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(54) COORDINATED SATELLITE-TERRESTRIAL FREQUENCY REUSE

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(22) Filed: **Mar. 14, 2005**

Related U.S. Application Data

(63) Continuation of application No. 09/918,709, filed on Aug. 1, 2001, now Pat. No. 6,892,068.

(60) Provisional application No. 60/222,605, filed on Aug. 2, 2000. Provisional application No. 60/245,194, filed on Nov. 3, 2000. Provisional application No. 60/250,461, filed on Dec. 4, 2000.

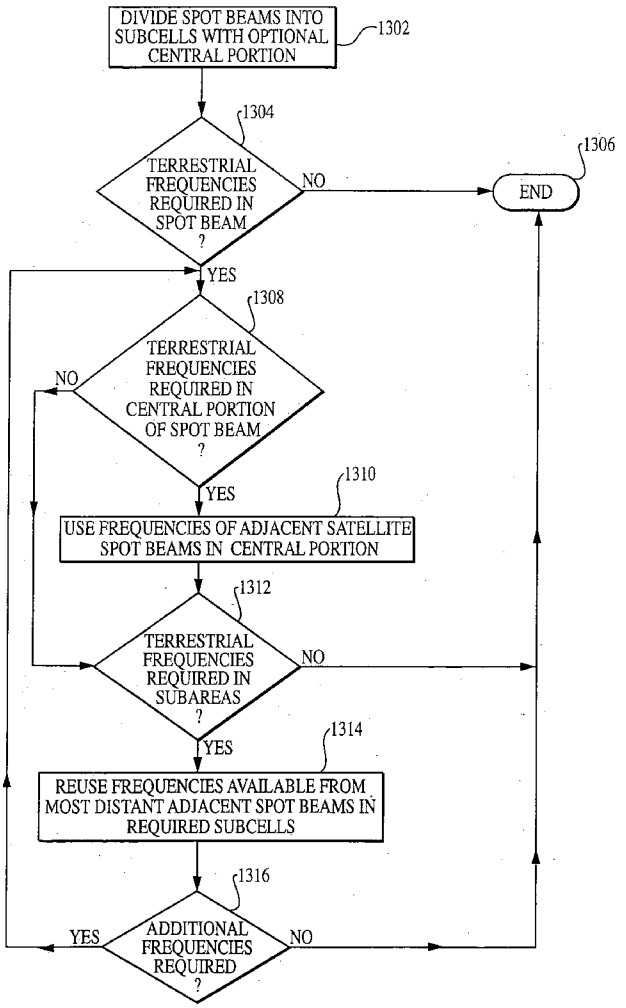
Publication Classification

(51) **Int. Cl.**[7] **H04Q 7/20**

(52) **U.S. Cl.** **455/429**; 455/447

(57) **ABSTRACT**

A system and method of operation for efficiently reusing and/or sharing at least a portion of the frequency spectrum between a first satellite spot beam and a second satellite spot beam, and/or an underlay terrestrial network associated with a second satellite spot beam. The spectrum is efficiently reused and/or shared between respective spot beams and/or associated underlay terrestrial systems in a manner minimizes interference between the respective satellite and terrestrial systems.



