type. The eight cell types will be arranged in a particular manner so as to minimize co-channel and adjacent channel interference while obtaining maximum coverage of an operating area for a communication system which has the frequency/polarization assignments of FIGURE 6A.

With attention now to FIGURE 7, a section of a multi-cell frequency re-use pattern is depicted. As shown in the Figure, the 16-cell four-by-four rectilinear grid 710 is comprised of the four two-by-two groups, 701 through 704. The 16-cell grid 710 is repeatable vertically and horizontally, referenced to the orientation of FIGURE 7, so as to be able to cover an area that is larger than the area covered by one instance of the grid 710. The cells in the grid 710 are arranged so that each cell occupies a unique rank and file position, where all the cells on the bottom row of FIGURE 7 are in the rank designated 720 and where all the cells in the left-most column of FIGURE 7 are in the file designated 730. The cells in the 16-cell rectilinear grid 710 are arranged so that rank and file adjacent cells are tangent but diagonally adjacent cells are not tangent. The rank and file designations are arbitrary and are only used as a convenience to accurately describe the arrangement of cells in the pattern. The rank and file designations are not part of the invention and should not be construed as limiting the invention in any way.

Referring now to FIGURE 8, the 4-cell group 703, located in the lower left-hand quadrant of the rectilinear grid 710 in FIGURE 7 is depicted. Each one of the four cells in the cell group 703 is a unique one of the eight cell types discussed above and shown in FIGURE 6B. The cell 650 is tangent to its rank and file adjacent cells, i.e., the cell 650 is tangent to the cells 610 and 660. The cells 610, 620, 650, and 660 are oriented in the cell group 703 such that the polarization of facing cells for rank and file adjacent cells is not the same. For example, the sector 650B in the cell 650 is of one polarization while its facing sector in the rank adjacent cell 660, the sector 660A is of the other polarization (reference the two polarizations in FIGURE 6A). By inspection of FIGURE 7 and FIGURE 8, it is shown that for each of the four cell groups, 701 through 704, the polarization of facing cells for rank and file adjacent cells is not the same. This orientation of the cells within a group works to minimize co-channel and adjacent channel interference as discussed above.

Referring back to FIGURE 7, and with attention now to the cell group 704, each one of the four cells in the cell group 704 is a unique one of the eight cell types discussed above and shown in FIGURE 6B. Additionally, each of the cells in the cell group 704 is of a different cell type from the cell types used in the cell group 703. In other words, of the eight cell types depicted in FIGURE 6B, four of those cell types are used in the cell group 703 and the other four of those cell types are used in the cell group 704. The orientation of the cells in the cell group 704 is similar to the orientation of the cells in the cell group 703 as discussed above: the polarization of facing cells for the rank and file adjacent cells is not the same. Furthermore, and preferably, the polarization of facing cells for the rank adjacent cells for the cells 620, 660, 630, and 670 are different, as shown in FIGURE 7.

Having discussed the orientation and arrangement of the cells in the four cell groups, it should be noted that there is a relationship between the cells in the cell groups 703 and 702 as well as a relationship between the cells in the cell groups 704 and 701. Referring to the cell groups 703 and 702 in FIGURE 7, it can be seen that the same four cell types appear in each of the cell groups and that the arrangement of the cells in each of the cell groups is the same, i.e., the cell 650 in the cell group 703 is the same cell type as the cell 650S in the cell group 702. However, the frequency/polarization assignments for each cell have been swapped between the pairs of opposing sectors. Whereas for the cell 650 in the cell group 703 the upper right and lower left sectors are of a first frequency/polarization combination, the same first frequency/polarization combination appears in the upper left and lower right sectors of the cell 650S in the cell group 702. The same is true for each cell in groups 703 and 702. Another way to view the relationship is that the cells in the cell group 702 have been rotated 90° from the orientation of the cells in the cell group 703. Likewise, the cells in the cell groups 704 and 701 are related in the same manner.

The reason for the change in orientation of the cells between cell groups 703/702 and 704/701 is to minimize co-channel interference between the sectors of the cells of the same cell type. If, for instance, the cell 650S was of the same orientation as the cell 650, the facing sectors 650A of the cell 650 and 650SC of the cell 650S would be operating on the same frequency with the same polarization. If a cell radius is designated as "R", the distance between the hubs of the cells 650 and 650S is $4R\sqrt{2}$. This distance may be insufficient to prevent co-channel interference. The swap of frequency/polarizations for the opposing sectors helps to overcome the problem of insufficient distance between the hubs. Using the frequency re-use plan of FIGURE 7, the distance between hubs with facing sectors operating with the same frequency/polarization is $8R\sqrt{2}$, which is double the distance from the example above. The pattern described above for the four-by-four rectilinear grid 710 can be repeated horizontally and vertically in order to provide coverage for an area larger than the grid 710. As shown in FIGURE 7, a rank and file of cells are repeated to illustrate the idea of horizontal and vertical repeatability. It is to be understood that the present invention is not limited to the specific number of cells shown in FIGURE 7 nor to the specific assignment of cells types or sector orientations. It is contemplated that any repeatable rectilinear grid using the concepts described above are within the scope of the patent.

Turning now to FIGURE 9, a different pattern of cells is depicted, referred to herein as the "shift and squish" pattern. As can be seen from FIGURE 7, the repeatable pattern of the rectilinear grid 710 allows for a sizeable area of dead space between the cells. The shift and squish pattern 910 eliminates much of that interstitial dead space. As with the rectilinear grid 710, the shift and squish pattern 910 comprises 16 cells of two each of eight cell types. The lower two rows of cells in the shift and squish pattern 910, similar to the lower two ranks of cells in the rectilinear grid pattern 710, are composed of one each of the eight cell types shown in FIGURE 6B. Also, the two upper rows of cells in the shift and squish pattern 910 are composed of another set of one each of the same eight cell types as the lower two rows, similar to the upper two ranks of cells in the rectilinear grid pattern 710 being composed of another set of one each of the same eight cell types as the lower two ranks. However, unlike the rectilinear grid 710, the upper to rows of cells of the shift and squish pattern 910 are not arranged in the same relative orientation as the lower two rows of cells within the shift and squish pattern 910. For example, the cells 901 through 904 are arranged in the order, from left to right, 901/902/903/904 while the corresponding cells 901S through 904S are arranged, left to right, 904S/901S/902S/903S. The same relationship holds for the cells in the other two rows of the grid 910. Additionally, the frequency/polarization assignments of the two pairs of opposing sectors for the cells of a corresponding cell type are swapped.

The shift and squish pattern 910 is repeatable as shown in FIGURE 9. The 16 cells in the pattern are arranged so that no one cell is tangentially adjacent, in any direction, to two cells of the same cell type. This relationship holds true as the pattern is repeated as shown in FIGURE 9.

The spacing between hubs of cells having facing sectors operating with the same frequency/polarization in the shift and squish pattern 910, such as cells 901 and 911, is approximately 10R, which is approximately 88% of the distance between hubs with facing sectors operating with the same frequency/polarization in the rectilinear grid 710. The distance between the hubs of cells 901 and 911 should be sufficient to prevent co-channel interference.

With reference now to FIGURE 10, a section of another multi-cell frequency re-use pattern is depicted. The 16-cell four-by-four rectilinear grid 1010 is comprised of the four two-by-two groups, 1001 through 1004. The 16-cell grid 1010 is repeatable vertically and horizontally, referenced to the orientation of FIGURE 10, so as to be able to cover an area that is larger than the area covered by one instance of the grid 1010. The cells in the grid 1010, similar to the cells in the grid 710 of FIGURE 7, are arranged so that each cell occupies a unique rank and file position and so that rank and file adjacent cells are tangent but diagonally adjacent cells are not tangent.

FIGURE 11A depicts the set 1100 of the eight available frequency channels used for a communication system with two polarizations available per frequency channel, similar to the set of frequencies 600 in FIGURE 6A. Of the 16 frequency/polarization degrees of freedom in the set 1100, the set 1103 of eight frequency/polarization degrees of freedom and the set 1104 of the eight other frequency/polarization degrees of freedom are depicted. The set 1103 of degrees of freedom are used in the frequency re-use pattern of FIGURE 10. The set 1104 of degrees of freedom are not necessary to populate the cells of the frequency re-use pattern of FIGURE 10 and are held in reserve for possible late use, as described below.

FIGURE 11B shows eight cell types used in the frequency re-use pattern rectilinear grid 1010 of FIGURE 10. As shown in FIGURE 11B, each sector of a particular cell of each of the eight cell types operates with unique frequency/polarization assignment relative to the other sectors of that cell. For each cell type, a pair of adjacent sectors operate with a first polarization and the other pair of adjacent sectors operate with a second polarization of the two available polarizations. Taking cell 1110 as an example, each sector 1110A through 1110D operates at a different frequency/polarization each from the other. With four frequencies and two polarizations per frequency available as shown in FIGURE 11A, there are eight degrees of freedom available. With the limitations to be discussed below, eight different cell types are used to populate the rectilinear grid 1010.

Referring now to FIGURE 12, the 4-cell group 1003, located in the lower left-hand quadrant of the rectilinear grid 1010 in FIGURE 10 is depicted. Each one of the four cells in the cell group 1003 is a unique one of the eight cell types discussed above and shown in FIGURE 11B. Additionally, facing sectors for each cell in the 4-cell group 1003 are of the same frequency/polarization, regardless of whether the cell is rank and file adjacent or diagonally adjacent. For example, as shown in FIGURE 12, the center-facing sectors for all four cells, 1110D, 1120C, 1150B, and 1160A, are all of the same frequency/polarization assignment. Additionally, the sector 1110C of the cell 1110 and the sector 1150A of the cell 1150 are facing and have the same frequency/polarization assignment. The same holds for the following sectors: 1150D and 1160C, 1160B and 1120D, and 1110B and 1120A. Furthermore, the opposing sectors of the diagonally adjacent cells in the 4-cell group 1003 have the same frequency/polarization assignment: the sectors 1150C and 1120B and the sectors 1110A and 1160D. These frequency/polarization assignments allow for repeatability of the pattern of rectilinear grid 1010, as seen in FIGURE 10, while minimizing co-channel and adjacent channel interference.

Referring back to FIGURE 10, and with attention now to the cell group 1004, each one of the four cells in the cell group 1004 is a unique one of the eight cell types discussed above and shown in FIGURE 11B. Additionally, each of the cells in the cell group 1004 is of a different cell type from the cell types used in the cell group 1003. In other words, of the eight cell types depicted in FIGURE 11B, four of those cell types are used in the cell group 1003 and the other four of those cell types are used in the cell group 1004. The orientation of the cells in the cell group 1004 is similar to the orientation of the cells in the cell group 1003 as discussed above: facing sectors for each cell in the 4-cell group 1004 are of the same frequency/polarization, regardless of whether the cell is rank and file adjacent or diagonally adjacent.

Having discussed the orientation and arrangement of the cells in the four cell groups, it should be noted that there is a relationship between the cells in the cell groups 1003 and 1002 as well as a relationship between the cells in the cell groups 1004 and 1001. Referring to the cell groups 1003 and 1002 in FIGURE 10, it can be seen that the same four cell types appear in each of the cell groups and that the arrangement of the cells and the orientation of the sectors within the cells in each of the cell groups is the same, i.e., the cell 1150 in the cell group 1003 is the same cell type as the cell 1150s in the cell group 1002. Likewise, the cells in the cell groups 1004 and 1001 are related in the same manner.

The rectilinear grid 1010 can be repeated horizontally and vertically similar to the repeatability of the rectilinear grid 710. Note that all of the inward-facing sectors of any two-by-two grid of four cells within the repeated pattern have the same frequency/polarization assignments. Such an arrangement allows for the synchronization of those inward-facing sectors as described more fully above.

The distance between any two facing sectors with the same frequency/polarization assignment that are not adjacent facing sectors is $6R\sqrt{2}$. This distance should be sufficient to prevent co-channel interference between the non-adjacent facing sectors with the same frequency/polarization assignment. If there is co-channel interference, the two groups of four cells that have the interfering non-adjacent facing sectors can also be synchronized to avoid the co-channel problem.

With reference directed towards FIGURE 13, a rectilinear grid 1310 is shown which is similar to the rectilinear grid 1010 of FIGURE 10. However, the grid 1310 includes sector overlays for those sectors, herein referred to as incumbent sectors, for which the capacity of the system is insufficient to support the user demands in those sectors. The added sector overlays are indicative of an added antenna and corresponding circuitry at the hub of the cell in which the overlay lies, as is known in the art. The added sector overlay typically is not a simple replacement for the incumbent sector. The added overlay operates at a different frequency than the incumbent sector but with the same polarization. This configuration allows for the sharing of protection, or redundant, equipment between the incumbent and overlay sectors. The size of the overlay sectors is typically equal to or less than the size of the incumbent sector. As shown in FIGURE 13, the overlay sectors are 45° sectors, but the present inventive system and method is not limited to 45° sectors. Additionally, FIGURE 13 shows the overlay sectors 1390 added to one of each of the sectors of the four cells 1 through 4, which is merely an exemplary use of overlay sectors. The present inventive system and method is not limited to adding an overlay sector to groups of four facing sectors and it contemplates adding fewer or more overlay sectors as required by user demand. Adding overlay sectors to each of four facing sectors of four adjacent cells enables the four added overlay sectors to be synchronized in a manner similar to the synchronization of the underlying four incumbent sectors. Naturally, less than four overlay sectors can be added and synchronized as well.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

WHAT IS CLAIMED IS:

1. A repeatable pattern of frequency reuse in a wireless communication system comprising:

sixteen substantially circular cells of approximately the same radius arranged in a four-by-four grid such that no two cells substantially overlap and where each cell is substantially tangent with its adjacent rank and file neighbors, wherein each cell includes a hub with four antennas wherein each antenna services a separate one of four substantially non-overlapping ninety degree sectors and is capable of communicating on each of eight frequencies and on either of two polarizations per frequency, whereby for each hub one set of opposing ninety degree sectors communicate on a one of said eight frequencies at a one of said polarizations and the other set of opposing ninety degree sectors communicate on a different one of said eight frequencies at the other of said polarizations;

eight cell types wherein each cell type communicates over a unique combination of frequencies;

a first and a second group of four cells, each group comprising a two-by-two grid of cells such that,

said first group of four cells comprising four different cell types of said eight cell types, said cells arranged so that facing sectors of rank and file adjacent cells are of a different polarity, and

said second group of four cells comprising the remaining four different cell types, said cells arranged so that facing sectors of rank and file adjacent cells are of a different polarity;

a third and a fourth group of four cells, each group comprising a two-by-two grid of cells such that,

said third group of four cells comprising the same four cell types as said first group wherein the frequency and polarization assignments are interchanged between the pairs of opposing sectors for each cell, said four cells arranged identically to the cells in said first group, and

said fourth group of four cells comprising the same four cell types as said second group wherein the frequency and polarization assignments are interchanged between the pairs of opposing sectors for each cell, said four cells arranged identically to the cells in said second group;

wherein said four groups of cells are arranged in said four-by-four grid so that said first and third group of cells are not rank and file adjacent and so that facing cells between rank and file adjacent groups are of different frequencies.

2. The pattern of Claim 1 wherein said polarizations are mutually orthogonal.

3. The pattern of Claim 1 wherein the communication system is a time division duplex system.

4. The pattern of Claim 3 wherein the communication system is an adaptive time division duplex system.

5. The pattern of Claim 4 wherein said eight frequencies are in the millimeter frequency range.

6. The pattern of Claim 5 wherein said eight frequencies are each in the range of 10-60 GHz.

7. The pattern of Claim 1 wherein the cells are not synchronized.

8. The pattern of Claim 7 wherein the sectors within the cells are not synchronized.

9. The pattern of Claim 1 wherein said sixteen cells are generally circular, are of approximately the same radius, and are arranged in a four-by-four square grid such that the distance between the centers of any two horizontally and any two vertically adjacent cells is approximately twice a cell radius.

10. A horizontally and vertically repeatable pattern of cells in a multi-cell pattern of cells forming a rectilinear grid in a communication system wherein each cell is divided into four ninety degree sectors with at least one antenna per sector whereby each antenna is capable of operating in one of two polarization modes for each communication frequency, the improvement wherein each cell uses two frequencies and adjacent sectors of each cell alternate in frequency and polarization.

11. The pattern of Claim 10 wherein said polarizations are mutually orthogonal.

12. The pattern of Claim 11 wherein diagonally alternate cells with the grid are rotated ninety degrees relative to each other.

13. The pattern of Claim 12 wherein the number of frequencies is eight.

14. The pattern of Claim 13 wherein each cell is one of eight cell types whereby each cell type uses a unique combination of frequencies and polarizations.

15. The pattern of Claim 14 wherein each cell type is repeated once within the pattern.

16. The pattern of Claim 15 wherein the communication system is a time division duplex system.

17. The pattern of Claim 16 wherein the communication system is an adaptive time division duplex system.

18. The pattern of Claim 17 wherein said eight frequencies are in the millimeter frequency range.

19. The pattern of Claim 18 wherein said eight frequencies are each in the range of 10-60 GHz.

20. In a horizontally and vertically repeatable pattern of cells in a multi-cell pattern of cells forming a rectilinear grid in a communication system wherein each cell is divided into four ninety degree sectors with at least one antenna per sector whereby each antenna is capable of operating in one of two polarization modes for each communication frequency, the method of reducing co-channel interference comprising the steps of:

(a) alternating adjacent sectors of each cell in frequency and polarization; and

(b) orienting at least one pair of alternate diagonal cells within the grid ninety degrees relative to each other.

21. The method of Claim 20 wherein adjacent channel interference is reduced.

22. The pattern of Claim 20 wherein said polarizations are mutually orthogonal.

23. The method of Claim 22 wherein the number of frequencies is eight.

24. The method of Claim 23 wherein each cell is one of eight cell types whereby each cell type uses a unique combination of frequencies and polarizations.

25. The method of Claim 24 wherein each cell type is repeated once within the pattern.

26. The pattern of Claim 22 wherein the communication system is a time division duplex system.

27. The pattern of Claim 26 wherein the communication system is an adaptive time division duplex system.

28. The pattern of Claim 27 wherein said eight frequencies are in the millimeter frequency range.

29. The pattern of Claim 28 wherein said eight frequencies are each in the range of 10-60 GHz.

30. In a pattern of sixteen cells arranged in a four-by-four grid in a multi-cell pattern of cells forming a rectilinear grid in a communication system wherein each cell is divided into four ninety degree sectors with at least one antenna per sector whereby each antenna is capable of operating in one of two polarization modes for each of eight communication frequencies whereby for each hub one set of opposing ninety degree sectors communicate on a one of said eight frequencies at a one polarization and the other set of opposing ninety degree sectors communicate on a different one of said eight frequencies at the other polarization, the method of reducing co-channel interference comprising the steps of:

(a) dividing the sixteen cells into four groups of four cells whereby each group comprises a two-by-two grid of cells;

(b) providing eight cell types wherein each cell type communicates over a unique combination of frequencies;

(c) providing a first group of four cells comprising four different cell types of said eight cell types, said cells arranged so that facing sectors of rank and file adjacent cells are of a different polarity;

(d) providing a second group of four cells comprising the remaining four different cell types, said cells arranged so that facing sectors of rank and file adjacent cells are of a different polarity;

(e) repeating said first and second group of cells diagonally within said sixteen cell pattern;

(f) rotating the frequency and polarization assignments in the sectors of each cell of the repeated first and second group of cells by ninety degrees relative to the frequency and polarization assignments in the sectors of the first and second group of cells.

