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(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S–126 25 Stockholm (SE).

(72) Inventors: ÖSTMAN, Thomas; Sotingeplan 8, S–163 61 Spånga (SE). HAGERMAN, Bo; Tjärhovsgatan 16, S–116 21 Stockholm (SE). MINICHIELLO, Pat; 246 de Beauharnois, Montréal, Québec H2N 1K3 (CA). DESGAGNE, Michel; 6606 des Marronniers, St. Hubert, Québec J3Y 8T4 (CA).

(74) Agent: NORIN, Klas; Ericsson Radio Systems AB, Common Patent Department, S–164 80 Stockholm (SE).

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(54) Title: SMART ANTENNA BEAM ASSIGNMENT AT MOBILE STATION CALL SETUP

(57) Abstract

A cellular communications network includes a plurality of cells whose base stations (122) have smart antenna capabilities and conventional sector antenna capabilities. At mobile station (142) call setup, the call is initially set up on a sector antenna supported, looser frequency reuse plan assigned, measurement traffic channel frequency provided by the serving base station. Higher quality direction of arrival angle measurements (210) are then made at the serving base station to identify a particular smart antenna narrow beam which could serve the mobile station. A replacement frequency supported by that narrow beam is then selected (214), and an intra–cell handoff of the call is ordered (216). In the event mobile station location information is needed (e.g., based on the call type or call priority), neighbouring base stations are instructed (304) to make (306) and report (308) on direction of arrival angle measurements towards the mobile station. The reported angles are then processed (310) using triangulation (or other suitable) techniques, in view of known base station geographic location, to determine an approximate location of the mobile station.

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SMART ANTENNA BEAM ASSIGNMENT AT MOBILE STATION CALL SETUP

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application for patent is related to and incorporates by reference previously filed, commonly assigned, co-pending United States Application for Patent Serial No. 08/994,586, filed December 19, 1997, entitled "Method and System for Improving Handoffs in Cellular Mobile Radio Systems".

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to a cellular telephone network implementing a smart antenna technology at its base stations and, in particular, to the assignment of a proper smart antenna beam for target base station activation at mobile station call setup.

Description of Related Art

It is well known in the art to utilize directive antennas in cellular communications networks. The most commonly recognized example of directive antenna use in cellular communications networks is based on the principle of sectorization, as is illustrated in FIGURE 1. A cell site 10 may comprise either one omnidirectional cell or a plurality, for example, three (or more), sector cells 12. Directive antennas 14, each with an appropriately selected beamwidth for the sector cell 12, are then utilized at each base station 16 to form a plurality of wide beams 18, one per sector cell, with the totality of the beams formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. In operation, each of the formed wide beams 18 is in continuous use to provide service within each corresponding sector cell 12.

Another example of directive antenna use in cellular communications networks is based on the use of smart antenna technology, as is illustrated in FIGURE 2A. Directive antennas 20 are utilized at each base station 16 of a cell site 10 to form a plurality of separate, perhaps slightly overlapping, narrow beams 22 within each sector cell 12, with the totality of the beams formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. In operation, and in contrast to the operation of the sectorized beams 18 of FIGURE 1, the narrow beams 22 are intermittently used only when necessary to provide service to one or more mobile stations 24, as is illustrated in FIGURE 2B. Put another way, in smart antenna technology, the base station 16 controls its directive antenna 20 to activate at any given time only those individual ones of the plurality of separate, perhaps slightly overlapping, narrow beams 22 as are needed to serve active mobile stations 24 within the cell site 10.

Selection of the proper narrow beam 22 to serve a mobile station is a very important base station task. If an incorrectly oriented beam 22 is selected, there is a chance that communications with the mobile station could be lost. Improper beam activation, or the activation of too many smart antenna beams, may also result in unacceptable levels of interference. There is accordingly a need for a technique for proper smart antenna narrow beam 22 selection. More particularly, there is a need for such a technique for use at each instance of a mobile station call setup.

SUMMARY OF THE INVENTION

Responsive to a mobile station call origination, the call is initially setup on a sector antenna supported measurement traffic channel frequency provided by the serving base station. In a preferred embodiment, this measurement traffic channel frequency would comprise a frequency assigned to serving base station based on a looser frequency reuse plan thus ensuring a highest quality channel as is possible. The serving base station, which also has smart antenna capability, further makes a direction of arrival azimuth orientation angle determination with respect to that mobile station operating on the measurement traffic channel frequency, and identifies a particular one of its separate narrow beams which could be used to serve that mobile station. Responsive to the narrow beam identification, a smart antenna supported replacement frequency is selected, the serving base station activates the identified beam, and an intra-cell handoff of the mobile station call from the measurement traffic channel frequency to the replacement frequency is ordered.