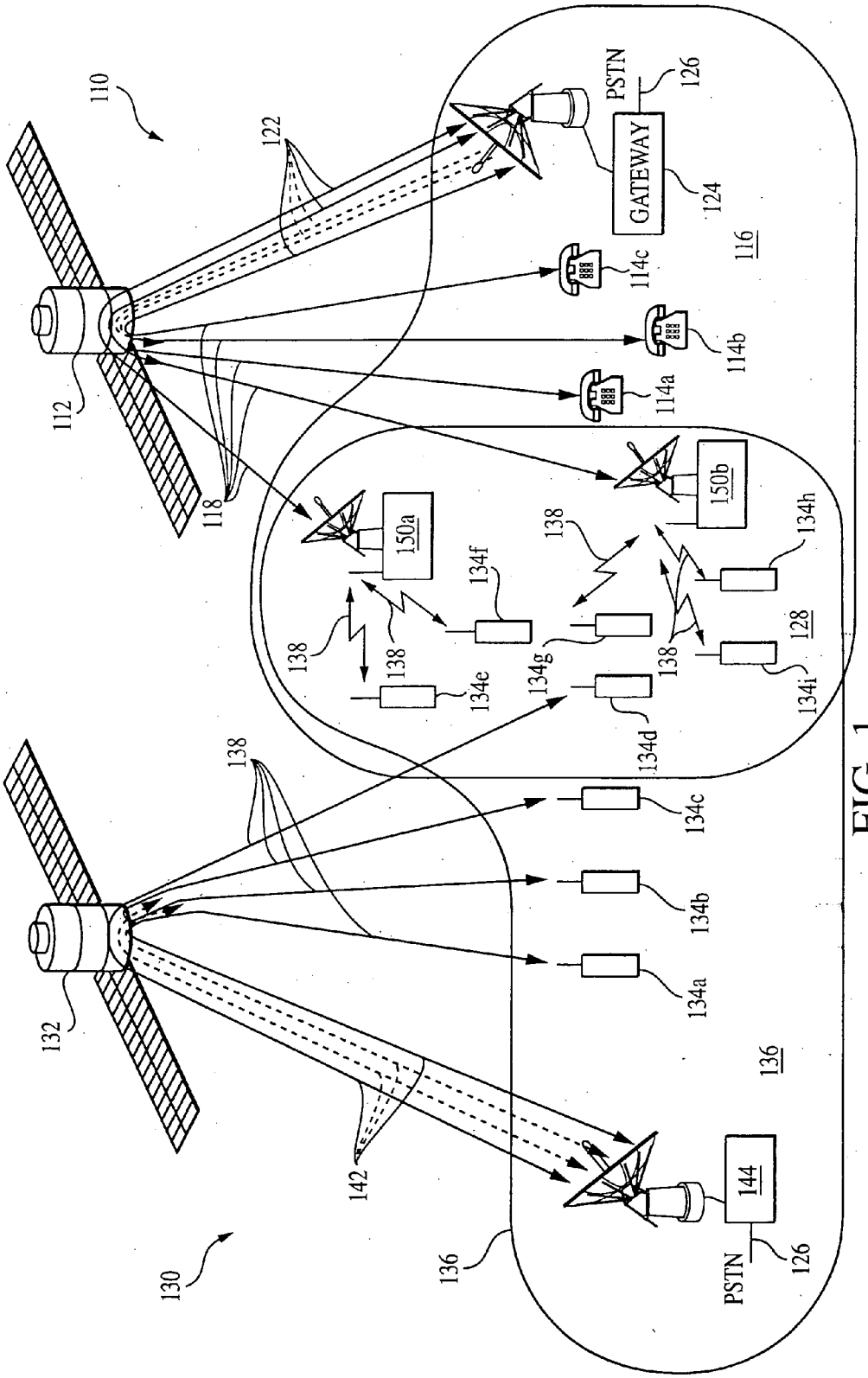


FIG. 1
PRIOR ART

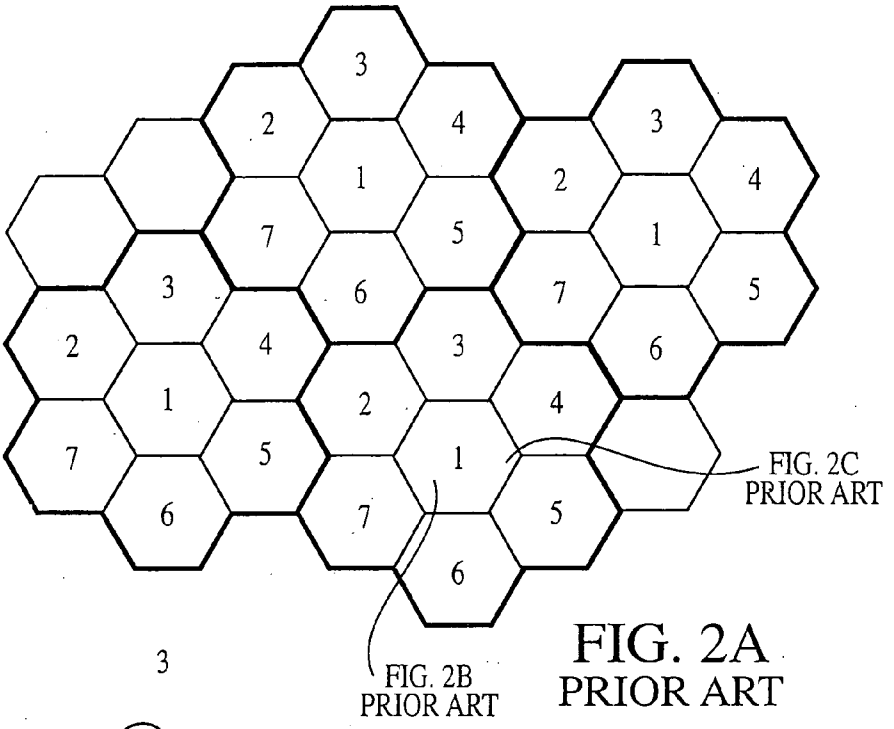


FIG. 2A
PRIOR ART

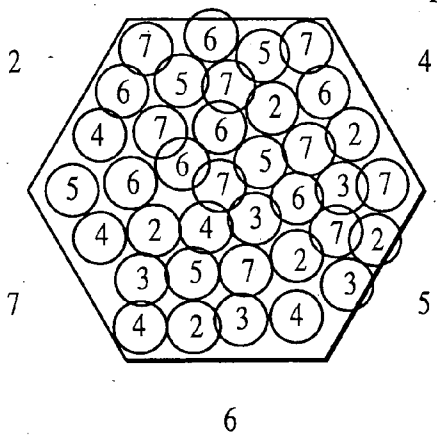


FIG. 2B
PRIOR ART

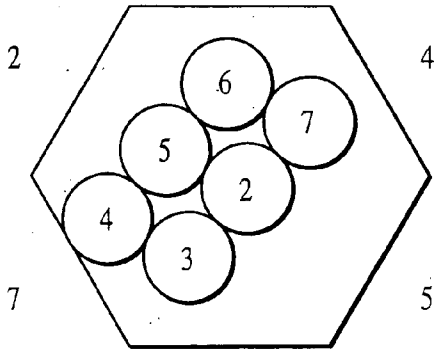


FIG. 2C
PRIOR ART

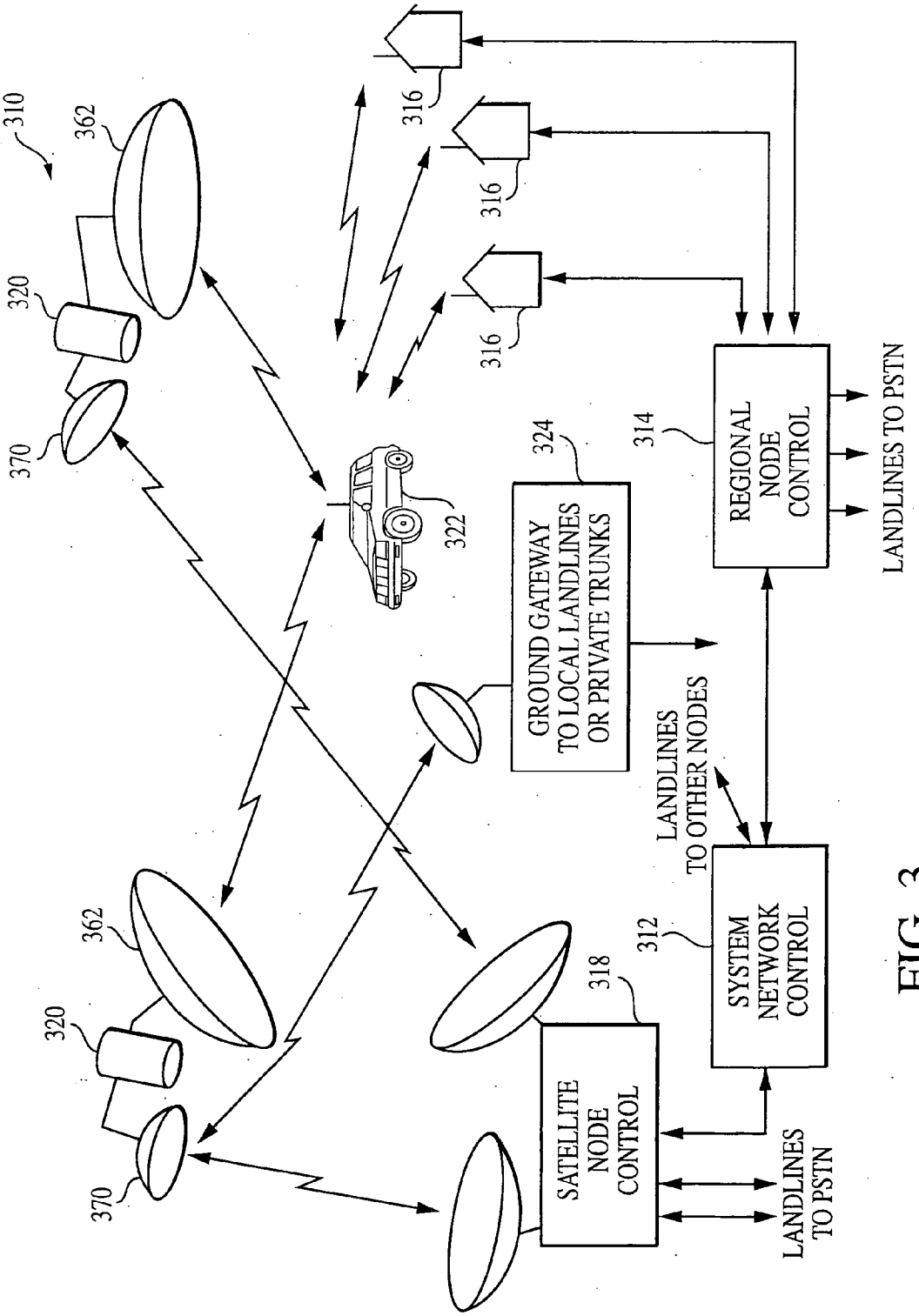


FIG. 3
PRIOR ART

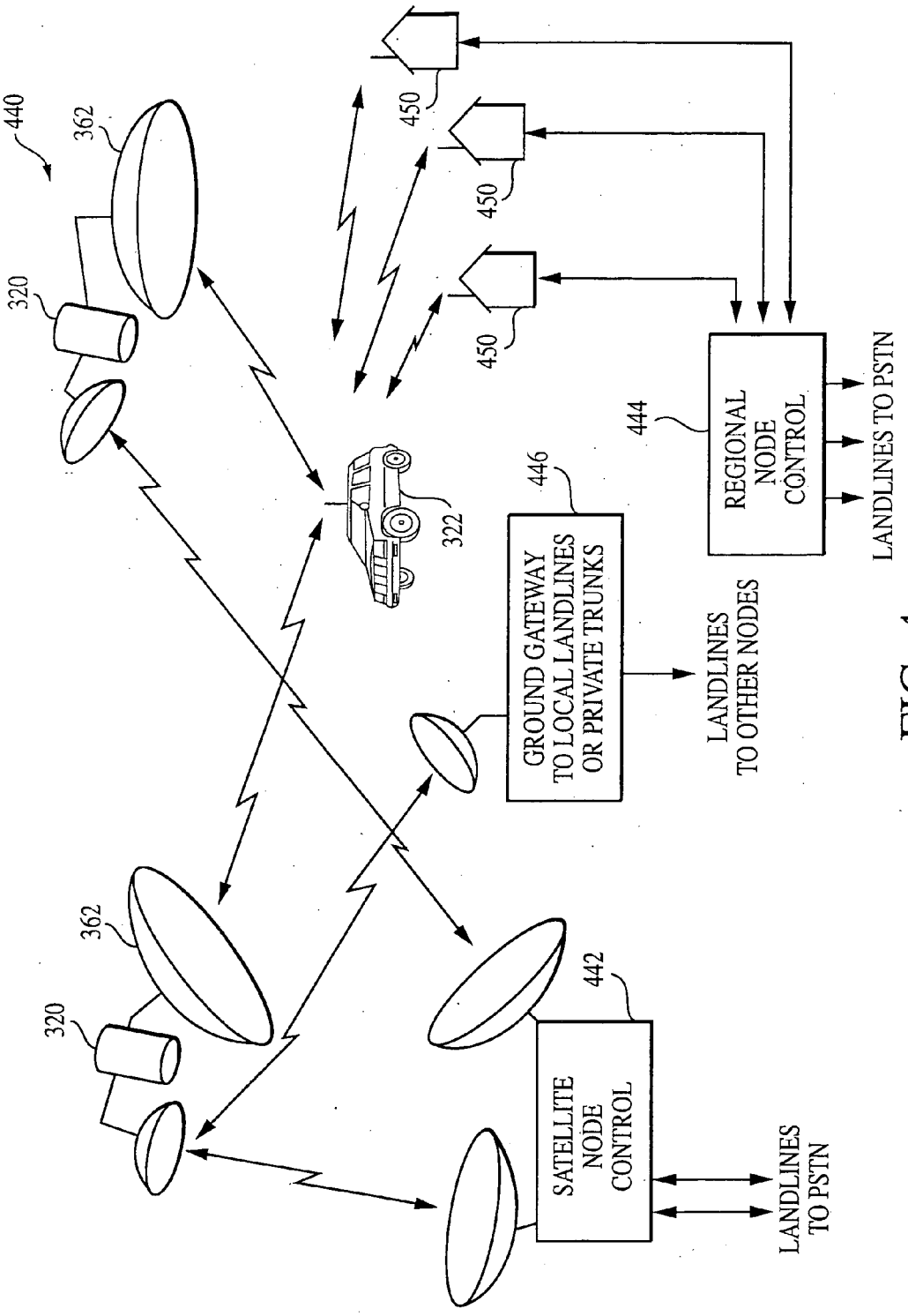


FIG. 4
PRIOR ART

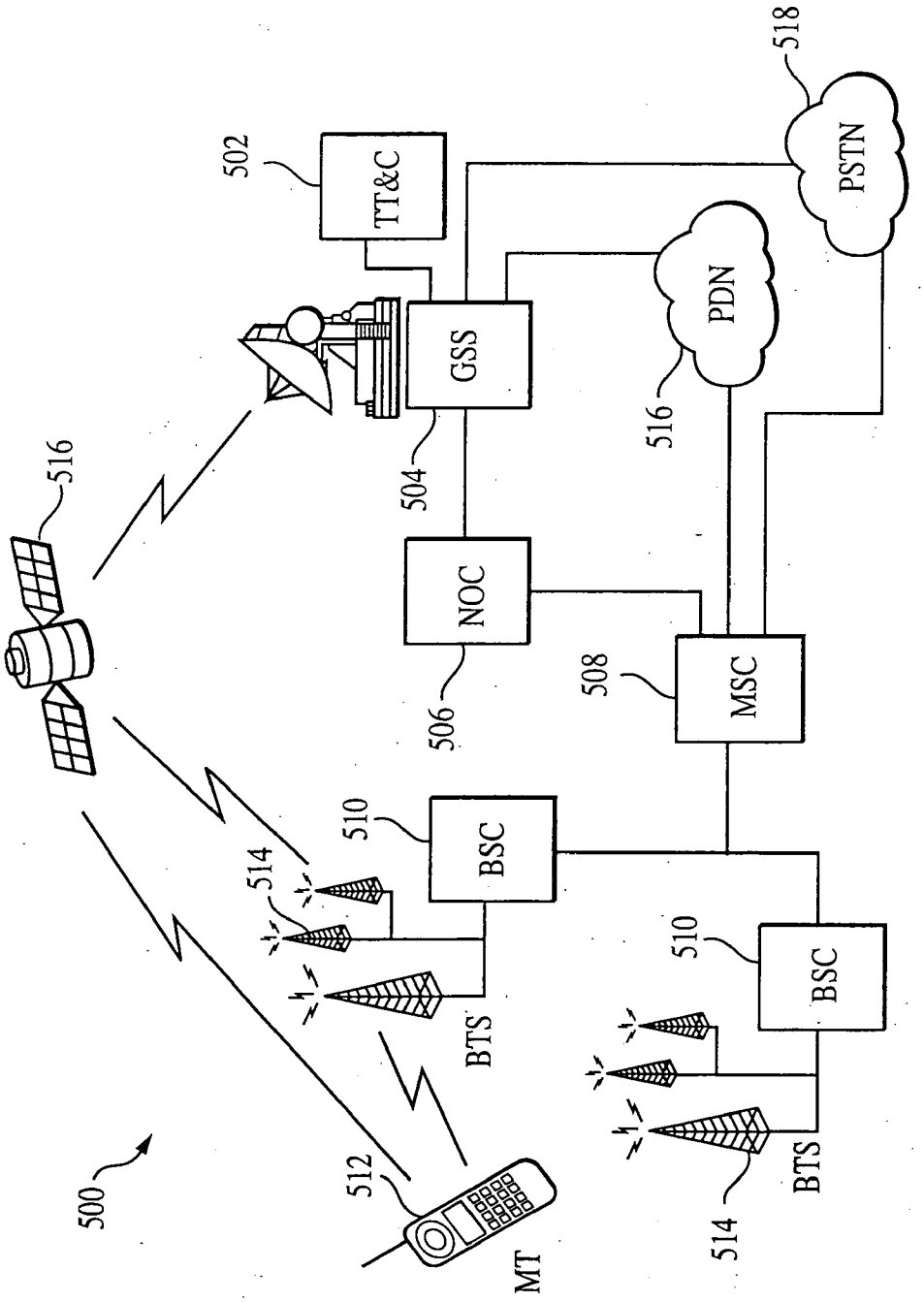

500
502
TT&C
504
GSS
506
NOC
508
MSC
510
BSC
510
BSC
512
MT
514
BTS
514
BTS
516
516
PDN
518
PSTN

FIG. 5

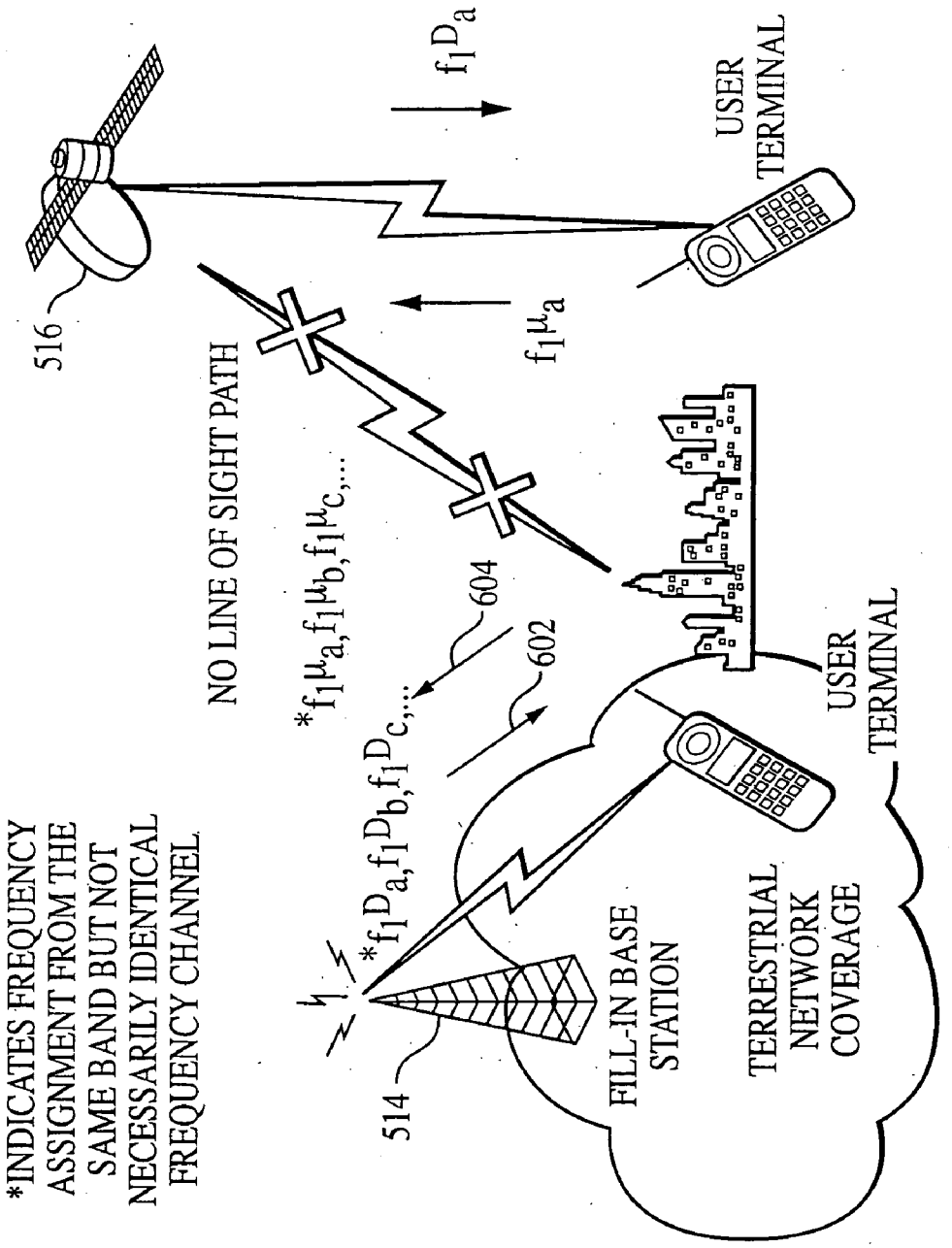

