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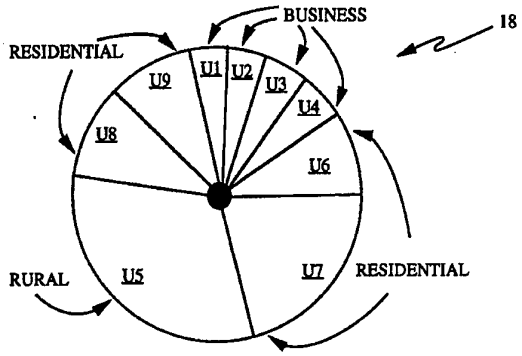
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(54) Title: DYNAMIC SECTORIZATION IN A SPREAD SPECTRUM COMMUNICATION SYSTEM



(57) Abstract

A system and method for dynamically varying traffic channel sectorization within a spread spectrum communication system is disclosed herein. In a preferred implementation the system is operative to convey information to at least one specified user in a spread spectrum communication system and includes a pseudorandom code generator (50) for generating, at a predetermined chip rate, a pseudorandom noise (PN) signal of a predetermined PN code. The PN signal is then combined with a first information signal in a spread spectrum transmitter (42) to provide a PN spread information signal. The system further includes at least one additional spread spectrum transmitter (44, 46) each for receiving through a respective delay element (52, 54) delayed versions of the PN signal for providing at least one additional modulation signal. A switching transmission network (74) is disposed to selectively transmit via antennas (85, 86) the first and additional modulation signals respectively to a first and at least one additional coverage area. Selective transmission of the first and the at least one additional modulation signal results in variation in size of a first user sector. The first user sector is associated with a first set of traffic channels, one of which is allocated to the specified user. The system may also be configured to selectively receive, and coherently combine, first and second modulation signals from first and second coverage areas.

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DYNAMIC SECTORIZATION IN A SPREAD SPECTRUM COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communication systems utilizing spread spectrum signals, and, more particularly, to a novel and improved method and apparatus for dynamic channel sectorization within a spread spectrum communication system.

II. Description of the Related Art

Communication systems have been developed to allow transmission of information signals from a source location to a physically distinct user destination. Both analog and digital methods have been used to transmit such information signals over communication channels linking the source and user locations. Digital methods tend to afford several advantages relative to analog techniques, including, for example, improved immunity to channel noise and interference, increased capacity, and improved security of communication through the use of encryption.

In transmitting an information signal from a source location over a communication channel, the information signal is first converted into a form suitable for efficient transmission over the channel. Conversion, or modulation, of the information signal involves varying a parameter of a carrier wave on the basis of the information signal in such a way that the spectrum of the resulting modulated carrier is confined within the channel bandwidth. At the user location the original message signal is replicated from a version of the modulated carrier received subsequent to propagation over the channel. Such replication is generally achieved by using an inverse of the modulation process employed by the source transmitter.

Modulation also facilitates multiplexing, i.e., the simultaneous transmission of several signals over a common channel. Multiplexed communication systems will generally include a plurality of remote subscriber units requiring intermittent service of relatively short duration rather than continuous access to the communication channel. Systems designed to enable communication over brief periods of time with a set of subscriber units have been termed multiple access communication systems.

A particular type of multiple access communication system is known as a spread spectrum system. In spread spectrum systems, the modulation

technique utilized results in a spreading of the transmitted signal over a wide frequency band within the communication channel. One type of multiple access spread spectrum system is a code division multiple access (CDMA) modulation system. Other multiple access communication system techniques, such as time division multiple access (TDMA), frequency division multiple access (FDMA) and AM modulation schemes such as amplitude companded single sideband are known in the art. However, the spread spectrum modulation technique of CDMA has significant advantages over these modulation techniques for multiple access communication systems. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Pat. No. 4,901,307, issued Feb. 13, 1990, entitled "*Spread Spectrum Multiple Access Communication System Using Satellite or Terrestrial Repeaters*", assigned to the assignee of the present invention.

In the above-referenced U.S. Pat. No. 4,901,307, a multiple access technique is disclosed where a large number of mobile system users each having a transceiver communicate through satellite repeaters or terrestrial base stations using CDMA spread spectrum communication signals. In using CDMA communications, the frequency spectrum can be reused multiple times thus permitting an increase in system user capacity. The use of CDMA results in a much higher spectral efficiency than can be achieved using other multiple access techniques.

In particular cellular CDMA systems communication between a base station and subscriber units within the surrounding cell region is achieved by spreading each transmitted signal over the available channel bandwidth by using a unique user spreading code. In such CDMA systems the code sequences used for spreading the spectrum are constructed from two different types of sequences, each with different properties to provide different functions. There is an outer code that is shared by all signals in a cell or sector that is used to discriminate between multipath signals. In addition, adjusting the phase of the outer code allows it to be used to discriminate between sets of users grouped into "sectors" within a given cell. For example, the users within a given cell may be partitioned into three sectors by providing three phases of the outer code. There is also an inner code that is used to discriminate between user signals transmitted over a plurality of "traffic channels" associated with each user sector. Specific transmitted signals are extracted from the communication channel by despreading the composite signal energy in the communication channel with the inner code associated with the transmitted signal to be extracted.

Referring to FIG. 1A, there is shown a first exemplary cell 10 in which

are disposed a plurality of subscriber units 12 and a base station 14. As is indicated by FIG. 1A, the cell 10 is partitioned into six coverage areas C1-C6. The base station 14 may include a set of six fixed-beam antennas (not shown) dedicated to facilitating communication with subscriber units in the coverage areas C1-C6, respectively. The subscriber units 12 are grouped into a plurality of user sectors, each of which support an equivalent number of traffic channels. As is indicated by FIG. 1A, a first residential user sector encompasses the coverage areas C1 and C6, while a second residential user sector spans the coverage area C4. Similarly, a user sector including primarily rural areas is associated with the coverage areas C2 and C3, while business users are concentrated within the coverage area C5.

As is indicated by FIG. 1A, it is necessary that certain user sectors be relatively narrow in order to accommodate demand during peak periods of system utilization. For example, the relatively narrow breadth of the business user sector is necessitated by the high concentration of business users within coverage area C5 desiring to communicate during working hours, e.g., between 8 a.m. and 5 p.m. That is, if the scope of the business user sector were expanded to include regions other than coverage area C5 it is possible that an insufficient number of traffic channels would be available during business hours to accommodate all those desiring to place calls. In contrast, the diffuse concentration of subscriber units 12 among rural dwellings allows the traffic channels associated with the rural user sector to be allocated among users distributed over two coverage areas C2-C3.

Unfortunately, during non-working hours a number of the traffic channels dedicated to the business user sector will likely go unused, since at such times there exist significantly fewer business callers and a correspondingly larger number of residential callers. Accordingly, it would be desirable to be able to provide a high concentration of traffic channels to business users within coverage area C5 during business hours, and to provide a relatively lower traffic channel concentration during non-working hours.

Although there exist antenna arrays capable of adaptively shaping a projected beam in response to changing user demand, implementation of such antenna arrays within the system of FIG. 1A would require corresponding modification of the fixed -beam architecture of the base station 14. In addition, the relatively sophisticated RF/microwave circuits typically employed in adaptive beam-forming networks result in increased system cost and complexity. Accordingly, it is an object of the invention to provide a cost-effective technique for varying the concentration of traffic

channels in response to changes in the distribution of users within a spread spectrum cellular communication system.

In the specific instance of a CDMA communication system, each user sector is capable of supporting a given level of traffic demand. Accordingly, it is a further object of the invention to tailor the size of specific user sectors within a CDMA communication to the traffic channel demand within the sector. Such efficient traffic channel allocation would enable optimum utilization of communication system resources, thereby minimizing the cost per user.

In addition to addressing the need for flexible traffic channel allocation as a consequence of the short-term changes in user demand described above, it is a further object of the invention to accommodate long-term changes in user demand. Such long-term variation in demand could arise from, for example, shifts in population distribution and building patterns within a given geographic area.

A further disadvantage of conventional fixed-beam systems, such as the system of FIG. 1A, is that relatively accurate estimates of user demand must typically be available prior to system installation. That is, system designers generally must be supplied with detailed information related to expected demand patterns in order that the fixed-beam base station be configured to provide the requisite traffic channel capacity to each user sector. Changes in usage patterns occurring proximate the installation period thus tend to prevent optimal utilization of the available traffic channels. It is therefore yet another object of the present invention to provide a communication system capable of being tailored, upon installation, in accordance with existing patterns of traffic channel demand.

SUMMARY OF THE INVENTION

The present invention provides a system and method for dynamically varying traffic channel sectorization within a spread spectrum communication system.

In a preferred embodiment, the system of the invention is operative to convey information to at least one specified user in a spread spectrum communication system. The system includes a first network for generating, at a predetermined chip rate, a first pseudorandom noise (PN) signal of a first predetermined PN code. The first PN signal is then combined with a first information signal in order to provide a resultant first modulation signal. The system further includes a second network for providing a second modulation signal by delaying the first modulation signal by a

predetermined delay inversely related to the PN chip rate. A switching transmission network is disposed to selectively transmit the first and second modulation signals respectively to first and second coverage areas. In this way selective transmission of the first and second modulation signals may be used to vary the size of the first user sector during different system operating periods. The first user sector is associated with a first set of traffic channels, one of which is allocated to the specified user.

BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects and features of the invention will be more readily apparent from the following detailed description and appended claims when taken in conjunction with the drawings, in which:

FIG. 1A shows an exemplary cell, included within a cellular communication system, in which is disposed a plurality of subscriber units and a base station.

FIG. 1B shows a second exemplary cell as sectorized in accordance with the invention during normal business hours.

FIG. 1C depicts the second exemplary cell as sectorized during evening hours in accordance with the invention.

FIG. 1D shows a block diagram representation of an exemplary base station communications transceiver in which the dynamic sectorization system of the invention is embodied.

FIG. 2 provides a block diagrammatic representation of a base station transmitter network configured to provide dynamic user sectorization in accordance with the invention.

FIG. 3 depicts a switch matrix, disposed within the base station transmitter, for providing a switchable connection between the information signal associated with each user sector and a set of six antenna drivers.

FIG. 4 depicts a block diagram of a base station transmitter network capable of providing increased user sectorization by utilizing both horizontally and vertically polarized antenna beams.

FIGS. 5A and 5B respectively provide top and side views of a dual-mode resonant patch antenna incorporated within a preferred implementation of the base station antennas.

FIG. 6 shows a block diagrammatic representation of a base station receiver network configured to provide dynamic user sectorization in accordance with the invention.

FIG. 7 provides a block diagrammatic representation of an exemplary spread spectrum transmitter.

FIG. 8 depicts a pilot generation network for providing I and Q channel pilot sequences.

FIG. 9 shows an exemplary implementation of an RF base station transmitter.

FIG. 10 is a block diagram of an exemplary diversity receiver disposed within a subscriber unit.

FIG. 11A illustratively represents the azimuth pattern of a 40 degree fixed beam assumed to be projected by a first base station antenna associated with one of the coverage areas C1-C6 (FIG. 1A).

FIG. 11B illustratively represents the azimuth pattern produced when an adjacent pair of fixed-beam base station antennas are driven in phase.

FIG. 12 shows a block diagrammatic representation of a base station transmitter network configured to provide dynamic user sectorization by projecting a set of in-phase beams to each user sector.

FIG. 13 depicts an alternate base station configuration for providing dynamic user sectorization by projecting a set of in-phase beams.

FIG. 14 shows a triangular arrangement of first, second and third phased array antenna panels collectively operating to provide a set of nine antenna beams.

FIG. 15 depicts a preferred implementation of the antenna panels of FIG. 14, each of which includes a 4x4 array of patch elements.

FIG. 16 is a block diagram of a beam-forming network used to drive a phased array antenna panel.

DESCRIPTION OF THE PREFERRED EMBODIMENT

I. Introduction

Turning now to FIG. 1B, there is shown a second exemplary cell 18 as sectorized in accordance with the invention during normal business hours. As is indicated by FIG. 1B, the second cell 18 is sectorized into a set of nine user sectors U1-U9. The second cell 18 is partitioned during business hours such that a set of four user sectors U1-U4, each spanning an angle of, for example, 20 degrees, are allocated to a densely populated business center. During business hours the less populated rural and residential areas of the cell are serviced by a set of relatively broader user sectors U5 and U6-U9, respectively. In an exemplary embodiment the angular width of the rural user sector U5 is set at 100 degrees, the residential user sectors U6, U8 and U9 are each of 40 degrees, and the residential user sector U7 is of 60 degrees. The narrow breadth of the user sectors U1-U4 is necessitated by the high

concentration of users within the business center desiring to communicate during working hours. In this way the confined scope of the user sectors U1-U4 ensures that a sufficient number of traffic channels are available during working hours to accommodate a desired number of users within the business center.

FIG. 1C depicts the second exemplary cell 18 as sectorized during evening (i.e., non-working) hours into a plurality of nine user sectors U1'-U9' in accordance with the invention. As is indicated by FIG. 1C, during non-working hours a single user sector U1' of 80 degrees, rather than the four 20-degree sectors U1-U4 required during working hours, is employed to service demand within the business center. Similarly, the population shift to residential areas during the evening hours requires the increased sectorization provided by the seven user sectors U2'-U6', and U7'-U9', relative to the four sectors U6-U9 required during the daytime. In the exemplary embodiment the angular width of residential user sectors U2'-U4' and U8'-U9' is set at 20 degrees, and the width of the residential user sectors U6' and U7' is set at 40 degrees. The rural user sector U5' remains at 100 degrees during both day and evening hours as a consequence of the typically minimal temporal variation in user demand throughout rural regions. The change in sectorization illustrated by FIGS. 1B-1C may be achieved using the dynamic sectorization system of the invention, the operation of which is described below with reference to the block diagram of FIG. 1D.

FIG. 1D shows a block diagram representation of an exemplary base station communications transceiver 25 in which the dynamic sectorization system of the invention is embodied. As is discussed below, the transceiver 25 operates to provide improved service to users disposed within a first cell of a cellular communications system by dynamically varying the allocation of traffic channels among various user sectors within the cell. The transceiver 25 is seen to include a controller 27, an antenna system 29 and transmit/receive channel banks 31. Controller 27 is typically programmed to provide channel set-up/assignment of the transmit/receive channel banks 31. The transmit/receive channel banks 31 are electromagnetically coupled to the antenna system 29 via a waveguide transmission line 32 or the like. Each individual channel bank may comprise, for example, a plurality of channel units capable of facilitating communication with a particular user. In the embodiment of FIG. 1D, the transmit/receive channel banks 31 supply beam-forming signals to the antenna system 29 so as to sectorize the first cell into a plurality of user sectors, each of which has associated therewith a

plurality of user traffic channels. Information signals are relayed between the channel banks 31 and an external communications network, e.g., a public switched telephone network (PSTN), over a data bus 33.