In accordance with another aspect of the invention, a mobile station call is setup on either a sector antenna supported or smart antenna supported traffic channel provided by a serving base station. More specifically, higher priority calls are set on measurement traffic channel frequency assigned in accordance with a looser frequency reuse plan. Responsive to a detected need to determine the approximate location of the mobile station, each base station for a cell neighboring the cell of the serving base station is instructed to make a direction of arrival (DOA) azimuth orientation angle determination towards the mobile station on the traffic channel. The angles determined by the neighboring base stations are then reported and processed, in view of the known geographic location of each reporting base station, to determine an approximate location of the mobile station using triangulation (or other suitable) techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be acquired by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

FIGURE 1, previously described, is a diagram of directive antenna beam coverage within a sectorized cell of a cellular communications network;

FIGURES 2A and 2B, previously described, are diagrams of directive antenna beam coverage within a smart antenna equipped cell of a cellular communications network;

FIGURES 3A and 3B are diagrams of directive antenna beam coverage within a combined sectorized/smart antenna cell of the present invention;

FIGURE 4 is a block diagram of a cellular system including base stations implementing the combined sectorized/smart antenna cell illustrated in FIGURES 3A and 3B;

FIGURE 5 is a flow diagram for cellular telephone system call set-up operation in accordance with the present invention;

FIGURE 6 is a flow diagram for cellular telephone system call handling operation in accordance with the present invention to make mobile station location determinations; and

FIGURE 7 illustrates a triangulation procedure for determining mobile station location that is implemented in the call handling operation of FIGURE 6.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to FIGURE 3A wherein there is shown a diagram of directive antenna beam coverage within a combined sectorized/smart antenna cell 100 of the present invention. A base station 102 for the cell 100 includes a first plurality of directive (sector) antennas 104 each operable to form a wide beam 106 for each sector 108, with the totality of the sector coverage formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. The base station 102 for the cell 100 further includes a second plurality of directive (smart) antennas 110, one for each sector. Each of the second plurality of directive (smart) antennas 160 is operable to form a plurality of separate, perhaps slightly overlapping, narrow beams 112 (either switched or steerable) within each sector 108, with the totality of the smart beams formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. For ease of illustration only one sector 108 is shown. It is further understood that only one physical directive antenna (comprising, for example, an antenna array) may be needed to implement the logical first and second directive antennas 104 and 110 in a particular sector. In operation, each of the wide beams 106 formed by the first directive antennas 104 is in continuous use to provide service within each corresponding sector 108 to mobile stations 114 present therein. With respect to the second directive antennas 110, however, only those narrow beams 112 which are needed to serve active mobile stations 114 therein are in use at a given time, as is illustrated in FIGURE 3B.

Reference is now made to FIGURE 4 wherein there is shown a block diagram of a cellular system 120 including base stations 122 implementing the combined sectorized/smart antenna cell illustrated in FIGURES 3A and 3B. Each base station 122 includes a plurality of transceivers (Tx/Rx) 124 which operate in either a digital or analog mode on a certain frequency assigned to the cell 100 where the base station is located. A first set 124(1) of at least one of these transceivers 124 (providing at least control and perhaps also traffic channels) are connected to the first plurality of directive (sector) antennas 104 supporting the sector beams 106 (see, FIGURES 3A and 3B). A second set 124(2) of a plurality of these transceivers 124 (most likely providing only traffic channels) are connected to the second plurality of directive (smart) antennas 110 supporting the smart antenna beams 112 (see, FIGURES 3A and 3B). Each base station 122 is connected to a mobile switching center (MSC) 126. This connection may be made either directly (as generally indicated at 128(1)) or through a base station controller (BSC) 130 (as generally indicated at 128(2)). The manner of operation of the mobile switching center 126, base station controller 130 and base stations 122 in a coordinated fashion to provide cellular telephone service to mobile stations is well known to those skilled in the art.

The base station 122 further includes a first location verification module (LVM1) 132 operable in connection with one or more of the first directive (sector) antennas 104 to make measurements on mobile station uplink communications. The location verification module 132 is provided with an order to make these measurements. This order specifies a frequency on which the measurements are to made, a time slot within which the measurements are to be made, and a digital voice color code (DVCC) necessary to unambiguously identify the mobile station whose uplink communications are to be measured. Responsive to the received order, the location verification module 132 tunes to the proper frequency within the proper time slot, decodes the DVCC, and then makes the uplink measurements on certain metrics such as signal strength and signal quality. The measurements are then reported for subsequent evaluation in connection with system operation, such as, for example, handoff determinations.

The base station 122 still further includes a second location verification module (LVM2) 134 operable in connection with one or more of the second directive (smart) antennas 110 to make measurements on mobile station uplink communications. The location verification module 134 is similarly provided with an order to make these measurements. This order specifies a frequency on which the measurements are to made, a time slot within which the measurements are to be made, and a digital voice color code (DVCC) necessary to unambiguously identify the mobile station whose uplink communications are to be measured. Responsive to the received order, the location verification module 134 tunes to the proper frequency within the proper time slot, decodes the DVCC, and then makes the uplink measurements on certain metrics such as signal strength and signal quality. The measurements are then reported for subsequent evaluation in connection with system operation, such as, for example, handoff determinations. The measurements may also be processed by the second location verification module 134 to determine a direction of arrival (DOA) azimuth orientation angle θ (see, FIGURE 3A) with respect to the mobile station.