31. The method of Claim 30 wherein adjacent channel interference is reduced.

32. The pattern of Claim 30 wherein said polarizations are mutually orthogonal.

33. The pattern of Claim 32 wherein the communication system is a time division duplex system.

34. The pattern of Claim 33 wherein the communication system is an adaptive time division duplex system.

35. The pattern of Claim 34 wherein said eight frequencies are in the millimeter frequency range.

36. The pattern of Claim 35 wherein said eight frequencies are each in the range of 10-60 GHz.

37. A pattern of frequency reuse in a wireless communication system including sixteen substantially circular cells of approximately the same radius arranged in a repeatable four-by-four grid forming a parallelogram so that the edge of any one cell is tangent to the edge of six other cells, wherein each cell includes a hub with four antennas wherein each antenna services a separate one of four substantially non-overlapping ninety degree sectors and is capable of communicating on each of eight frequencies and on either of two polarizations per frequency, whereby for each hub one set of opposing ninety degree sectors communicate on a one of said eight frequencies at a one polarization and the other set of opposing ninety degree sectors communicate on a different one of said eight frequencies at the other polarization, said pattern comprising:

eight cell types wherein each cell type communicates over a unique combination of frequencies;

a first group of four cells comprising four different cell types of said eight cell types, said cells arranged so that the centers of each cell are collinear and the edges of adjacent cells are tangent, whereby facing sectors of adjacent cells are of a different polarity;

a second group of four cells comprising the remaining four different cell types, said cells arranged so that the centers of each cell are collinear and the edges of adjacent cells are tangent, whereby facing sectors of adjacent cells are of a different polarity, and whereby said first and second groups of cells are arranged so that each cell of each group is adjacent to and tangent to at least one cell of the other group of cells;

a third group of four cells comprising the same four cell types as said first group wherein the frequency and polarization assignments are exchanged between the pairs of opposing sectors for each cell, said four cells arranged so that the centers of each cell are collinear and the edges of adjacent cells are tangent, and whereby said second and third groups of cells are arranged so that each cell of each group is adjacent to and tangent to at least one cell of the other group, and whereby no cell adjacent to a cell in the third group is also adjacent to a cell in the first group with a corresponding combination of frequencies as said cell in the third group;

a fourth group of four cells comprising the same four cell types as said second group wherein the frequency and polarization assignments are exchanged between the pairs of opposing sectors for each cell, said four cells arranged so that the centers of each cell are collinear and the edges of adjacent cells are tangent, and whereby said third and fourth groups of cells are arranged so that each cell of each group is adjacent to and tangent to at least one cell of the other group, and whereby no cell adjacent to a cell in the fourth group is also adjacent to a cell in the second group with a corresponding combination of frequencies as said cell in the fourth group.

38. The pattern of Claim 37 wherein said sixteen cells are generally hexagonal in shape.

39. The pattern of Claim 37 wherein said pattern is repeated horizontally and vertically.

40. The pattern of Claim 37 wherein said polarizations are mutually orthogonal.

41. The pattern of Claim 40 wherein the communication system is a time division duplex system.

42. The pattern of Claim 41 wherein the communication system is an adaptive time division duplex system.

43. The pattern of Claim 42 wherein said eight frequencies are in the millimeter frequency range.

44. The pattern of Claim 43 wherein said eight frequencies are each in the range of 10-60 GHz.

45. The pattern of Claim 44 wherein the cells are not synchronized.

46. The pattern of Claim 45 wherein the sectors within the cells are not synchronized.

47. A pattern of frequency reuse in a wireless communication system including sixteen cells arranged in a four-by-four grid including four sub-clusters arranged in a two-by-two grid of four cells, wherein each cell includes a hub with four antennas in which each antenna services a separate one of four substantially non-overlapping ninety degree sectors and is capable of communicating on each of eight frequencies and on either of two polarizations per frequency, wherein for each hub each sector communicates on a different frequency in which two adjacent sectors communicate at a one polarization and the other two adjacent sectors communicate at the other polarization, said pattern comprising:

eight cell types wherein each cell type communicates over a unique combination of frequencies whereby the eight cell types are comprised of four frequencies at said one polarity and four frequencies at said other polarity;

a first sub-cluster comprising four different cell types of said eight cell types, said cells arranged so that facing sectors of adjacent cells communicate on a same frequency and a same polarization;

a second sub-cluster comprising the remaining four different cell types, said cells arranged so that facing sectors of adjacent cells communicate on a same frequency and a same polarization;

a third sub-cluster identical to said first sub-cluster;

a fourth sub-cluster identical to said second sub-cluster;

wherein said sub-clusters are arranged in said four-by-four grid so that said first and third sub-clusters are not adjacent and so that said facing cells between adjacent sub-clusters communicate on a same frequency and a same polarization.

48. The pattern of Claim 47 wherein said polarizations are mutually orthogonal.

49. The pattern of Claim 47 wherein the communication system is a time division duplex system.

50. The pattern of Claim 49 wherein the communication system is an adaptive time division duplex system.

51. The pattern of Claim 50 wherein said eight frequencies are in the millimeter frequency range.

52. The pattern of Claim 51 wherein said eight frequencies are each in the range of 10-60 GHz.

53. The pattern of Claim 52 wherein ones of said cells are synchronized.

54. The pattern of Claim 53 wherein adjacent sectors communicating on a same frequency and a same polarization are synchronized.

55. The pattern of Claim 54 wherein said adjacent sectors communicate with a common dynamic asymmetric synchronization.

56. The pattern of Claim 47 including at least one additional sector communicating on a frequency and polarization combination of said eight frequencies and two polarizations that is not used in said pattern, whereby said additional sector is overlayed on at least one of the sectors in said pattern that has a similar polarization to the polarization of said additional sector.

57. The pattern of Claim 56 wherein said additional sector is a ninety-degree sector.

58. The pattern of Claim 56 wherein said additional sector is a forty-five degree sector.

59. A method of reducing co-channel interference in a horizontally and vertically repeatable pattern of cells in a multi-cell pattern of cells forming a rectilinear grid in a communication system wherein each cell includes a hub with four antennas wherein each antenna services a separate one of four substantially non-overlapping ninety degree sectors and is capable of communicating in one of two polarization modes for each communication frequency used by the communication system, whereby for each hub one set of opposing ninety degree sectors communicate on a one of said communication frequencies at a one of said polarizations and the other set of opposing ninety degree sectors communicate on a different one of said communication frequencies at the other of said polarizations, the method comprising the steps of:

(a) providing eight cell types wherein each cell type comprises a unique combination of said two sets of frequency and polarization;

(b) providing two sub-clusters of cells each of four cells arranged in a two-by-two grid wherein a first sub-cluster comprises four cells each of a different cell type of said eight cell types and wherein a second sub-cluster comprises four cells each of a different cell type of the remaining four cell types;

(c) alternating said two sub-clusters horizontally and vertically within the multi-cell pattern of cells; and

(d) orienting each pair of alternate diagonal cells within the multi-cell pattern of cells ninety degrees relative to each other.

60. The method of Claim 59 wherein adjacent channel interference is reduced.

61. The pattern of Claim 59 wherein said polarizations are mutually orthogonal.

62. The method of Claim 61 wherein the number of frequencies is eight.

63. The method of Claim 61 wherein the number of frequencies is at least eight.

64. The method of Claim 63 wherein each cell type is repeated once within the pattern.

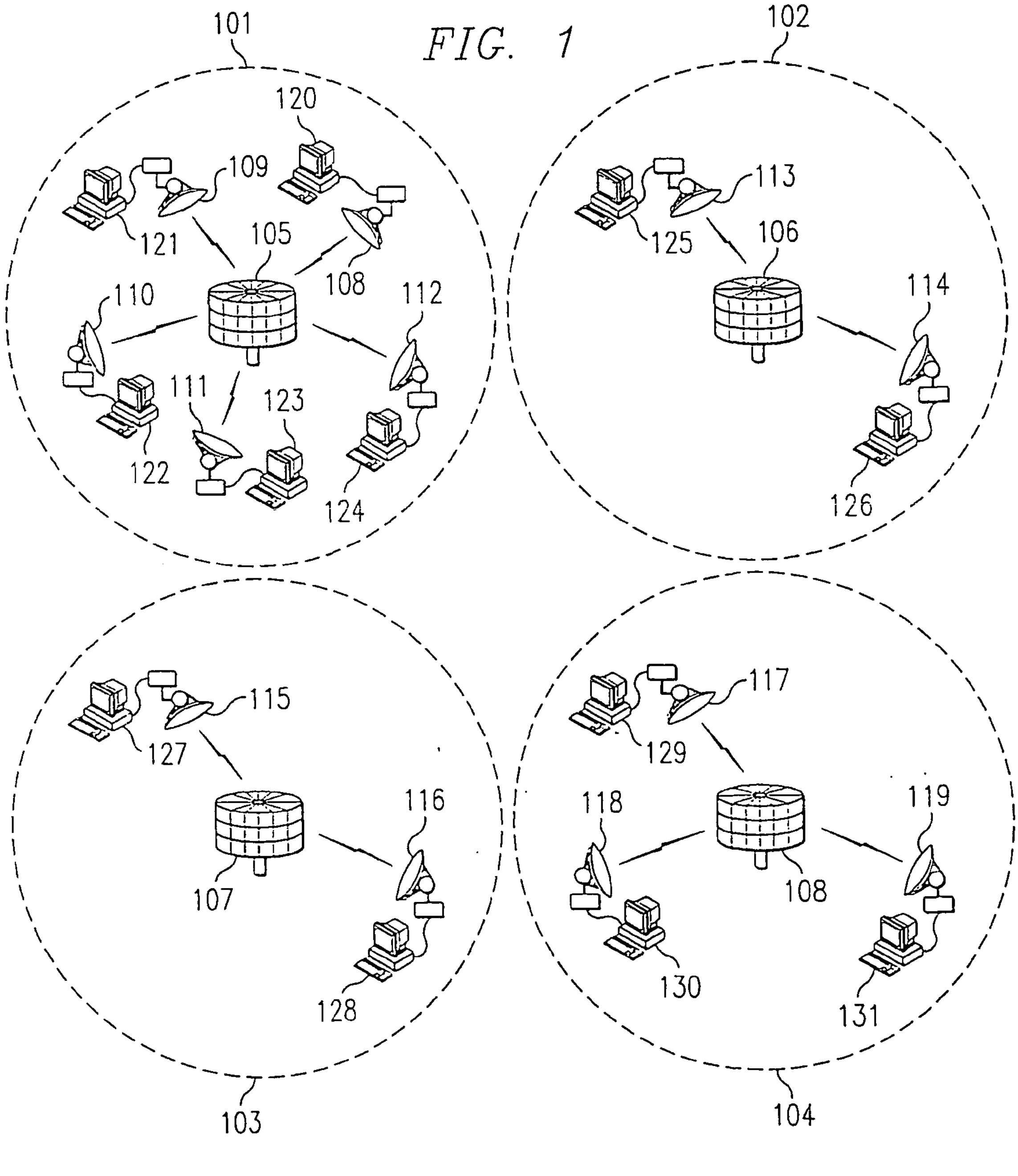
65. The pattern of Claim 61 wherein the communication system is a time division duplex system.

66. The pattern of Claim 65 wherein the communication system is an adaptive time division duplex system.

67. The pattern of Claim 66 wherein said eight frequencies are in the millimeter frequency range.

68. The pattern of Claim 67 wherein said eight frequencies are each in the range of 10-60 GHz.

FIG. 1


101
102
103
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112
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121
122
123
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126
127
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129
130
131

FIG. 2A

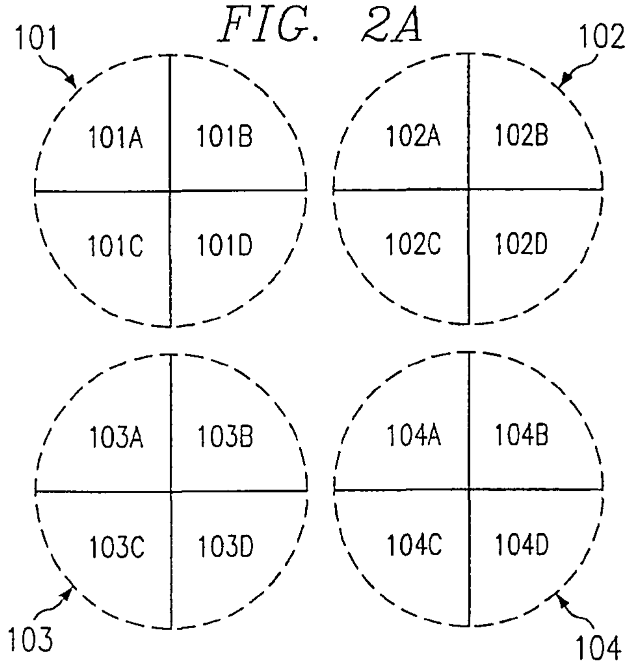

101
102
101A
101B
102A
102B
101C
101D
102C
102D
103A
103B
104A
104B
103C
103D
104C
104D
103
104

FIG. 2B

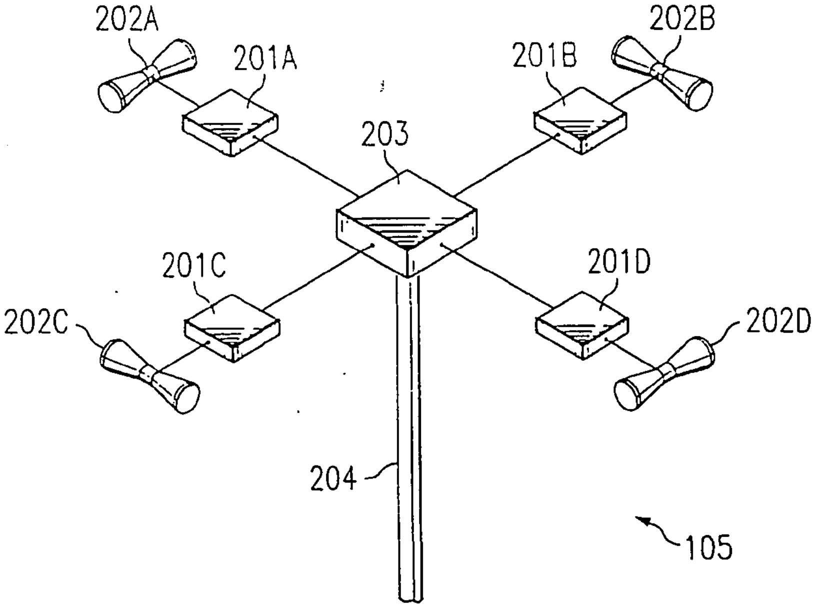

202A
201A
201B
202B
203
201C
201D
202C
202D
204
105

FIG. 3

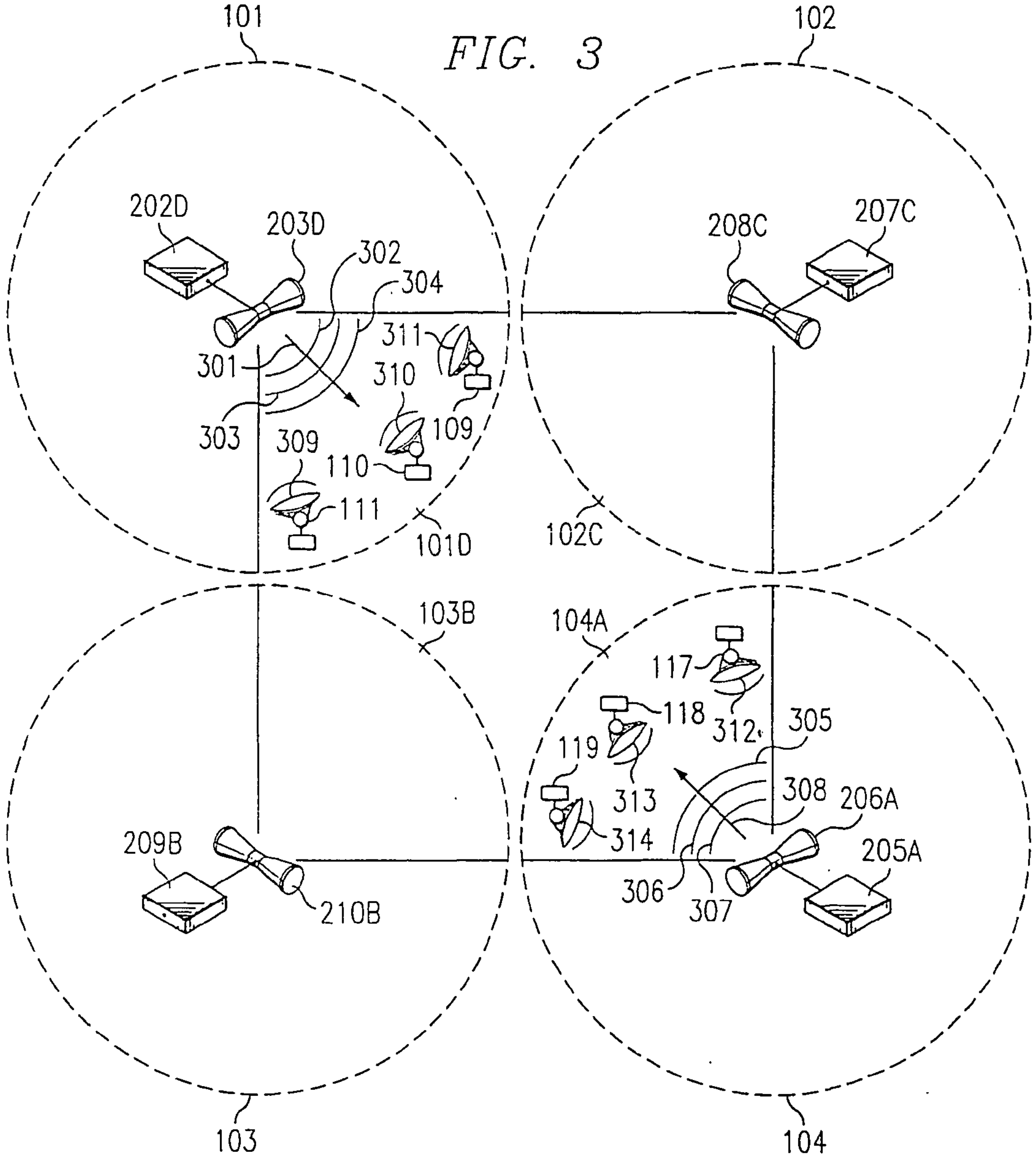
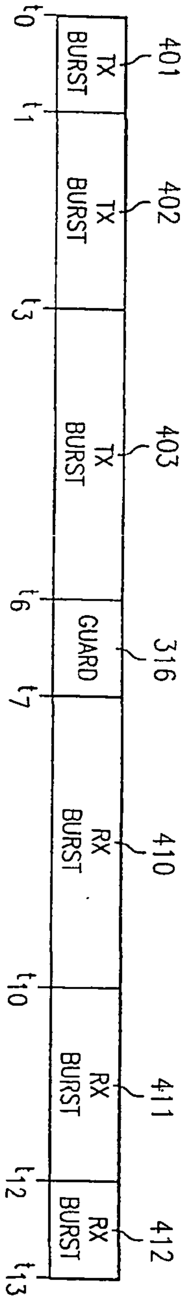
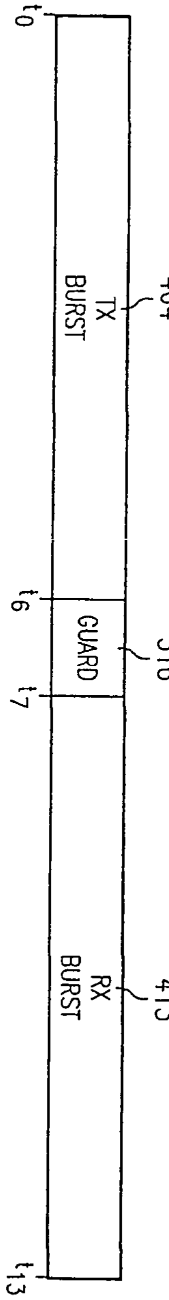

101
102
202D
203D
302
304
311
301
310
303
309
109
110
111
101D
102C
208C
207C
103B
104A
117
118
312
305
119
313
308
206A
314
205A
209B
210B
306
307
103
104