In a first preferred embodiment of the invention a fixed number of traffic channels are associated with each user sector. Under this constraint the present invention contemplates accommodating variation in user demand within the various regions of the cell by adjusting the relative size of each user sector. For example, a number of relatively narrow user sectors could be employed to service the users within a particular area of the cell during periods of high user demand. This maximizes the likelihood that a traffic channel will be available to all those desiring to establish communication during such periods of heightened demand. Conversely, during periods of minimum demand a relatively fewer number of user sectors of wider width could be utilized to provide the requisite traffic channel capacity. Such widening of the user sectors associated with a particular cell area during periods of reduced demand allows for efficient use of the fixed number of traffic channels assigned to each user sector. That is, by increasing the geographic extent of user sectors during periods of minimal demand the number of likely system users included within each user sector can be held relatively constant. This prevents excess traffic channel capacity from developing in user sectors directed to a given geographic area in the event of decreases in user concentration, i.e., demand, within the given area.

It is to be understood, however, that in alternate embodiments of the present invention the number of traffic channels allocated to a particular user sector may be varied in response to changing demand conditions. In addition, the present invention may enable even further improvement in traffic channel utilization by allowing for alteration of both the geographic size of, and the number of traffic channels associated with a given user sector.

In a presently preferred embodiment of the invention statistics relating to channel usage within each user sector are monitored by the associated ones of the channel banks 31 and conveyed to controller 27 by way of a first control bus 34. Control information from the controller 27 respectively received by the channel banks 31 and the antenna system 29 over the first control bus 34, and a second control bus 35, allows traffic channels to be allocated to user sectors on the basis of the usage statistics supplied by the channel banks 31. That is, the beam pattern projected by antenna system 29 is adjusted in order that a selected set of traffic channels

are provided to each user sector. In the presently preferred embodiment the monitored channel usage is displayed to an operator (not shown) by controller 27, thus allowing specification of the desired cell sectorization. In an automated mode, controller 27 is programmed to assign channels and/or sector size based upon channel usage statistics.

In other embodiments of the invention the controller 27 may be configured to monitor channel usage by virtue of information received from the channel banks 31 over the first control bus 34. The pertinent channel usage information could again be displayed to an operator in order to enable appropriate adjustment of the size of each user sector. Alternately, the controller 27 could be programmed to automatically provide channel setup/assignment commands to the channel banks 31 on the basis of the monitored channel usage, again obviating the need for control information to be supplied by an operator.

Although in the presently preferred embodiments of the invention the size of each user sector is adjusted through alteration of the beam pattern projected by the antenna system 29, in other implementations an equivalent modification of sector size could be achieved through processing of the beam-forming signals supplied by the channel banks 31. In such implementations the beam-forming signals processed by the channel banks 31 would be weighted and combined prior to being provided to, or received from, the antenna system 29. In this way dynamic sectorization could be achieved by providing control information to signal processing electronics (not shown) coupled to the channel banks 31, rather than by supplying such information to the antenna system 29.

Referring again to FIG. 1D, it would appear that one way of accommodating variation in user demand would be to configure the base station antenna system 29 to provide a plurality of fixed antenna beams using an associated set of fixed-beam antenna elements. In such an arrangement each base station antenna would project a beam of fixed width over one of a set of adjacent coverage areas. Differing numbers of the coverage areas would then be assigned to each user sector on the basis of expected usage requirements. In this way changes in user concentration could be addressed by dynamically varying the number of fixed antenna beams used to carry the traffic channels associated with a given sector.

One difficulty presented by such an approach is that significant distortion in beam pattern could be expected to arise proximate the boundaries between coverage areas included within a given user sector. As was discussed in the Background of the Invention, in certain cellular

communication systems a long PN code of predetermined phase is used to modulate the information signals carried by the traffic channels of a given user sector. If such information signals modulated with the long PN code of the given user sector were then projected by a pair of fixed-beam antennas into adjacent coverage areas, an arbitrary phase difference would exist between the identical PN-modulated signals carried by each beam. Such phase difference could be engendered by, for example, variation in the lengths of the signal paths from the beam-forming network of the base station to each fixed-beam antenna. Since these PN-modulated signals are not aligned in phase, at the boundary of the beam coverage area the resulting coherent interference would tend to distort beam pattern by producing nulls and other irregularities. The resultant signal fading accompanying such pattern distortion would then degrade the signal to noise ratio of the PN-modulated signal received by any proximately located subscriber unit receivers.

II. Dynamic Sectorization Using Transmit Antenna Array

As is described hereinafter, in a preferred embodiment the present invention contemplates using an arrangement of fixed-beam antennas to dynamically vary the area encompassed by each user sector. As employed herein, the term "dynamic user sectorization" is intended to be descriptive of the process of varying the size of a set of user sectors between successive system operating periods. In accordance with the invention, a delay is introduced between each pair of identical PN-modulated signals projected to adjacent coverage areas within a given user sector, thereby decorrelating each such pair of signals. In the preferred embodiment a delay having a duration slightly longer than the period of a chip of the PN long code is used to decorrelate the signals projected to adjacent coverage areas within each user sector. A subscriber unit positioned at a coverage area boundary is thus able to discriminate between, and hence to separately receive, the decorrelated PN-modulated signals provided to the adjacent coverage areas. The separately received signals are then time-aligned within the receiver using conventional techniques of diversity reception, and are despread using a locally-generated replica of the long PN code.

Applying the technique of the invention to the system of FIG. 1A, delays would be introduced at least between the signals projected to coverage areas C1 and C6 of the first residential user sector, and between the signal pairs provided to coverage areas C2/C3 of the rural user sector. Although in a preferred embodiment delays are also introduced between the signal pairs

projected to adjacent coverage areas within different user sectors (e.g., between the signal pair provided to coverage areas C3/C4), such signal pairs are assumed to be independently decorrelated as a consequence of the differing PN long code phase associated with each user sector.

Referring to FIG. 2, there is shown a block diagrammatic representation of a base station transmitter network 40 configured to provide dynamic user sectorization in accordance with the invention. The network 40 is seen to include first, second and third spread spectrum transmitters 42, 44, and 46 for processing baseband information signals to be transmitted over traffic channels associated with first (#1), second (#2) and third (#3) user sectors. A PN long code generator 50 provides the long PN code used by the transmitters 42, 44 and 46 in modulating the information signals transmitted to each user sector. The relative phases of the PN long codes supplied to the transmitters 42, 44 and 46 are offset by predetermined margins by phase delay elements 52 and 54. In the preferred embodiment the phase delay elements 52 and 54 provide delays approximately equivalent in duration to 768 PN chips. Within the transmitters 42, 44 and 46 the PN-modulated information signals are used to bi-phase modulate a quadrature pair of sinusoids. The modulated sinusoids are then summed, bandpass filtered, shifted to an RF carrier frequency, and provided to transmit amplifiers 58, 60 and 62. The amplified signals produced by the amplifiers 58, 60 and 62 comprise the PN-modulated information signals to be provided via an RF carrier to user sectors #1, #2, and #3, respectively. The outputs of each of the amplifiers 58, 60 and 62 are respectively connected to six-way splitter networks 66, 68 and 70. As is indicated by FIG. 2, the splitter networks 66, 68 and 70 are coupled to a switch matrix 74.

As is described in further detail with reference to FIG. 3, the switch matrix 74 provides a switchable connection between the information signal associated with each user sector and a set of six antenna drivers 75-80. That is, the switch matrix 74 allows the information signals from any user sector to be routed to users within any of the coverage areas C1-C6. The antenna drivers 75-80 are associated with a set of six base station antennas 85-90, each antenna 85-90 being operative to project a beam over one of the coverage areas C1-C6 (FIG. 1A). Each antenna driver 75-80 is further seen to include an input summation node 92. The summation nodes 92 are each coupled to switch matrix 74 through a set of three input signal lines, each signal line carrying the PN-modulated information signals corresponding to either user sector #1, #2 or #3.

As noted above, in a preferred embodiment delays are introduced

between the signals projected to any pair of adjacent coverage areas. Accordingly, the antenna drivers 75-80 are seen to include delay elements 95a-95f capable of providing delays slightly longer than the chip period of the PN code provided by PN long code generator 50. In a preferred embodiment alternate ones of the delay elements 95a-95f (e.g., elements 95b, 95d, and 95f) are designed to provide a delay slightly longer than a single PN chip period, while the remaining delay elements (e.g., elements 95a, 95c, and 95e) are omitted (zero delay). The delay elements 95a-95f could be realized using one or more surface acoustic wave (SAW) filters. Alternately, a coiled optical fiber of predetermined length could be used to create the desired delay. Each antenna driver 75-80 also includes a power amplifier 96 for providing an output signal to one of the antennas 85-90.

Referring to FIG. 3, there is shown an illustrative representation of that portion of the switch matrix 74 operative to switchably connect the six-way splitter 66 to each of the antenna drivers 75-80. In particular, digitally-controlled attenuators 97a-97f are interposed between the outputs of the splitter 66 and the antenna drivers 75-80. If, for example, it was desired that the first user sector encompass coverage areas C2-C4, then attenuators 97a, 97e and 97f would be set to maximum attenuation, while the attenuators 97b-97d would be turned off (i.e., set to provide zero attenuation). In a preferred embodiment the switch matrix 74 includes two other sets of six digital attenuators (not shown), substantially identical to the attenuators 97a-97f, for switchably connecting the splitters 68 and 70 to the antenna drivers 75-80.

The attenuators 97a-97f will preferably have a dynamic range of approximately 30 dB, and should be capable of being adjusted in 1 dB increments. In this way the beam projected to a particular coverage area may be gradually extinguished, and then gradually established once again, during a transition between sector configurations. For example, if it were desired to modify the scope of the first user sector so that it included only coverage areas C3-C4 rather than C2-C4, attenuator 97b would be incrementally adjusted from zero to maximum attenuation. Assuming it were desired to simultaneously increase the scope of the second user sector, the setting of an attenuator (not shown) connected between the second antenna driver 76 and the splitter 68 sector would contemporaneously be changed from maximum to zero attenuation. The digital attenuators 97a-97f are of a type available from, for example, Anzac Corp., Part No. AT-210.

Although in the implementation of FIG. 3 the switch matrix 74 is configured to allow any user sector to encompass any combination of

coverage areas C1-C6, it is understood that in alternate embodiments the matrix 74 could be simplified by limiting the potential scope to three or four coverage areas.

Referring to FIGS. 1 and 2, each of the antennas 85-90 is designed to project a 60 degree beam to one of the six coverage areas C1-C6. It is understood, however, that increased sectorization could be achieved by utilizing nine antennas, each of which would be designed to project a 40 degree beam. In addition, dual-mode antennas capable of providing both horizontally and vertically polarized beams could be employed to accommodate up to twice as many users within each coverage area. As is described below with reference to FIG. 4, separate antenna drivers are used to generate the signals projected by each horizontally and vertically polarized beam.

Referring to FIG. 4, there is shown block diagram of a base station transmitter network 100 disposed to provide increased user sectorization by employing both horizontally and vertically polarized antenna beams. The network 100 is seen to include first, second and third pairs of spread spectrum transmitters 102a-102b, 104a-104b, and 106a-106b, for processing baseband information signals to be transmitted over first (#1a-b), second (#2a-b) and third (#3-b) paired sets of traffic channels associated with a corresponding set of three user sectors. As is described below, the sets of traffic channels #1a, #2a and #3a may be selectively projected to each coverage area using horizontally-polarized beams, while the traffic channels #1b, #2b and #3b may be similarly selectively projected using vertically-polarized beams. A PN long code generator (not shown) provides the long PN code used by the transmitters 102a-102b, 104a-104b, and 106a-106b in modulating the information signals transmitted to each user sector. Again, the relative phases of the PN long codes supplied to the transmitters 102a-102b, 104a-104b, and 106a-106b are offset by phase margins equivalent to a predetermined number of PN chips.

Within the transmitters 102a-102b, 104a-104b, and 106a-106b the PN-modulated information signals are used to bi-phase modulate a quadrature pair of sinusoids. The modulated sinusoids are then summed, bandpass filtered, shifted to an RF carrier frequency, and amplified. The outputs of each of the transmitters 102a-102b, 104a-104b, and 106a-106b are respectively connected to six-way splitter networks 112a-112b, 114a-114b, and 116a-116b. As is indicated by FIG. 4, the splitter networks 112a-112b, 114a-114b, and 116a-116b are coupled to a switch matrix 120.

The switch matrix 120 provides a switchable connection between the

information signals transmitted over the paired sets of traffic channels (e.g. #1a and #1b) of each user sector and a set of six antenna drivers 125a-125b through 130a-130b. Application of the output of each antenna driver 125a-130a to antennas 135-140 results in the projection of horizontally-polarized to beams coverage areas C1-C6, while application of the output of each antenna driver 125b-130b to antennas 135-140 results in the projection of a vertically-polarized beam to each coverage area C1-C6. As is indicated by FIG. 4, the switch matrix 120 is configured such that the two sets of users associated with each user sector may be serviced within each of the coverage areas C1-C6.

Referring to FIG. 4, there is shown an illustrative representation of that portion of the switch matrix 120 operative to switchably connect the six-way splitters 112a-b to each of the antenna drivers 125a-b through 130a-b. In particular, digitally-controlled attenuators 142 and 144 are interposed between the outputs of the six-way splitters 112a-b and each of the antenna drivers 125a-b through 130a-b. In a preferred embodiment the switch matrix 120 includes two other sets of twelve digital attenuators (not shown), for switchably connecting the splitters 114a-114b and 116a-116b to the antenna drivers 125a-125b through 130a-130b.

Each pair of antenna drivers (e.g., drivers 125a-b) is connected to one of six base station antennas 135-140, each antenna 135-140 being operative to project a horizontally-polarized and a vertically-polarized beam over one of the coverage areas C1-C6 (FIG. 1A). As noted above, in a preferred embodiment delays are introduced between the signals projected to any pair of adjacent coverage areas. Accordingly, alternate pairs of antenna drivers (e.g., drivers 105a-b, 107a-b) are disposed to provide delays slightly longer than a single PN chip period. In other respects the antenna drivers 105a-105b through 110a-110b are substantially similar to the antenna drivers 75-80.

FIGS. 5A and 5B respectively provide top and side views of a dual-mode resonant patch antenna capable of realizing the antennas 135-140. The patch element 160 shown in FIG. 5A is one-half carrier wavelength in each dimension and is suspended above a ground plane 162 (FIG. 5B) by a post 163. The patch element 160 is seen to be separated from the ground plane 162 by a separation distance S. In the preferred embodiment the distance S is selected such that sufficient bandwidth is provided to span both the transmit and receive frequency bands. The vertically-polarized mode is created by resonating the patch element 160 such that voltage maxima occur proximate upper and lower edges 170 and 172 of the patch element 160, and such that a voltage null occurs in the middle. Similarly, the

horizontally-polarized mode is created by resonating the patch 160 such that voltage maxima arise at left and right edges 176 and 178 of the patch element 160. In a preferred embodiment the vertically-polarized mode is excited via a voltage probe applied to the center of the upper 170 and lower 172 edges of the patch element 160. In like manner the horizontal mode is induced using voltage probes connected to the right and left edges 176 and 178.

III. Dynamic Sectorization within a Receive Network

Referring to FIG. 6, there is shown a block diagrammatic representation of a base station receiver network 200 configured to provide dynamic user sectorization in accordance with the invention. The network 200 is seen to be generally complementary to the transmitter network 40 (FIG. 2) in that a decorrelating delay is introduced between signals received from adjacent coverage areas. The receiver network 200 and the transmitter network 40 may be simultaneously coupled to the antennas 85-90 through a duplexer (not shown).