Although illustrated as having separate location verification modules for the first plurality of directive (sector) antennas 104 and the second plurality of directive (smart) antennas 110, it will of course be understood that only one location verification module is typically needed for most applications and it is preferably used in conjunction with, and connected to, one or more of the second directive (smart) antennas 110. It is also possible to utilize a single location verification module in connection with both the first plurality of directive (sector) antennas 104 and the second plurality of directive (smart) antennas 110. It is further understood that the location verification module(s) is capable of making measurements on either analog or digital traffic channels, as needed.

The base station 122 still further includes a smart antenna controller 136. The smart antenna controller 136 operates responsive to a determined direction of arrival (DOA) azimuth orientation angle θ (see, FIGURE 3A) identification with respect to a certain mobile station, and then identifies a certain one of the plurality of separate, perhaps slightly overlapping, narrow beams 112 corresponding to that angle for serving the mobile station. The smart antenna controller 136 then configures one of the second directive antennas 110 for operation to activate the identified beam 112 for handling communications with the mobile station (see, FIGURE 3B).

At least one of the transceivers 124 which is included in the first set 124(1) of transceivers 124 is assigned a frequency for traffic channel use for each sector 108 in accordance with a first frequency reuse plan. For purposes of this disclosure, this frequency is referred to as a "measurement" traffic channel frequency for the reasons discussed herein. As an example, the measurement traffic channel frequencies may be assigned to the transceivers 124 within the first set of transceivers 124(1) of each base station 122 in accordance with a 7/21 reuse plan. The remaining transceivers 124 within the second set 124(2) of transceivers are assigned frequencies for traffic channel use in accordance with a second frequency reuse plan, wherein the first frequency reuse plan has a larger reuse distance than the second frequency reuse plan (i.e., the first set 124(1) of transceivers are assigned frequencies in accordance with a looser frequency reuse plan than the second set 124(2) of transceivers). As an example, these frequencies may be assigned to the remaining transceivers 124 within the second set 124(2) in accordance with a 3/9 reuse plan.

Reference is now made to FIGURE 5 wherein there is shown a flow diagram for cellular telephone system call set-up operation in accordance with the present invention. In step 200, the mobile station signals the base station of its desire to originate a call. This signal is passed on from the base station to the mobile switching center. Responsive to the signal, the mobile switching center selects in step 202 a measurement traffic channel frequency provided by the first set 124(1) of transceivers 124 (and a time slot thereon if appropriate) for the serving base station 122 (depending on the sector within which the mobile station is located) to support a traffic channel for the call setup. A signal is then sent by the mobile switching center in step 204 (through the serving base station) to the mobile station identifying the selected measurement traffic channel frequency associated with the first frequency reuse plan. The mobile station then accesses the selected measurement traffic channel frequency in step 206 and support of the call begins using one of the base station first directive (sector) antennas 104. At this point, the location verification module 134 operable in connection with the second directive (smart) antenna 110 makes measurements on the measurement traffic channel frequency supporting the call in step 208. These measurements allow the base station to make a direction of arrival (DOA) azimuth orientation angle determination towards the mobile station and further identify which one of the plurality of separate, perhaps slightly overlapping, narrow beams 112 correspond with that angle and thus would be needed to serve the mobile station within the cell using the second directive antenna 110 (step 210). This information is reported to the mobile switching center in step 212. Responsive thereto, the mobile switching center selects in step 214 a replacement frequency 124 (and a time slot thereon if appropriate) for the serving base station 122 supported by the second set 124(2) of transceivers to support a replacement traffic channel for the call. A signal is then sent by the mobile switching center in step 216 (through the serving base station) to the mobile station identifying the selected replacement frequency supported by the second set 124(2) of transceivers and ordering the mobile station to engage in an intra-cell handoff from the previously selected measurement traffic channel frequency to the assigned replacement frequency associated with the second frequency reuse plan. Responsive to the signal, the base station activates the proper narrow beam 112 with the selected replacement frequency in step 218 that is either identified in or corresponds to the direction of arrival information provided in the signal sent by the mobile switching center. The mobile station then tunes to and accesses (step 220) the assigned replacement frequency (in the proper time slot). When mobile station access is detected (step 222), the mobile switching center 118(1) switches the call (step 224) to complete the intra-cell handoff procedure and support of the call continues using one of the base station second directive (smart) antennas 110.

Reference is now made to FIGURE 6 wherein there is shown a flow diagram for cellular telephone system call handling operation in accordance with the present invention to make mobile station location determinations. A call is setup in step 300 on a selected traffic channel. This traffic channel may comprise one of the traffic channels supported by the frequencies which are provided through use of one of the base station first directive (sector) antennas 104. More specifically, calls of a certain type or priority (such as emergency services calls) may be specifically setup (in the manner described above) and then held on the measurement traffic channel frequency provided by the transceiver 124 in the first set 124(1) associated with the first frequency reuse plan. Alternatively, this traffic channel may comprise one of the traffic channels supported by the frequencies associated with the second frequency use plan which are provided through use of the base station second directive (sector) antennas 110. In either case, in an instance where determining the approximate location of the mobile station becomes important, the serving base station notifies the mobile switching center in step 302. Responsive to this notification, the mobile switching center signals in step 304 each base station for a cell neighboring the cell of the serving base station. This signal instructs each neighboring base station to utilize its location verification module 134 in step 306 to make a direction of arrival (DOA) azimuth orientation angle determination towards the mobile station, and measure received power. The determined angles and power measurements are then reported by the base stations in step 308 back to the mobile switching center. At the mobile switching center, the reported determined angles and power measurements are processed, in view of the known geographic location of each reporting base station, to determine in step 310 an approximate location of the mobile station using triangulation (or other suitable, such as arcuation) techniques. This step 310 procedure is illustrated in FIGURE 7 with respect to base station reports concerning direction of arrival (DOA) azimuth orientation angle (θ_1, θ_2 and θ_3), and measured power level, determinations made towards the mobile station, and the processing of those angles, and power levels, to identify corresponding vectors 140 (and/or arcs, not shown) with the mobile station 114 approximately located at the intersection point 142 of these vectors (and/or arcs).