FIG. 4A



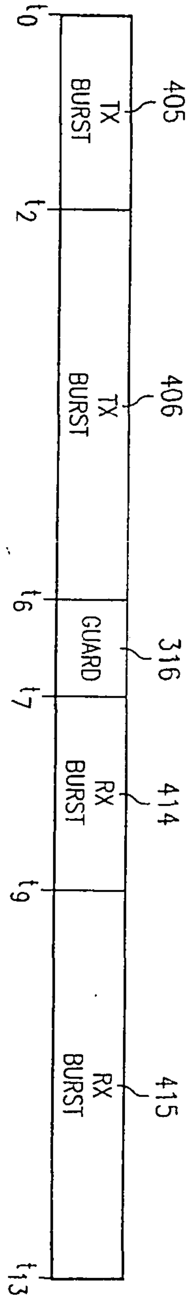
TRANSMIT AND RECEIVE FRAME TIMING AT BANDWIDTH SCHEDULE 202D

FIG. 4B



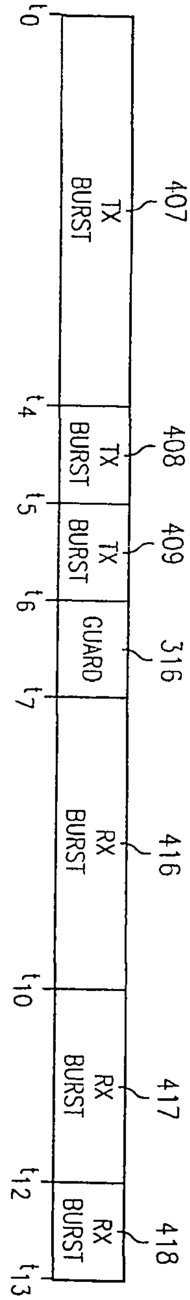
TRANSMIT AND RECEIVE FRAME TIMING AT BANDWIDTH SCHEDULE 207C

FIG. 4C



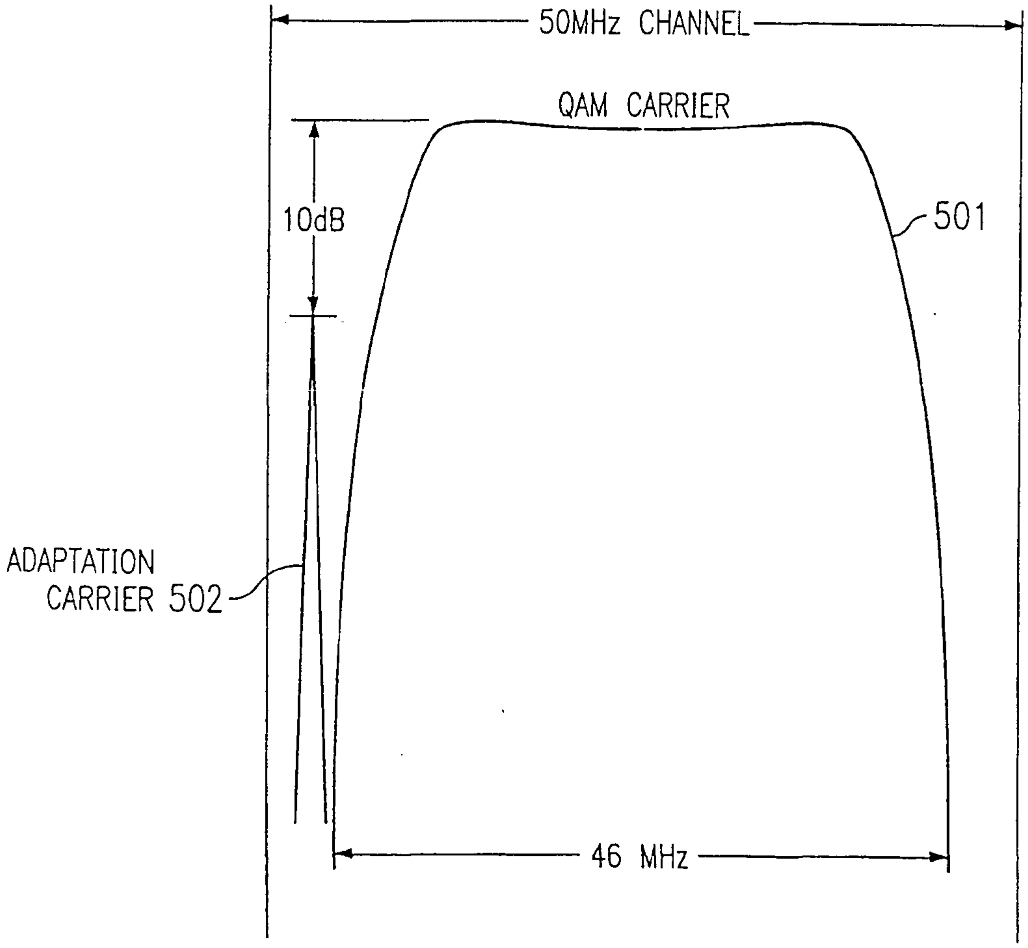
TRANSMIT AND RECEIVE FRAME TIMING AT BANDWIDTH SCHEDULE 205A

FIG. 4D



TRANSMIT AND RECEIVE FRAME TIMING AT BANDWIDTH SCHEDULE 209B

FIG. 5


50MHz CHANNEL
QAM CARRIER
10dB
501
ADAPTATION
CARRIER 502
46 MHz

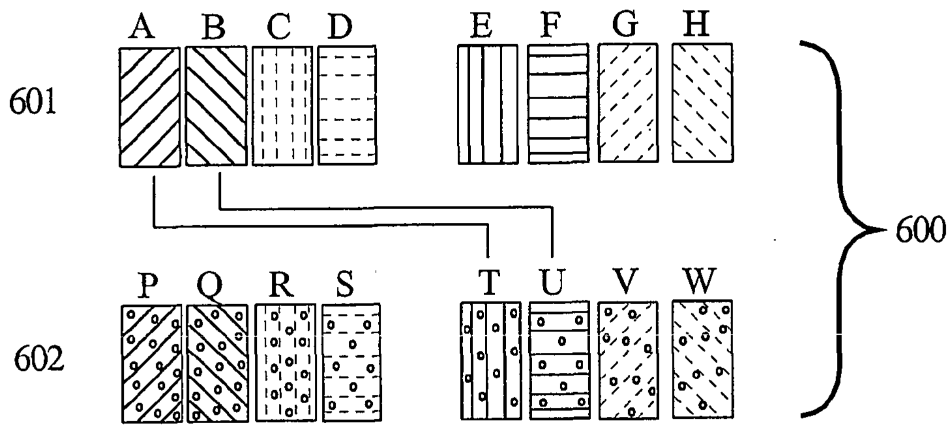


FIGURE 6A

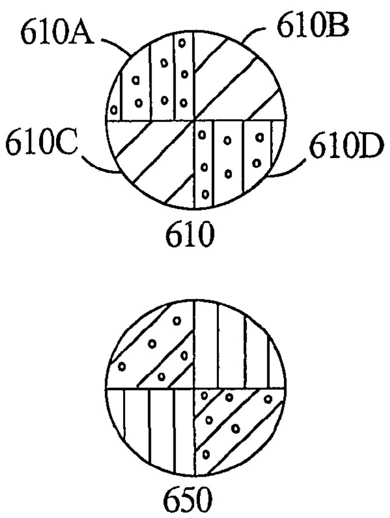


FIGURE 6B

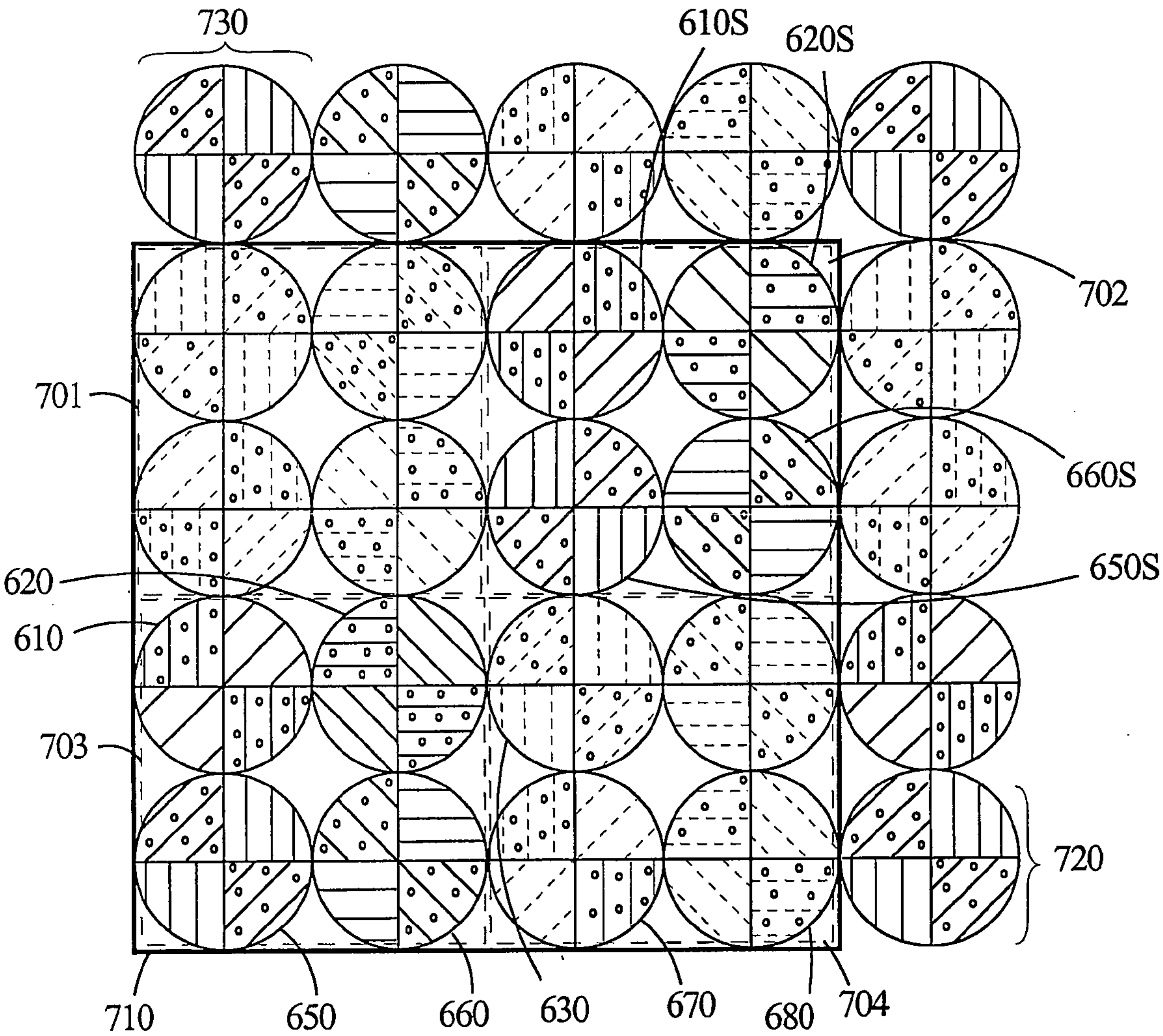

730
610S
620S
702
701
660S
650S
620
610
703
720
710
650
660
630
670
680
704

FIGURE 7

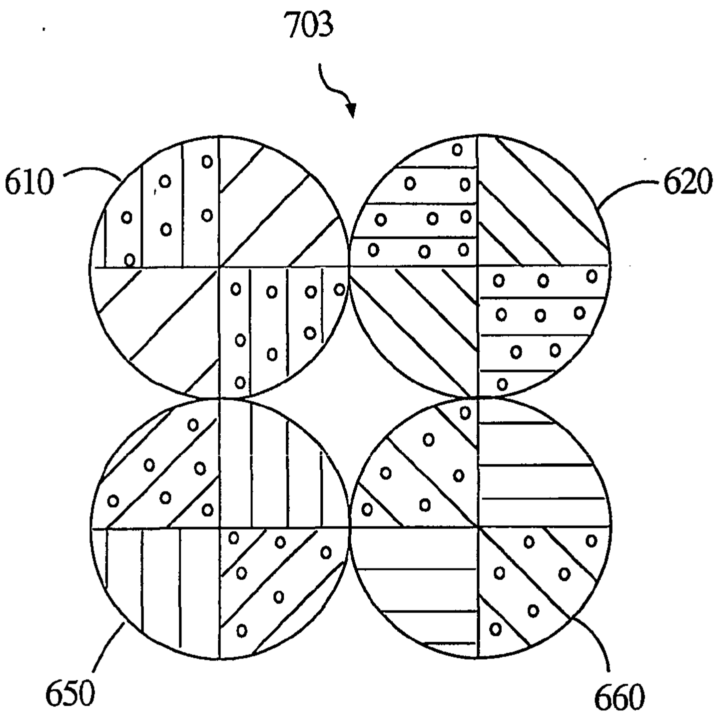


FIGURE 8

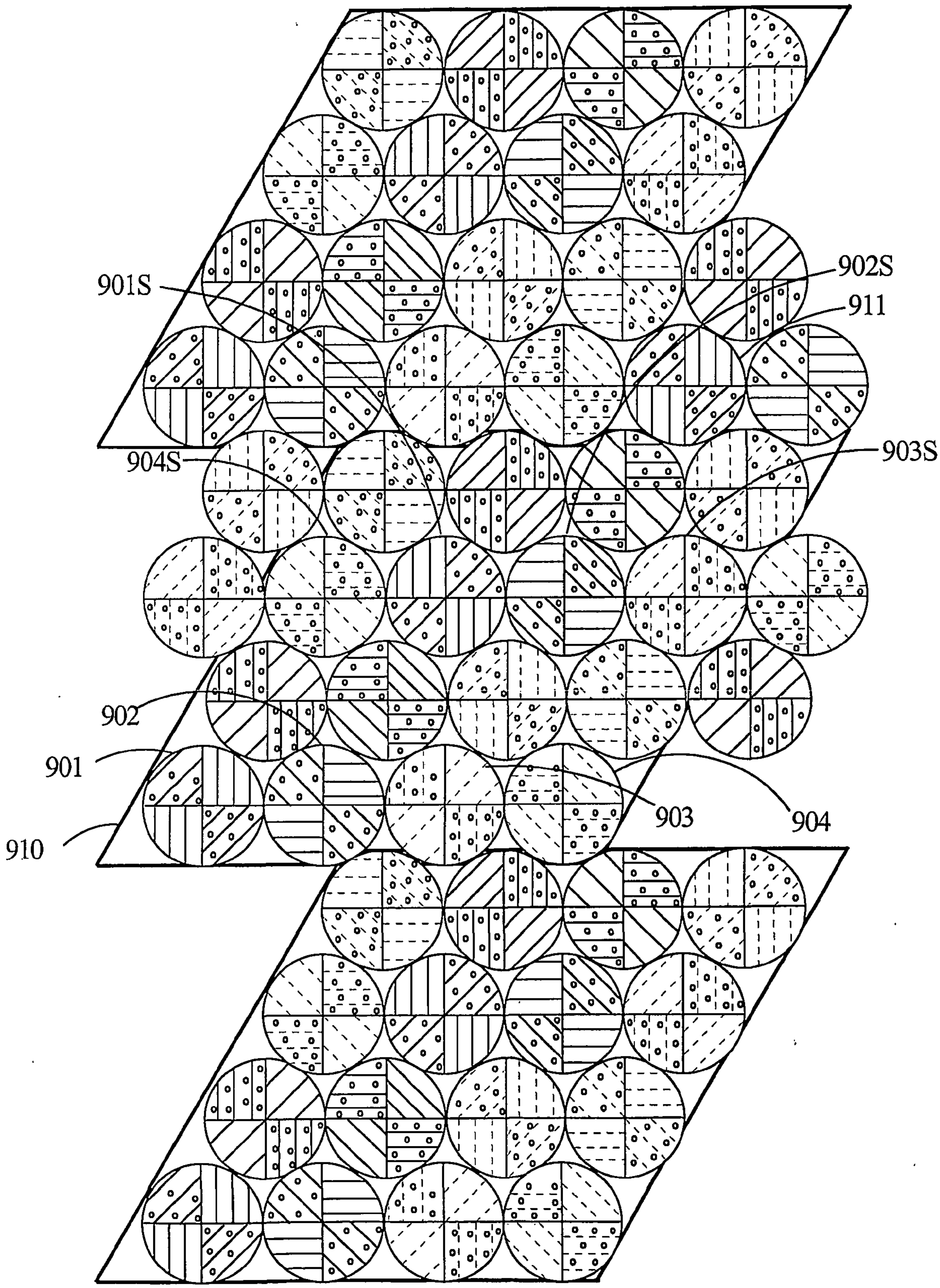


FIGURE 9

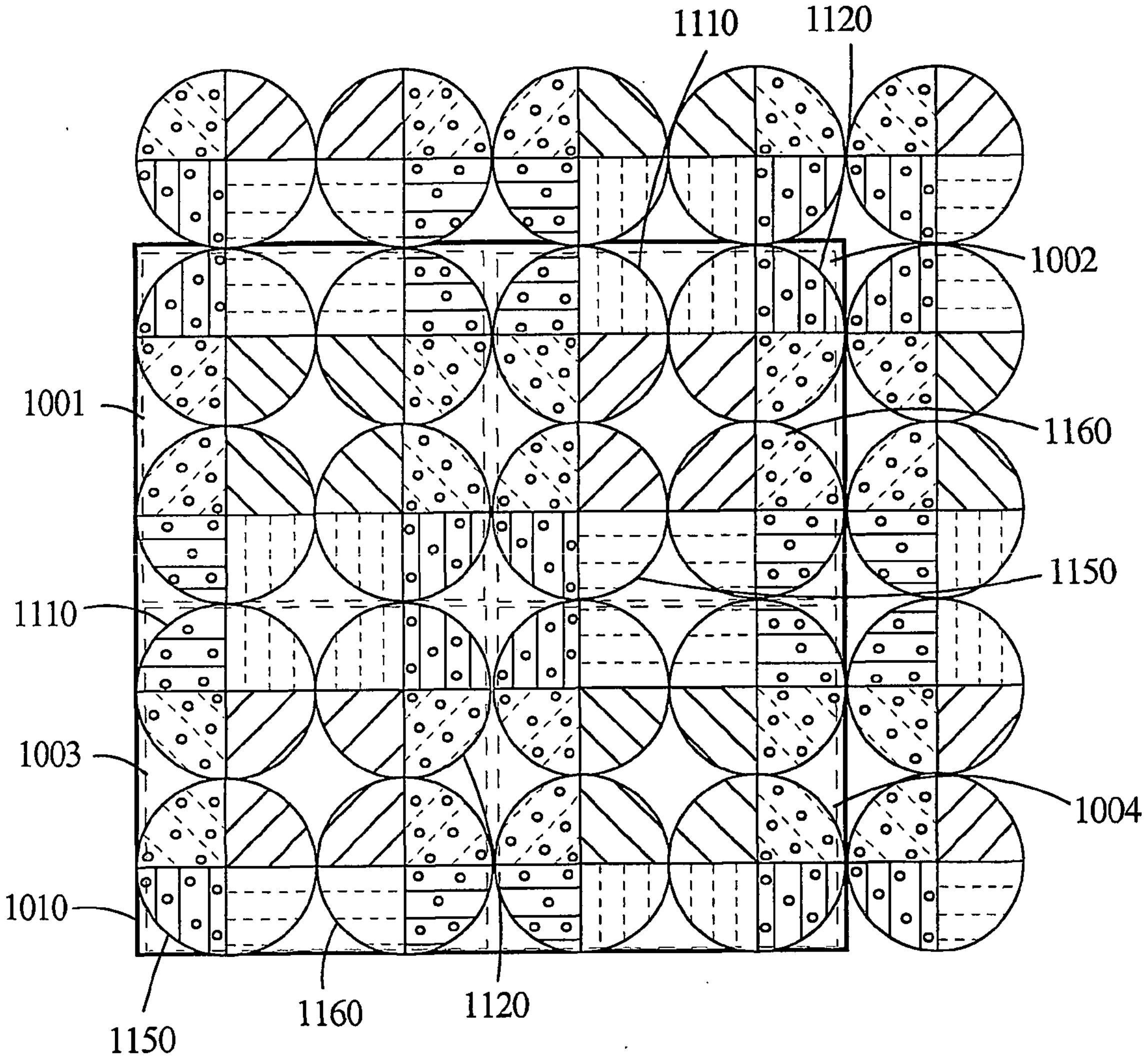

1110
1120
1002
1001
1160
1150
1110
1003
1004
1010
1150
1160
1120

FIGURE 10

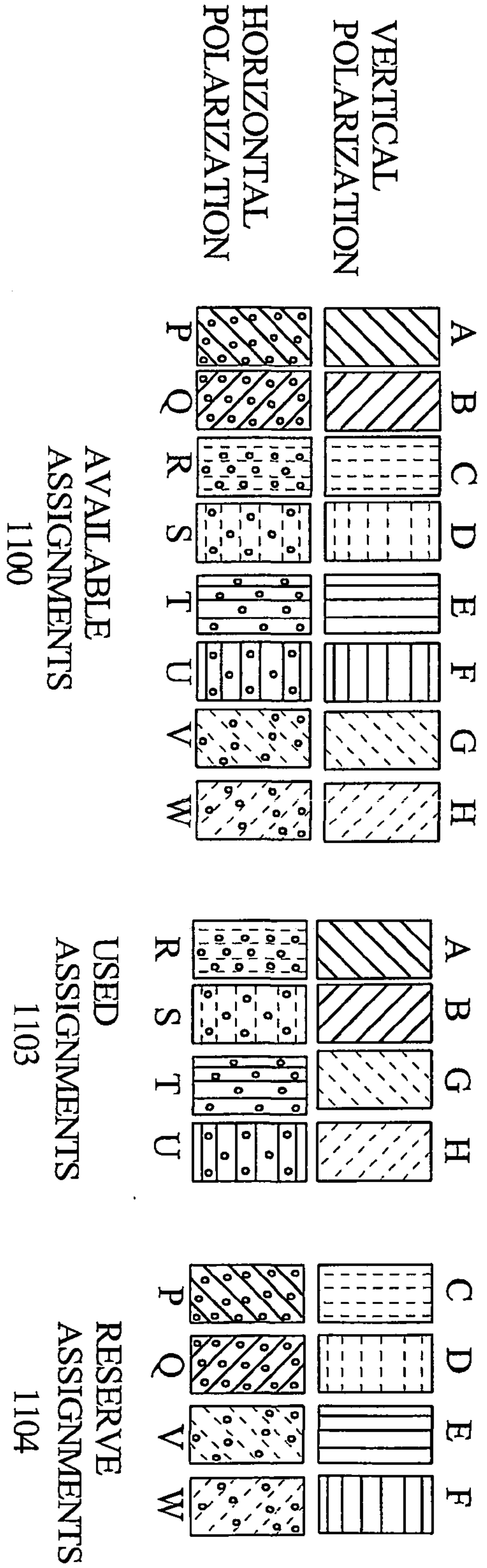

VERTICAL POLARIZATION
HORIZONTAL POLARIZATION
A B C D E F G H
P Q R S T U V W
AVAILABLE ASSIGNMENTS 1100
A B G H
R S T U
USED ASSIGNMENTS 1103
C D E F
P Q V W
RESERVE ASSIGNMENTS 1104