The signals received from the coverage areas C1-C6 through antennas 85-90 are respectively provided to receive amplifiers 210-215. The receive amplifiers 210-215 each include a low-noise amplifier (LNA) 220 having a passband centered about the frequency of the received RF carrier. The amplifiers 210-215 are further seen to include delay elements 225a-225f capable of providing delays slightly longer than the chip period of the PN long code used to discriminate between user sectors. In a preferred embodiment alternate ones of the delay elements 225a-225f (e.g., elements 225b, 225d, and 225f) are designed to provide a delay slightly longer than a single PN chip period, while the remaining delay elements are omitted (zero delay). The delay elements 225a-225f could be realized using one or more surface acoustic wave (SAW) filters. Alternatively, a coiled optical fiber of predetermined length could be used to create the desired delay.

The output of each delay element 225a-225f is provided to a 3-way splitter 230 connected to a switch matrix 232. The switch matrix 232 is substantially identical to the switch matrix 74, and hence provides a switchable connection between each output of the 3-way splitters 230 and an input to one of three 6-way summation networks 240-242. The summation networks 240-242 are coupled to a corresponding set of three diversity receivers 250-252 through amplifiers 254-256, each diversity receiver capable of being implemented in the manner described below with reference to FIG. 10. Each diversity receiver 250-252 frequency downconverts, and digitizes the received signal into composite I and Q components. The composite I

and Q components then demodulated, combined, deinterleaved and decoded.

Each I and Q component may be comprised of data signals from a given subscriber unit received by two or more of the antennas 85-90 associated with adjacent coverage areas C1-C6 of a given user sector. The received signals associated with each coverage area, as selected by a searcher receiver in combination with a controller, are each processed by a different one of multiple data receivers or demodulators, which are also referred to as "fingers" (not shown). From the composite I and Q components each finger extracts, by despreading, the I and Q components RI and RQ of the pilot and data signals associated with each coverage area. A PN long code generator 260 provides the long PN code used by the receivers 250-252 in demodulating the information signals received from each user sector. The relative phases of the PN long codes supplied to the receivers 251-252 are offset by predetermined margins by phase delay elements 270 and 272. In the preferred embodiment the phase delay elements 52 and 54 provide delays approximately equivalent in duration to 768 PN chips.

IV. Dynamic Sectorization within a CDMA System

Referring to FIG. 7, there is shown a block diagrammatic representation of a spread spectrum transmitter suitable for realizing the spread spectrum transmitters 42, 44 and 46 (FIG. 2). The spread spectrum transmitter of FIG. 7 is of the type described in U.S. Patent No. 5,103,459, issued 1992, entitled "*System and Method for Generating Signal Waveforms in a CDMA Cellular Telephone System*", which is assigned to the assignee of the present invention, and which is herein incorporated by reference. In the transmitter of FIG. 7, data bits 300 consisting of, for example, voice converted to data by a vocoder, are supplied to an encoder 302 where the bits are convolutional encoded with code symbol repetition in accordance with the input data rate. When the data bit rate is less than the bit processing rate of the encoder 302, code symbol repetition dictates that encoder 302 repeat the input data bits 300 in order to create a repetitive data stream at a bit rate which matches the operative rate of encoder 302. The encoded data is then provided to interleaver 304 where it is convolutional interleaved. The interleaved symbol data is output from interleaver 304 at an exemplary rate of 19.2 ksps to an input of exclusive-OR 306.

In the system of FIG.7 the interleaved data symbols are scrambled to provide greater security in transmissions over the channel. Scrambling of the voice channel signals may be accomplished by pseudonoise (PN) coding

the interleaved data with a PN code specific to an intended recipient subscriber unit. These scrambling codes comprise the "inner" PN codes to which reference was made in the Background of the Invention. Such PN scrambling may be provided by the PN generator 308 using a suitable PN sequence or encryption scheme. The PN generator 308 will typically include a long PN generator for producing a unique PN code at a fixed rate of 1.2288 MHz. This PN code is then passed through a decimator (not shown), with the resulting 9.2 MHz scrambling sequence being supplied to the other input of exclusive-OR 306 in accordance with subscriber unit identification information provided thereto. The output of exclusive-OR 306 is then provided to one input of exclusive-OR 310.

Again referring to FIG. 7, the other input of exclusive-OR gate 310 is connected to a Walsh code generator 312. Walsh generator 312 generates a signal corresponding to the Walsh sequence assigned to the data channel over which information is being transmitted. The Walsh code provided by generator 312 is selected from a set of 64 Walsh codes of length 64. The 64 orthogonal codes correspond to Walsh codes from a 64 by 64 Hadamard matrix wherein a Walsh code is a single row or column of the matrix. The scrambled symbol data and Walsh code are exclusive-OR'ed by exclusive-OR gate 310 with the result provided as an input to both of the exclusive-OR gates 314 and 316.

Exclusive-OR gate 314 also receives a PN_I signal, while the other input of exclusive-OR gate 316 receives a PN_Q signal. In CDMA applications the PN long code generator 50 (FIG. 2) operates to provide both PN_I and PN_Q sequences to the spread spectrum transmitters 42, 44 and 46. The PN_I and PN_Q signals are pseudorandom (PN) signals corresponding to a particular user sector covered by the CDMA system and relate respectively to in-phase (I) and quadrature phase (Q) communication channels. The PN_I and PN_Q signals are respectively exclusive-OR'ed with the output of exclusive-OR gate 310 so as to further spread the user data prior to transmission. The resulting I-channel code spread sequence 322 and Q-channel code spread sequence 326 are used to bi-phase modulate a quadrature pair of sinusoids. Each quadrature pair of sinusoids is summed within transmitters 42, 44 and 46, is shifted to an RF frequency, and is provided to one of the amplifiers 58, 60 and 62.

In the preferred embodiment, a pilot channel containing no data modulation is transmitted together with the I-channel and Q-channel spread sequences S_I and S_Q. The pilot channel may be characterized as an unmodulated spread spectrum signal used for signal acquisition and

tracking purposes. In systems incorporating a plurality of base station transmitters in adjacent cells, the set of communication channels provided by each will be identified by a unique pilot signal. However, rather than using a separate set of PN generators for the pilot signals, it is realized that a more efficient approach to generating a set of pilot signals is to use shifts in the same basic sequence. Utilizing this technique an intended receiver unit sequentially searches the whole pilot sequence and tunes to the offset or shift that produces the strongest correlation.

Accordingly, the pilot sequence will preferably be long enough that many different sequences can be generated by shifts in the basic sequence to support a large number of pilot signals in the system. In addition, the separation or shifts must be great enough to ensure that there is no interference in the pilot signals. Hence, in an exemplary embodiment the pilot sequence length is chosen to be 2^{15}, which allows for 512 distinct pilot signals with offsets in a basic sequence of 64 chips.

Referring to FIG. 8, a pilot generation network 330 includes a Walsh generator 340 for providing the Walsh "zero" W_0 sequence consisting of all zeroes to exclusive-OR combiners 344 and 346. The Walsh sequence W_0 is multiplied by the PN_I and PN_Q sequences using the exclusive-OR combiners 344 and 346, respectively. Since the sequence W_0 includes only zeroes, the information content of the resultant sequences depends only upon the PN_I and PN_Q sequences. The sequences produced by exclusive-OR combiners 344 and 346 are provided as inputs to Finite Impulse Response Filters (FIR) filters 350 and 352. The filtered sequences output from FIR filters 350 and 352, respectively corresponding to I-channel and Q-channel pilot sequences P_I and P_Q, are supplied to the RF transmitter 382.

Referring to FIG. 9, there is shown an exemplary implementation of the RF transmitter 382. Transmitter 382 includes an I-channel summer 370 for summing the PN_I spread data signals S_{Ii}, i=1 to N, with the I-channel pilot P_I. Similarly, a Q-channel summer 372 serves to combine the PN_Q spread data signals S_{Qi}, i=1 to N, with the Q-channel pilot P_I. Digital to analog (D/A) converters 374 and 376 are provided for converting the digital information from the I-channel and Q-channel summers 370 and 372, respectively, into analog form. The analog waveforms produced by D/A converters 374 and 376 are provided along with local oscillator (LO) carrier frequency signals $\cos(2\pi ft)$ and $\sin(2\pi ft)$, respectively, to mixers 388 and 390 where they are mixed and provided to summer 392. The quadrature phase carrier signals $\sin(2\pi ft)$ and $\cos(2\pi ft)$ are provided from suitable frequency sources (not shown). These mixed IF signals are summed in summer 392

and provided to mixer 394.

Mixer 394 mixes the summed signal with an RF frequency signal from frequency synthesizer 396 so as to provide frequency upconversion to the RF frequency band. The RF signal includes in-phase (I) and quadrature phase (Q) components, and is bandpass filtered by bandpass filter 398 and output to one of the RF amplifiers 58, 60, 62 (FIG. 2). It should be understood that differing implementations of the RF transmitter 382 may employ a variety of signal summing, mixing, filtering and amplification techniques not described herein, but which are well known to those in the art.

FIG. 10 is a block diagram of an exemplary diversity receiver associated with one of the subscriber units 12 (FIG. 1A), and hence is disposed to receive the RF signals transmitted by one or more of the antennas 85-90 of the base station 40 (FIG. 2). In FIG. 10 the RF signal transmitted by base station 40 is received by antenna 410 and provided to a diversity RAKE receiver which is comprised of analog receiver 412 and digital receiver 414. The signal as received by antenna 410 and provided to analog receiver 412 may be comprised of multipath propagations of the same pilot and data signals intended for individual or multiple subscriber receivers. Analog receiver 412, which is configured in the exemplary embodiment as a QPSK modem, frequency downconverts, and digitizes the received signal into composite I and Q components. The composite I and Q components are provided to digital receiver 414 for demodulation. The demodulated data is then provided to digital circuitry 416 for combining, deinterleaving and decoding.

Each I and Q component output from analog receiver 412 may be comprised of corresponding data signals transmitted by two or more of the antennas 85-90 associated with adjacent coverage areas C1-C6 of a given user sector. As discussed above, a phase offset is introduced between the data signals provided to adjacent coverage areas in a particular user sector. In digital receiver 414 the received signals associated with each coverage area, as selected by a searcher receiver 415 in combination with a controller 418, are each processed by a different one of multiple data receivers or demodulators 420a-420c, which are also referred to as "fingers". Although only three data demodulating fingers (demodulators 420a-420c) are illustrated in FIG. 10, it should be understood that more or less fingers may be used. From the composite I and Q components each finger extracts, by despreading, the I and Q components RI and RQ of the pilot and data signals associated with each coverage area.

In an exemplary implementation each subscriber unit 12 is assigned

one of a set of a set of 64 orthogonal Walsh codes W_i of length 64. This allows a set of channels including a pilot channel, 63 I-channel, and 63 Q-channels to be transmitted using a given pair of spreading sequences PN_I and PN_Q. The extracted pilot signal is used for time alignment within a symbol combiner (not shown) within the subscriber unit receiver. When the subscriber unit is positioned proximate the boundary of adjacent coverage areas assigned to the same user sector, the estimates of the data transmitted to each coverage area are time-aligned and added together, thereby improving signal to noise ratio.

V. Dynamic Sectorization Using In-Phase Beam Pattern

As was discussed above, in the preferred embodiment a delay is introduced between the beams projected to adjacent antenna coverage areas so as to decorrelate the signals transmitted to each area. This approach is designed to substantially eliminate destructive interference between the beams provided to adjacent coverage areas, thereby preventing the formation of nulls and other beam pattern distortion. A diversity receiver associated with a subscriber unit positioned near the coverage area boundary is thus able to separately receive the decorrelated signals, and to subsequently combine the separately received signals.

In an alternate embodiment of the invention the cellular base station is designed to effect dynamic user sectorization by providing a set of fixed beams projected in precise phase alignment. Referring to FIG. 11A, there is shown the azimuth pattern of a 40 degree fixed beam assumed to be projected by a first base station antenna associated with one of the coverage areas C1-C6 (FIG. 1A). If a second base station antenna, disposed to provide a second 40 degree fixed beam to an adjacent coverage area, is driven in phase with the first base station antenna the pattern shown in FIG. 11B is produced. It is thus apparent that the width of a user sector may be increased in proportion to the number of beams excited. Since the beams are generated in phase, the beams constructively interfere near coverage area boundaries and hence are effectively coherently combined within the base station rather than within the subscriber unit receiver.

Referring to FIG. 12, there is shown a block diagrammatic representation of a base station transmitter network 440 configured to provide dynamic user sectorization by projecting a set of in-phase beams to each user sector. The network 440 is seen to be substantially similar to the network of FIG. 2, where like reference numerals are used in identifying substantially similar system components. Rather than including phase delay elements 95a-95f, the antenna drivers 75-80 are seen to include phase

equalizers 444a-444f adjusted such that the antennas 85-90 are driven in phase. Adjustment of the equalizers 444a-444f may be performed, for example, during base station installation by applying an identical test signal to each driver 75-80.

More specifically, during a calibration procedure a set of test signals of identical amplitude and phase are provided to the antenna drivers 75-80. The outputs of adjacent pairs of antenna cables 445a-445f, respectively associated with the antennas 85-90, are then connected to the dual input ports of a power combiner. The phase equalizer within the antenna driver coupled to one of the antenna cables is then adjusted until the output of the power combiner is maximized. This procedure is repeated for each adjacent pair of antenna drivers, i.e., for the drivers 75 and 76, the drivers 76 and 77, and so on.

An analogous procedure is used to calibrate the receive network 200 (FIG. 6). In particular, a set of test signals of identical amplitude and phase are injected at the ports of the antenna cables 224a-224f nominally coupled to the antennas 85-90. A power combiner having six input ports and a single output port is then connected to the splitters 230 of an adjacent pair of the receive amplifiers 210-215. A phase equalizer (not shown) within one of the receive amplifiers connected to the power combiner is then adjusted until output power from the combiner is maximized. This process is then repeated for each adjacent pair of receive amplifiers 210-215.

FIG. 13 depicts an alternate base station configuration 450 for providing dynamic user sectorization by projecting a set of in-phase beams. As is indicated by FIG. 13, phase alignment is maintained between adjacent beams by locating the switch matrix and antenna drivers proximate the antennas 85-90. That is, in the configuration of FIG. 13 the switch matrix 74 and antenna drivers 85-90 follow, rather than precede, the transmission cables 452-454 within the base station antenna tower 458. The direct coupling of the drivers 75-80 to the antennas 85-90 advantageously prevents phase differences due to cable length variation and the like from being introduced between the beams transmitted to adjacent coverage areas.

VI. Antenna Subsystem

In both the decorrelated phase and controlled phase embodiments of the invention (see, e.g., FIGS. 2 and 12), the size of a given user sector is varied by using a combination of one or more beams to provide the information signal for the sector. Each such beam may be created using any one of a number of conventional techniques. For example, a set of distinct

fixed-beam antennas could be used to project a set of beams of predetermined angle. In this approach the antennas are mounted and aligned such that each beam encompasses a predetermined coverage area. In an exemplary embodiment a set of six antennas are used to provide a 60 degree beam to each of six coverage areas (see, e.g., FIG. 1A).