*INDICATES FREQUENCY ASSIGNMENT FROM THE SAME BAND BUT NOT NECESSARILY IDENTICAL FREQUENCY CHANNEL
516
NO LINE OF SIGHT PATH
f_1D_a
USER TERMINAL
$f_1\mu_a$
$*f_1\mu_a, f_1\mu_b, f_1\mu_{c,...}$
604
602
$*f_1D_a, f_1D_b, f_1D_{c,...}$
514
FILL-IN BASE STATION
TERRESTRIAL NETWORK COVERAGE
USER TERMINAL

FIG. 6

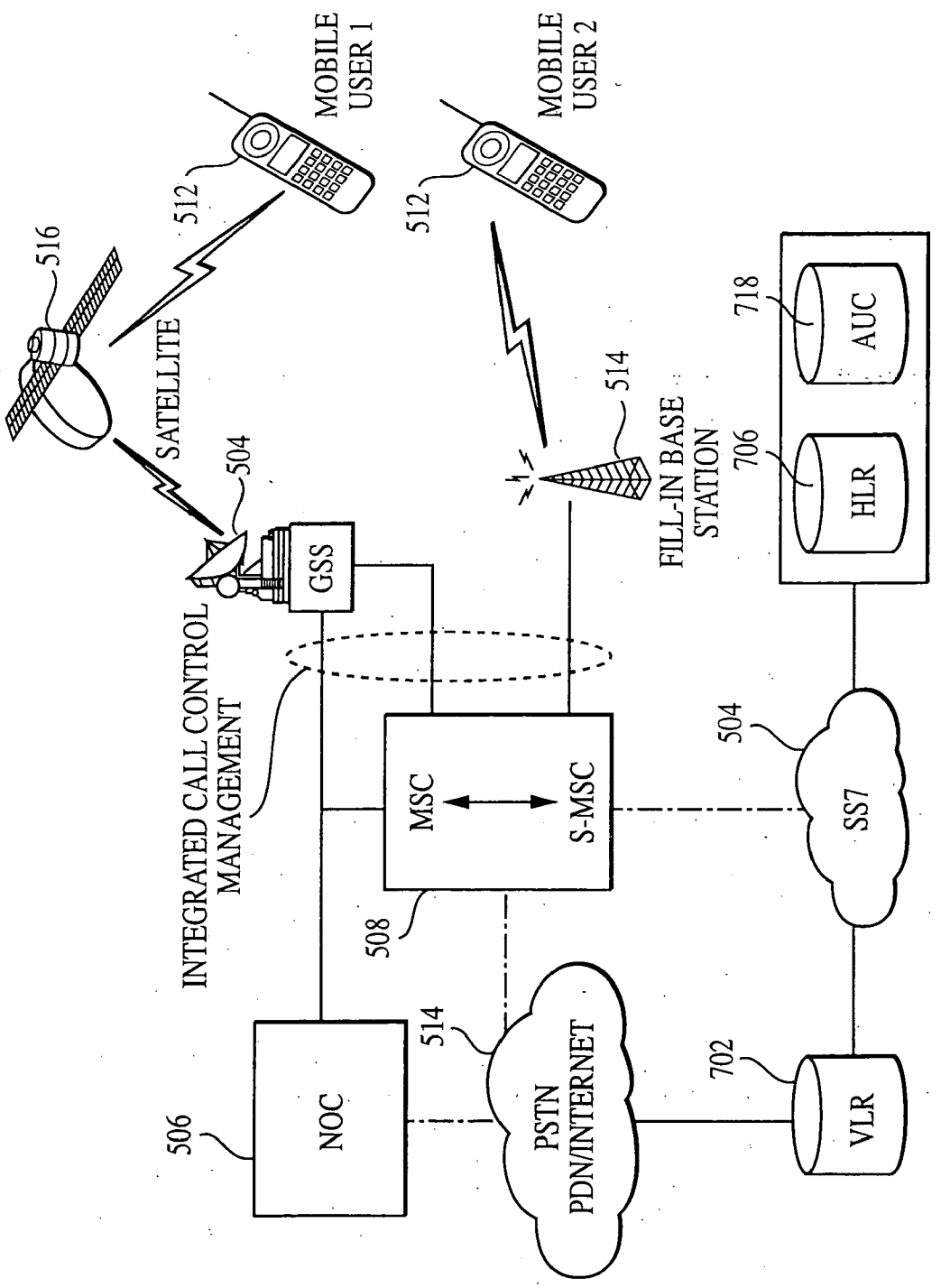

MOBILE USER 1
MOBILE USER 2
512
512
516
SATELLITE
504
GSS
INTEGRATED CALL CONTROL MANAGEMENT
514
FILL-IN BASE STATION
718
AUC
706
HLR
504
SS7
MSC
S-MSC
508
506
NOC
514
PSTN PDN/INTERNET
702
VLR