Although preferred embodiments of the method and apparatus of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A method for operating a cellular communications network, comprising the steps of:

setting up a mobile station call initially on a sector antenna supported measurement traffic channel frequency provided by the serving base station;

making direction of arrival azimuth orientation angle measurements on the mobile station call at the serving base station to identify a particular smart antenna narrow beam which could serve the mobile station;

selecting a smart antenna narrow beam supported traffic channel replacement frequency provided by the serving base station to handle the mobile station call; and

engaging in an intra-cell handoff of the mobile station call from the sector antenna supported measurement traffic channel frequency to the smart antenna narrow beam supported traffic channel replacement frequency.

2. The method as in claim 1 further including the steps of:

identifying a plurality of base stations neighboring the serving base station, each neighboring base station having a smart antenna capability;

making direction of arrival azimuth orientation angle measurements on the mobile station call by each of the identified neighboring base stations;

processing the direction of arrival azimuth orientation angle measurements, in view of known geographic location of the serving and neighboring base stations to determine mobile station location.

3. The method as in claim 2 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to the sector antenna supported measurement traffic channel frequency initially supporting the mobile station call.

4. The method as in claim 2 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to the smart antenna supported traffic channel frequency supporting the mobile station call following intra-cell handoff.

5. The method as in claim 2 further including the steps of:

making received power measurements on the mobile station call by each of the identified neighboring base stations;

processing the received power measurements, in view of known geographic location of the serving and neighboring base stations to determine mobile station location.

6. The method as in claim 1 wherein the measurement traffic channel frequency is associated with a first frequency reuse plan, and wherein the replacement frequency is associated with a second frequency reuse plan, and wherein the first frequency reuse plan has a larger reuse distance than the second frequency reuse plan.

7. A cellular communications network, comprising:

a base station supporting both sector antenna and smart antenna capability;

wherein the base station operates to:

initially set up a mobile station call on a sector antenna supported measurement traffic channel frequency; and

determine and report direction of arrival azimuth orientation angle measurements on the mobile station call at the base station to identity a particular smart antenna narrow beam which could serve the mobile station;

a control node operable responsive to the reported measurements to:

select a smart antenna narrow beam supported traffic channel replacement frequency provided by the serving base station to handle the mobile station call; and

signal the mobile station to engage in an intra-cell handoff to the smart antenna narrow beam supported traffic channel replacement frequency; and

wherein the base station further operates responsive to the signal to activate the identified particular smart antenna beam to serve the mobile station call following the intra-cell handoff.

8. The network as in claim 7 wherein:

the control node comprises a mobile switching center serving the serving base station;

the direction of arrival azimuth orientation angle measurements are reported to the mobile switching center; and

the signal is issued from the mobile switching center.

9. The network as in claim 7 wherein the measurement traffic channel frequency is associated with a first frequency reuse plan, and wherein the replacement

frequency is associated with a second frequency reuse plan, and wherein the first frequency reuse plan has a larger reuse distance than the second frequency reuse plan.

10. The network as in claim 7 further including:

a plurality of neighboring base stations, each of the neighboring base stations also supporting a smart antenna capability;

wherein each neighboring base station operates to determine and report direction of arrival azimuth orientation angle measurements on the mobile station call at the base station; and

wherein the control node further operates to process the reported direction of arrival azimuth orientation angle measurements, in view of known geographic location of the serving and neighboring base stations, to determine mobile station location.

11. The network as in claim 10 wherein the processing node implements triangulation techniques to approximately locate the mobile station from the reported direction of arrival azimuth orientation angle measurements.

12. The network as in claim 10 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to the sector antenna supported measurement traffic channel frequency initially supporting the mobile station call.

13. The network as in claim 10 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to the smart antenna supported traffic channel frequency supporting the mobile station call following intra-cell handoff.

14. The network as in claim 10:

wherein each neighboring base station operates to determine and report received power measurements on the mobile station call at the base station; and

wherein the control node further operates to process the reported received power measurements, in view of known geographic location of the serving and neighboring base stations, to determine mobile station location.

15. A method for operating a cellular communications network, comprising the steps of:

setting up a mobile station call on a traffic channel frequency provided by the serving base station;

identifying a plurality of base stations neighboring the serving base station;

making direction of arrival azimuth orientation angle measurements on the mobile station call by each of the identified neighboring base stations; and

processing the direction of arrival azimuth orientation angle measurements, in view of known geographic location of the serving and neighboring base stations, to determine mobile station location.