Alternately, a phased array antenna may be used to simultaneously form more than a single beam. For example, FIG. 14 shows a triangular arrangement of first, second and third phased array antenna panels 480, 482 and 484, which collectively operate to provide a set of nine antenna beams to coverage areas C1-C9. In particular, antenna panel 480 projects three 40-degree fixed beams to coverage areas C1-C3, while antenna panels 482 and 484 project 40-degree fixed beams to coverage areas C4-C6, and C7-C9, respectively.

As is indicated by FIG. 15, in a preferred implementation the face of each antenna panel includes a 4x4 array of patch elements, the elements within each column being respectively identified by the reference numerals 486-489. Assuming an RF carrier frequency of 850 MHz, each patch element may be fabricated from a square section of dielectrically-loaded patch material of area 4 in^2. This results in each square antenna panel 482-484 being of an area of approximately 4 sq. ft.

Referring to FIG. 16, there is shown a phased array antenna and beam-forming network 490 disposed to provide three beams from a single antenna face. A switch matrix (not shown) provides the information signals corresponding to user sectors #1, #2 and #3 via input signal lines 494a-494c. The beam-forming network 490 includes 4-way splitters 495a-c respectively connected to signal lines 494a-c. The four outputs from each splitter 495a-c are connected via phase delay elements 496 to one of four summation nodes 498-501. The composite signals from summation nodes 498-501 are respectively provided to power amplifiers 504-507. As is indicated by FIG. 16, each column of array elements 486-489 is driven by one of the amplifiers 504-507. In alternate implementations a separate power amplifier is utilized to drive each array element 486-489.

In an exemplary embodiment the delay elements 496 are adjusted such that each of three beams are projected at a 40-degree angle to one of three adjacent coverage areas. The three beams projected by a single antenna panel would then span an arc of 120 degrees. Three such panels could be mounted to provide a set of nine beams encompassing an arc of 360 degrees.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention.

The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein. For example, in addition to addressing the need for flexible traffic channel allocation as a consequence of short-term changes in user demand, the method and apparatus of the invention may be employed to accommodate long-term changes in user demand. Such long-term variation in demand could accompany, for example, shifts in population distribution and building patterns within a given geographic area.

WHAT IS CLAIMED IS:

CLAIMS

1. A system for conveying information to at least one user in a spread spectrum communication system, comprising:

means for generating, at a predetermined chip rate, a first pseudorandom noise (PN) signal of a first predetermined PN code;

first means for combining said first PN signal and a first information signal, and for providing a resultant first modulation signal;

means for providing a second modulation signal by delaying said first modulation signal by a predetermined delay inversely related to said chip rate;

means for selectively transmitting said first and second modulation signals respectively to first and second coverage areas,

whereby selective transmission of said first and second modulation signals results in variation in size of a first user sector in which is included said at least one user.

2. The system of claim 1 wherein said means for selectively transmitting includes means for transmitting said first and second modulation signals such that said second coverage area at least partially overlaps said first coverage area.

3. The system of claim 2 further including:

means for providing a third modulation signal and for providing a fourth modulation signal corresponding to a delayed version of said third modulation signal;

means for selectively transmitting said third and fourth modulation signals respectively to said second coverage area and to a third coverage area,

whereby selective transmission of said third and fourth modulation signals results in variation in size of a second user sector.

4. The system of claim 2, said system further including:

means for generating, at said predetermined chip rate, a second pseudorandom noise (PN) signal of said predetermined PN code, said first and second PN signals being offset in phase,

second means for combining said second PN signal a second information signal, and for providing a resultant third modulation signal, and

means for providing a fourth modulation signal by delaying said

third modulation signal by a predetermined delay inversely related to predetermined said chip rate.

5. The system of claim 4 wherein said means for selectively transmitting includes means for selectively transmitting said first and second modulation signals respectively to said first and second coverage areas exclusively during a first system operating period, and for selectively transmitting said third and fourth modulation signals respectively to said first and second coverage areas exclusively during a second system operating period.

6. The system of claim 1 further including a receiver for receiving said first and second modulation signals and for providing said first information signal to said at least one user on the basis thereof

7. The system of claim 6 wherein said receiver includes means for generating a replica of said PN code, and means for demodulating said first and second modulated signals into first and second demodulated signals using said replica of said first PN code.

8. The system of claim 7 wherein said receiver includes means for coherently combining said first and second demodulated signals.

9. In a cellular subscriber communication system in which users within at least one cell communicate information signals between one another via at least one cell-site using spread spectrum communication signals wherein said one cell-site includes a cell-site transmitter, said transmitter comprising:

first means for providing first and second sets of spread spectrum information signals to be conveyed to users within a first user sector of said first cell, said means for providing including means for generating said second set of spread spectrum information signals by delaying each of said information signals included within said first set; and

first means for selectively transmitting, during a first system operating period, said first and second sets of spread spectrum information signals respectively to first and second coverage areas within said at least one cell wherein size of said first user sector is varied through selective transmission of said first and second sets of spread spectrum information signals.

10. The transmitter of claim 9 wherein said first means for selectively transmitting includes first and second antennas for projecting first and second beams over said first and second coverage areas, respectively, said first beam carrying said first set of spread spectrum information signals and said second beam carrying said second set of spread spectrum information signals.

11. The transmitter of claim 10 wherein said first means for providing includes means for splitting each of said information signals included within said first set into a pair of identical subsignals and for delaying one of the subsignals of each pair.

12. The transmitter of claim 11 wherein said means for selectively transmitting includes:

means for selectively attenuating each of said subsignals, and

means for coupling one of said subsignals within each pair to said first antenna and for coupling the other of said subsignals within each pair to the second antenna.

13.. The transmitter of claim 9 further including:

second means for providing third and fourth sets of spread spectrum information signals for reception by users within a second user sector of said first cell, said second means for providing including means for generating said fourth set of spread spectrum information signals by delaying each of said information signals included within said third set;

second means for selectively transmitting, during a second system operating period, said third and fourth sets of spread spectrum information signals respectively to said first and second coverage areas within said at least one cell, thereby allowing size of a second user sector included within said at least one cell to be varied in accordance with user concentration in said second sector.

14. The system of claim 9 further including a receiver, said receiver comprising:

means for receiving one of said information signals included within said first set and for receiving a delayed version of said one information signal included within said second set;

means for coherently combining said received information signals

and for providing the resultant signal to a system user.

15. A system for conveying information to at least one user in a spread spectrum communication system, comprising:

means for generating a first pseudorandom noise (PN) signal of a first predetermined PN code;

first means for combining said first PN signal and a first information signal, and for providing a resultant first modulation signal;

means for providing a second modulation signal by replicating said first modulation signal;

means for aligning said first and second modulation signals in phase, and for selectively transmitting the resultant phase-aligned first and second modulation signals respectively to first and second coverage areas,

whereby selective transmission of said first and second modulation signals results in variation in size of a first user sector in which is included said at least one user.

16. The system of claim 15 wherein said means for selectively transmitting includes means for selectively transmitting said first and second modulation signals respectively to said first and second coverage areas exclusively during a first system operating period, and for selectively transmitting third and fourth modulation signals respectively to said first and second coverage areas exclusively during a second system operating period, said third modulation signal being substantially identical to, and aligned in phase with, said fourth modulation signal.

17. In a cellular subscriber communication system in which users within at least one cell communicate information signals between one another via at least one cell-site using spread spectrum communication signals wherein said one cell-site includes a cell-site transmitter, said transmitter comprising:

first means for providing first and second sets of spread spectrum information signals for reception by users within a first user sector of said first cell, said means for providing including means for generating said second set of spread spectrum information signals by replicating each of said information signals included within said first set;

means for aligning in phase each of said information signals within said first set with the corresponding replica thereof within said second set so as to form first and second sets of phase-aligned information signals;

first means for selectively transmitting, during a first system operating period, said first and second sets of phase-aligned information signals respectively to first and second coverage areas within said at least one cell wherein size of said first user sector is varied through selective transmission of said first and second sets of phase-aligned information signals.

18. A method of conveying information to at least one user in a spread spectrum communication system, comprising the steps of:

generating, at a predetermined chip rate, a first pseudorandom noise (PN) signal of a first predetermined PN code;

combining said first PN signal and a first information signal, and providing a resultant first modulation signal;

providing a second modulation signal by delaying said first modulation signal by a predetermined delay inversely related to said chip rate;

selectively transmitting said first and second modulation signals respectively to first and second coverage areas,

whereby selective transmission of said first and second modulation signals results in variation in size of a first user sector in which is included said at least one user.

19. The method of claim 18 wherein said step of selectively transmitting includes the step of transmitting said first and second modulation signals such that said second coverage area at least partially overlaps said first coverage area.

20. The method of claim 19 further including the steps of:

providing a third modulation signal, and providing a fourth modulation signal corresponding to a delayed version of said third modulation signal;

selectively transmitting said third and fourth modulation signals respectively to said second coverage area and to a third coverage area,

whereby selective transmission of said first and second modulation signals results in variation in size of a second user sector.

21. The method of claim 19 further including the steps of:

generating, at said predetermined chip rate, a second pseudorandom noise (PN) signal of said predetermined PN code, said first and second PN

signals being offset in phase,

combining said second PN signal and a second information signal, and providing a resultant third modulation signal, and

providing a fourth modulation signal by delaying said third modulation signal by a predetermined delay inversely related to said predetermined chip rate.

22. The method of claim 21 wherein said step of selectively transmitting includes the step of selectively transmitting said first and second modulation signals respectively to said first and second coverage areas exclusively during a first system operating period, and the step of selectively transmitting said third and fourth modulation signals respectively to said first and second coverage areas exclusively during a second system operating period.

23. The method of claim 18 further including the steps of receiving said first and second modulation signals and providing said first information signal to said at least one user on the basis thereof.

24. The method of claim 23 further including the steps of generating a replica of said PN code, and demodulating said first and second modulated signals into first and second demodulated signals using said replica of said first PN code.

25. The method of claim 24 further including the step of coherently combining said first and second demodulated signals.

26. In a cellular subscriber communication system in which users within at least one cell communicate information signals between one another via at least one cell-site using spread spectrum communication signals wherein said one cell-site includes a cell-site transmitter, a method of signal transmission from said cell-site comprising the steps of:

providing first and second sets of spread spectrum information signals to be conveyed to users within a first user sector of said first cell, said step of providing including the step of generating said second set of spread spectrum information signals by delaying each of said information signals included within said first set; and

selectively transmitting, during a first system operating period, said first and second sets of spread spectrum information signals respectively to

first and second coverage areas within said at least one cell wherein size of said first user sector is varied through selective transmission of said first and second sets of spread spectrum information signals.

27. A method of conveying information to at least one user in a spread spectrum communication system, comprising the steps of:

generating, at a predetermined chip rate, a first pseudorandom noise (PN) signal of a first predetermined PN code;

combining said first PN signal and a first information signal, and providing a resultant first modulation signal;

providing a second modulation signal by replicating said first modulation signal;

aligning said first and second modulation signals in phase, and selectively transmitting the resultant phase-aligned first and second modulation signals respectively to first and second coverage areas.

28. A system for receiving information transmitted by at least one user in a spread spectrum communication system, comprising:

means for selectively receiving a first signal from a first coverage area and for selectively receiving a second signal from a second coverage area, said first and second signals being respectively received through first and second antennas associated with said first and second coverage areas, said first and second signals being modulated by a first pseudorandom noise (PN) signal of a first predetermined PN code;

means for delaying said first signal received through said second antenna by a first delay so as to produce a delayed signal, said delay being inversely related to a chip rate of said PN signal; and

means for coherently combining said second signal received through said second antenna with said delayed signal, and for providing a resultant first modulation signal;

whereby selective reception of said first and second signals results in variation in size of a first user sector in which is included said at least one user.

29. The system of claim 28 further including:

means for selectively receiving a third signal from said second coverage area and for selectively receiving a fourth signal from a third coverage area, said third and fourth signals being respectively received through said second and through a third antenna;

means for delaying said third signal received through said second antenna by said first delay so as to produce a second delayed signal; and

means for coherently combining said fourth signal received through said third antenna with said second delayed signal;

whereby selective reception of said third and fourth signals results in variation in size of a second user sector.

30. The system of claim 1 wherein said means for selectively transmitting said first and second modulation signals includes the step of selectively transmitting first and second polarization components of said first modulation signal and first and second polarization components of said second modulation signal.

31. A communications transceiver disposed within a first cell of a cellular communication system, said transceiver comprising:

an antenna system for projecting an antenna beam pattern over said first cell;

channel bank means, electromagnetically coupled to said antenna system, for supplying beam-forming signals to said antenna system such that said antenna beam pattern is projected so as to sectorize said first cell into a plurality of user sectors, each of said user sectors having a plurality of traffic channels associated therewith; and

controller means for monitoring usage of said plurality of traffic channels associated with each user sector, and for supplying control information to said antenna system in order that size of said user sectors are adjusted in accordance with said monitored traffic channel usage.

32. In a cellular communication system including at least one cell sectorized into a plurality of user sectors, a method for dynamically varying user sectorization of said at least one cell comprising the steps of:

monitoring usage of a plurality of traffic channels assigned to said plurality of user sectors, each of said user traffic channels being assigned to a user within said at least one cell; and

adjusting geographic size of said user sectors based on said monitored usage of said plurality of traffic channels.

33. The method of claim 32 further including the steps of:

projecting an antenna beam pattern over said at least one cell, said antenna beam pattern carrying information signals associated with said

plurality of user traffic channels, and

varying said projection of said antenna beam pattern in accordance with said monitored usage of said plurality of traffic channels.