FIGURE 11A

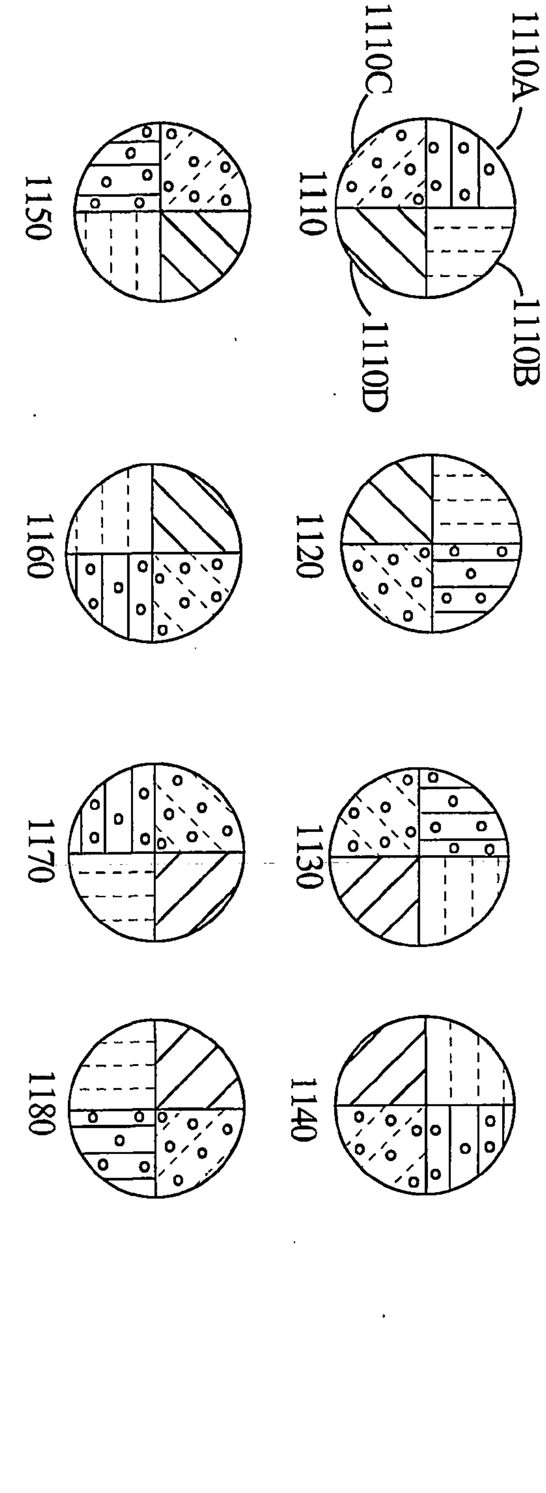

1110A
1110C
1110B
1110D
1110
1120
1130
1140
1150
1160
1170
1180

FIGURE 11B

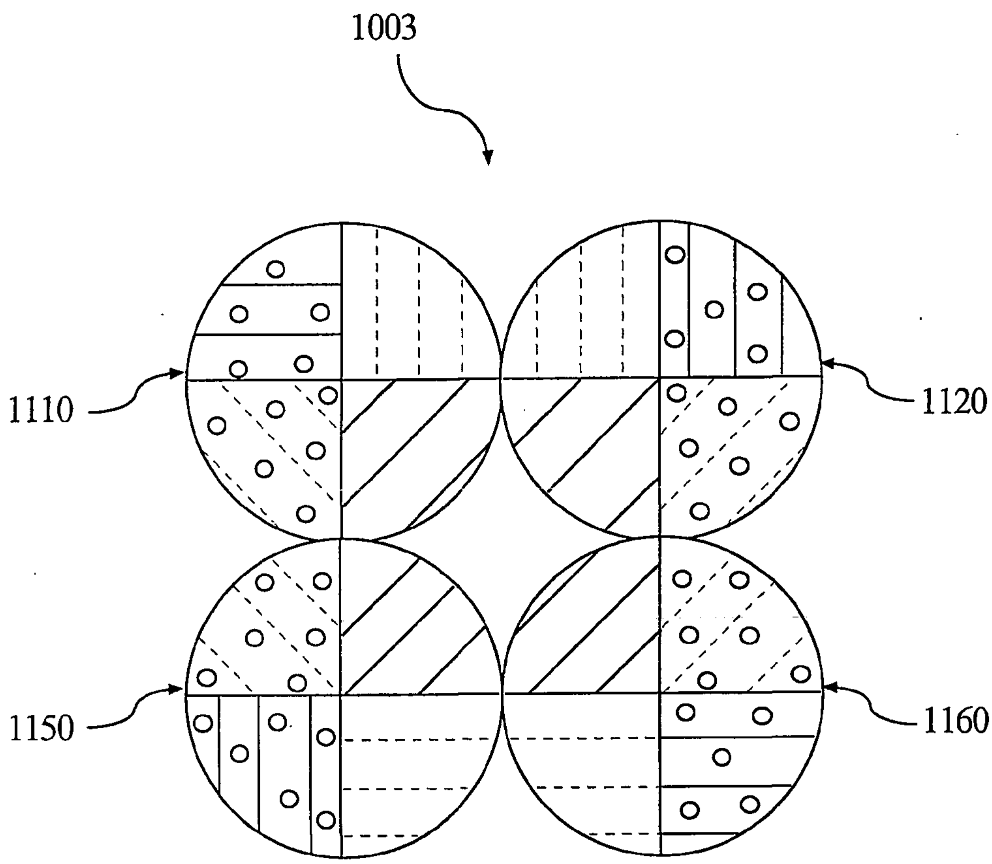


FIGURE 12

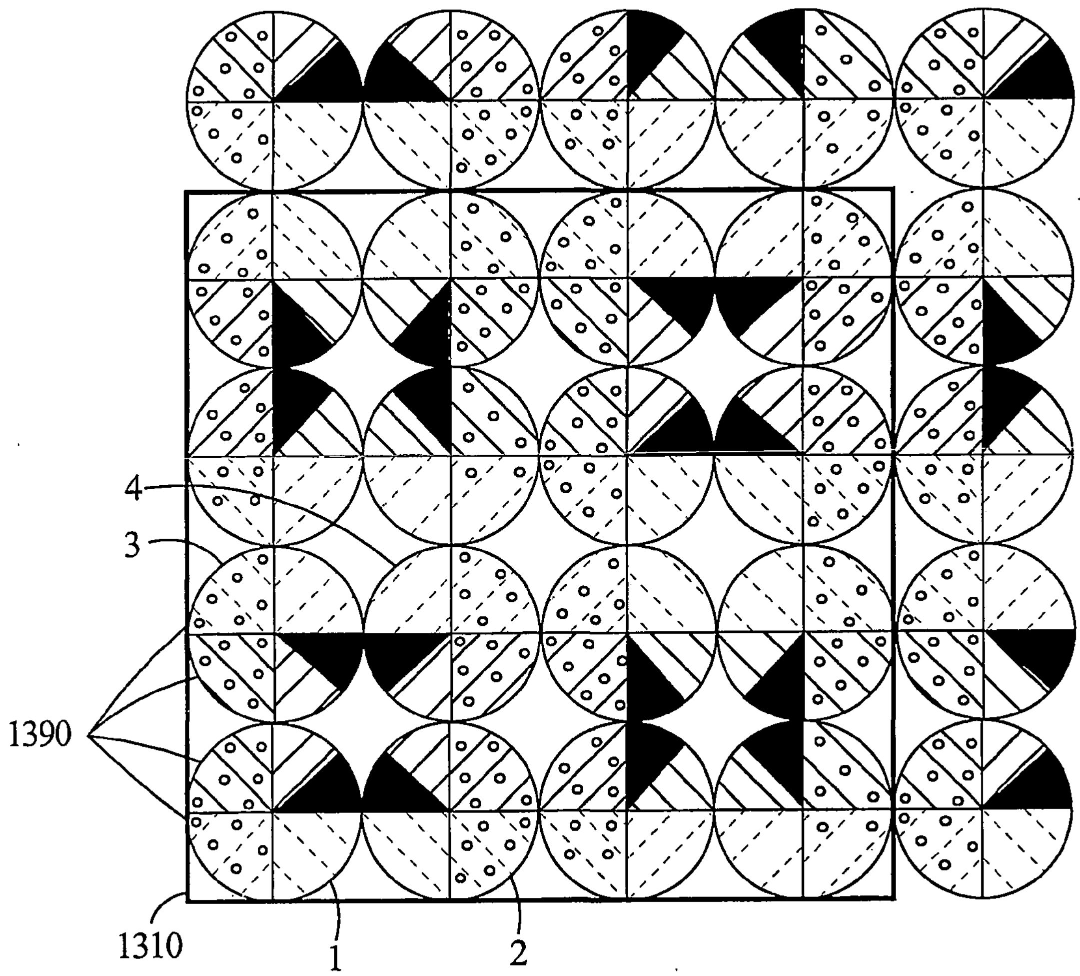


FIGURE 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/47153

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :IPC: H04Q 7/20
US CL : 455/446,502,561
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/446,502,561

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPAT,EPO AND JPO

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

EAST AND WEST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 6,275,704 B1 (DIXON) 14 AUGUST 2001, col.1 lines 63-68 and col.2 lines 1-29.	1,10,30,37, 47,59
Y,P	US 6,205,337 B1 (BOCH) 20 MARCH 2001, fig.4 and col.3 lines 44-61.	2-12,20- 29,31-36, 38-46,48-58,60-68
Y,P	US 6,304,762 B1 (MYERS et al) 16 OCTOBER 2001, fig.1.	1,30,37,47,59
A,P	US 6,216,244 B1 (MYERS et al) 10 APRIL 2001, fig.1	1-68

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 FEBRUARY 2002	18 APR 2002

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
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Facsimile No. (703) 305-3230

Authorized officer
TILAHUN B. GESESSE
Telephone No. (703) 308-5873

[19] 中华人民共和国国家知识产权局

[51] Int. Cl[7]
H04Q 7/20

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[43] 公开日 2004 年 10 月 6 日

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[22] 申请日 2001.12.10 [21] 申请号 01822220. X
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[71] 申请人 哈里斯宽带无线接入公司
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代理人 董 莘

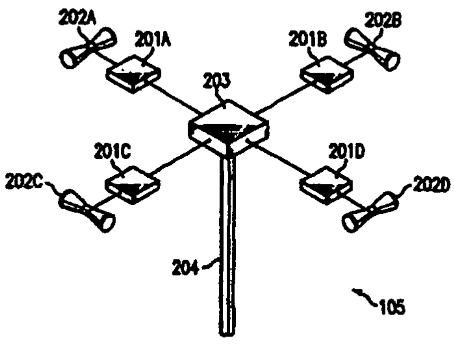
IHC030955

权利要求书 8 页 说明书 21 页 附图 15 页

[54] 发明名称 无线通信系统中用于在扇区化小区模式中频率再用的系统和方法

[57] 摘要

本发明涉及一种在无线通信系统中频率再用的系统和方法。本发明的系统和方法尤其提供对服务区的最大覆盖，其中小区(101、102、103 和 104)模式均具有一个扇区化(101A－101D)集线器(105)天线模式(202A－202D)，其中只有有限数量的通信信道可用。



ISSN1008-4274

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1. 一种无线通信系统中的可重复频率再用模式，包括：

16 个半径近似相同的基本上为圆形的小区，以 4 ×4 格栅排列，以便没有两个小区基本上重叠，而且每个小区基本上与其相邻的行和列小区正切，每个小区包含一个具有 4 个天线的集线器，每个天线服务 4 个基本上不重叠的 90°扇区中的一个，而且能在每 8 个频率以及在每频率的任何两个极化上通信，从而对每个集线器，一个反向 90°扇区集合在所述 8 个频率的其中一个上和在一个所述极化上通信，而另一反向 90°扇区集合在所述 8 个频率的一个不同频率上和另一所述极化上通信；

8 个小区类型，其中每个小区类型通过一个唯一的频率组合通信；

第一和第二个 4 小区小组，每个小组包含一个 2 ×2 的小区格栅以便，

所述第一个 4 小区小组包含所述 8 个小区类型中的 4 个不同小区类型，所述小区的排列方式使得行和列相邻小区的对面扇区具有不同极化，以及

所述第二个 4 小区小组包含另外 4 个不同的小区类型，所述小区的排列方式使得行和列相邻小区的对面扇区具有不同极化；

第三和第四个 4 小区小组，每个小组包含一个 2 ×2 的小区格栅以便，

所述第三个 4 小区小组包含与所述第一个小组相同的 4 个小区类型，其中在每个小区的反向扇区对之间交换频率和极化指配，所述 4 个小区的排列方式与所述第一个小组中的小区相同，以及

所述第四个 4 小区小组包含与所述第二个小组相同的 4 个小区类型，其中在每个小区的反向扇区对之间交换频率和极化指配，所述 4 个小区的排列方式与所述第二个小组中的小区相同；

其中所述 4 个小区小组排列在所述 4 ×4 格栅中，以便所述第一

和第三个小区小组为非行和列相邻，而行和列相邻小组之间的对面小区采用不同频率。

2. 权利要求1的模式，其中所述极化相互正交。

3. 权利要求1的模式，其中所述通信系统为时分双工系统。

4. 权利要求3的模式，其中所述通信系统为自适应时分双工系统。

5. 权利要求4的模式，其中所述8个频率在毫米频率范围内。

6. 权利要求5的模式，其中所述8个频率均在10-60 GHz的范围内。

7. 权利要求1的模式，其中所述小区不同步。

8. 权利要求7的模式，其中所述小区内的扇区不同步。

9. 权利要求1的模式，其中所述16个小区通常为圆形，接近相同半径，而且以4×4方格排列，以便任何两个水平和任何两个垂直相邻小区的中心之间的距离接近小区半径的两倍。

10. 一种在通信系统中形成直线格栅的多小区小区模式中的水平和垂直可重复的小区模式，其中每个小区被划分为4个90°扇区，每个扇区有至少一个天线，从而每个天线对每个通信频率能工作在两种极化模式中的一种，其中每个小区使用两个频率，而且每个小区的相邻扇区在频率和极化上交替。

11. 权利要求10的模式，其中所述极化相互正交。

12. 权利要求11的模式，其中带有格栅的对角线交替小区相对旋转90度。

13. 权利要求12的模式，其中频率数为8。

14. 权利要求13的模式，其中每个小区为8个小区类型中的一个，从而每个小区类型采用频率和极化的唯一组合。

15. 权利要求14的模式，其中每个小区类型在所述模式内重复一次。

16. 权利要求15的模式，其中所述通信系统为时分双工系统。

17. 权利要求16的模式，其中所述通信系统为自适应时分双工

系统。

18. 权利要求 17 的模式，其中所述 8 个频率在毫米频率范围内。

19. 权利要求 18 的模式，其中所述 8 个频率均在 10-60 GHz 的范围内。

20. 在通信系统中形成直线格栅的多小区小区模式的水平和垂直可重复的小区模式中，其中每个小区被划分为 4 个 90°扇区，每个扇区有至少一个天线，从而每个天线对每个通信频率能工作在两种极化模式中的一种，降低共道干扰的方法包括步骤：

（a） 在频率和极化上轮换每个小区的相邻扇区；以及

（b） 使格栅内的至少一对交替的对角线小区相对改变 90°。

21. 权利要求 20 的模式，其中相邻信道干扰被降低。

22. 权利要求 20 的模式，其中所述极化相互正交。

23. 权利要求 22 的模式，其中频率数为 8。

24. 权利要求 23 的模式，其中每个小区为 8 个小区类型中的一个，从而每个小区类型采用频率和极化的唯一组合。

25. 权利要求 24 的模式，其中每个小区类型在所述模式内重复一次。

26. 权利要求 22 的模式，其中所述通信系统为时分双工系统。

27. 权利要求 26 的模式，其中所述通信系统为自适应时分双工系统。

28. 权利要求 27 的模式，其中所述 8 个频率在毫米频率范围内。

29. 权利要求 28 的模式，其中所述 8 个频率均在 10-60 GHz 的范围内。

30. 在通信系统中形成直线格栅的多小区小区模式的以 4×4 格栅排列的 16 小区模式中，其中每个小区被划分为 4 个 90°扇区，每个扇区有至少一个天线，从而每个天线对 8 个通信频率均能工作在两种极化模式中的一种，从而对每个集线器，一个反向 90°扇区集合

在所述 8 个频率的其中一个上和在一个极化上通信，而另一反向 90°扇区集合在所述 8 个频率的一个不同频率上和另一极化上通信，降低共道干扰的方法包括步骤：

（a）将所述 16 个小区划分为 4 个 4 小区小组，从而每个小组包括一个 2×2 的小区格栅；

（b）提供 8 个小区类型，其中每个小区类型通过一个唯一的频率组合通信；

（c）提供第一个 4 小区小组，其包含所述 8 个小区类型中的 4 个不同小区类型，所述小区的排列方式使得行和列相邻小区的对面扇区具有不同极化；

（d）提供第二个 4 小区小组，其包含另外 4 个不同的小区类型，所述小区的排列方式使得行和列相邻小区的对面扇区具有不同极化；

（e）在所述 16 小区模式内在对角线上重复所述第一和第二个小区小组；

（f）相对第一和第二小区小组的扇区中的频率和极化指配，旋转重复的第一和第二小区小组的每个小区的扇区中的频率和极化指配 90°。

31. 权利要求 30 的模式，其中相邻信道干扰被降低。

32. 权利要求 30 的模式，其中所述极化相互正交。

33. 权利要求 32 的模式，其中所述通信系统为时分双工系统。

34. 权利要求 33 的模式，其中所述通信系统为自适应时分双工系统。

35. 权利要求 34 的模式，其中所述 8 个频率在毫米频率范围内。

36. 权利要求 35 的模式，其中所述 8 个频率均在 10-60 GHz 的范围内。

37. 一种无线通信系统中的频率再用模式，包括 16 个半径近似相同的基本上为圆形的小区，以形成平行四边形的可重复 4×4 格栅

排列，以便任何一个小区的边缘与其他6个小区的边缘正切，其中每个小区包含一个具有4个天线的集线器，其中每个天线服务4个基本上不重叠的90°扇区中的一个，而且能在每8个频率以及在每频率的任何两个极化上通信，从而对每个集线器，一个反向90°扇区集合在所述8个频率的其中一个上和在一个极化上通信，而另一反向90°扇区集合在所述8个频率的一个不同频率上和另一极化上通信，所述模式包括：

8个小区类型，其中每个小区类型通过一个唯一的频率组合通信；

第一个4小区小组包含所述8个小区类型中的4个不同小区类型，所述小区的排列方式使得每个小区的中心共线，而且相邻小区的边缘正切，从而相邻小区的对面扇区具有不同极化；

第二个4小区小组包含另外4个不同的小区类型，所述小区的排列方式使得每个小区的中心共线，而且相邻小区的边缘正切，从而相邻小区的对面扇区具有不同极化，而且所述第一和第二个小区小组的排列方式使得每个小组的每个小区与另一小区小组的至少一个小区相邻和正切；

第三个4小区小组包含与所述第一个小组相同的4个小区类型，其中在每个小区的反向扇区对之间交换频率和极化指配，所述4个小区的排列方式使得每个小区的中心共线，而且相邻小区的边缘正切，从而所述第二和第三个小区小组的排列方式使得每个小组的每个小区与另一小组的至少一个小区相邻和正切，而且没有与第三小组中的小区相邻的小区也与在第一小组中具有与第三小组中的所述小区对应的频率组合的小区相邻；

第四个4小区小组包含与所述第二个小组相同的4个小区类型，其中在每个小区的反向扇区对之间交换频率和极化指配，所述4个小区的排列方式使得每个小区的中心共线，而且相邻小区的边缘正切，从而所述第三和第四个小区小组的排列方式使得每个小组的每个小区与另一小组的至少一个小区相邻和正切，而且没有与第