16. The method as in claim 15 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to a sector antenna supported measurement traffic channel frequency supporting the mobile station call.

17. The method as in claim 15 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to a smart antenna supported traffic channel frequency supporting the mobile station call.

18. A cellular communications network, comprising:

a base station operating to set up a mobile station call on a traffic channel frequency;

a plurality of neighboring base stations, each of the neighboring base stations operating to determine and report direction of arrival azimuth orientation angle measurements on the mobile station call; and

a control node operable responsive to the reported measurements to process the reported direction of arrival azimuth orientation angle measurements, in view of known geographic location of the serving and neighboring base stations, to determine mobile station location.

19. The network as in claim 18 wherein:

the control node comprises a mobile switching center serving the base stations; and

the direction of arrival azimuth orientation angle measurements are reported to the mobile switching center.

20. The network as in claim 18 wherein the processing node implements triangulation techniques to approximately locate the mobile station from the reported direction of arrival azimuth orientation angle measurements.

21. The network as in claim 18 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to a sector antenna supported measurement traffic channel frequency supporting the mobile station call.

22. The network as in claim 18 wherein the direction of arrival azimuth orientation angle measurements are made by the neighboring base stations with respect to a smart antenna supported traffic channel frequency supporting the mobile station call.

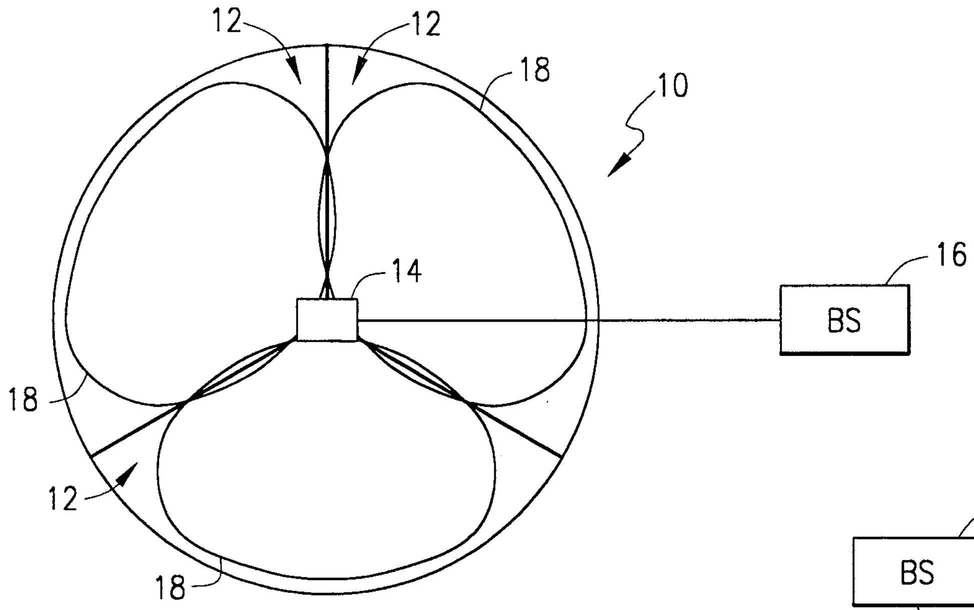


FIG. 1
(PRIOR ART)

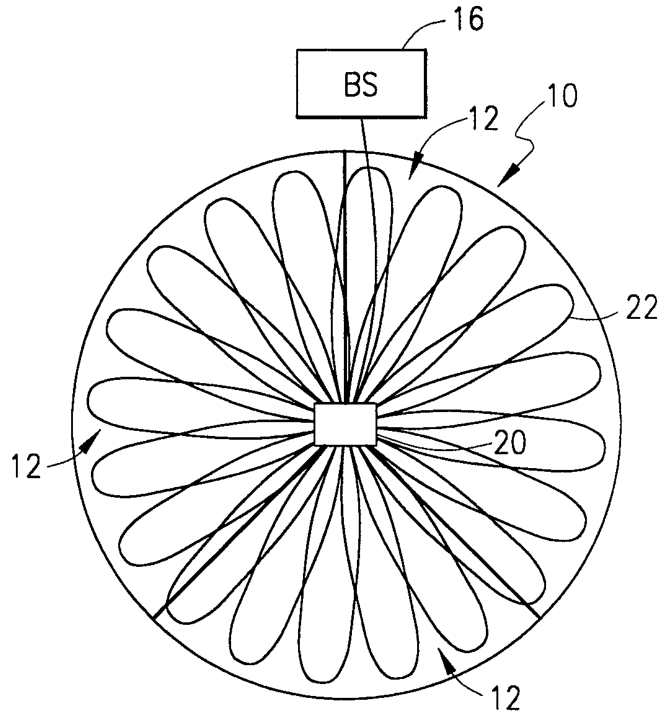


FIG. 2A
(PRIOR ART)