FIG. 7

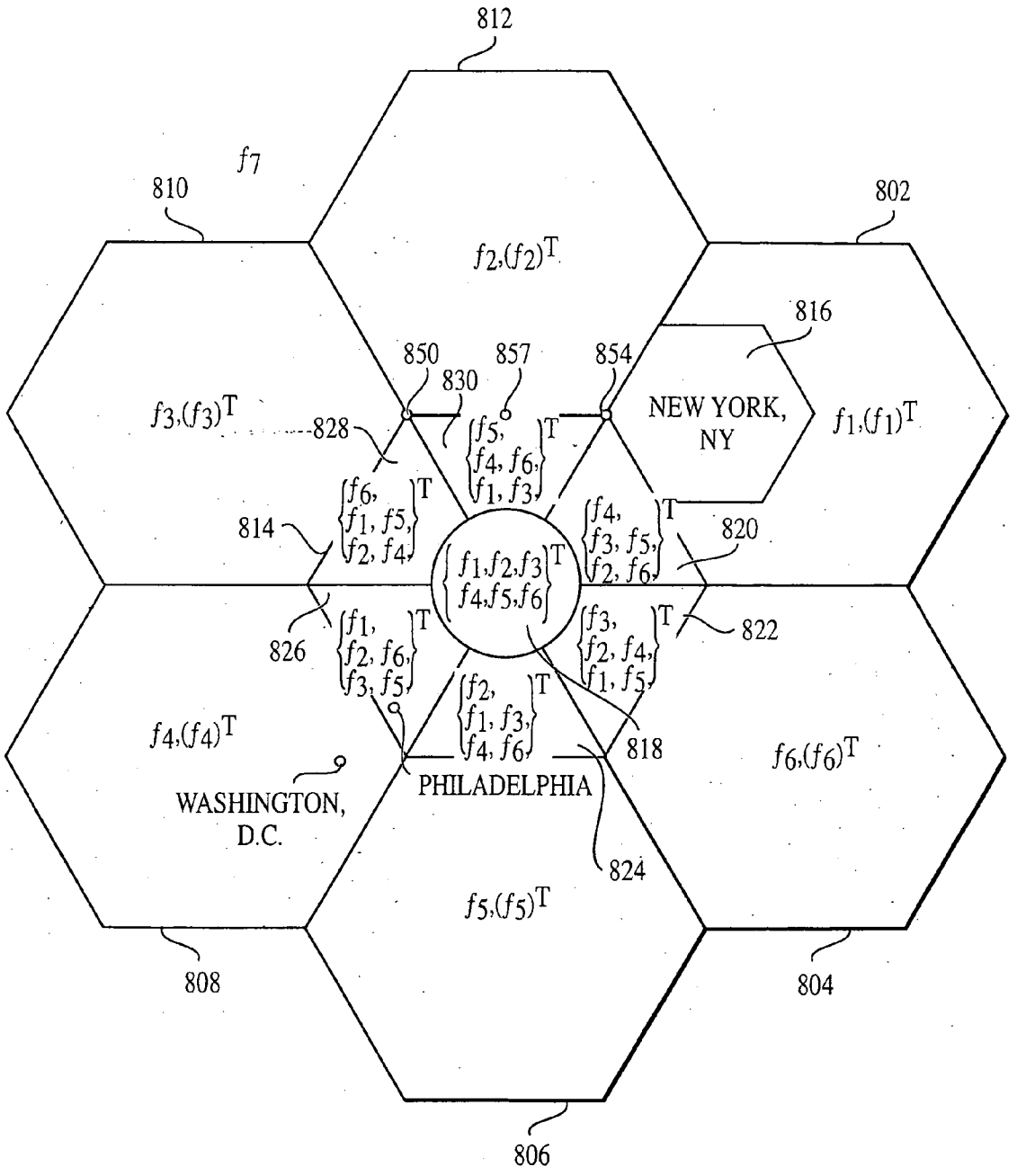

812
f_7
810
802
$f_2,(f_2)^T$
816
850
857
854
830
$f_3,(f_3)^T$
828
NEW YORK, NY
$f_1,(f_1)^T$
$\{f_5, f_4, f_6, f_1, f_3\}^T$
$\{f_6, f_1, f_5, f_2, f_4\}^T$
814
$\{f_4, f_3, f_5, f_2, f_6\}^T$
820
$\{f_1,f_2,f_3 f_4,f_5,f_6\}^T$
826
$\{f_1, f_2, f_6, f_3, f_5\}^T$
$\{f_3, f_2, f_4, f_1, f_5\}^T$
822
$\{f_2, f_1, f_3, f_4, f_6\}^T$
$f_4,(f_4)^T$
818
$f_6,(f_6)^T$
WASHINGTON, D.C.
PHILADELPHIA
824
$f_5,(f_5)^T$
808
804
806

FIG. 8a

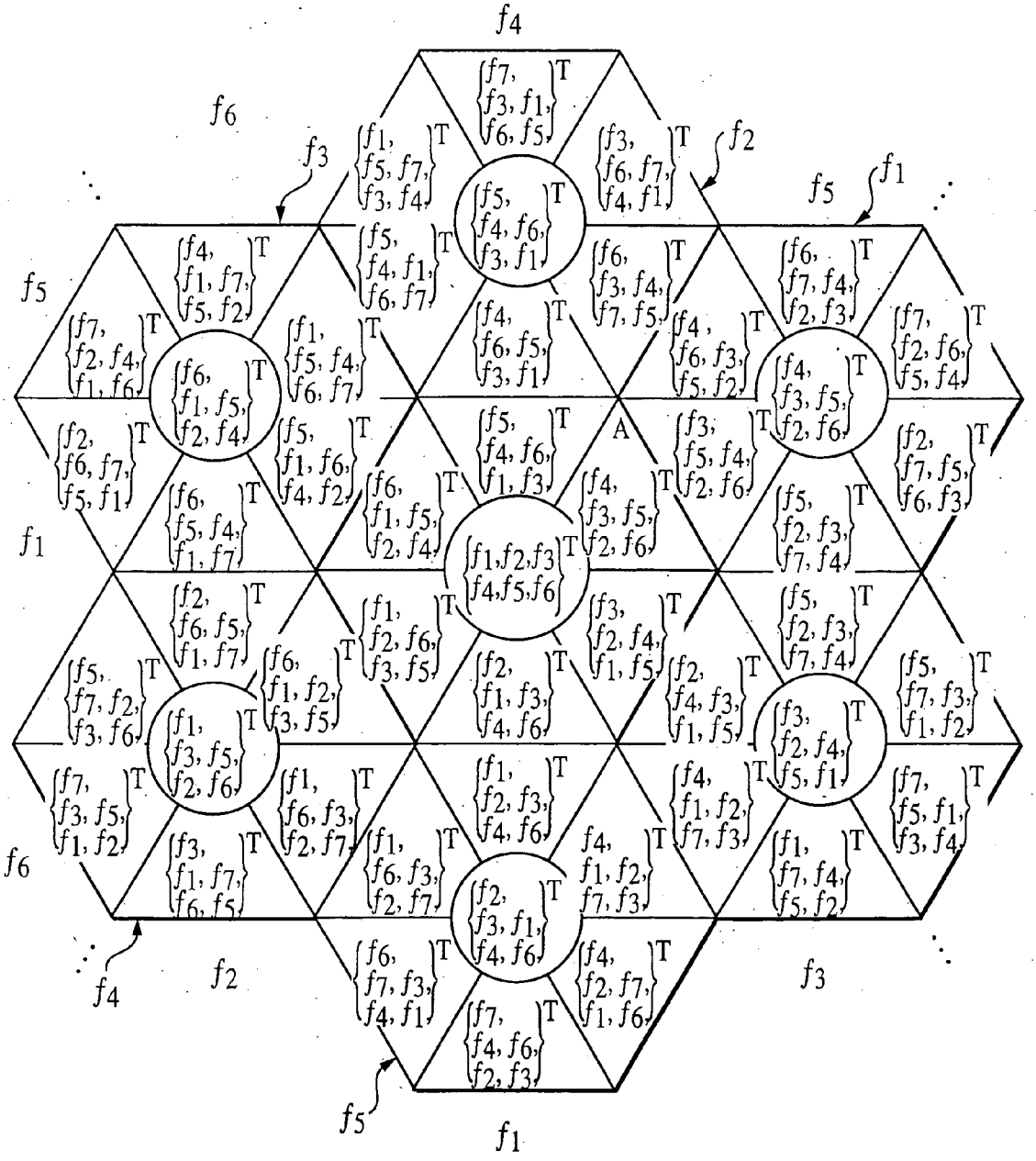


FIG. 8b

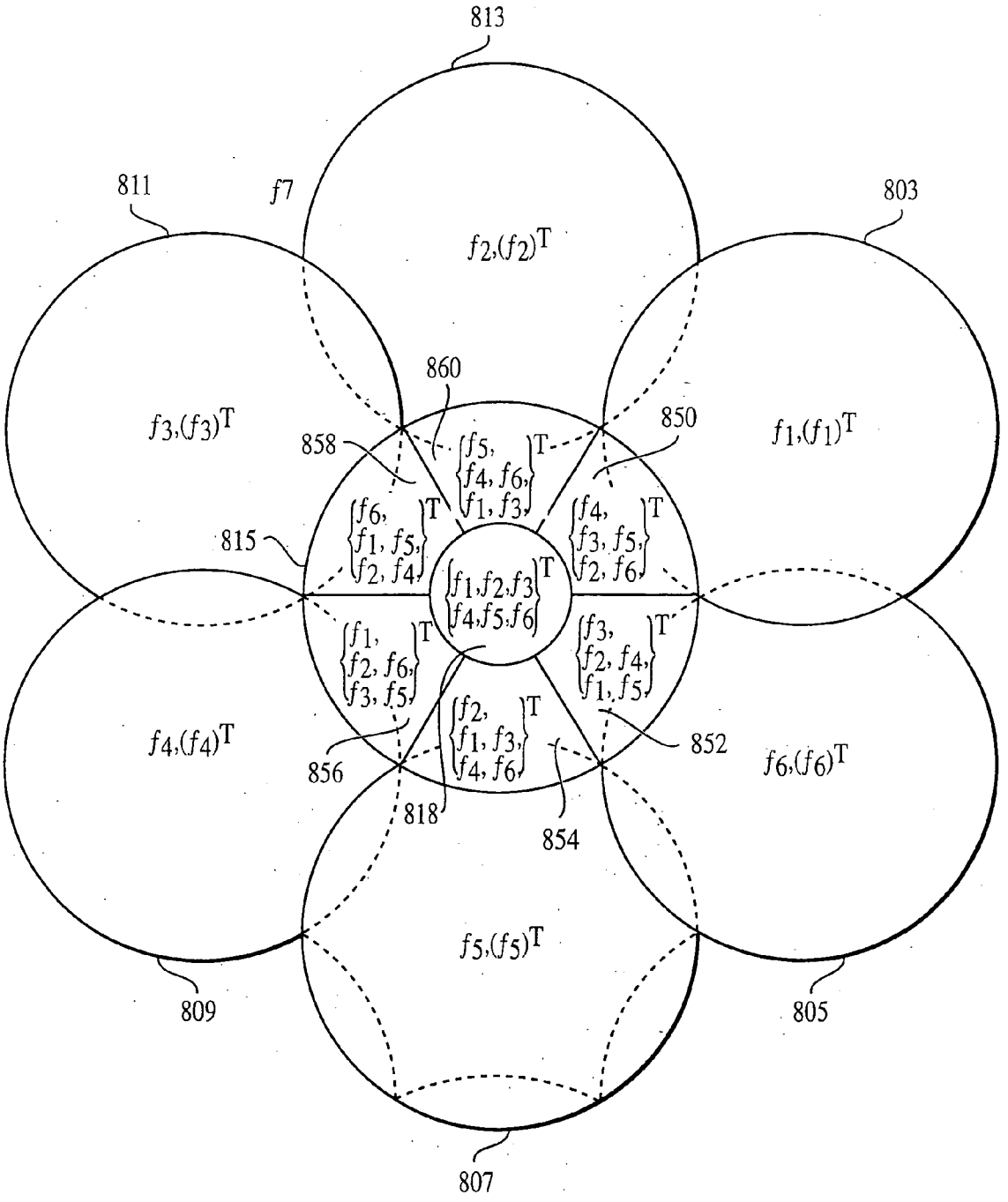

813
811
f7
803
$f_2,(f_2)^T$
860
$f_3,(f_3)^T$
858
850
$f_1,(f_1)^T$
$\{f_5, f_4, f_6, f_1, f_3\}^T$
$\{f_6, f_1, f_5, f_2, f_4\}^T$
$\{f_4, f_3, f_5, f_2, f_6\}^T$
815
$\{f_1, f_2, f_3, f_4, f_5, f_6\}^T$
$\{f_1, f_2, f_6, f_3, f_5\}^T$
$\{f_3, f_2, f_4, f_1, f_5\}^T$
$f_4,(f_4)^T$
$\{f_2, f_1, f_3, f_4, f_6\}^T$
852
$f_6,(f_6)^T$
856
818
854
$f_5,(f_5)^T$
809
805
807