四小组中的小区相邻的小区也与在第二小组中具有与第四小组中的所述小区对应的频率组合的小区相邻。

38. 权利要求37的模式，其中所述16个小区通常为六角形。

39. 权利要求 37 的模式，其中所述模式在水平和垂直方向上重复。

40. 权利要求37的模式，其中所述极化相互正交。

41. 权利要求40的模式，其中所述通信系统为时分双工系统。

42. 权利要求 41 的模式，其中所述通信系统为自适应时分双工系统。

43. 权利要求 42 的模式，其中所述 8 个频率在毫米频率范围内。

44. 权利要求43的模式，其中所述8个频率均在10-60 GHz的范围内。

45. 权利要求44的模式，其中所述小区不同步。

46. 权利要求45的模式，其中所述小区内的扇区不同步。

47. 一种无线通信系统中的频率再用模式，包括以 4 ×4 格栅排列的16个小区，其中含有以 2 ×2 格栅的 4 小区排列的 4 个子群集，其中每个小区包含一个具有 4 个天线的集线器，其中每个天线服务 4 个基本上不重叠的 90 °扇区中的一个，而且能在每 8 个频率以及在每频率的任何两个极化上通信，其中对每个集线器，每个扇区在一个不同频率上通信，其中两个相邻扇区在一个极化上通信，而另两个相邻扇区在另一极化上通信，所述模式包括:

8 个小区类型，其中每个小区类型通过一个唯一的频率组合通信，从而这8个小区类型由位于所述一个极化的4个频率和位于所述另一极化的4个频率构成;

第一个子群集包含所述 8 个小区类型中的 4 个不同小区类型，所述小区的排列方式使得相邻小区的对面扇区在相同频率和相同极化上通信，以及

第二个子群集包含另外 4 个不同的小区类型，所述小区的排

列方式使得相邻小区的对面扇区在相同频率和相同极化上通信;

与所述第一个子群集相同的第三个子群集;

与所述第二个子群集相同的第四个子群集;

其中所述子群集排列在所述 4 ×4 格栅中，以便所述第一和第三个子群集不相邻，而相邻子群集之间的所述对面小区在相同频率和相同极化上通信。

48. 权利要求 47 的模式，其中所述极化相互正交。

49. 权利要求 47 的模式，其中所述通信系统为时分双工系统。

50. 权利要求 49 的模式，其中所述通信系统为自适应时分双工系统。

51. 权利要求 50 的模式，其中所述 8 个频率在毫米频率范围内。

52. 权利要求 51 的模式，其中所述 8 个频率均在 10-60 GHz 的范围内。

53. 权利要求 52 的模式，其中所述各个小区同步。

54. 权利要求 53 的模式，其中在相同频率和相同极化上通信的相邻扇区同步。

55. 权利要求 54 的模式，其中所述相邻扇区以通用动态非对称同步通信。

56. 权利要求 47 的模式，包括至少一个附加扇区，在所述模式中未使用的所述 8 个频率和两个极化的一个频率和极化组合上通信，从而所述附加扇区覆盖在所述模式中与所述附加扇区的极化具有类似极化的至少一个扇区上。

57. 权利要求 56 的模式，其中所述附加扇区为 90°扇区。

58. 权利要求 56 的模式，其中所述附加扇区为 45°扇区。

59. 在通信系统中形成直线格栅的多小区小区模式的水平和垂直可重复的小区模式中，降低共道干扰的方法，其中每个小区包含一个具有 4 个天线的集线器，其中每个天线服务 4 个基本上不重叠的 90 °扇区中的一个，而且对所述通信系统使用的每个通信频率能在两

个极化模式的一个上通信，从而对每个集线器，一个反向 90°扇区集合在一个所述通信频率上和在一个所述极化上通信，而另一反向 90°扇区集合在一个不同的所述通信频率上和另一所述极化上通信，该方法包括步骤:

（a）提供 8 个小区类型，其中每个小区类型包含所述两个频率和极化集合的一个唯一组合;

（b）提供两个小区子群集，四个小区的每个小区以 2×2 格栅排列，其中第一个子群集包括 4 个小区，每个小区均为所述 8 个小区类型中的一个不同小区类型，而且其中第二个子群集包括 4 个小区，每个小区均为另外 4 个小区类型中的一个不同小区类型;

（c）在所述多小区小区模式内水平和垂直轮换所述子群集; 以及

（d）将所述多小区小区模式内的每对交替的对角线小区相对改变 90°。

60. 权利要求 59 的方法，其中相邻信道干扰被降低。

61. 权利要求 59 的方法，其中所述极化相互正交。

62. 权利要求 61 的方法，其中频率数为 8。

63. 权利要求 61 的方法，其中频率数至少为 8。

64. 权利要求 63 的方法，其中每个小区类型在所述模式内重复一次。

65. 权利要求 61 的模式，其中所述通信系统为时分双工系统。

66. 权利要求 65 的模式，其中所述通信系统为自适应时分双工系统。

67. 权利要求 66 的模式，其中所述 8 个频率在毫米频率范围内。

68. 权利要求 67 的模式，其中所述 8 个频率均在 10-60GHz 的范围内。

无线通信系统中用于在扇区化小区模式中频率再用的系统和方法

相关申请

本申请涉及：标题为“用于宽带毫米波数据通信的系统和方法”的共同待审、共同转让的美国专利申请序号 09/434,707，标题为“使使用动态非对称的多载波时分复用系统效率最高”的共同未决、共同受让的美国专利申请序号 09/604,437，以及标题为“用于 TDD 的频率再用”的共同待审、共同转让的美国专利申请序号 09/607,456，这些专利申请在此结合作为参考。本专利申请还与标题为“在无线通信系统中用于扇区同步的带内信令的系统和方法”的共同受让的美国专利申请同时申请。

技术领域

本发明涉及通信系统和方法，尤其涉及一种通过同步发射和接收模式优化点到多点无线系统的带宽的系统和方法。

背景技术

无线链路在为各种应用提供数据通信链路上已经变得越来越重要。例如，因特网服务提供商已经开始在城市环境内使用无线链路以避免传统的有线连接或光纤的安装费用。在点到多点体系结构中使用无线链路系统为多个用户提供服务更佳。点到多点系统通常由服务多个子设备（有时称为远程设备、节点、或用户设备）的多个集线器设备构成。这些子设备通常与该系统上的单个节点相关。例如，单个子设备可与 LAN 相连以允许 LAN 上的 PC 通过这种点到多点系统桥接到其它网络。每个子设备通过无线信道与一个特定的集线器设备通信。在点到多点系统中，集线器设备可控制与一个特定覆盖区域相关的多个子设备的一部分之间的通信。集线器设备调度发射和接收突发往返子设备。集线器设备通过这些帧可将从特定子设备接收的数据分

组分发到同一覆盖区内的另一子设备，传统的有线网络主干，或另一集线器设备。

点到多点系统，如在上面参考和共同受让的标题为“用于 TDD 的频率再用”的专利申请中公开的点到多点系统，包含多个相邻放置的集线器设备提供集合覆盖区。另外，这些集线器可拥有它们各自的覆盖区，这些覆盖区被划分为特定扇区——如 30 或 90 度扇区。另外，这些集线器可利用频分或其它技术提供多个通信信道。

信道再用技术已经被开发用来允许再用网络内的信道，而不会引入程度无法接受的干扰。这些信道再用技术的目的是使信道可用性最大，同时避免相邻集线器之间出现共道干扰。显然，这些信道再用技术是增大点到多点系统的带宽的重要工具。然而，根据本发明，已经意识到，点到多点系统包含的结构特性可被用来优化信道可用性大于采用传统信道再用技术的可用性，同时避免共道干扰。

例如，通过点到多点系统的数据业务可能是突发性的，而不是以固定或连续数据率。具体来说，在子设备上执行的因特网浏览器应用在从站点下载 HTML 代码时通常需要大量的下行链路带宽，而用户读出与该 HTML 代码相关的显示时只需少量或无需带宽。另外，诸如浏览器的许多应用的带宽需求可能是不对称的。具体来说，因特网浏览器经常下载大量数据，但上载量在比例上却极少。因此，点到多点系统可实现动态带宽分配（DBA）技术以使与非对称、突发性业务相关的数据吞吐量最大。

发明内容

因此，本发明的一个目的是根据在网络的特定部分之间点到多点系统的独特特性，提供一种能使点到多点系统的带宽最大的系统和方法。

本发明的另一目的是提供一种用于同步动态分配带宽的系统和方法。

本发明的另一目的是提供一种用于同步集线器设备的相关组的扇区或其它部分的接收和发射模式，以使点到多点系统的带宽最大的

系统和方法。

本发明的另一目的是在点到多点系统中提供一种用于扇区到扇区遥测的系统和方法。

本发明的另一目的是提供一种高效通信信道用于本发明的系统和方法，这种通信信道允许在单个集线器快速动态分配带宽时同步相邻集线器。

本发明的另一目的是在无线通信系统中提供一种频率再用模式。

本发明的另一目的是在由利用每通信频率两极化的 4*4 格栅中的 16 个小区构成的无线通信系统中提供一种可重复的频率再用模式。

本发明的另一目的是在由组合到 4 小区的 4 个子群集的 16 个小区构成的无线通信系统中提供一种可重复的频率再用模式，其中该模式中的对面扇区同步。

本发明的还一目的是通过频率再用模式提供一种降低共道和/或相邻信道干扰的方法。

通过工作于一种点到多点系统的系统和方法可实现本发明的这些和其他目的，特征和技术优势，这种点到多点系统包含多个集线器以及在与所述集线器相关的覆盖区内分布的多个子设备。点到多点系统优选利用频谱划分技术，如频分，时分或正交码分，将其通信带宽划分为信道。而且集线器通过扇区天线与它们覆盖区内的子设备通信。通过利用频谱划分和扇区天线，点到多点系统的优选实施例通过信道再用方案协调信道分配。另外，优选实施例通过经同一信道的时分双工（TDD）方案将单个信道划分为发射和接收模式。在此 TDD 方案中，集线器在发射模式中将信息发送给子设备，而在接收模式中从子设备接收信息。此外，点到多点系统的集线器优选在发射和接收模式之间可动态分配带宽以实现非对称通信模式。利用本发明的优选实施例的子设备还包括定向天线。

诸如在相邻集线器的相邻扇区的共道干扰是一个严重的问题，

具体来说，由于集线器天线通常指向网络的其他集线器以便为服务区提供复合覆盖，因此集线器到集线器暴露是个问题。例如，优选实施例的集线器可利用覆盖方位在30到90度之间的扇区天线，这些天线的方位面向位于相邻集线器的类似扇区天线。子设备暴露对本优选实施例的点到多点系统来说并不是那么严重的问题，因为这些点到多点系统的子设备使用高定向天线。因此，子设备不会受到来自其他子设备或其他集线器设备的严重的共道干扰。

信道再用方案可用于减小集线器到集线器共道干扰。例如，通过仔细分配网络的集线器使用的信道，可实现接近1的再用性能。此外，通过先进的信道规划技术，如在上面参考的标题为"TDD 频率再用"的专利申请中示意和描述，以及下面将描述的，可实现更高的信道再用性能。

然而，允许信道再用率更高的方法或系统优化将系统总体带宽更大。本发明在一个实施例中是通过同步集线器的发射和接收模式实现这个目标的。本发明的一个实施例同步地理相邻集线器的群集中对面扇区的动态带宽分配，同时允许这些集线器的其他扇区通过频率再用和对面扇区同步独立分配带宽。集线器相邻的意思是，这些集线器在特定方向是最近的相邻集线器。在这个实施例中，通过优选保护时间以适应正好跨越两个集线器覆盖半径的同步距离，使发射和接收模式之间的保护时间最短。例如，当最大再用为6R，再用进度为9，采用30度扇区，4.5公里小区时，保护时间接近100微秒，或接近本实施例的信道容量的5%，以从再用群集中的最大距离处提供传播。然而，由于本发明同步相邻集线器的对面扇区，因此同步距离大为缩短。因此，在本实施例中，保护时间只占据信道容量的.5%。此外，在这个优选实施例中系统的计算需求大为降低，因为对于任何特定的同步确定，网络中更少部分同步。而且对面扇区同步简化了同步遥测的实现。

在本发明的另一实施例中，描述了一种频率再用模式，其中利用一种可重复的小区模式以容许再用多个频率指配，在这些频率指配

中每频率有两个极化模式可用。这种频率再用模式在可用于操作通信系统的频率指配或通信信道的数量受限时特别有用。为了为特定工作区域提供充分覆盖，必须提供再用这些可用频率的小区模式以避免盲点，或避免在同一区域使用的频谱上在相邻信道之间出现干扰（这种干扰在本领域的技术上称为“相邻信道干扰”），或避免在相邻区域极化相同、频率相同的两个小区之间出现干扰（这种干扰在本领域的技术上称为“共道干扰”）。

通过将该模式中的小区形状理想化为圆形以及进一步理想化每个小区具有相似半径，这种小区的可重复模式的形状可以认为是平面上的覆盖。显然，这种理想化，如平面和间隔距离一致的基本上相同的小区，在现实世界中是极少出现的。然而，应理解的是，本发明的系统和方法并不局限于这种理想化，而是可适用于现实环境，其中在考虑到微小变化，以虑及阻塞、地形特征、小区规模不同、小区间隔不规则等等时，可使用全部的频率再用模式。虽然本发明下面的说明在将讨论由理想化的小区等构成的理想化可重复模式，但这种理想化不应认为是对本发明的限制。

对于规模基本上相同而且形状为圆形的小区来说，在多小区模式中这些小区的一种排列方式可以看作方格，其中在同一行或同一列相邻的两个小区的边缘在一个点正切。在这种排列方式中，在对角线上相邻的小区不正切。在另一种多小区排列方式中，该模式中的小区与 6 个相邻小区均正切。如果这些小区被理想化为六角形，则这种模式将表现为蜂窝形状。

本发明人根据经验确定对于具有 90° 扇区的小区来说，宽带无线接入系统的有效频率再用需要最少 8 个频率指配和两个极化。基于全球范围频率的典型许可证分配大小的考虑，这对时分双工（“TDD”）系统中 90° 扇区化的小区的频率/极化指配是合理要求。例如，在欧洲，对 28 GHz 频带预期的许可证分配为 2 ×112 MHz 或 224 MHz，而对 42 GHz 频带则接近 500 MHz。大部分的北美宽带无线接入运营商拥有超过 200 MHz 的频率分配。在欧洲新兴

的流行信道规模为 28 MHz，而在北美为 25 MHz。这些信道规模加上频率的预期许可证分配对 8 个或更多可用频道留有余地。

虽然 90°扇区相比较小扇区尺寸，如 60°，45°和 30°扇区，具有某些不便，但 90°扇区尺寸是对几乎所有的宽带无线接入运营商和标准组织的规划基准。例如，宽扇区相比窄扇区 RF 性能有些折衷。小区直径被减小从而需要更多数量的集线器/小区以覆盖给定区域。较宽扇区还将引起更大的共道和相邻信道干扰的可能性。

尽管 90°扇区具有操作缺陷，但 90°扇区方案具有重要的经济优势。一个优势是室外设备的成本较低。由于采用 90°扇区，相比较小尺寸的扇区，需要较少扇区，由此需要较少无线电设备、天线以及相关设备，无论是基本的还是冗余的。另外，运营商的一个重大开销是屋顶权，地产所有着趋于根据天线的数量对在他们建筑物的屋顶上放置设备的权利收费，因此 90°扇区意味着屋顶权的开销更低。而且，扇区更宽能提供更大的 RF 覆盖，这在系统的早期部署中具有重要的意义。

前面已经相当概括地归纳了本发明的特征和技术优点以便更好地理解下面对本发明的详细描述。之后将描述本发明的其它特征和优点，这些构成了本发明的权利要求书的主题。本领域的技术人员应理解的是，在此公开的概念和特定实施例可很容易地用作修改或设计用于实现本发明的相同目的的其他结构的基础。本领域的技术人员还应意识到，这些等效结构并不偏离在所附权利要求书中陈述的本发明的精神和范围。通过联系附图参考下面的描述可更好地理解被认为是本发明特点的新颖特征，无论是结构上的还是操作方法上的，以及其他目的和优点。然而，还应特别理解的是，每个特征仅提供用于示意和描述目的，而且并不认为是对本发明的限制的定义。

附图说明

为更完整地理解本发明以及其优点，现在联系附图参考下面的描述，其中：

图 1 描绘了在群集体系结构中排列的点到多点系统示例；

图 2A 描绘了图 1 所示的点到多点系统的示意性扇区配置；

图 2B 示意了对于图 2A 中的一个小区，集线器的扇区化天线排列方式；

图 3 示意了特定扇区，以及从集线器到特定扇区内的多个子设备的发射的传播；

图 4A-4D 均示意了与相邻集线器的反向扇区相关的一系列 RX 和 TX 帧的时序图；

图 5 示意了 QAM 载波信号和相关自适应载波的示例性功率分集频谱；

图 6A 示意了每个频率信道具有两个极化以用于频率在用的一组 8 个频率信道；

图 6B 示意了利用具有图 6A 所示每频率信道两个极化的一组 8 个频率信道的 8 个独特的小区类型；

图 7 示意了在 4*4 直线栅格中的 16 个小区的可重复模式，其中每个小区分为 4 个 90°扇区，对立扇区工作在具有相同极化的相同频率信道上；

图 8 示意了来自图 7 的 16 个小区的可重复模式的一个 4 小区组合；

图 9 示意了在形成平行四边形的 4*4 栅格中的 16 小区可重复模式，其中每个小区分为 4 个 90°扇区，对立扇区工作在具有相同极化的相同频率信道上；

图 10 示意了图 7 的可重复模式，其中对面扇区工作在相同频率信道和极化上一允许对面扇区的集线器天线之间发射和接收同步；

图 11A 示意了具有图 6A 所示的每频率信道两个极化的一组 8 个频率信道，指示在图 10 该模式中使用的频率信道和极化以及在保留的图 10 的模式中未使用的频率信道和极化；

图 11B 示意了利用具有图 11A 所示的每频率信道两个极化的一组 4 个频率信道的 8 个唯一的小区类型，用于图 10 的频率再用模式；

图 12 示意了来自图 10 的 16 小区可重复模式的一个 4 小区组合；

图 13 示意了具有附加频率信道扇区重叠的可重复模式以便增大系统用户的容量需求；

具体实施方式

图 1 示意了一种应用本发明的示例性点到多点系统。该系统优选以群集结构部署。所示意的群集由多个集线器（105、106、107、108）构成，尽管根据本发明也可使用数量不同于所示配置的群集。应理解的是，应用本发明的通信网络还可包含另外的群集，与应用本发明的群集或者远程放置或者相邻放置。

集线器 105、106、107 和 108 为小区 101、102、103 和 104 提供覆盖。在小区 101、102、103 和 104 中分别部署了多个子设备（109-119）。另外，处理器系统（120-131）分别与各个子设备相关。应理解的是，点到多点系统的子设备也可与处理器系统的 LAN 网络相关。作为选择，点到多点系统的子设备可与中间网络连接。例如，子设备可与中间的 ATM 交换机连接。还应理解的是，应用本发明的系统可包含任意大量的集线器、小区以及子设备。为简化本发明的描述，以 4 个小区为例描述该示例性实施例。

图 2A 示意了图 1 所示的点到多点系统的示例性扇区配置。前面指出，该系统被划分为与小区 101、102、103 和 104 相关的覆盖区。此外，本示例的小区 101、102、103 和 104 被扇区化为 90°扇区（101A-101D、102A-102D、103A-103D 以及 104A-104D），尽管根据本发明也可同步其它扇区尺寸。如在图 2B 为集线器 105 示意的，集线器 105、106、107 和 108 通过扇区天线往返扇区发射和接收信号。扇区天线 202A-202D 可利用用于每个扇区的分立天线单元。作为选择，扇区天线可利用多个窄波束天线单元以合成扇区覆盖。在此配置中，在这个组合的其他扇区天线中可检测到从与任何扇区 101D、102C、103B 以及 104A 相关的扇区天线发送的射频信号能量。

分配给点到多点系统的频谱总体被优选细分为信道。本发明可使用各种信道划分方法，如时分、频分信道，跳频信道，以及正交码信道。这些信道被划分为离散集合。另外，根据再用进程在点到多点系统的扇区间分配信道集合。在此示例系统中，为示意本发明，RF 信号 302-307 在同一信道上传输。应理解的是，其他信令也可与该示例的发射和接收信号同时出现在其他信道上。

根据优选实施例，根据信道再用方案，在不同信道集合提供特定小区的至少相邻扇区。例如，为扇区 104B 和 104C 使用分配的信道不同于为扇区 104A 使用分配的信道。然而，依赖于扇区天线的前后分离，旁瓣性能等等，在小区中也可再用信道集合，如扇区 104B 和 104C 和/或 104A 和 104D 内部。