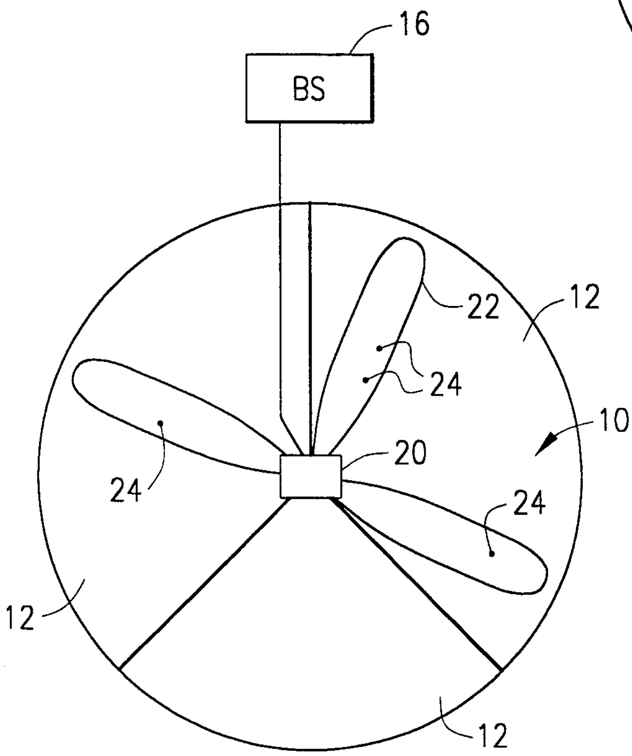
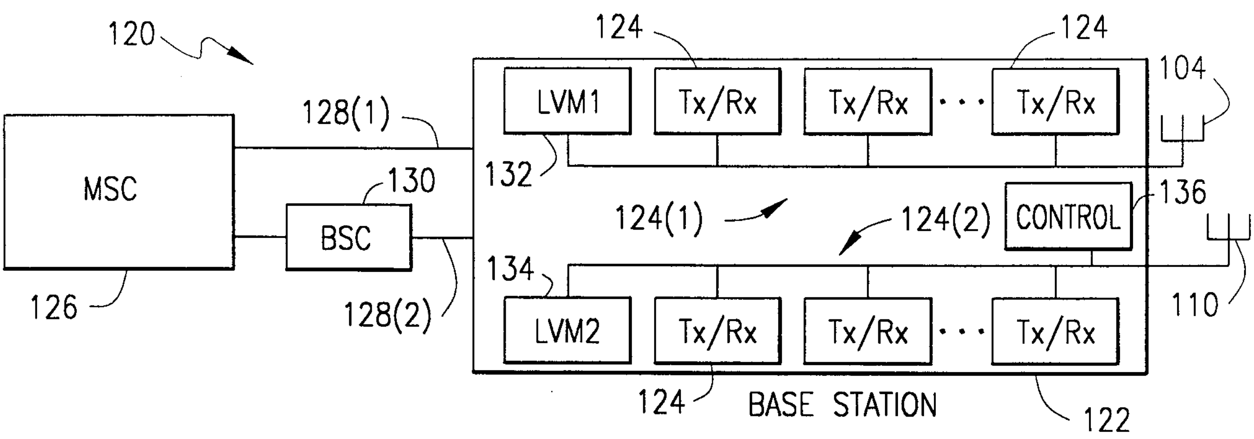