FIG. 8c

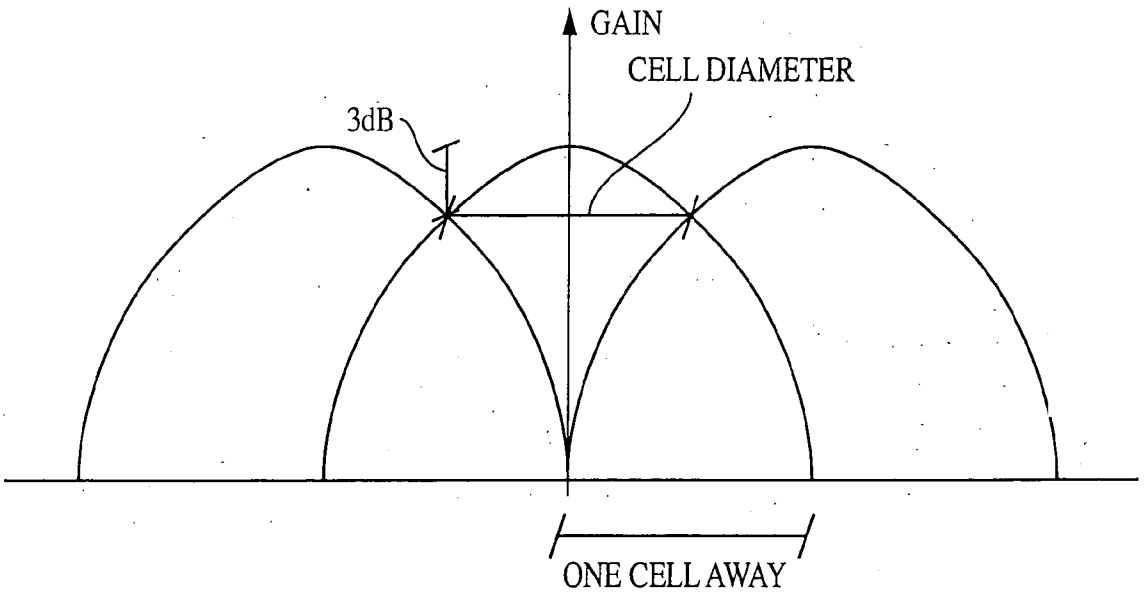

GAIN
CELL DIAMETER
3dB
ONE CELL AWAY

FIG. 9

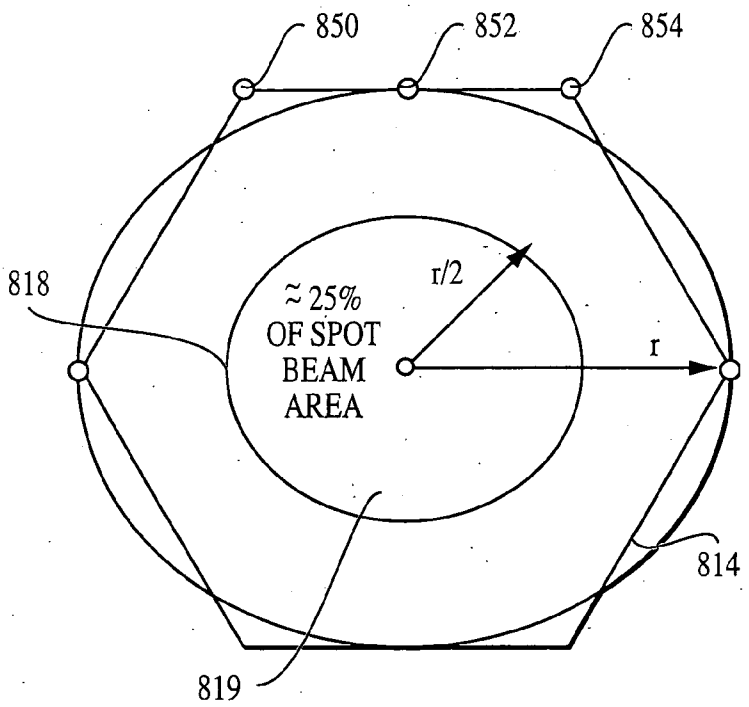

850
852
854
818
≈ 25%
OF SPOT
BEAM
AREA
r/2
r
814
819

FIG. 10

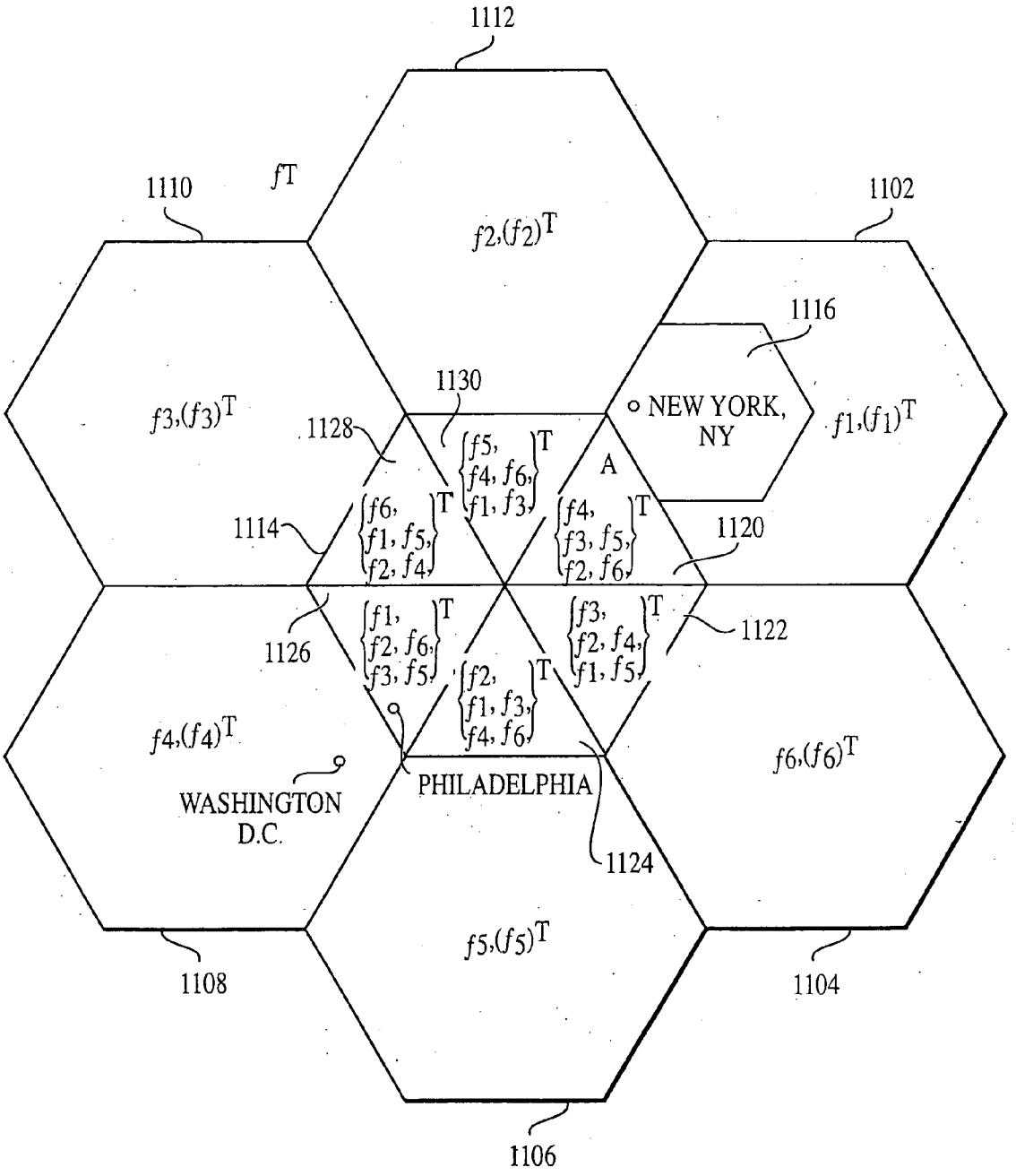

1112
1110
fT
1102
f2,(f2)T
1116
1130
f3,(f3)T
1128
NEW YORK, NY
f1,(f1)T
{f5, f4, f6, f1, f3}T
A
{f6, f1, f5, f2, f4}T
{f4, f3, f5, f2, f6}T
1114
1120
1126
{f1, f2, f6, f3, f5}T
{f3, f2, f4, f1, f5}T
1122
{f2, f1, f3, f4, f6}T
f4,(f4)T
f6,(f6)T
WASHINGTON D.C.
PHILADELPHIA
1124
f5,(f5)T
1108
1104
1106

FIG. 11a

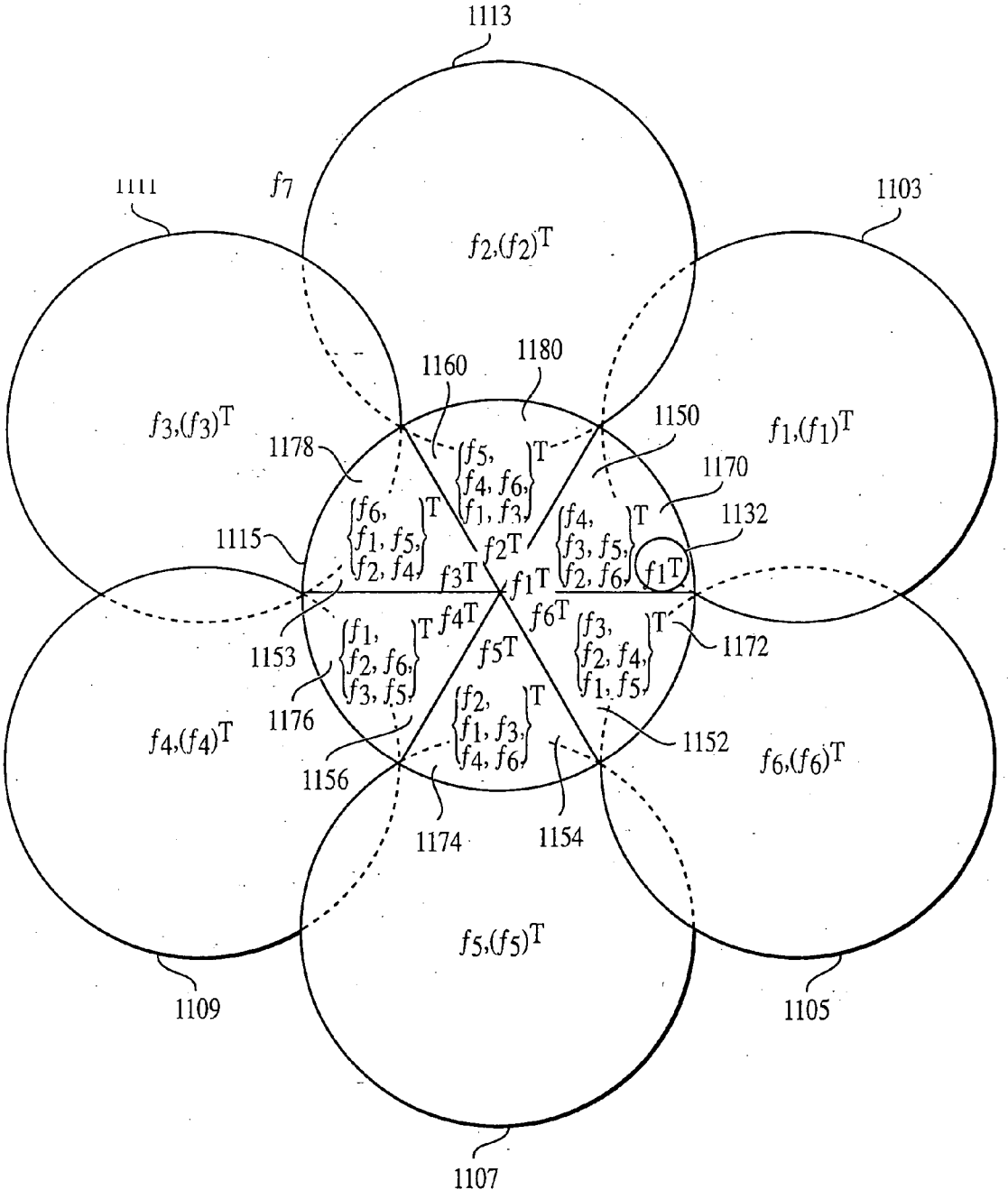

1113
1111
f_7
1103
$f_2,(f_2)^T$
1160
1180
$f_3,(f_3)^T$
1150
$f_1,(f_1)^T$
1178
1170
1115
1132
f_2T
f_3T
f_1T
f_4T
f_6T
f_5T
1153
1172
1176
1152
$f_4,(f_4)^T$
$f_6,(f_6)^T$
1156
1174
1154
$f_5,(f_5)^T$
1109
1105
1107