图 3 示意了分别从集线器 105 和 106 广播的一系列 RF 发射信号（301-306）。集线器 105 在扇区 101D 内发射一系列以方向 301 传播的 RF 时间突发或时隙信号（302、303 和 304）。由于集线器 105 使用扇区天线，因此与 RF 信号 302、303 和 304 相关的能量通过扇区 101D 传播。RF 信号 302 包含子设备 109 的信息。RF 信号 303 包含子设备 110 的信息。RF 信号 304 包含子设备 111 的信息。类似地，集线器 108 在扇区 104A 内发射一系列以方向 308 传播的 RF 时间冲突或时隙信号（305、306 和 307）。由于集线器 104 使用扇区天线，因此与 RF 信号 305、306 和 307 相关的能量通过扇区 104A 传播。RF 信号 305 可包含子设备 117 的信息。RF 信号 306 可包含子设备 118 的信息。RF 信号 307 可包含子设备 119 的信息。

最后，RF 信号 302、303 和 304 将传播超出小区 104 的界限到达小区 101、102 和 103。因此，RF 信号 302、303 和 304 在小区 101、102 和 103 可能造成共道干扰。在本优选实施例的点到多点系统中，子设备利用指向相关集线器的高定向天线，因此，一般远离一个群集的其余集线器。因此，子设备通常不会受到来自 RF 信号 302、303 和 304 的共道干扰。

然而，当 RF 信号到达特定集线器时，如果集线器对于与 RF 信

号 302、303 和 304 相关的特定信道处于接收模式，则集线器 105、106 和 107 将经受共道干扰。根据一个优选实施例，集线器 108 对扇区 104A 使用如同集线器 105 对扇区 101D，集线器 106 对扇区 102C 以及集线器 107 对扇区 103B 使用的相同信道集合。因此，RF 信号 302、303 和 304 可能造成共道干扰，这依赖于它们到达集线器 106、107 和 108 的时间。应理解的是，如果 RF 信号 302、303 和 304 在集线器 106、107 和 108 处于发射模式时到达，则 RF 信号 302、303 和 304 的影响可以忽略不计。类似地，如果集线器在 RF 信号 305、306 和 307 到达时对与这些信号相关的信道处于接收模式，则 RF 信号 305、306 和 307 可能在集线器 105、106 和 107 造成共道干扰。

另外，扇区 101D 和 104A 中的子设备广播 RF 信号 309-314。前面指出，这个系统的优选实施例的子设备使用高定向天线。这种系统的结构使得高定向天线将辐射的 RF 能量集中到以相应的集线器为中心的极窄波束内。因此，这些子设备与系统中的另一天线耦合而造成共道干扰的可能性很小。应理解的是，此示例系统假设 RF 信号 302-207 和 RF 信号 309-314 是通过相同频道传输的。因此，这个示意本发明的示例系统在 TDMA 突发周期控制 RF 信号传输的时序。

本发明和方法的优选实施例同步点到多点系统内的特定传输以防止集线器传输造成共道干扰。当然，根据本发明除了发射窗口同步外，接收窗口也可同步。依赖于信道之间的分离量，可能独立同步相邻扇区内的单个信道。通过同步单个信道，自适应时分双工方案可使基于每个信道的吞吐量最大。然而，这种方案需要较大的处理能量，因此需要更高的设备成本和复杂性，以计算最佳接收和发射非对称。因此，本优选实施例对在相邻扇区内使用的所有信道都能同步发射和接收。通过这种方式，本发明的系统和方法在保持成本和复杂性为优选级别的同时能使非对称时分双工算法的性能更高。

图 4A-4D 描绘了集线器 105、106、107 和 108 的扇区 101D、102C、103B 和 104A 的发射和接收帧的示例时序图。优选每个集线器同步以便在时刻 t_0 开始其发射模式。集线器 105 发射 TX 突发 401-

403，其分别包含用于子设备 109-111 的信息。集线器 106 发射包含子设备 114 的信息的 TX 突发 404。集线器 107 发射突发 405 和 406，其包含分别用于子设备 115 和 116 的信息。集线器 108 发射突发 407-409，其分别包含用于子设备 117-119 的信息。而且，优选同步每个集线器以便在时刻 t_6 结束其发射模式。

另外同步集线器 105-108 以便集线器 105-108 从时刻 t_6 到时刻 t_7 不发射。而且，集线器 105-108 从时刻 t_6 到时刻 t_7 不从子设备接收突发。在这个周期期间，发射和接收延迟产生了保护时间 316。优选保护时间 316 的持续时间，以便与相应突发相关的 RF 信号在任何可能经受共道干扰的集线器将进入接收模式之前传播出该集线器。相邻扇区同步使得这个实施例中的同步距离稍微大于两个集线器半径（集线器 105 和 108 之间的距离）。具备适当再用规划的相邻扇区同步已经足矣，因为使用这些信道的非同步扇区空间分隔将足够大或面向不同方向以避免共道干扰。

在上面参考的标题为“TTD 频率再用”的专利申请中包含了对这种频率再用规划的示例讨论。在使用频率再用的环境中，通过在配置启动操作期间用于物理配置集线器的集线器的非易失存储器中存储指配信道，可为集线器和它们各自的扇区指配信道。或者，根据动态信道指配算法可以动态指配信道。在这种情况下，信道控制器可实现特定的动态指配算法，并且周期性地传递指配的信道给集线器以用于各自的扇区。

在时刻 t_7，集线器 105-108 同步以进入接收模式。此刻，集线器 105-108 可从它们各自的子设备接收发射而不用检测从其他集线器发送的 RF 信号。在接收模式期间，集线器 105 分别从子设备 109-111 接收 RX 突发 410-412。集线器 106 从子设备 114 接收 RX 突发 413。类似地，集线器 107 分别从子设备 115 和 116 接收 RX 突发 414 和 415。集线器 108 分别从子设备 117-119 接收 RX 突发 416-418。集线器 105-108 优选同步以在时刻 t_{13} 结束它们的接收模式。

另外，这个实施例还具有其他优点。首先，相邻集线器能够直

接通信，因此可协调帧定时和/或信道分配而无需独立的遥测线路。其次，在同步方式中协调信道分配所必需的遥测带宽在相邻集线器配置中大为降低。此外，相邻扇区同步所需的计算容量比群集宽度的同步要少得多。

应理解的是，本发明通过除更高信道再用外的其他考虑使得系统利用和性能更高。通过同步相邻扇区或相邻天线束，本发明并不对与其他扇区或天线束相关的发射和接收非对称施加任何其他的任意限制。例如，可能相邻扇区中的子设备总共需要大量的发射带宽，但在某个特定时刻只需要极小的接收带宽。同时有可能非相邻扇区的子设备总共需要相反的带宽需求。如果整个扇区组都同步，则在相邻和非相邻扇区中都将浪费一部分带宽。因此，本发明独立于其他非对称操作相邻扇区的发射和接收非对称。通过分隔非对称关系，系统可适应整个系统固有的在各个时刻改变的带宽需求。

还应理解的是，本发明并不要求集线器 105-108 在确切的时刻开始或结束它们的发射模式或接收模式。然而，更为精确的同步将缩短保护时间，从而使得系统的吞吐量最大。此外，本发明并不需要为子设备提供任何特定的信道带宽分配。应理解的是，可使用任何数量的信道划分技术。在单个发射/接收周期期间所有带宽可分配给一个特定的子设备。或者，在 TDM/TDMA 方案中，在扇区中的每个子设备可在每个发射/接收周期接收指定部分的可用带宽。或者，可根据轮询方案分配子设备带宽。集线器可实现任何数量的算法以便为特定子设备调度带宽。也可通过其他技术划分接收和发射模式。例如，子设备可利用 CSMA/CD 技术发送突发给集线器。或者，系统可利用竞争周期和无竞争周期用于子设备访问通信信道。

应理解的是，根据本发明在所选择的信道上在集线器和子设备之间可出现其他各种信令。例如，集线器可发送预定用于所有子设备的广播突发。集线器可发送控制信道突发。另外，集线器可发送包含定时信息或网络分配向量的信标信号以使子设备与集线器同步。这些信令可包含请求发送，允许发送，或确认数据突发。

应理解的是，本发明并不需要严格定义发射和接收模式。例如，TDM/TDMA 电话系统严格定义了接收和发射模式的定时和持续时间以优化系统传输话音业务。相反，本发明可在具有非对称发射和接收模式的系统内部工作。而且，本发明也可用于动态改变发射和接收模式的持续时间的系统中。在上面参考的标题为"宽带毫米波数据通信的系统和方法"的专利申请中描述了本发明可使用的示例性动态带宽分配系统和方法。根据一个优选实施例，为便于动态改变分配给发射和接收模式的带宽，本优选实施例的集线器拥有的同步扇区将这些变化传递给对应的集线器和/或公共控制系统。因此，本发明的另一方面能提供用于同步受共道耦合的集线器的发射和接收模式的遥测通信信道。

可采用若干方案来提供这种通信信道。来自 ILEC（平覆？本地交换载波）的租用连接可用于同步遥测。然而，优选使用与点到多点系统相关的通信资源，而不是 ILEC 连接。因此，扇区同步遥测可使用与点到多点网络相关的回程。回程可在任何形式的通信装置中实现，如宽带光纤网关或其他宽带数据级连接，T1 通信线路，有线通信系统等等。然而，对利用这种控制信道实现扇区同步的群集的每个集线器来说，需要与回程连接或与回程相连的其他系统。尽管这在许多系统中可能足够了，但这不是最佳方案，因为特定系统可能拥有不与该回程相连的集线器。

图 5 示意了涉及与主载波带相邻的窄载波带的同步遥测的优选选项。在本发明的一个优选实施例中，点到多点系统的频谱被划分为离散的 50 MHz 信道。基本数据通信通过占据大约 46 MHz 的正交调幅（QAM）载波 501 实现。另外，在 50MHz 信道的保护空间建立窄带自适应载波 502，优选带宽为 130 kHz，以提供同步遥测。集线器优选利用两极 FSK 调制以通过自适应载波 502 传递信息。在一个优选实施例中，自适应载波 502 包含 100 Kbps 信令率，用于 10^{-12} BER 的 10dB C/N，1/2 级联编码，以及低于 QAM 功率级别 10dB 的发射功率。通过利用这种类型的信道，可通过集线器的特定群集的相邻扇

区天线束发送和/或接收控制信道。

应理解的是，窄带自适应载波 502 提供优化用于 50 MHz 系统的优选信令信道。然而，应理解的是，并不需要遥测控制信道实现为窄带载波。如果本发明用于宽带点到多点系统中，则遥测控制信道可以是跨越较大频谱处理的扩展频谱。另外，并不需要在与预定信道相关的保护空间放置自适应载波 502。自适应载波可利用明确分配的频谱实现。

在优选实施例中，利用本发明的相邻集线器可从它们各自的子设备接收带宽请求。集线器可基于带宽计算进行计算。在这种类型的系统中，带宽控制器可位于一个集线器以通过自适应载波 502 接收带宽计算的结果。或者，带宽控制器可实现为到达相应集线器的独立系统链路。

带宽控制器利用接收的计算为同步的扇区确定最佳发射和接收模式持续时间。控制集线器利用自适应载波将所确定的发射和接收模式持续时间传递给集线器。集线器在此时刻利用这些持续时间来为相邻扇区内它们各自的子设备分配发射和接收资源。应理解的是，控制器可接收带宽请求并直接进行计算。然而，优选在集线器进行计算，因为它能更为有效地分配处理需求。还应理解的是，在自适应载波链路被中断的情况下，集线器可包含控制接收和发射模式的逻辑。例如，集线器可暂时回复用于发射和接收模式的预定长度。或者，集线器可暂时定义相同长度的发射和接收模式。

例如，本发明的带宽控制器可监视在前向和反向链路上的瞬时业务需求，从而确定适当量的 ATDD 和/或操作载波信道所用的非对称。本发明的优选实施例的带宽控制器可在本发明的集线器的处理器（CPU）和相关存储器（RAM）上工作。控制器可在非易失寄存器包含相邻天线束和相应信道的记录以便实现所希望的同步。或者，带宽控制器可工作于动态改变扇区和/或动态分配信道给各个扇区的环境中。在此环境中，带宽控制器可与影响扇区配置和/或信道分配算法的那部分系统通信以获得涉及相邻天线束和它们的信道的信息。当

然，附加和/或其他装置，如具备控制其操作的适当算法的基于计算机系统的通用处理器，可用于操作本发明的带宽控制器。

现在参考图 6A，集合 600 是对每频道两极化可用的通信系统的 8 个可用频道的概念描述，在此也称为“频率”。频率集合 601 位于一个极化上，而频率集合 602 位于另一极化上。优选频率集合 601 和频率集合 602 的极化相互正交以使工作在相同频率但不同极化的天线之间的干扰可能性最小，这将在下面进一步讨论。极化可以是水平和垂直对齐，或左斜和右斜对齐，但不局限于这些方式。

应理解的是，尽管下面的讨论研究用于 8 个频率和两个极化的频率再用模式，但本发明的系统和方法并不局限于 8 个频率和 2 个极化。有关在此公开的频率再用模式的原理同样适用于对使用本发明的系统和方法的频率再用模式的通信系统有 8 个以上可用频率的情形。

图 6B 描绘了 8 个小区，如图 2A 所示的小区，其中每个小区被分为 4 个 90°基本上不重叠的扇区。每个小区的集线器至少每扇区有一个天线，例如，图 2B 所示的集线器 105。如图 6B 所示，小区的反向扇区工作于相同频率/极化指配。以小区 610 为例，扇区 601A 和 601D 工作于频率/极化 601A，而扇区 610B 和 610C 工作于频率/极化 602T。尽管只显示这种扇区指定用于小区 610，但应理解的是，这种扇区指定可适用于每个小区，而且在整个说明书和附图中都适用。由于存在图 6A 所示的 8 个频率和每频率 2 个极化，因此存在 16 种唯一的可用频率/极化扇区指配，或“自由度”。在频率再用方案中，使相邻信道和共道干扰最小很重要，以便使小区中频率/极化扇区指配之间的“距离”最大，即，优选最大频率间隔和正交极化指配。另外，对于自适应时分双工系统（“ATDD”），频率间隔的最大化能使与小区内独立的动态非对称帧使用相关的耦合问题减少到最小。优选如图 6A 所示的 16 个自由度的指配模式，因为这种模式导致小区的扇区指配之间的“距离”最大。本发明的系统和方法计划使用其他的 16 自由度指配模式。

利用上面讨论的扇区指配模式，如果一次使用每个 16 扇区指配

或16自由度，则可能存在8个唯一的“小区类型”。图6B中的每个小区就是一个唯一的小区类型。这8个小区类型将以特定方式排列以便使共道和相邻信道干扰最小，同时对具有图6A的频率/极化指配的通信系统获得最大的操作区域覆盖。

现在关注图7，描述多小区频率再用模式的一部分。如图所示，16小区4×4直线格栅710由4个2×2小组，即701-704构成。参考图7的方位，16小区格栅710在垂直和水平方向上可重复，以便覆盖区域能大于格栅710的一个实例所覆盖的区域。在格栅710中如此排列小区使得每个小区能占据一个唯一的行和列位置，其中在图7的最下一行上的所有小区在指定行720内，而在图7的最左列的所有小区在指定列730内。在16小区直线格栅710中如此排列小区使得行和列相邻的小区正切，但在对角线上相邻的小区不正切。行和列的指定是任意的，只用于方便精确地描述该模式中小区的排列。这种行和列指定并不是本发明的一部分，因此无论如何不应认为是对本发明的限制。

现在参考图8，描绘位于图7的直线格栅710的左下象限内的4小区小组703。在小区小组703中四个小区的每个小区都是在上面讨论和在图6B示意的8个小区类型中的唯一一个。小区650与其行和列相邻小区正切，即，小区650与小区610和小区660相切。小区610、620、650和660定位于小区小组703,以便对于行和列相邻小区对面小区的极化不相同。例如，小区650中的扇区650B是一种极化，而其在行相邻小区660中的对面扇区，即扇区660A，为另一种极化（参考图6A中的两种极化）。通过观察图7和图8，可以看到对4个小区小组701-704，行和列相邻小区的对面小区的极化均不相同。这种在小组内定位小区的方式能使上面讨论的共道和相邻信道干扰最小。

再次参考图7，并且现在关注小区小组704，小区小组704中的4个小区均是在上面讨论和在图6B中显示的8个小区类型中的唯一一个。另外，小区小组704中的每个小区的小区类型不同于小区小组

703 中使用的小区类型。换言之，在图 6B 所示的 8 个小区类型中，其中有 4 个小区类型用在小区小组 703，而另外 4 个小区类型用在小区小组 704。小区小组 704 中小区的定位类似于上面讨论的小区小组 703 中小区的定位，即，行和列相邻小区的对面小区的极化不相同。此外，并且优选对于小区 620、660、630 和 670，行相邻小区的对面小区的极化不同，如图 7 所示。

上面已经讨论了在 4 个小区小组中小区的定位和排列方式，应指出，在小区小组 703 和 702 中小区之间存在关系，而且在小区小组 704 和 701 中小区之间也存在关系。参考图 7 中的小区小组 703 和 702，可以看到在每个小区小组中出现相同的 4 个小区类型，而且在每个小区小组中小区的排列方式相同，即在小区小组 703 中小区 650 与小区小组 702 中的小区 650S 是相同的小区类型。然而，在反向扇区对之间已经交换了每个小区的频率/极化指配。然而，对于小区小组 703 中的小区 650 来说，右上和左下扇区为第一频率/极化组合，在小区小组 702 中小区 650S 的左上和右下扇区出现相同的第一频率/极化组合。对于小组 703 和 702 中的每个小区情况也是这样。观察这种关系的另一方式是小区小组 702 中的小区已经从小区小组 703 中的小区方向旋转 90°。同样地，小区小组 704 和 701 中的小区以相同方式相关。

改变小区小组 703/702 和 704/701 之间的小区的方向的原因是使同一小区类型的小区的扇区之间的共道干扰最小。如果，例如，小区 650S 与小区 650 为同一方向，则小区 650 的对面扇区 650A 和小区 650S 的扇区 650SC 将工作在具有相同极化的相同频率上。如果小区半径指定为“R”，则小区 650 和 650S 的集线器之间的距离为 $4R\sqrt{2}$，这个距离不足以防止共道干扰。对反向扇区交换频率/极化有助于克服集线器之间距离不足的问题。利用图 7 的频率再用方案，对面扇区工作于相同频率/极化的集线器之间的距离为 $8R\sqrt{2}$，这是上一例子距离的 2 倍。上述用于 4×4 直线格栅 710 的模式可以在水平和垂直方向上重复，以便为大于格栅 710 的区域提供覆盖。如图 7 所

示，重复小区的行和列以示意水平和垂直可重复性的观点。应理解的是，本发明并不局限于图 7 所示的特定数量的小区，也不局限于特定的小区类型指配或扇区方向。可以认为，利用上述概念的可重复直线格栅都在本专利的范围之内。

现在转到图 9，描绘一种不同的小区描述，在此称为“移位和挤压（shift and squish）”模式。从图 7 中可看出，直线格栅 710 的可重复模式使得在小区之间出现一个相当大的静区。位移和挤压模式 910 能消除大部分的这种隙间静区。如同采用直线格栅 710 一样，位移和挤压模式 910 包含两个均为 8 小区类型的 16 个小区。在移位和挤压模式 910 的下两行小区，类似于直线格栅模式 710 中的下两行小区，由图 6B 所示的一个 8 小区类型构成。同样，在移位和挤压模式 910 中的上两行小区也由与下两行相同的一个 8 小区类型的另一集合构成，类似于在直线格栅模式 710 中上两行小区由与下两行相同的一个 8 小区类型的另一集合构成。然而，与直线格栅 710 不同的是，移位和挤压模式 910 的上两行小区与移位和挤压模式 910 内的下两行小区的不是以相同的相对方向排列。例如，小区 901-904 以从左至右的顺序排列为 901/902/903/904，而对应的小区 901S-904S 从左至右排列为 904S/901S/902S/903S。在格栅 910 的其他两行中的小区也保持相同关系。另外，对应小区类型的小区中两对反向扇区的频率/极化指配也被交换。

移位和挤压模式 910 如图 9 所示可重复。该模式中 16 个小区的排列方式使得没有一个小区在任何一个方向与同一小区类型中的两个小区正切相邻。由于这种模式如图 9 所示可重复，因此这种关系有效。