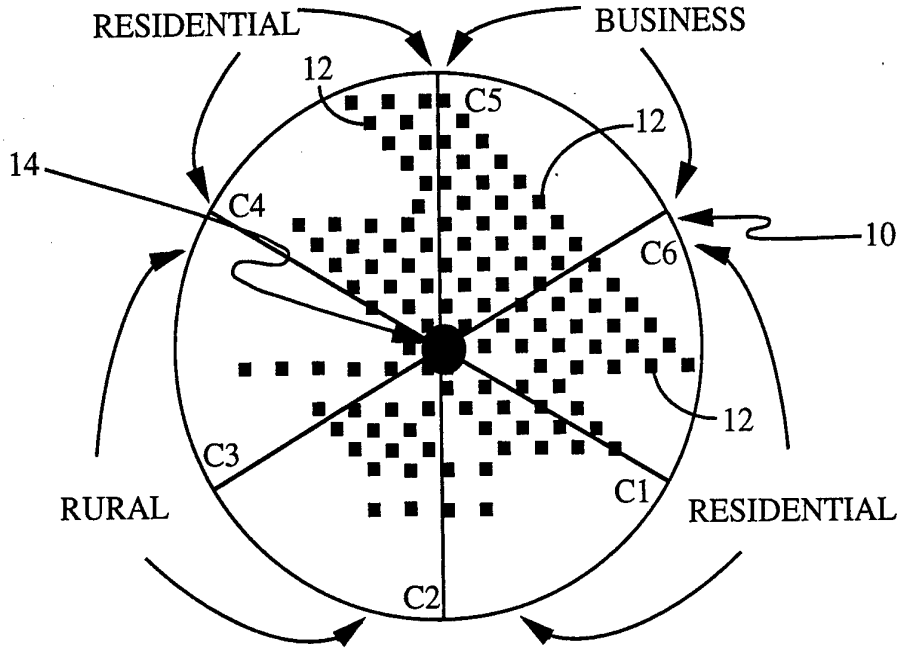

RESIDENTIAL
BUSINESS
12
C5
12
14
C4
10
C6
12
C3
C1
RURAL
RESIDENTIAL
C2

FIG. 1A

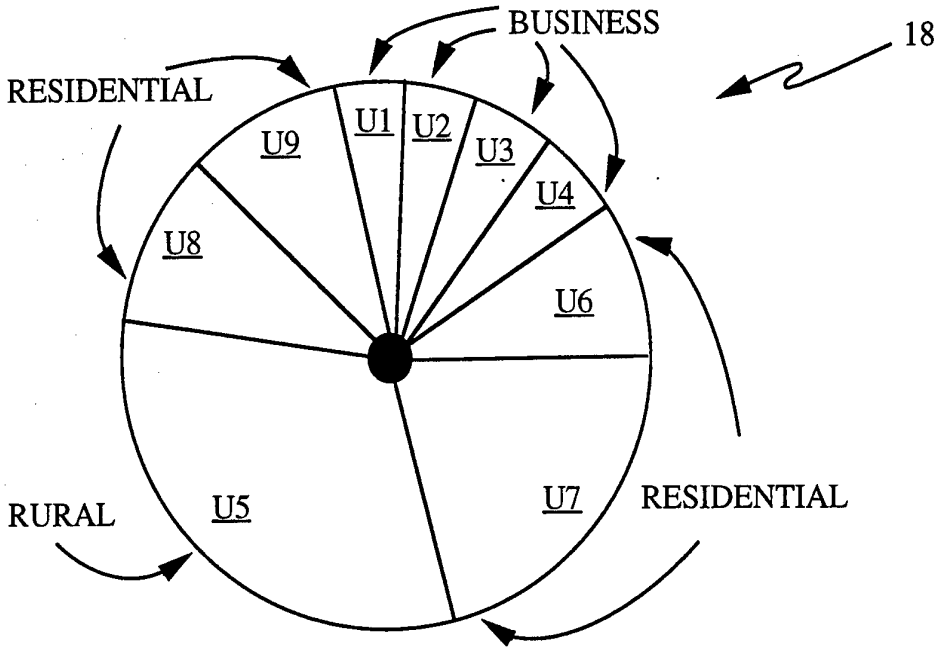

BUSINESS
18
RESIDENTIAL
U1
U2
U3
U4
U6
U7
RESIDENTIAL
U8
U9
RURAL
U5

FIG. 1B

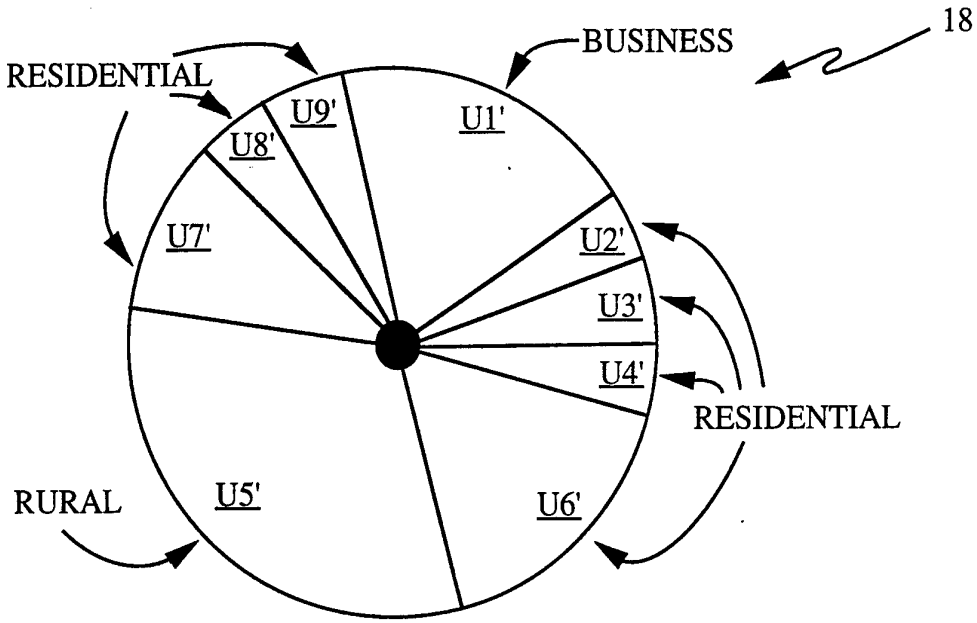

18
BUSINESS
RESIDENTIAL
U9'
U1'
U8'
U7'
U2'
U3'
U4'
RESIDENTIAL
RURAL
U5'
U6'

FIG. 1C

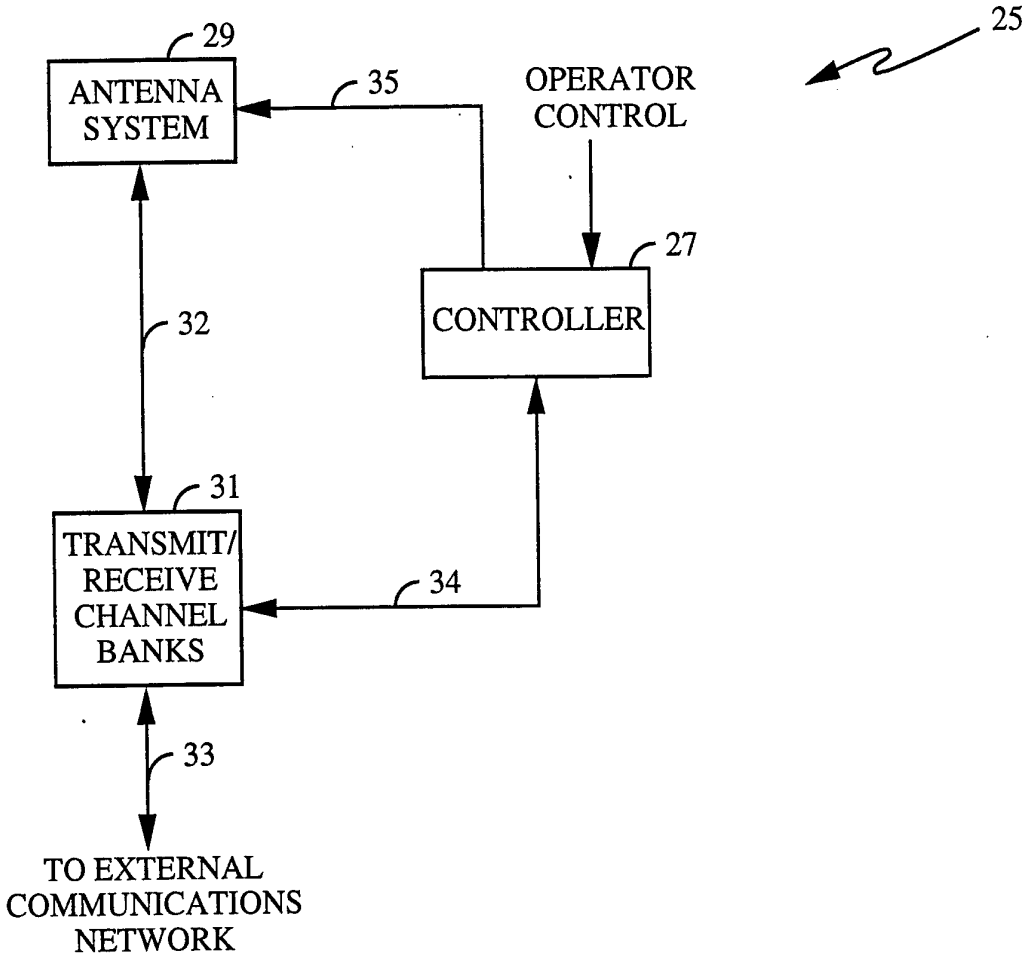

25
29
ANTENNA SYSTEM
35
OPERATOR CONTROL
27
CONTROLLER
32
31
TRANSMIT/ RECEIVE CHANNEL BANKS
34
33
TO EXTERNAL COMMUNICATIONS NETWORK

FIG. 1D

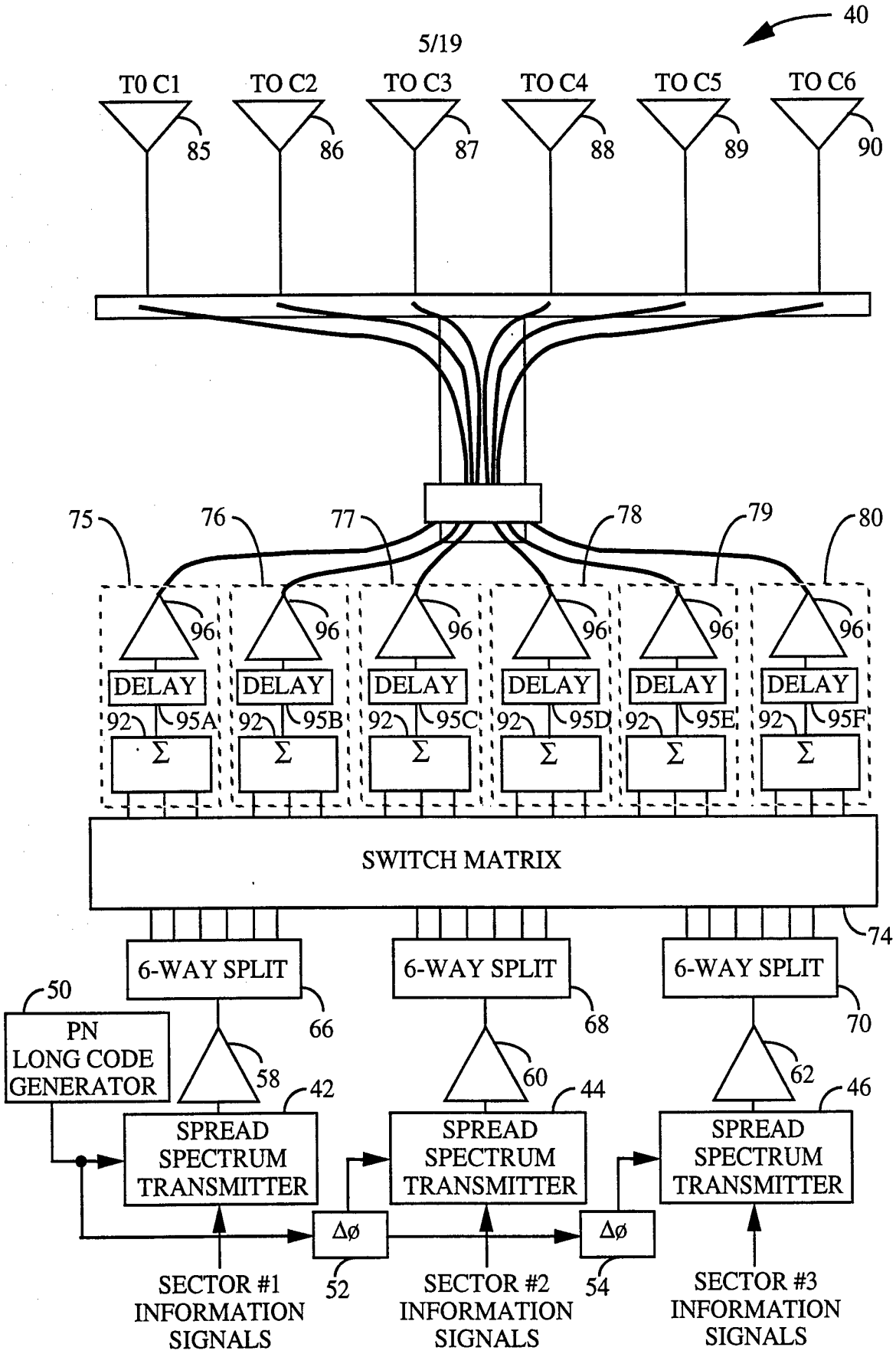

40
TO C1
TO C2
TO C3
TO C4
TO C5
TO C6
85
86
87
88
89
90
75
76
77
78
79
80
96
DELAY
92
95A
95B
95C
95D
95E
95F
Σ
SWITCH MATRIX
74
6-WAY SPLIT
66
68
70
50
PN
LONG CODE
GENERATOR
58
60
62
42
44
46
SPREAD
SPECTRUM
TRANSMITTER
Δø
52
54
SECTOR #1
INFORMATION
SIGNALS
SECTOR #2
INFORMATION
SIGNALS
SECTOR #3
INFORMATION
SIGNALS