FIG. 11b

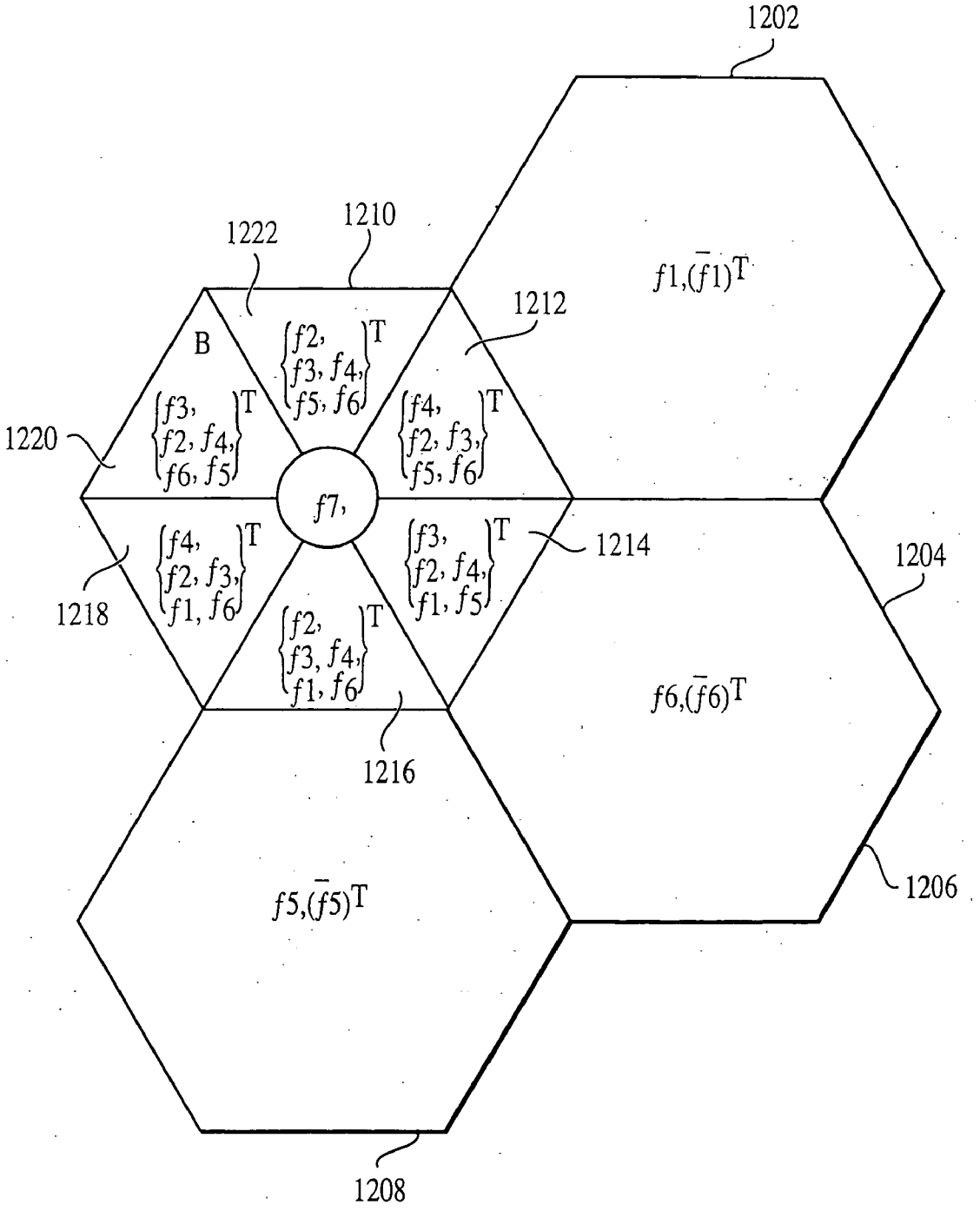

1202
1210
1222
1212
B
1220
1214
1204
1218
1216
1206
1208
$f1,(\bar{f}1)^T$
$f6,(\bar{f}6)^T$
$f5,(\bar{f}5)^T$
$f7,$

FIG. 12

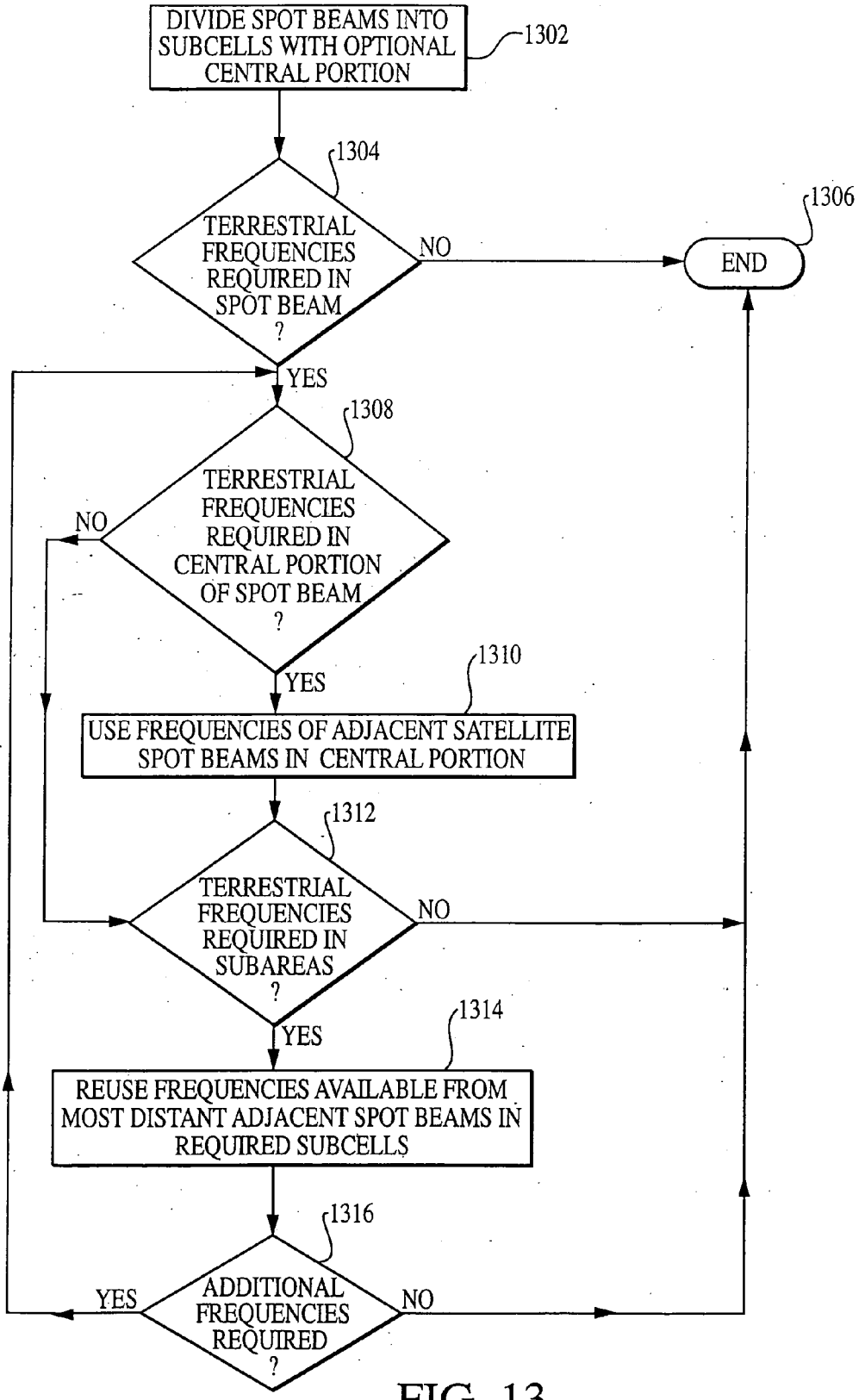

DIVIDE SPOT BEAMS INTO SUBCELLS WITH OPTIONAL CENTRAL PORTION
1302
1304
TERRESTRIAL FREQUENCIES REQUIRED IN SPOT BEAM ?
NO
1306
END
YES
1308
TERRESTRIAL FREQUENCIES REQUIRED IN CENTRAL PORTION OF SPOT BEAM ?
NO
YES
1310
USE FREQUENCIES OF ADJACENT SATELLITE SPOT BEAMS IN CENTRAL PORTION
1312
TERRESTRIAL FREQUENCIES REQUIRED IN SUBAREAS ?
NO
YES
1314
REUSE FREQUENCIES AVAILABLE FROM MOST DISTANT ADJACENT SPOT BEAMS IN REQUIRED SUBCELLS
1316
ADDITIONAL FREQUENCIES REQUIRED ?
YES
NO