在移位和挤压模式 910 中具有工作于相同频率/极化的对面扇区的小区，如小区 901 和 911 的集线器之间的间隔接近 10R，这是在直线格栅 710 中具有工作于相同频率/极化的对面扇区的集线器之间距离的大约 88%。小区 901 和 911 的集线器之间的距离应足以防止共道干扰。

现在参考图 10，描绘另一种多小区频率再用模式的一部分。这种 16 小区 4 ×4 直线格栅 1010 由 4 个 2 ×2 小组，1001-1004 构成。参考图 10 的方向，16 小区格栅 1010 在垂直和水平方向上可重复，以便能覆盖面积大于格栅 1010 的一个实例所覆盖的区域。格栅 1010 中小区的排列类似于图 7 中格栅 710 的小区，以便每个小区占据一个唯一的行和列位置，而且行和列相邻小区正切，但在对角线上相邻的小区不正切。

图 11A 描绘了用于每频信两极化可用的通信系统的 8 个可用频道集合 1100，其类似于图 6A 中的频率集合 600。在集合 1100 的 16 个频率/极化自由度中，描绘了 8 个频率/极化自由度的集合 1103 和另外 8 个频率/极化自由度集合 1104。在图 10 的频率再用模式中使用自由度集合 1103。自由度集合 1104 不必填充图 10 的频率再用模式的小区，其保留用于将来可能的用途，这将在下面进行描述。

图 11B 示意了在图 10 的频率再用模式直线格栅 1010 中使用的 8 个小区类型。如图 11B 所示，每 8 个小区类型的一个特定小区的每个扇区相对该小区的其他扇区工作于唯一的频率/极化指配。对每个小区类型来说，有一对相邻扇区工作于第一极化，而另一对相邻扇区工作于两种可能极化中的第二极化。以小区 1110 为例，每个扇区 1110A-1110D 均工作于互不相同的频率/极化。由于采用图 11A 所示的 4 个频率和每频率两个可用极化，因此存在 8 个可用自由度。由于有下面讨论的限制，采用 8 个不同的小区类型来填充直线格栅 1010。

现在参考图 12，描绘位于图 10 的直线格栅 1010 中左下象限的 4 小区小组 1003。在小区小组 1003 中，4 个小区的每个小区都是上面讨论和在图 11B 中示意的 8 个小区类型中的唯一一个。另外，在 4 小区小组 1003 中，每个小区的对面扇区为相同频率/极化，而与该小区是行和列相邻还是对角线相邻无关。例如，如图 12 所示，对于所有 4 个小区的面向中心的扇区，1110D、1120C、1150B 和 1160A，都为相同的频率/极化指配。另外，小区 1110 的扇区 1110C 和小区

1150 的扇区 1150A 面对面，并且具有相同的频率/极化指配。对于下述扇区：1150D 和 1160C，1160B 和 1120D，以及 1110B 和 1120A，情形也相同。此外，在 4 小区小组 1003 中对角线相邻小区的反向扇区具有相同的频率/极化指配：扇区 1150C 和 1120B 以及扇区 1110A 和 1160D。这些频率/极化指配使得直线格栅 1110 的模式可重复，这从图 10 可看出，同时使共道和相邻信道干扰最小。

再次参考图 10，现在关注小区小组 1004，在小区小组 1004 中，4 个小区中的每个小区都是上面讨论和在图 11B 所示的 8 个小区类型中的唯一一个。另外，小区小组 1004 中每个小区的小区类型与在小区小组 1003 中使用的小区类型不同。换言之，在图 11B 描绘的 8 个小区类型中，其中 4 个小区类型用于小区小组 1003，而另外 4 个小区类型用于小区小组 1004。在小区小组 1004 中小区的定位类似于上面讨论的在小区小组 1003 中小区的定位：4 小区小组 1004 中每个小区的对面扇区具有相同频率/极化，而不管这个小区是行和列相邻还是对角线相邻。

上面已经讨论了在 4 小区小组中小区的定位和排列方式，应指出，在小区小组 1003 和 1002 的小区之间存在关系，而且在小区小组 1004 和 1001 的小区之间也存在关系。参考图 10 中的小区小组 1003 和 1002，可以看出在每个这些小区小组中均出现相同的 4 个小区类型，而且在每个小区小组中小区的排列方式和小区内的扇区定位都相同，即，小区小组 1003 中的小区 1150 与小区小组 1002 中的小区 1150S 为相同小区类型。同样，小区小组 1004 和 1001 中的小区以相同方式相关。

直线格栅 1010 也可在水平和垂直方向上重复，类似于直线格栅 710 的可重复性。应指出，在可重复模式内任何 2 ×2 格栅的 4 个小区的向内扇区具有相同的频率/极化指配。这种排列方式使得这些向内扇区同步，这已经在上面进行了充分描述。

具有相同频率/极化指配但非相邻对面扇区的任何两个对面扇区之间的距离为 $6R\sqrt{2}$。这个距离应足以防止在具有相同频率/极化指配

的非相邻对面扇区之间出现共道干扰。如果存在共道干扰，也可同步具有干扰的非相邻对面扇区的两组 4 小区以避免共道干扰问题。

参考图 13，示意类似于图 10 的直线格栅 1010 的直线格栅 1310。然而，格栅 1310 包含这些扇区的扇区覆盖，在此称为重叠扇区。为此，系统的容量不足以支持这些扇区内的用户需求。所增加的扇区覆盖表示在存在覆盖的小区的集线器处增加的天线和对应电路。增加的扇区覆盖通常不是对重叠扇区的简单替换。增加的覆盖工作不同于重叠扇区的频率上，但具有相同极化。这种配置使得能共用在重叠和覆盖扇区之间的保护或冗余设备。覆盖扇区的大小通常等于或小于重叠扇区的大小。如图 13 所示，重叠扇区为 45°扇区，但本发明的系统和方法并不局限于 45°扇区。另外，图 13 示意了添加到 4 个小区 1-4 的每个扇区的其中一个的覆盖扇区 1390，这仅仅是覆盖扇区的一种使用例子。本发明的系统和方法并不局限于添加覆盖扇区到 4 个对面扇区小组中，而是可根据用户的需要添加或多或少覆盖扇区。为 4 个相邻小区的 4 个对面扇区都添加覆盖扇区使得，添加的 4 个覆盖扇区能以类似于 4 个基础重叠扇区的同步方式同步。自然地，也可添加和同步少于 4 个覆盖扇区。

尽管已经详细描述了本发明及其优点，但应理解的是，在此可进行各种变化、替换和修改而不偏离所附权利要求书定义的本发明的精神和范围。此外，本申请的范围并不局限于在此说明书中描述的过程、机械、产品、材料成分、装置、方法和步骤。本领域的技术人员从本发明的说明书中将理解，根据本发明也可使用当前存在或今后将开发的能执行与在此描述的对应实施例基本上相同功能或实现基本上相同结果的过程、机械、产品、材料成分、装置、方法或步骤。因此，所附权利要求书在其范围内包含这些过程、机械、产品、材料成分、装置、方法或步骤。

图1

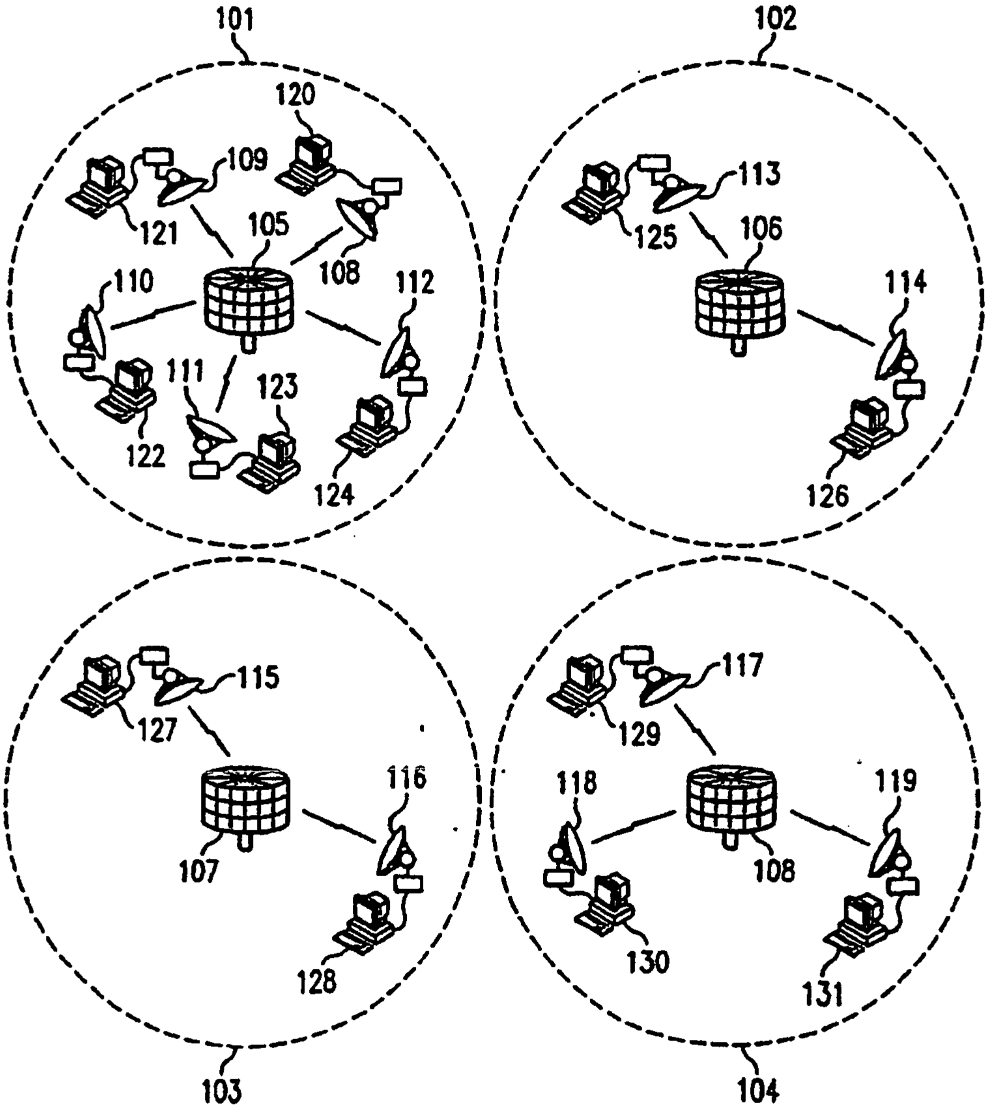

101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131

图2A

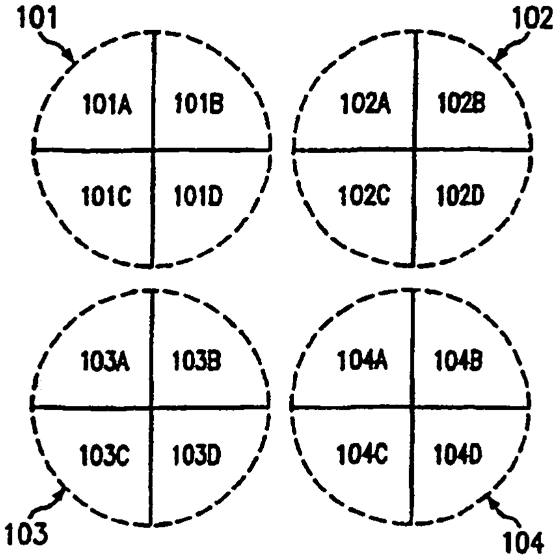

101
102
101A
101B
101C
101D
102A
102B
102C
102D
103A
103B
103C
103D
104A
104B
104C
104D
103
104

图2B

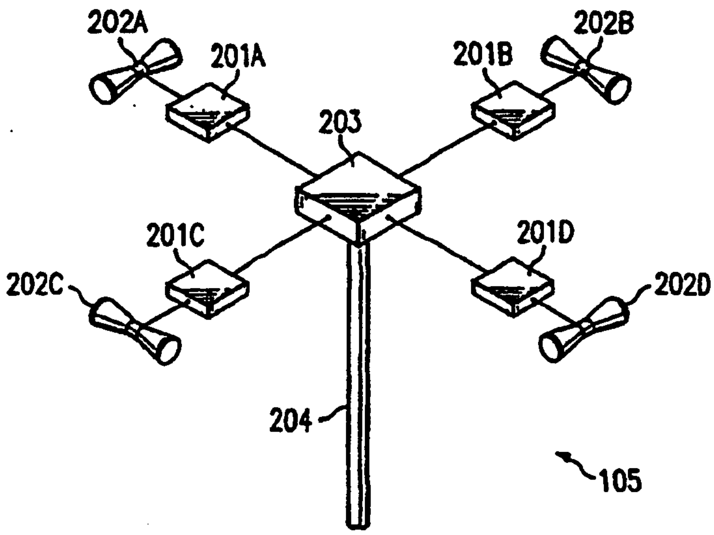
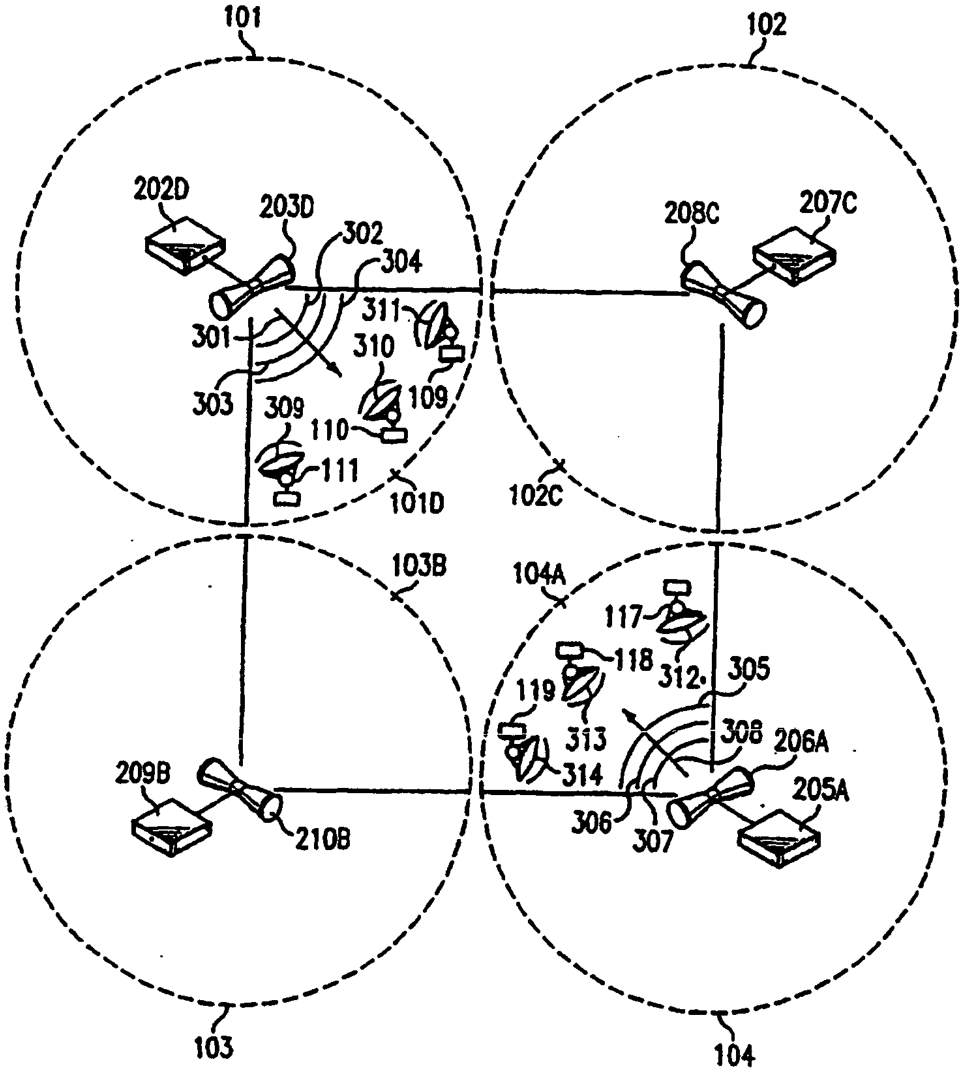

202A
201A
201B
202B
203
201C
201D
202C
202D
204
105

图3



101
102
202D
203D
302
304
301
311
310
109
303
309
110
111
101D
102C
208C
207C
103B
104A
117
118
312
305
119
313
308
206A
314
205A
306
307
209B
210B
103
104