FIG. 2

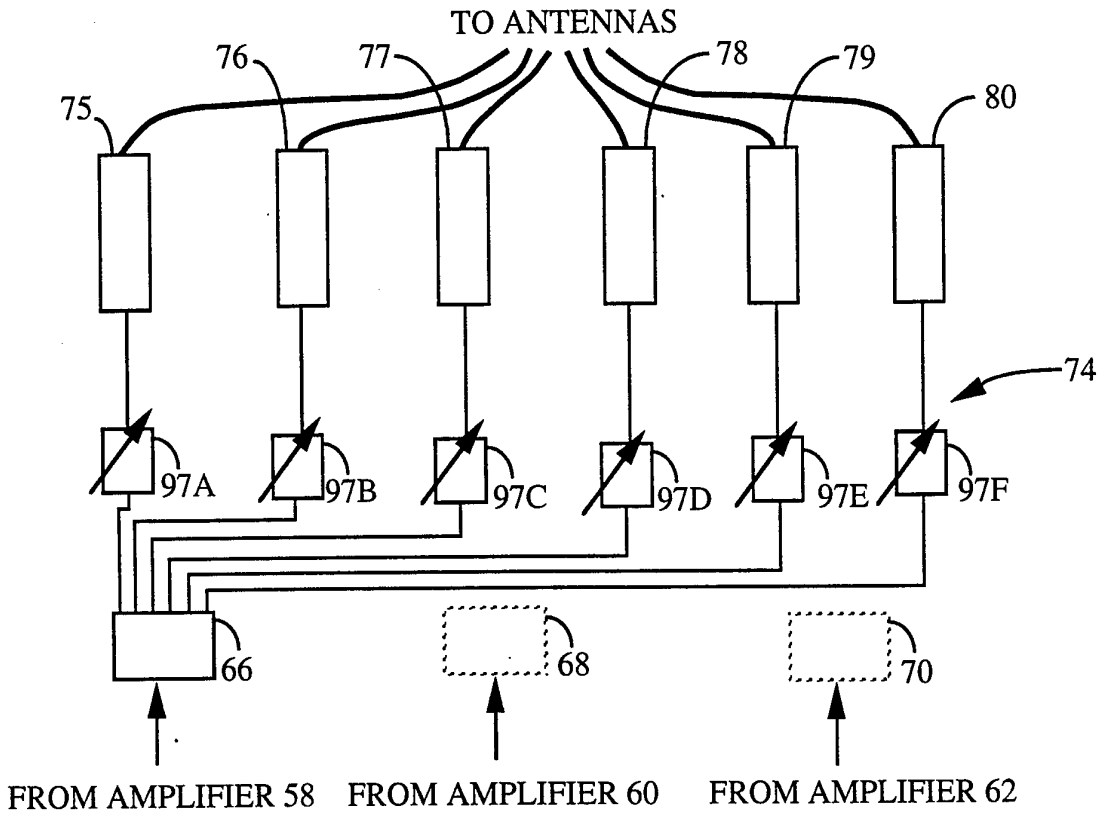

TO ANTENNAS
75
76
77
78
79
80
74
97A
97B
97C
97D
97E
97F
66
68
70
FROM AMPLIFIER 58
FROM AMPLIFIER 60
FROM AMPLIFIER 62

FIG. 3

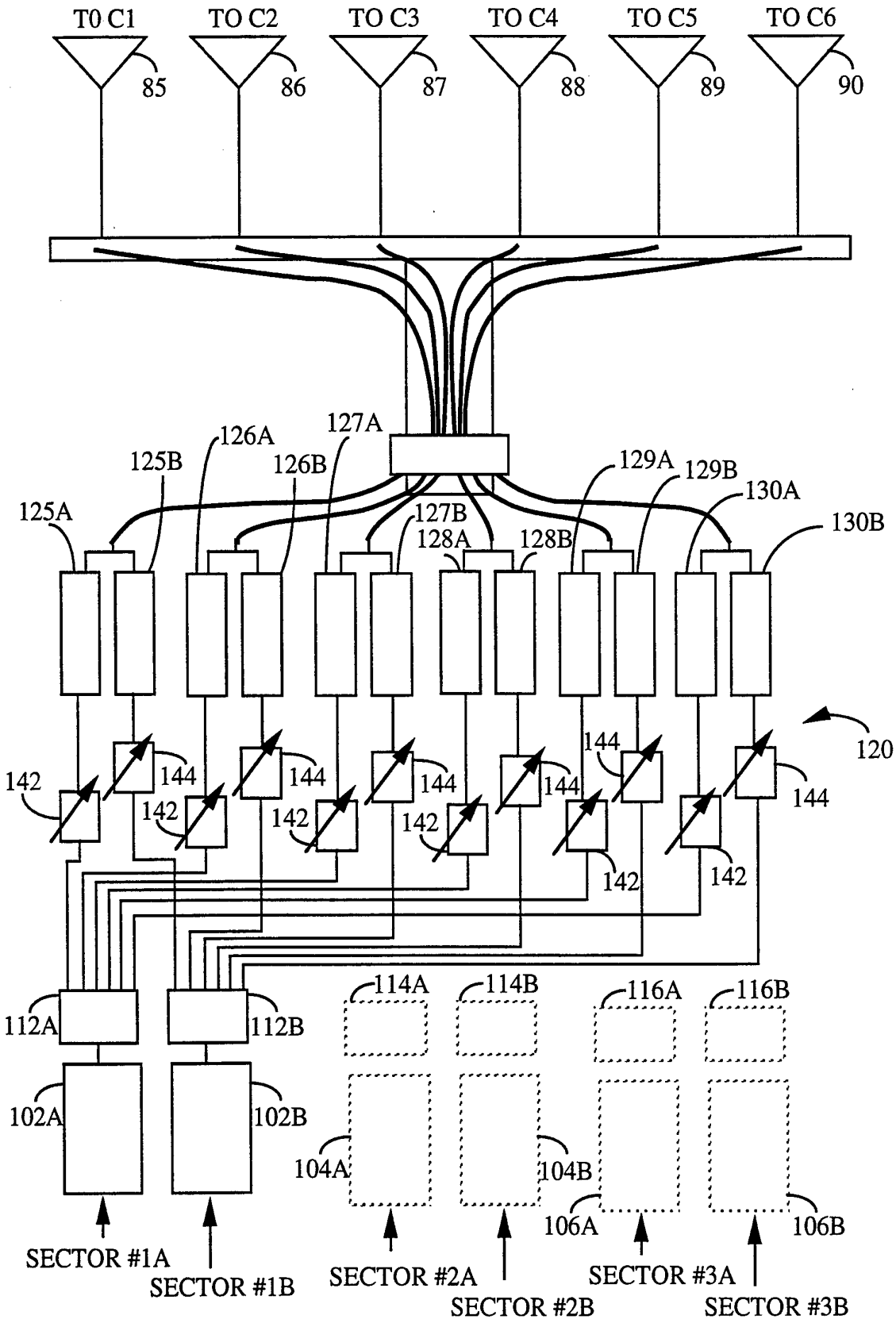

T0 C1
TO C2
TO C3
TO C4
TO C5
TO C6
85
86
87
88
89
90
125A
125B
126A
126B
127A
127B
128A
128B
129A
129B
130A
130B
120
142
144
112A
112B
114A
114B
116A
116B
102A
102B
104A
104B
106A
106B
SECTOR #1A
SECTOR #1B
SECTOR #2A
SECTOR #2B
SECTOR #3A
SECTOR #3B

FIG. 4

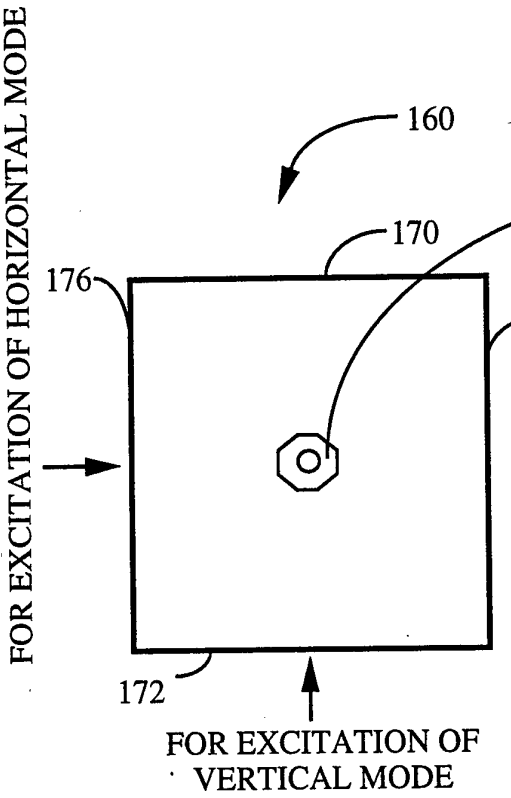

FOR EXCITATION OF HORIZONTAL MODE
160
163
170
176
178
172
FOR EXCITATION OF VERTICAL MODE

FIG. 5A

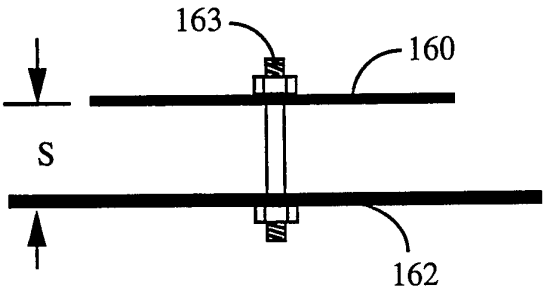

163
160
S
162

FIG. 5B

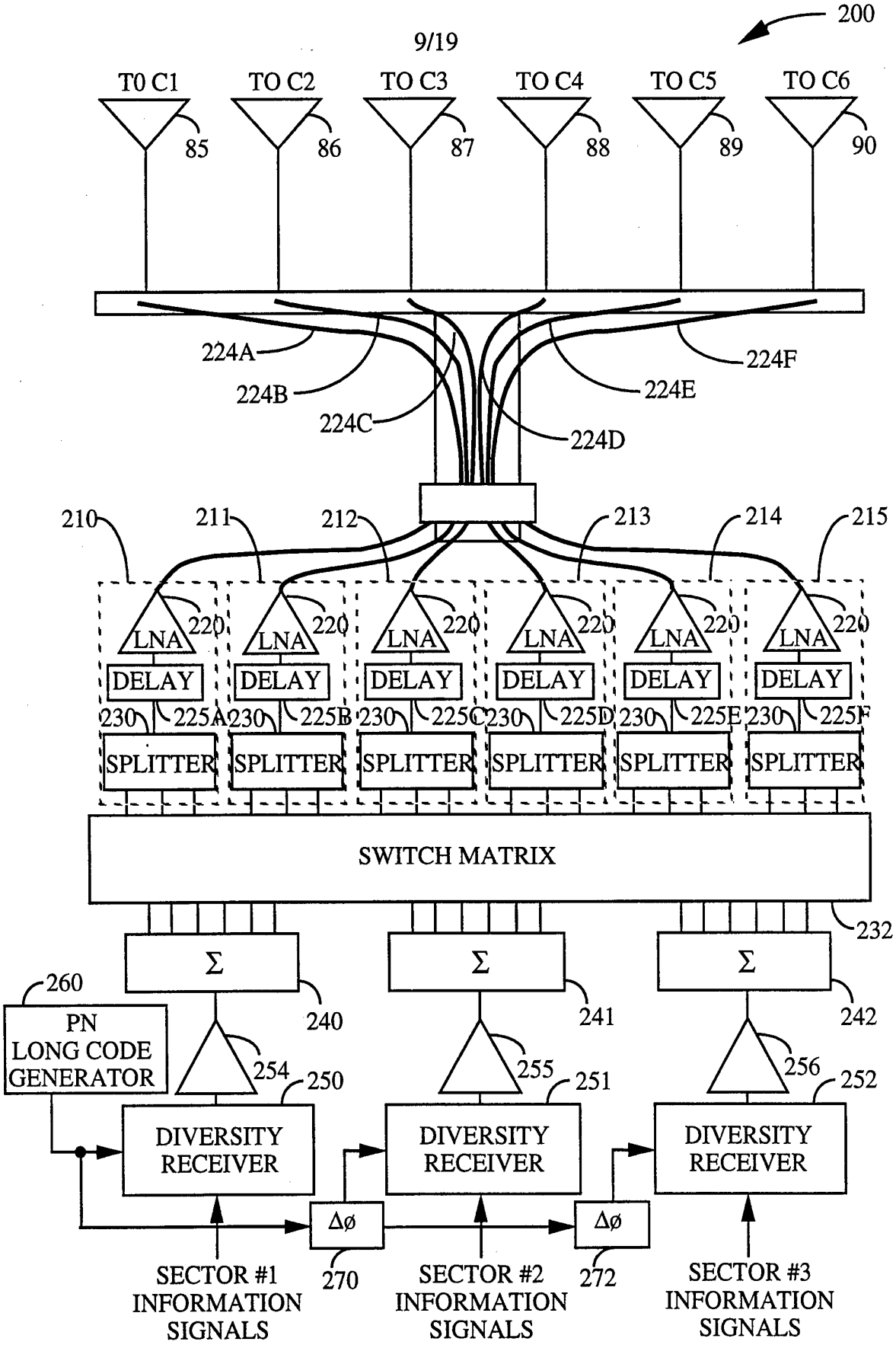

200
T0 C1
TO C2
TO C3
TO C4
TO C5
TO C6
85
86
87
88
89
90
224A
224B
224C
224D
224E
224F
210
211
212
213
214
215
LNA
220
DELAY
230
225A
225B
225C
225D
225E
225F
SPLITTER
SWITCH MATRIX
232
Σ
240
241
242
260
PN
LONG CODE
GENERATOR
254
255
256
250
251
252
DIVERSITY
RECEIVER
Δø
270
272
SECTOR #1
INFORMATION
SIGNALS
SECTOR #2
INFORMATION
SIGNALS
SECTOR #3
INFORMATION
SIGNALS

FIG. 6

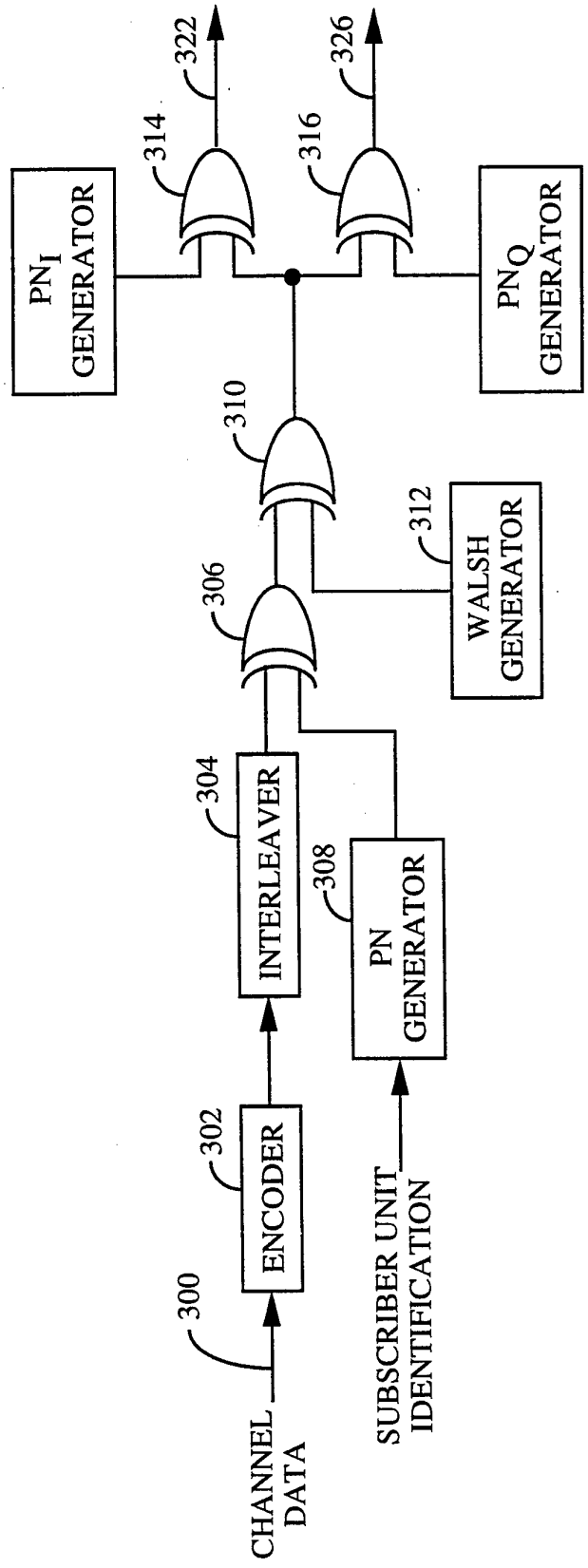

CHANNEL DATA
300
ENCODER
302
INTERLEAVER
304
PN GENERATOR
308
SUBSCRIBER UNIT IDENTIFICATION
306
WALSH GENERATOR
312
310
PN$_I$ GENERATOR
PN$_Q$ GENERATOR
314
316
322
326