FIG. 13

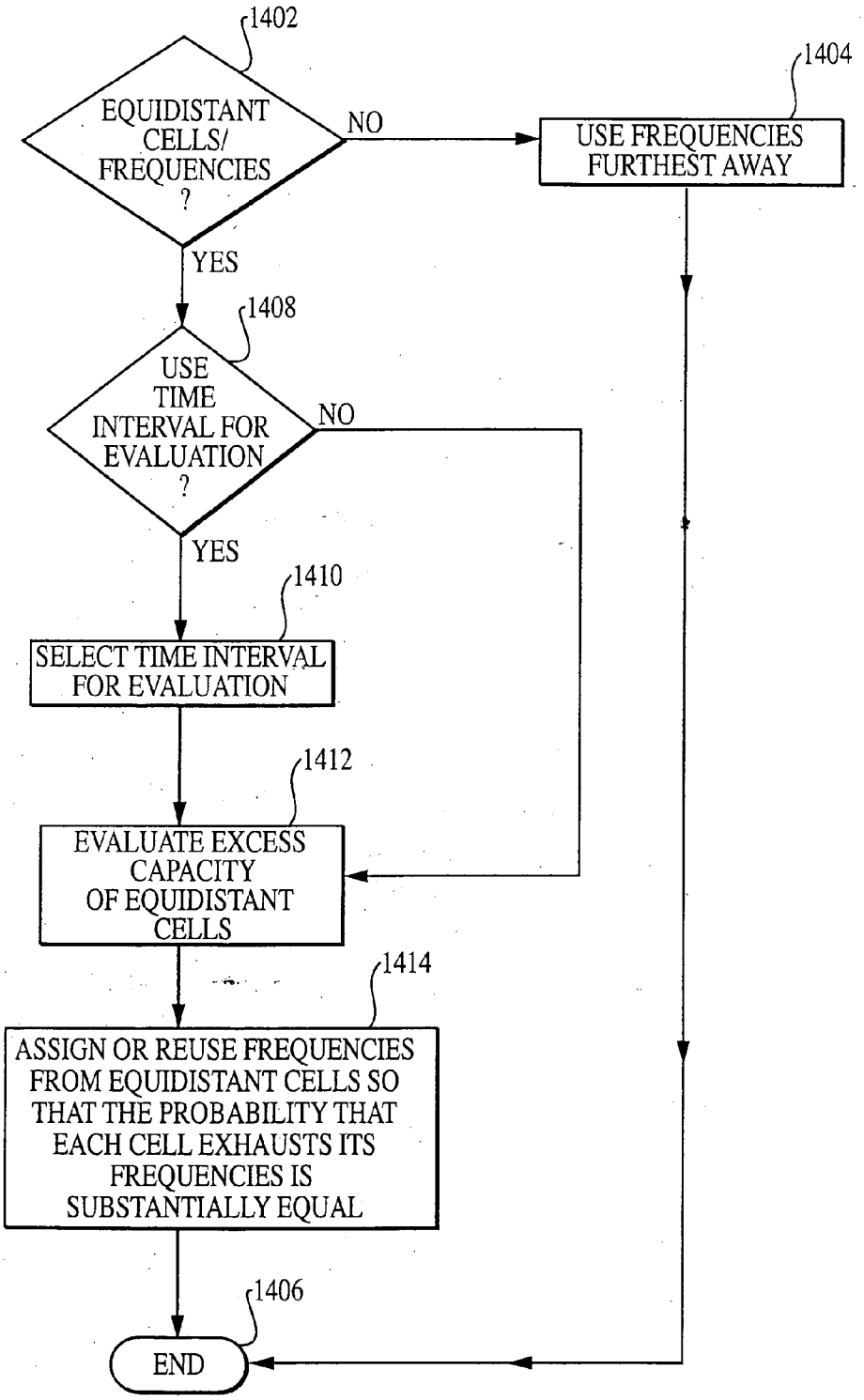

1402
EQUIDISTANT CELLS/ FREQUENCIES ?
NO
1404
USE FREQUENCIES FURTHEST AWAY
YES
1408
USE TIME INTERVAL FOR EVALUATION ?
NO
YES
1410
SELECT TIME INTERVAL FOR EVALUATION
1412
EVALUATE EXCESS CAPACITY OF EQUIDISTANT CELLS
1414
ASSIGN OR REUSE FREQUENCIES FROM EQUIDISTANT CELLS SO THAT THE PROBABILITY THAT EACH CELL EXHAUSTS ITS FREQUENCIES IS SUBSTANTIALLY EQUAL
1406
END

FIG. 14

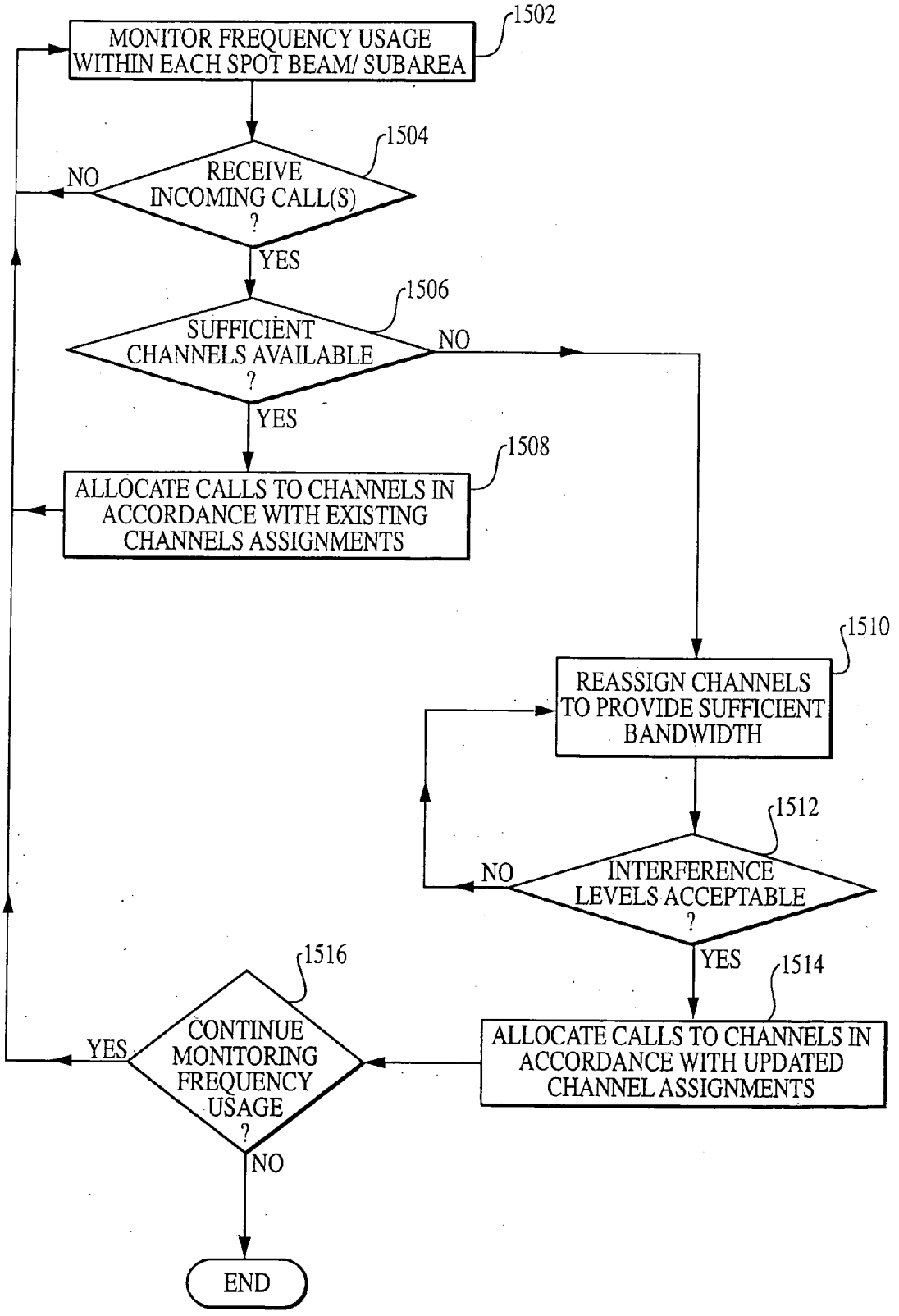

MONITOR FREQUENCY USAGE WITHIN EACH SPOT BEAM/ SUBAREA
1502
RECEIVE INCOMING CALL(S) ?
1504
NO
YES
SUFFICIENT CHANNELS AVAILABLE ?
1506
NO
YES
ALLOCATE CALLS TO CHANNELS IN ACCORDANCE WITH EXISTING CHANNELS ASSIGNMENTS
1508
REASSIGN CHANNELS TO PROVIDE SUFFICIENT BANDWIDTH
1510
INTERFERENCE LEVELS ACCEPTABLE ?
1512
NO
YES
ALLOCATE CALLS TO CHANNELS IN ACCORDANCE WITH UPDATED CHANNEL ASSIGNMENTS
1514
CONTINUE MONITORING FREQUENCY USAGE ?
1516
YES
NO
END