FIG. 2B
(PRIOR ART)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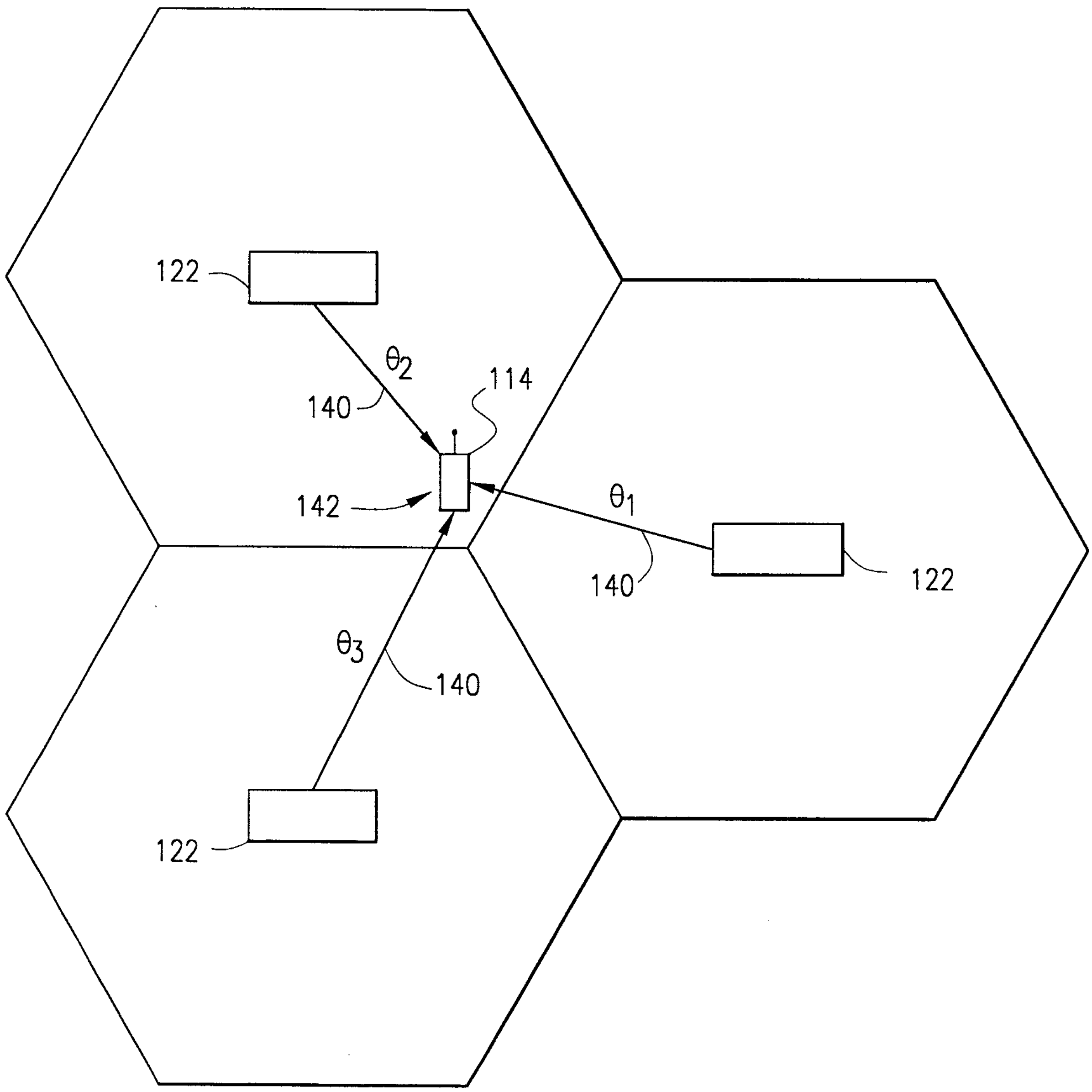
MSC
126
128(1)
BSC
130
128(2)
LVM1
132
Tx/Rx
124
124
104
124(1)
124(2)
CONTROL
136
134
LVM2
110
BASE STATION
122

FIG. 4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θ2
114
140
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θ1
140
122
θ3
140
122