FIG. 7

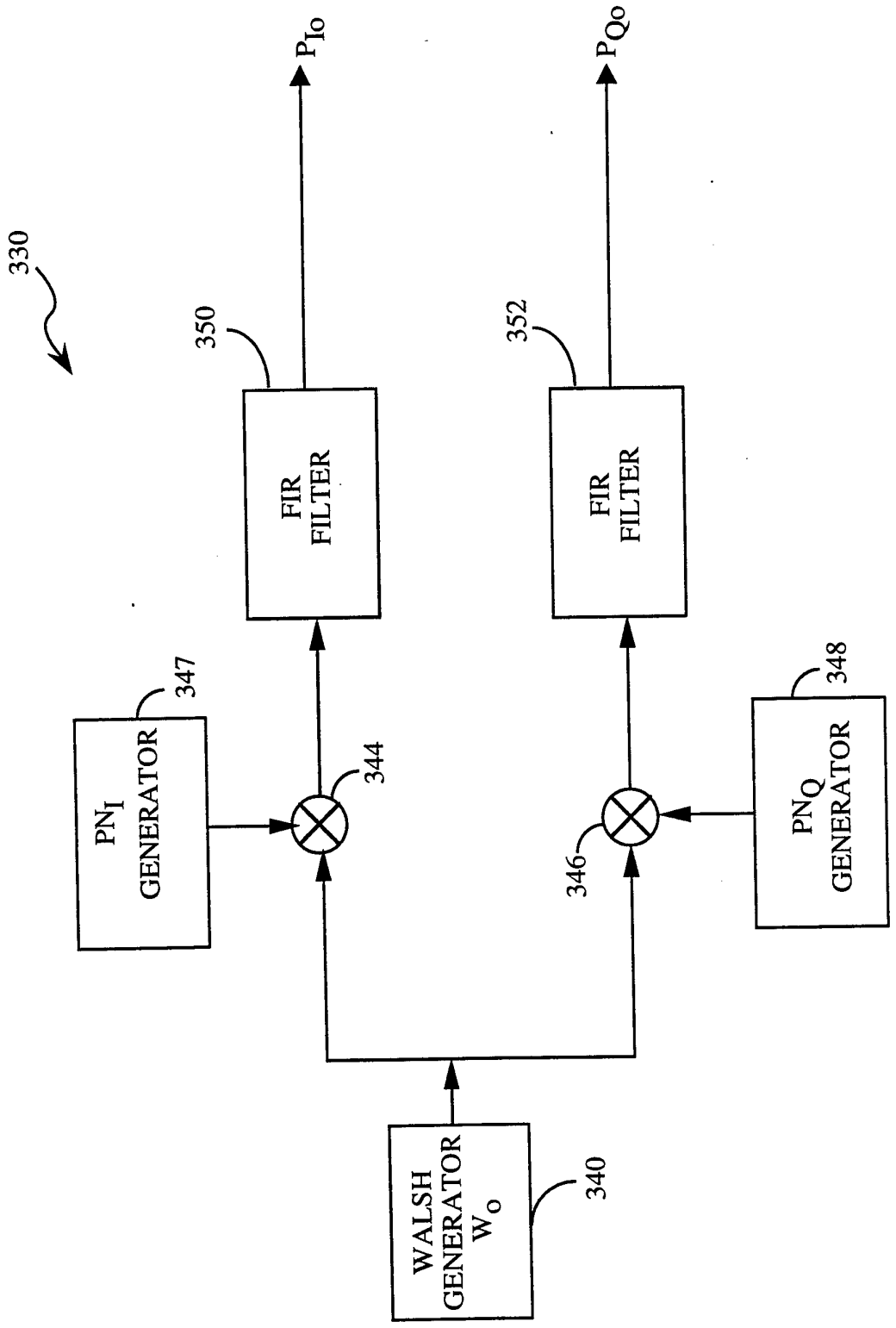

330
350
352
P_{Io}
P_{Qo}
FIR FILTER
FIR FILTER
347
348
344
346
PN_I GENERATOR
PN_Q GENERATOR
WALSH GENERATOR W_o
340

FIG. 8

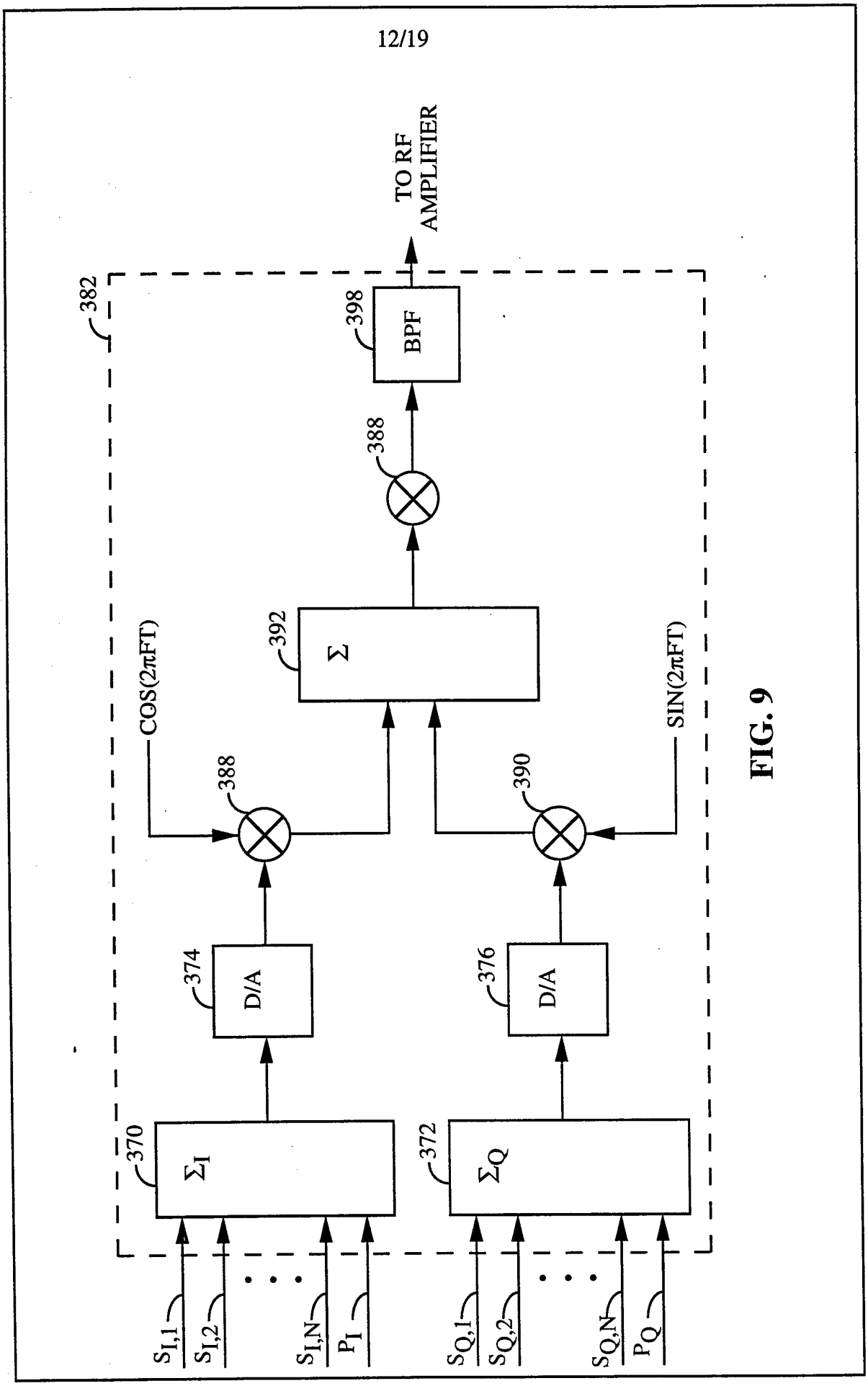

TO RF AMPLIFIER
382
398
BPF
388
392
Σ
COS(2πFT)
SIN(2πFT)
388
390
374
D/A
376
D/A
370
ΣI
372
ΣQ
SI,1
SI,2
SI,N
PI
SQ,1
SQ,2
SQ,N
PQ

FIG. 9

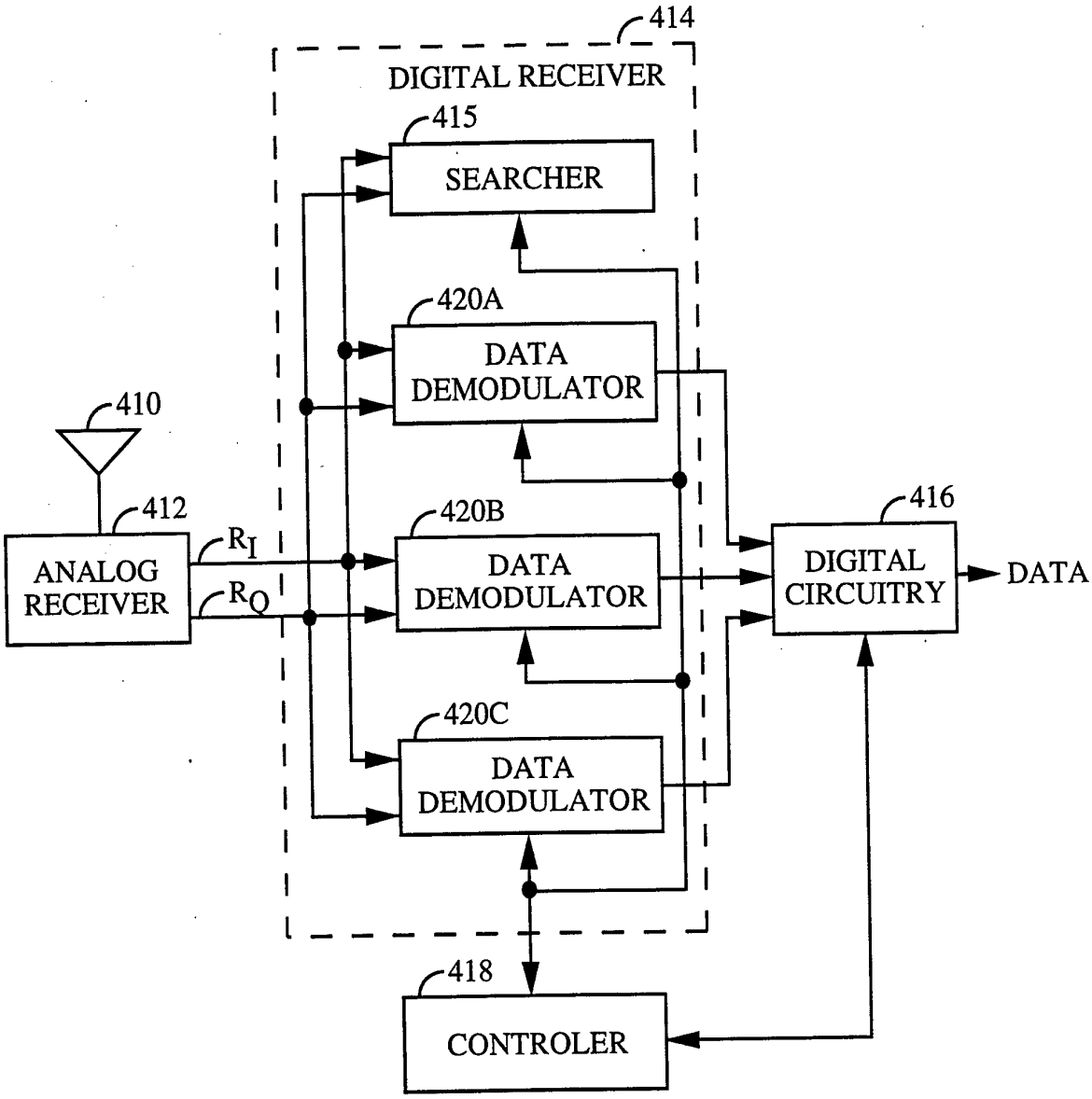

414
DIGITAL RECEIVER
415
SEARCHER
420A
DATA DEMODULATOR
410
412
ANALOG RECEIVER
R_I
R_Q
420B
DATA DEMODULATOR
416
DIGITAL CIRCUITRY
DATA
420C
DATA DEMODULATOR
418
CONTROLER