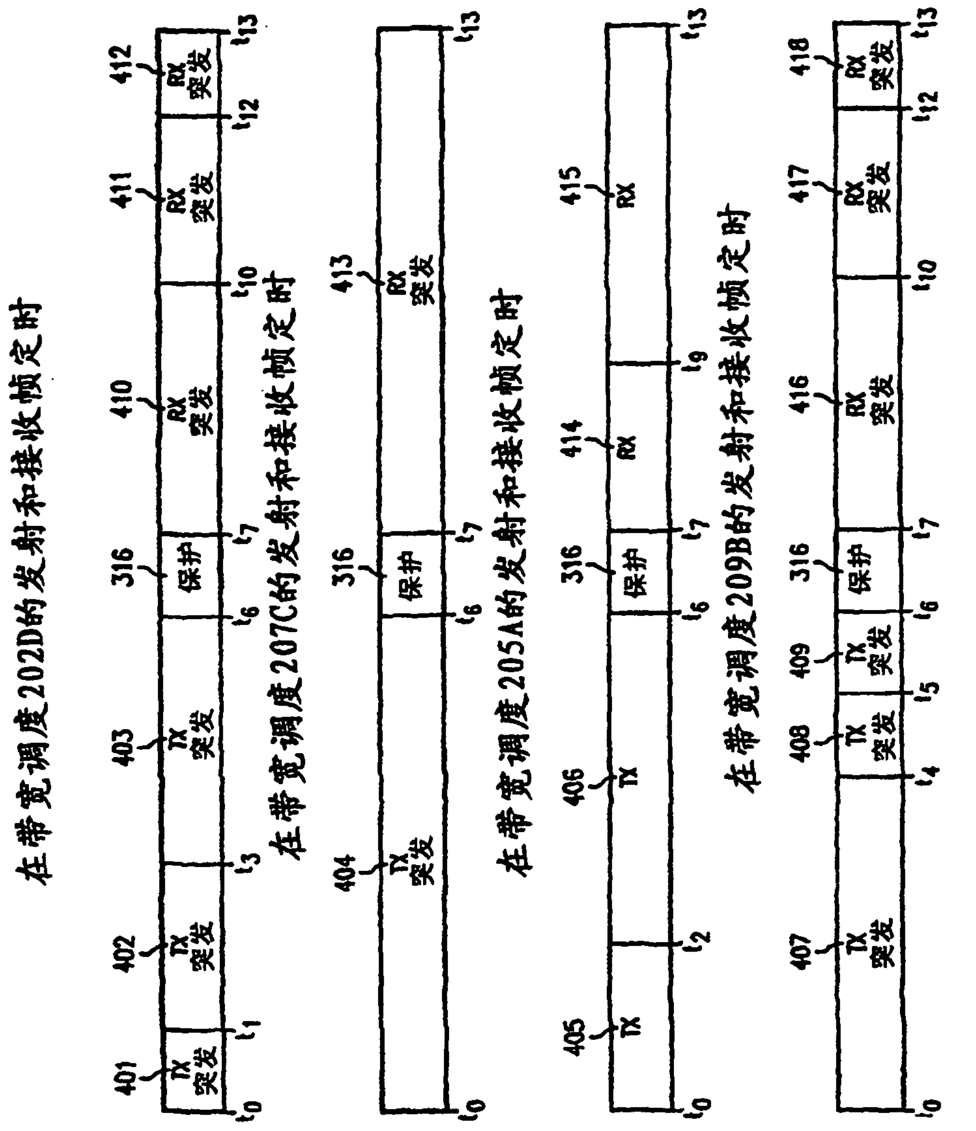


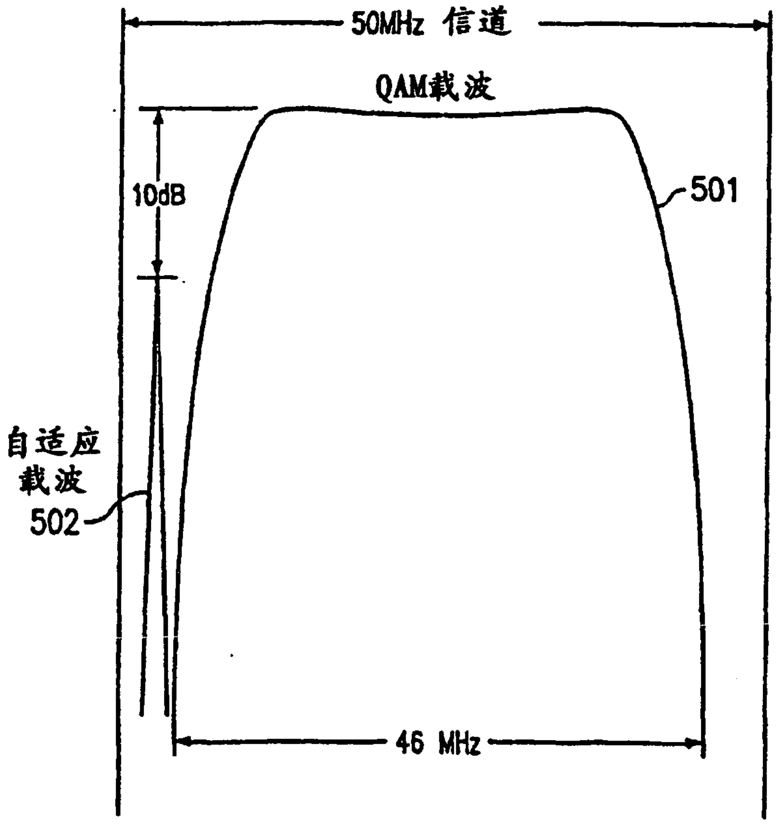
图4A

图4B

图4C

图4D

图5



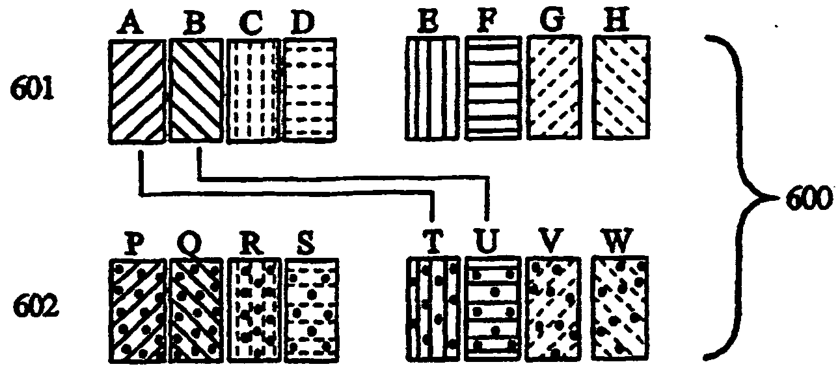


图6A

图6B

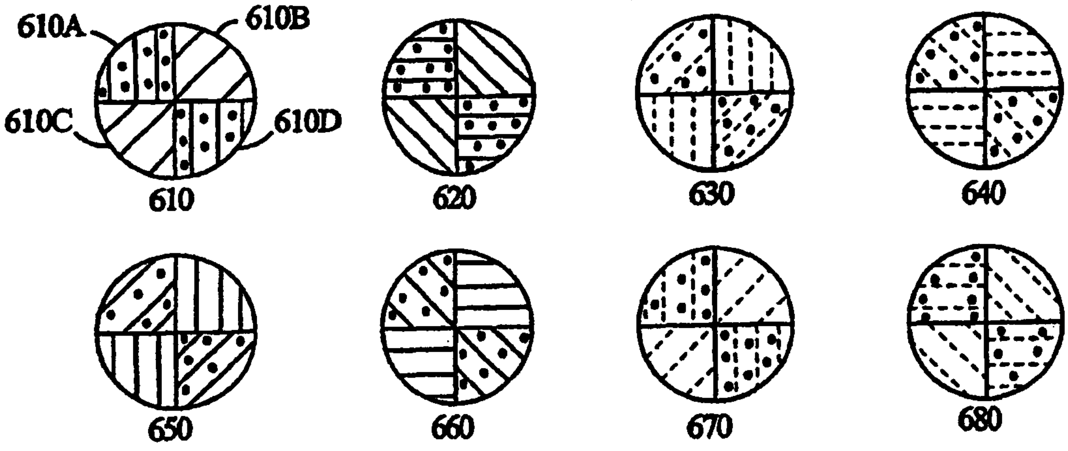


图7

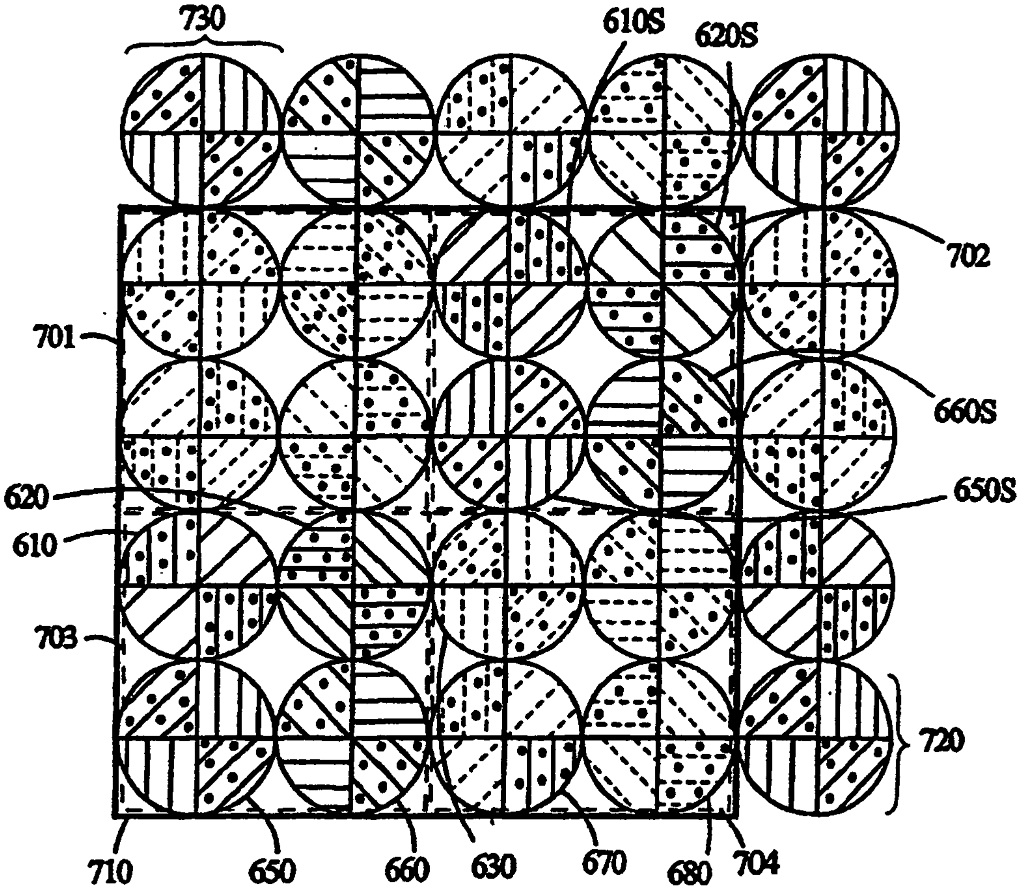

730
610S
620S
702
701
660S
620
650S
610
703
720
710
650
660
630
670
680
704

图8

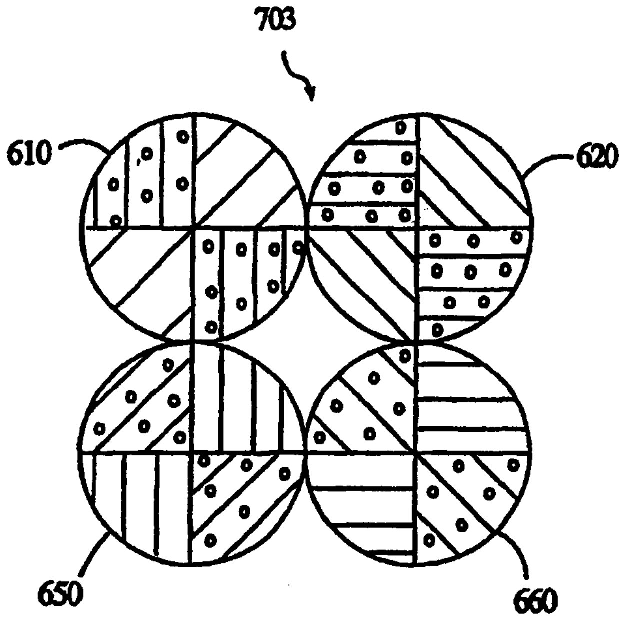


图9

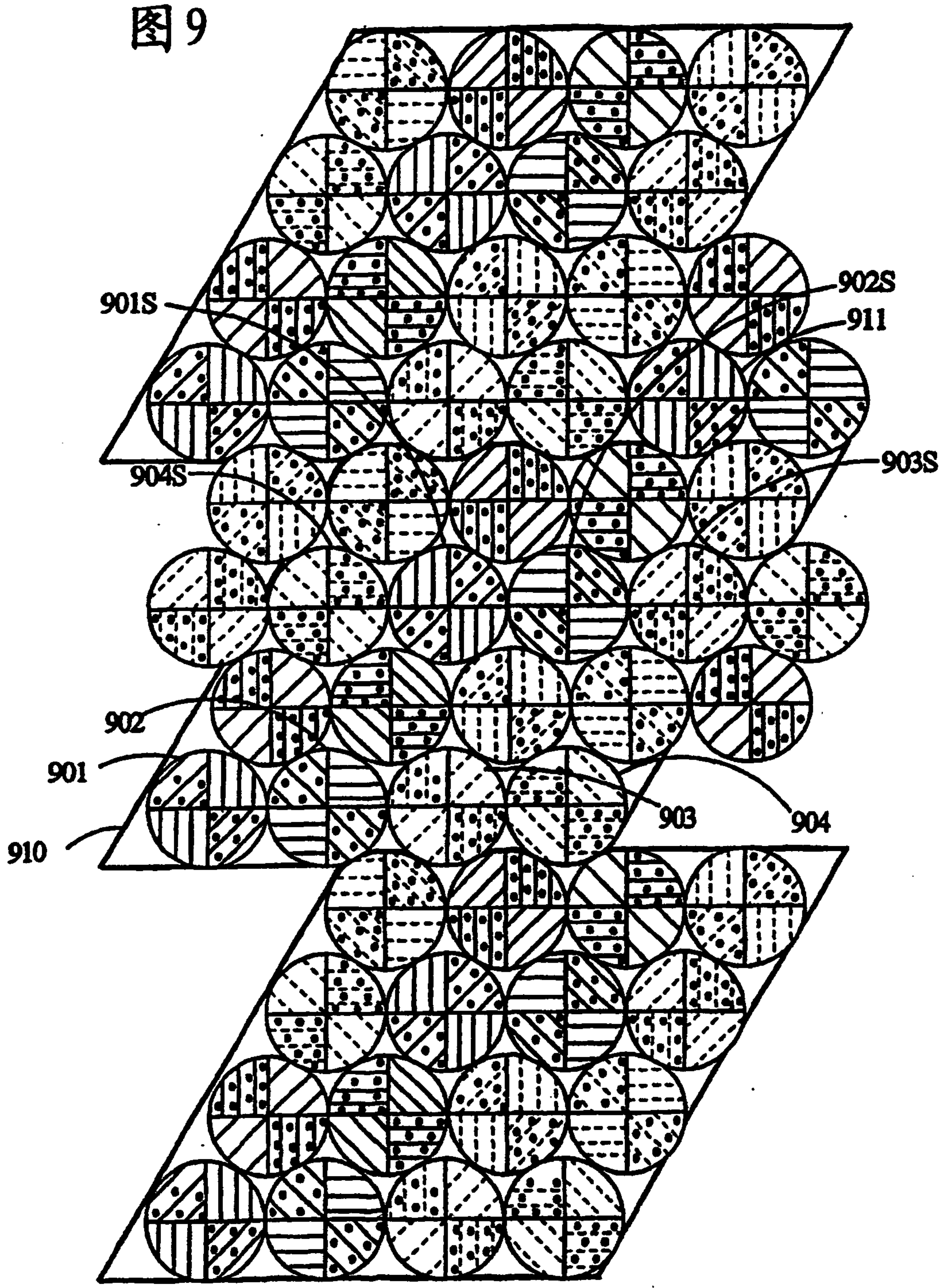


图10

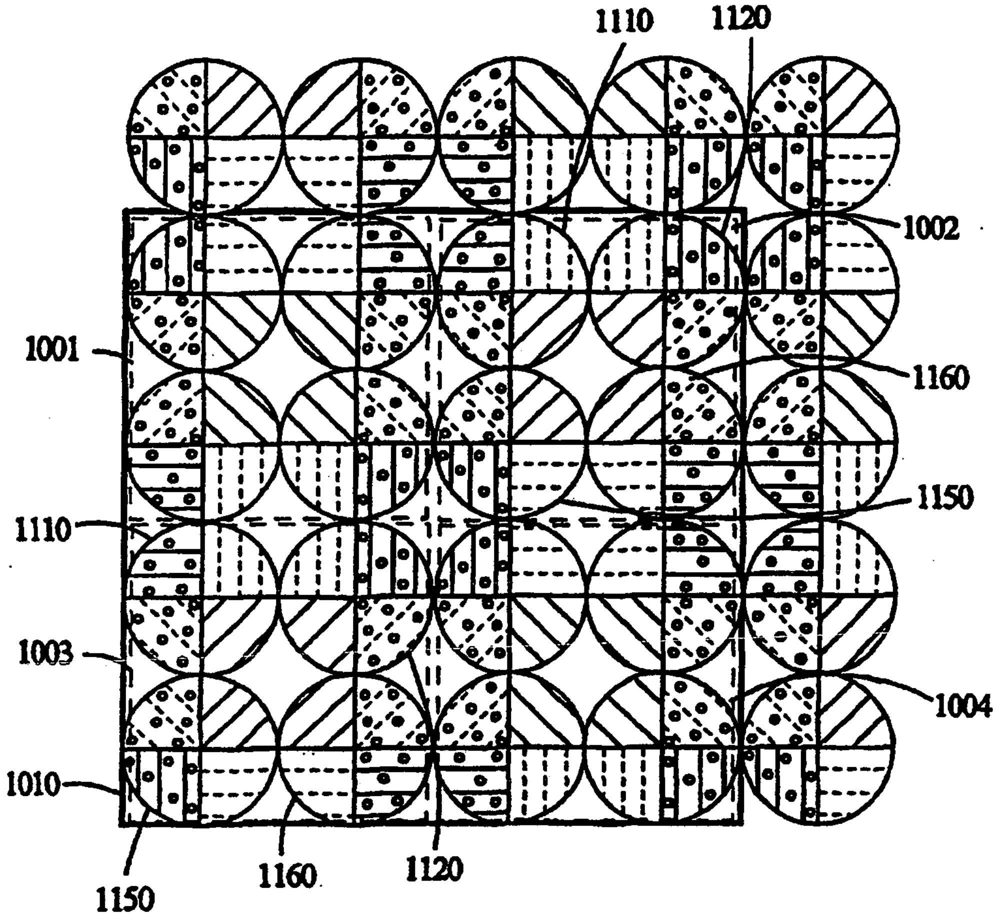

1110
1120
1002
1001
1160
1150
1110
1003
1004
1010
1150
1160
1120

图11A

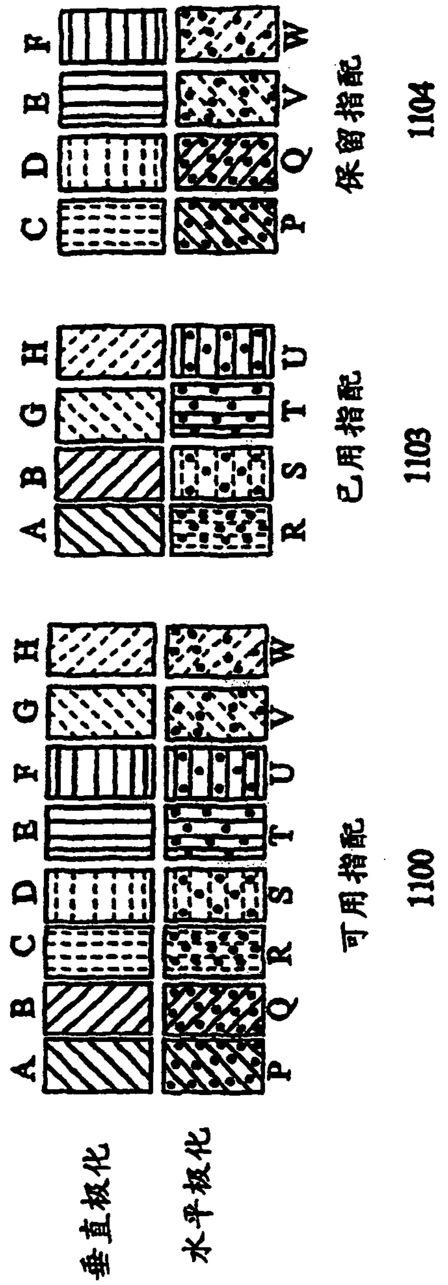

垂直极化
水平极化
A B C D E F G H
P Q R S T U V W
可用指配
1100
A B G H
R S T U
已用指配
1103
C D E F
P Q V W
保留指配
1104

图11B

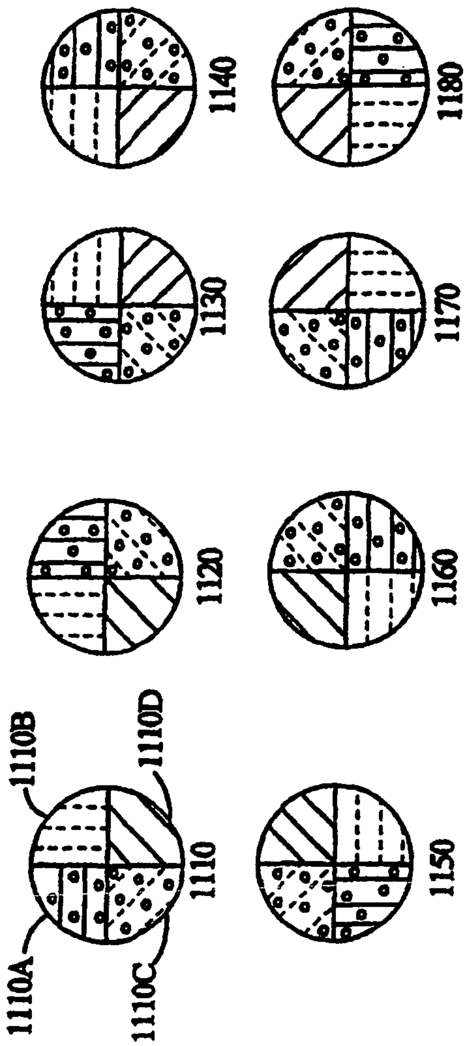

1110A
1110B
1110C
1110D
1110
1120
1130
1140
1150
1160
1170
1180

图12

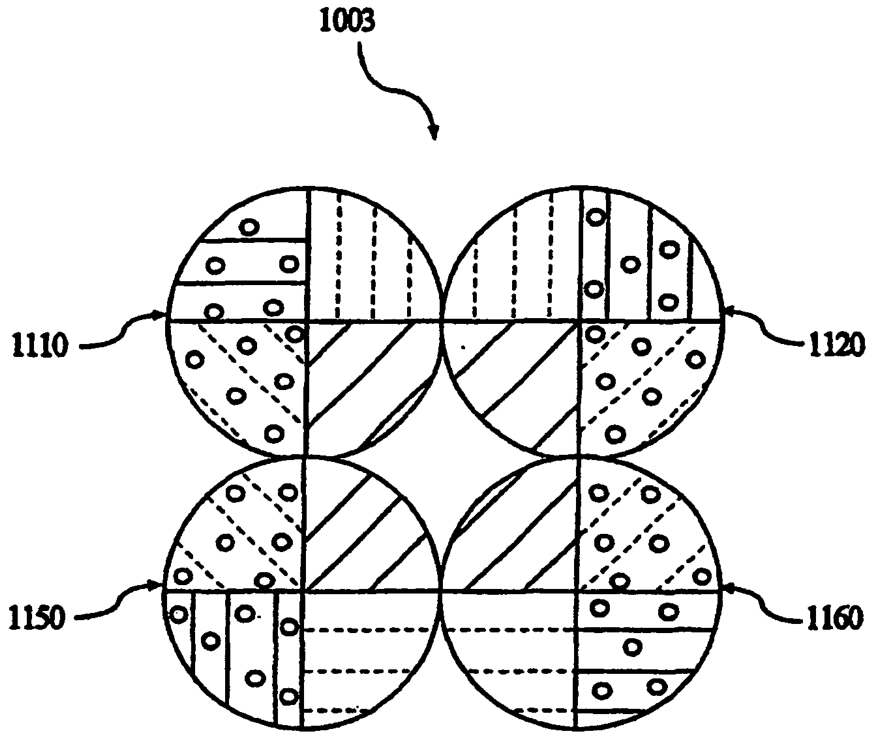


图13