FIG. 7

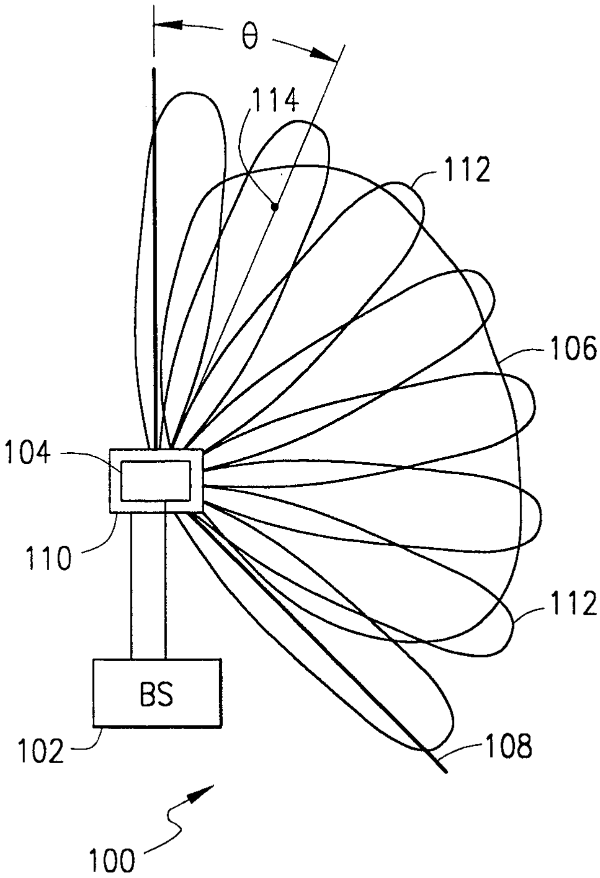

θ
114
112
106
104
110
112
BS
102
108
100

FIG. 3A

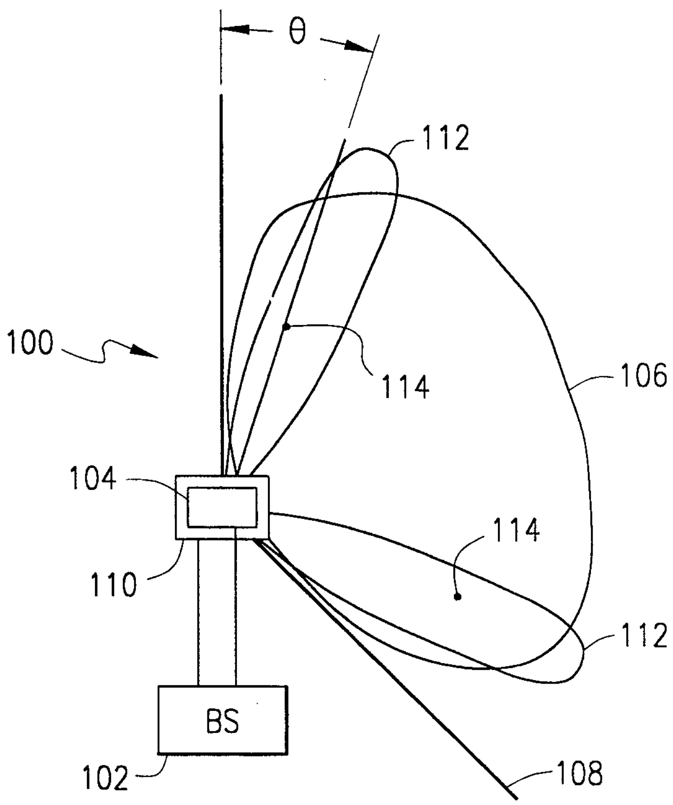
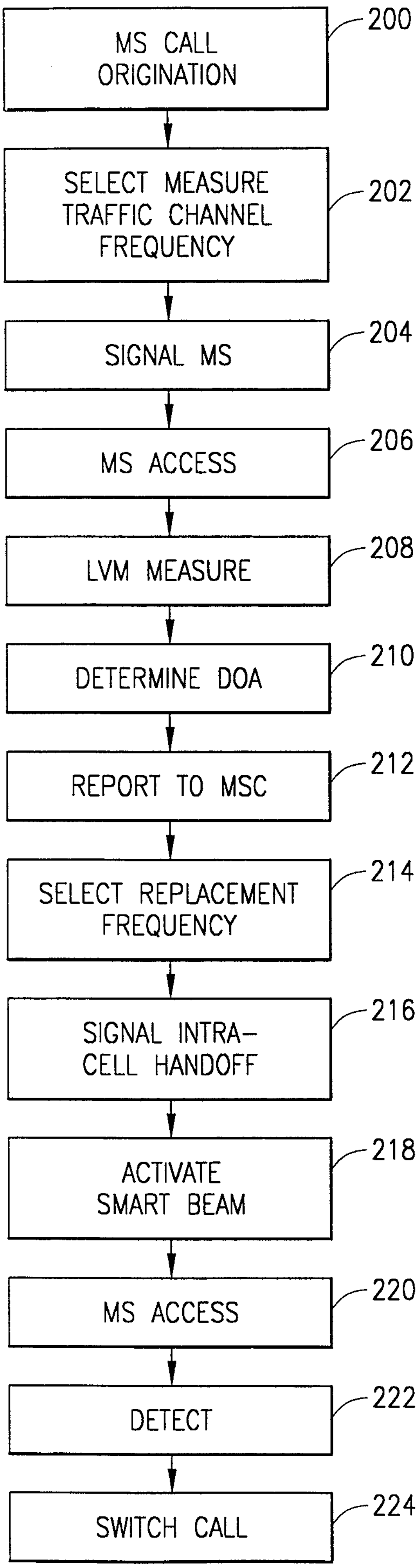

θ
112
100
114
106
104
114
110
112
BS
102
108

FIG. 3B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202
SIGNAL MS
204
MS ACCESS
206
LVM MEASURE
208
DETERMINE DOA
210
REPORT TO MSC
212
SELECT REPLACEMENT FREQUENCY
214
SIGNAL INTRA-CELL HANDOFF
216
ACTIVATE SMART BEAM
218
MS ACCESS
220
DETECT
222
SWITCH CALL
224

FIG. 5

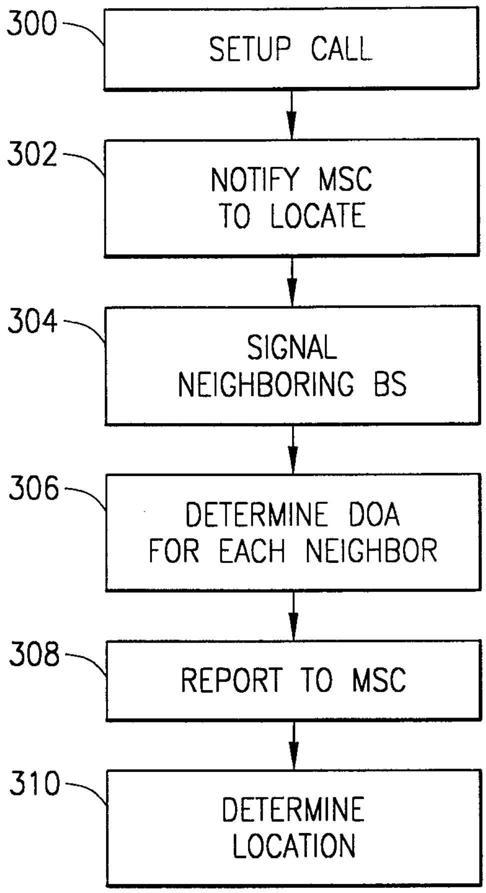
300
SETUP CALL
302
NOTIFY MSC TO LOCATE
304
SIGNAL NEIGHBORING BS
306
DETERMINE DOA FOR EACH NEIGHBOR
308
REPORT TO MSC
310
DETERMINE LOCATION

FIG. 6