FIG. 10

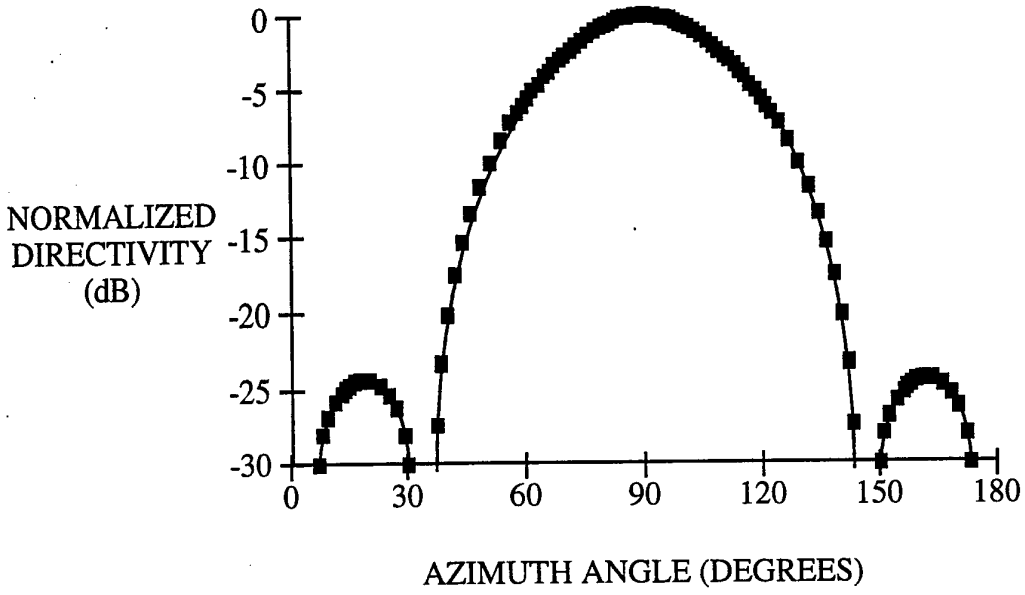


FIG. 11A

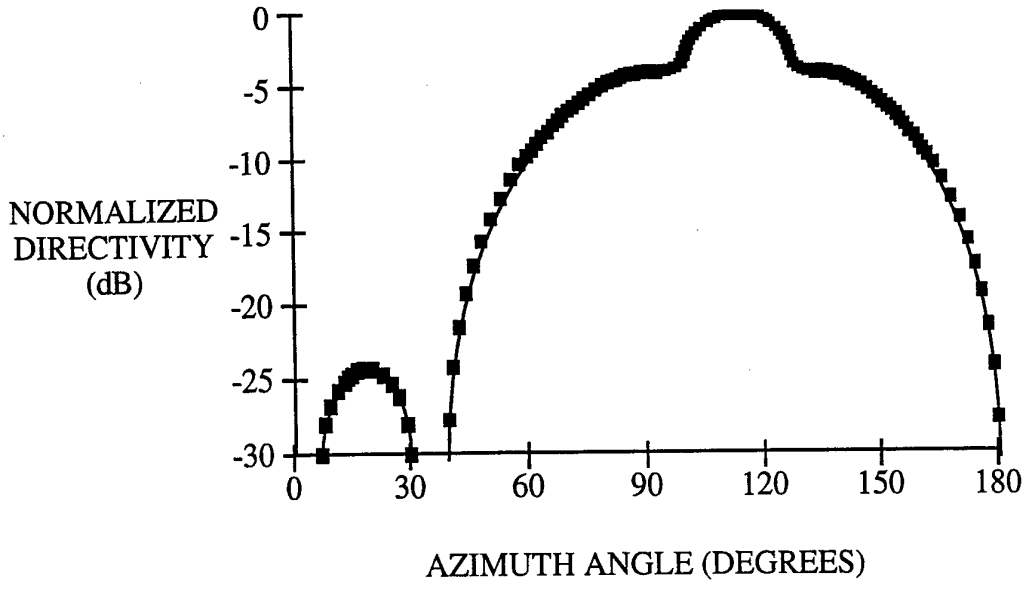


FIG. 11B

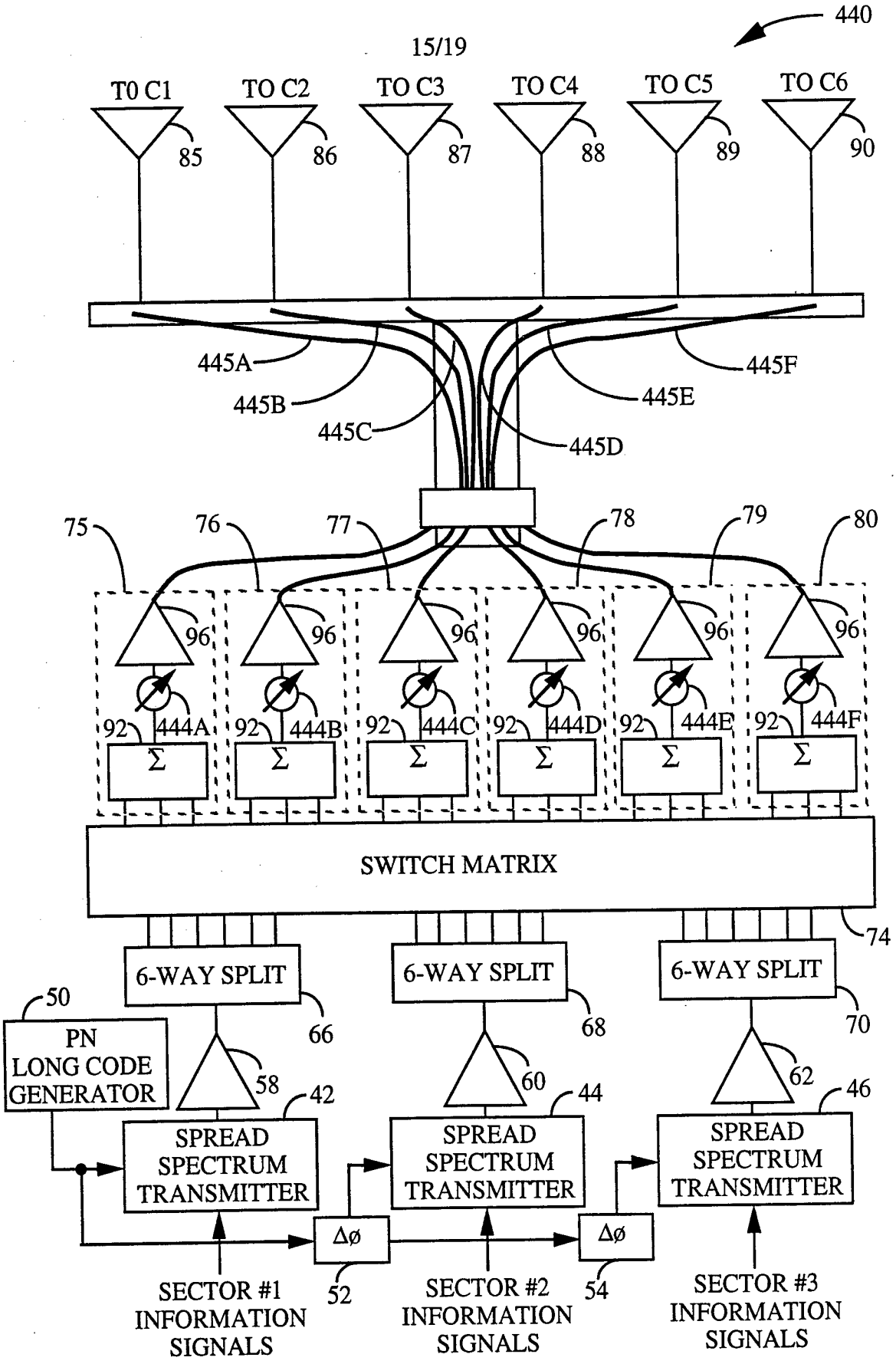

440
TO C1
TO C2
TO C3
TO C4
TO C5
TO C6
85
86
87
88
89
90
445A
445B
445C
445D
445E
445F
75
76
77
78
79
80
96
92
444A
444B
444C
444D
444E
444F
Σ
SWITCH MATRIX
74
6-WAY SPLIT
6-WAY SPLIT
6-WAY SPLIT
66
68
70
50
PN
LONG CODE
GENERATOR
58
60
62
42
44
46
SPREAD
SPECTRUM
TRANSMITTER
SPREAD
SPECTRUM
TRANSMITTER
SPREAD
SPECTRUM
TRANSMITTER
Δø
Δø
52
54
SECTOR #1
INFORMATION
SIGNALS
SECTOR #2
INFORMATION
SIGNALS
SECTOR #3
INFORMATION
SIGNALS

FIG. 12

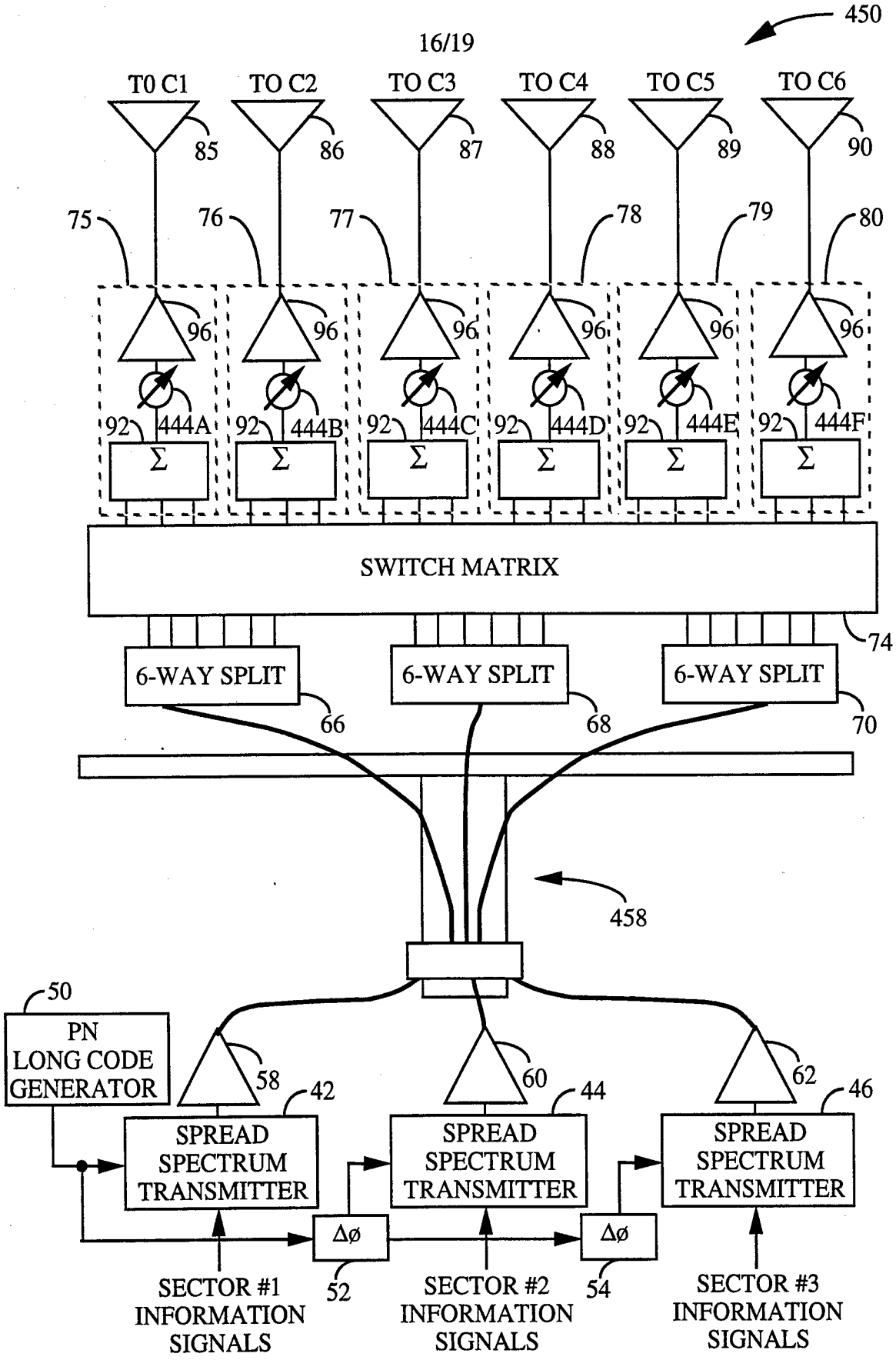

450
TO C1
TO C2
TO C3
TO C4
TO C5
TO C6
85
86
87
88
89
90
75
76
77
78
79
80
96
92
444A
444B
444C
444D
444E
444F
Σ
SWITCH MATRIX
74
6-WAY SPLIT
6-WAY SPLIT
6-WAY SPLIT
66
68
70
458
50
PN
LONG CODE
GENERATOR
58
60
62
42
44
46
SPREAD
SPECTRUM
TRANSMITTER
SPREAD
SPECTRUM
TRANSMITTER
SPREAD
SPECTRUM
TRANSMITTER
Δø
Δø
52
54
SECTOR #1
INFORMATION
SIGNALS
SECTOR #2
INFORMATION
SIGNALS
SECTOR #3
INFORMATION
SIGNALS

FIG. 13

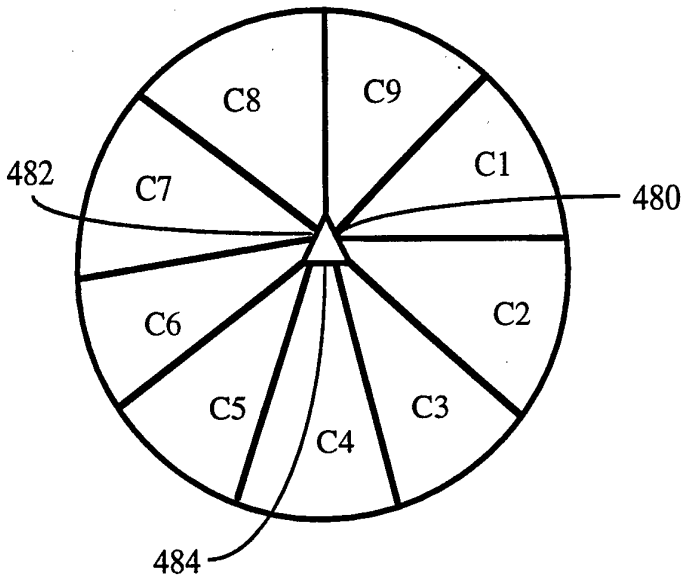


FIG. 14

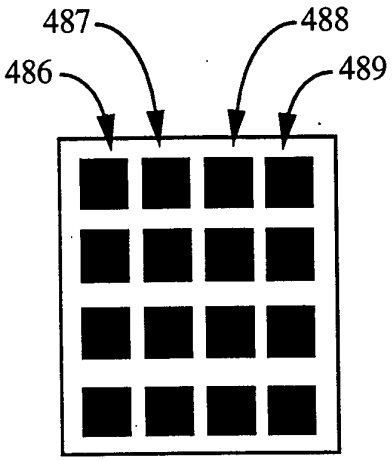


FIG. 15

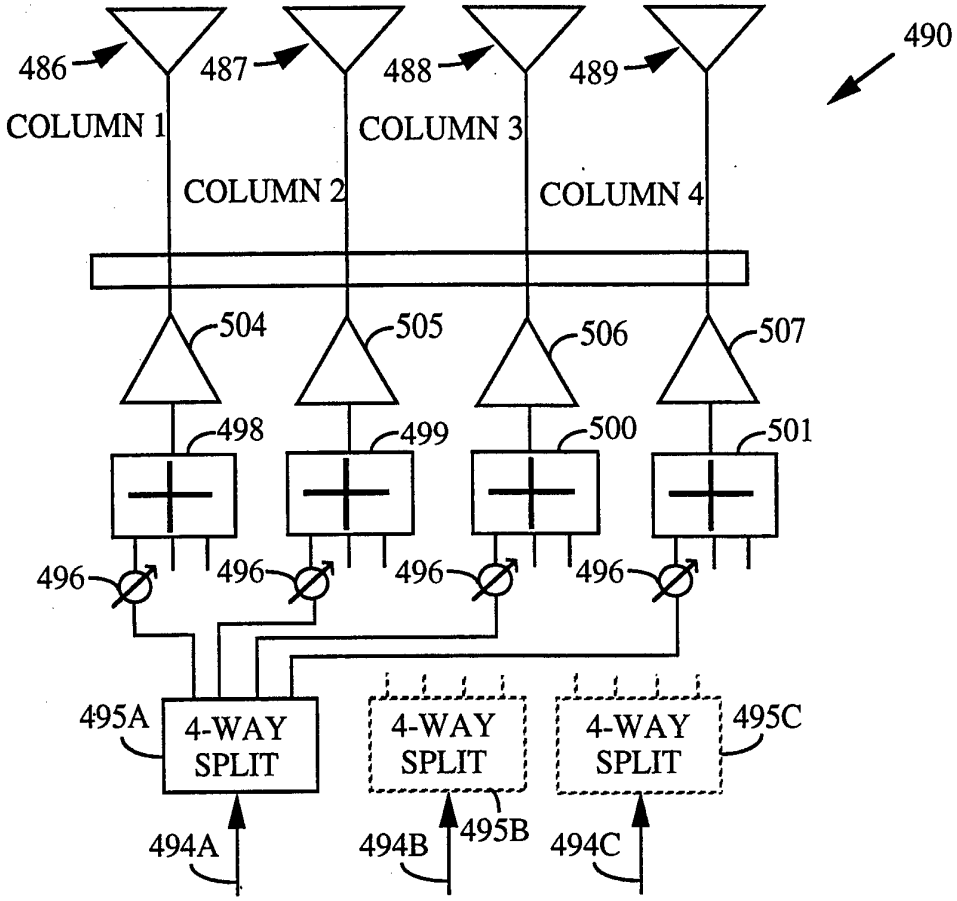

490
486
487
488
489
COLUMN 1
COLUMN 2
COLUMN 3
COLUMN 4
504
505
506
507
498
499
500
501
496
496
496
496
495A
4-WAY SPLIT
4-WAY SPLIT
4-WAY SPLIT
495C
494A
494B
495B
494C

FIG. 16