FIG. 15

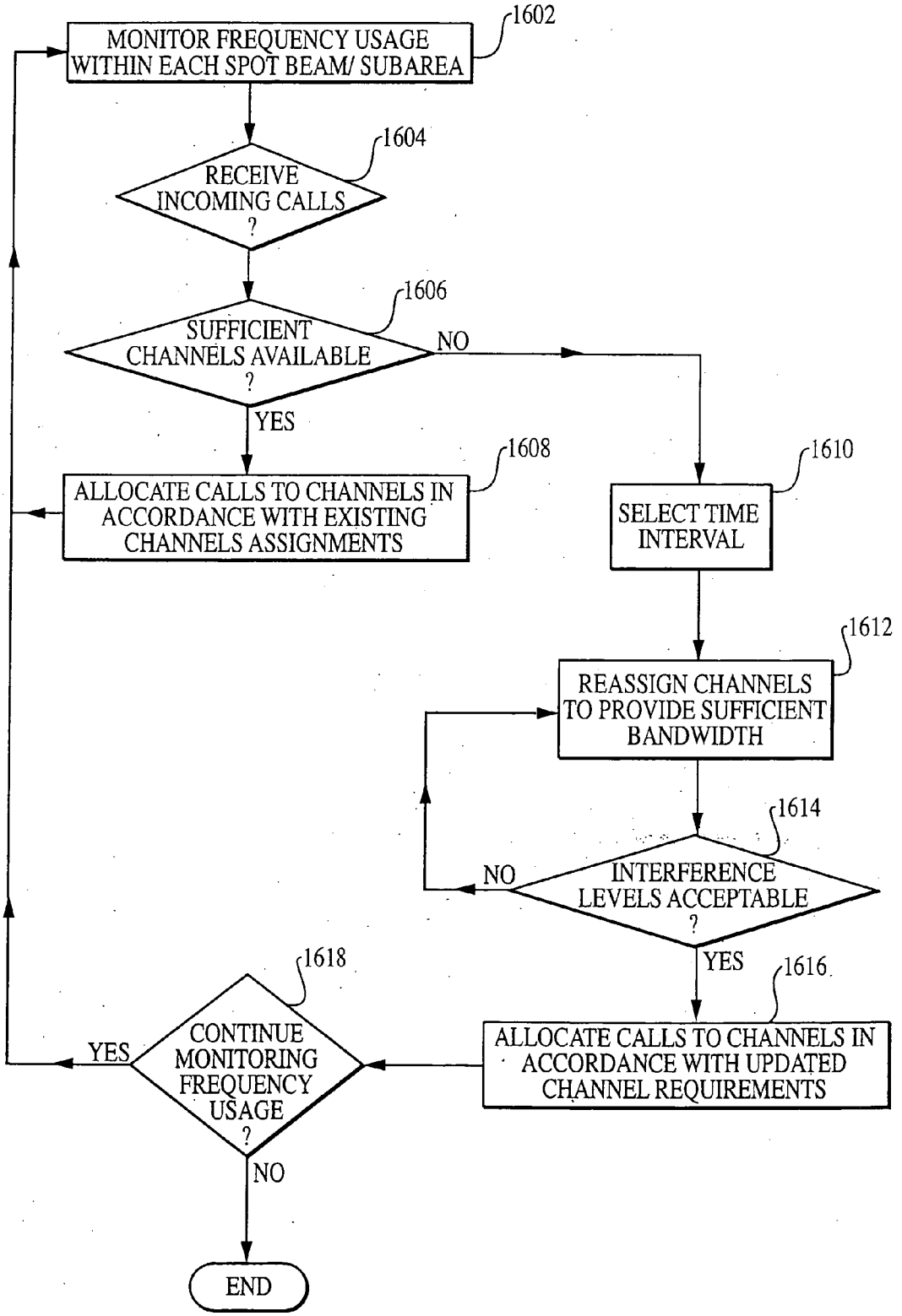

MONITOR FREQUENCY USAGE WITHIN EACH SPOT BEAM/ SUBAREA
1602
RECEIVE INCOMING CALLS ?
1604
SUFFICIENT CHANNELS AVAILABLE ?
1606
NO
YES
ALLOCATE CALLS TO CHANNELS IN ACCORDANCE WITH EXISTING CHANNELS ASSIGNMENTS
1608
SELECT TIME INTERVAL
1610
REASSIGN CHANNELS TO PROVIDE SUFFICIENT BANDWIDTH
1612
INTERFERENCE LEVELS ACCEPTABLE ?
1614
NO
YES
ALLOCATE CALLS TO CHANNELS IN ACCORDANCE WITH UPDATED CHANNEL REQUIREMENTS
1616
CONTINUE MONITORING FREQUENCY USAGE ?
1618
YES
NO
END

FIG. 16

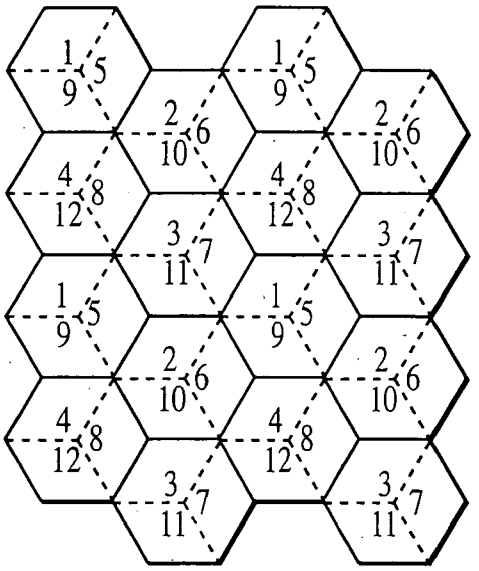


FIG. 17a

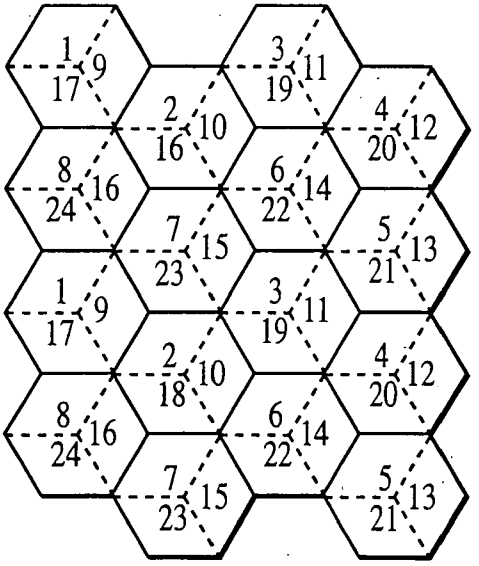
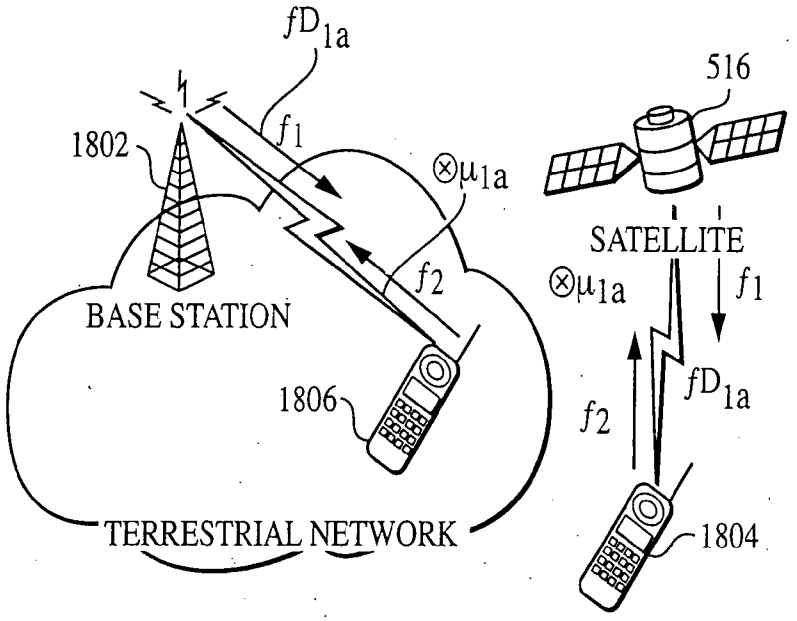
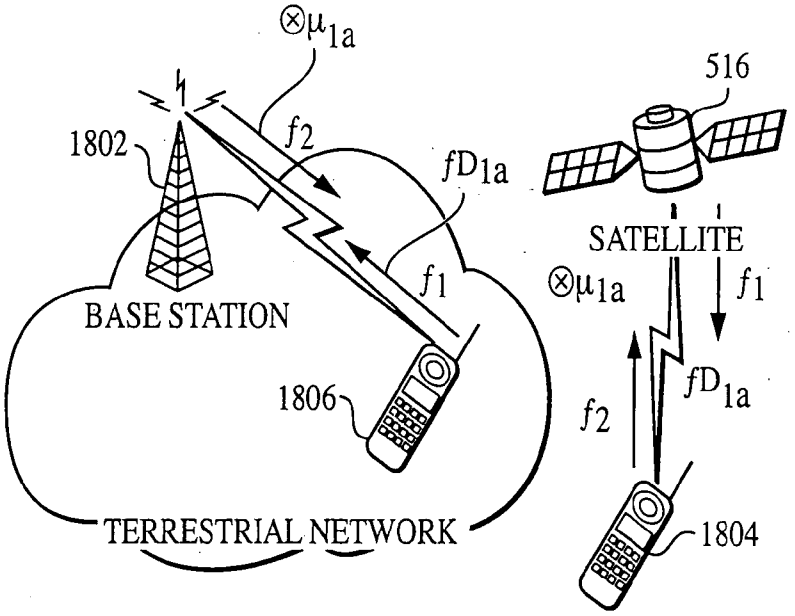


FIG. 17b



NORMAL MODE OPERATION

FIG. 18a



REVERSED MODE OPERATION

FIG. 18b

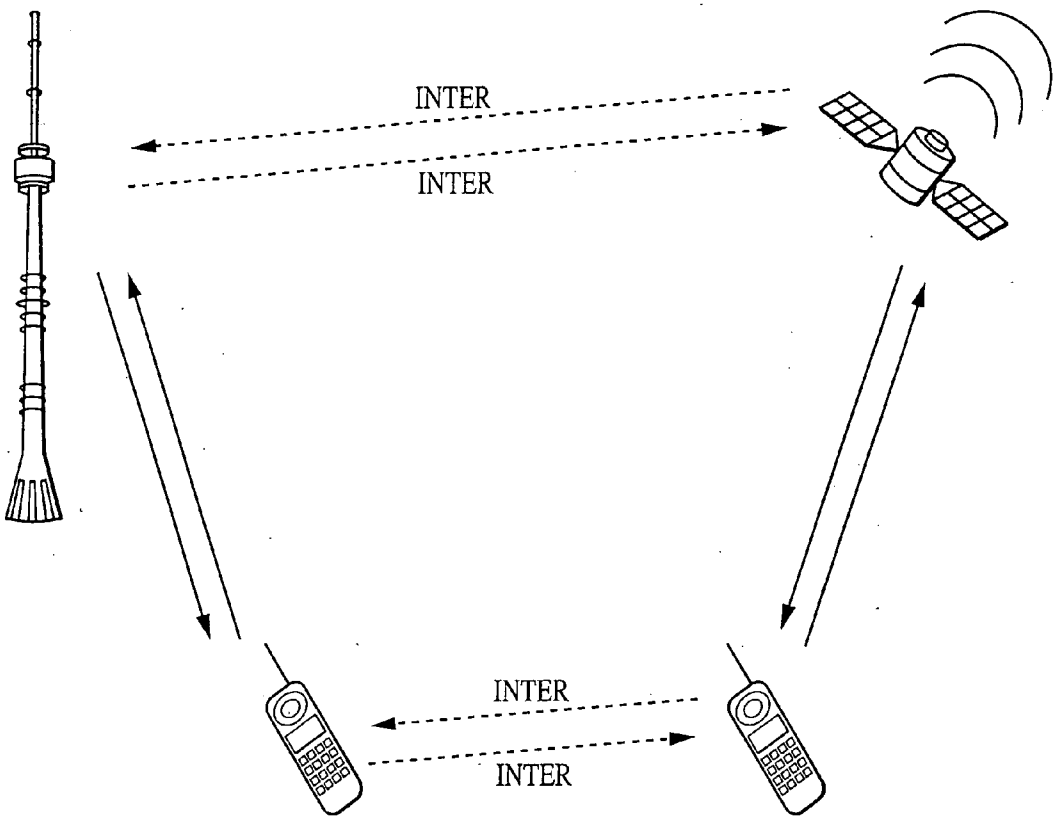


FIG. 19

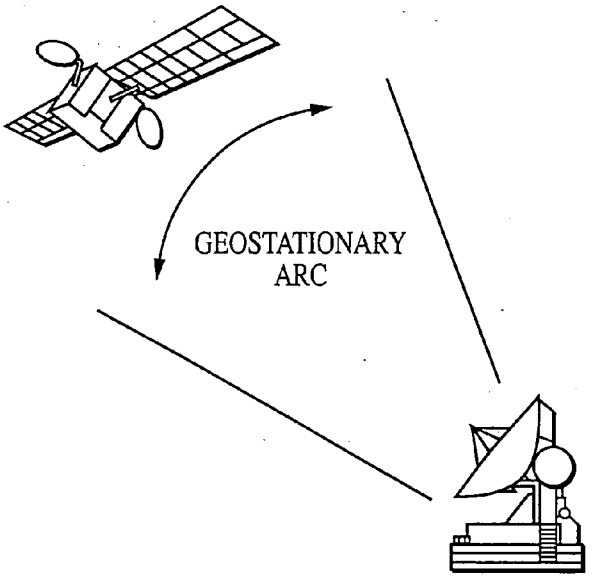


FIG. 20

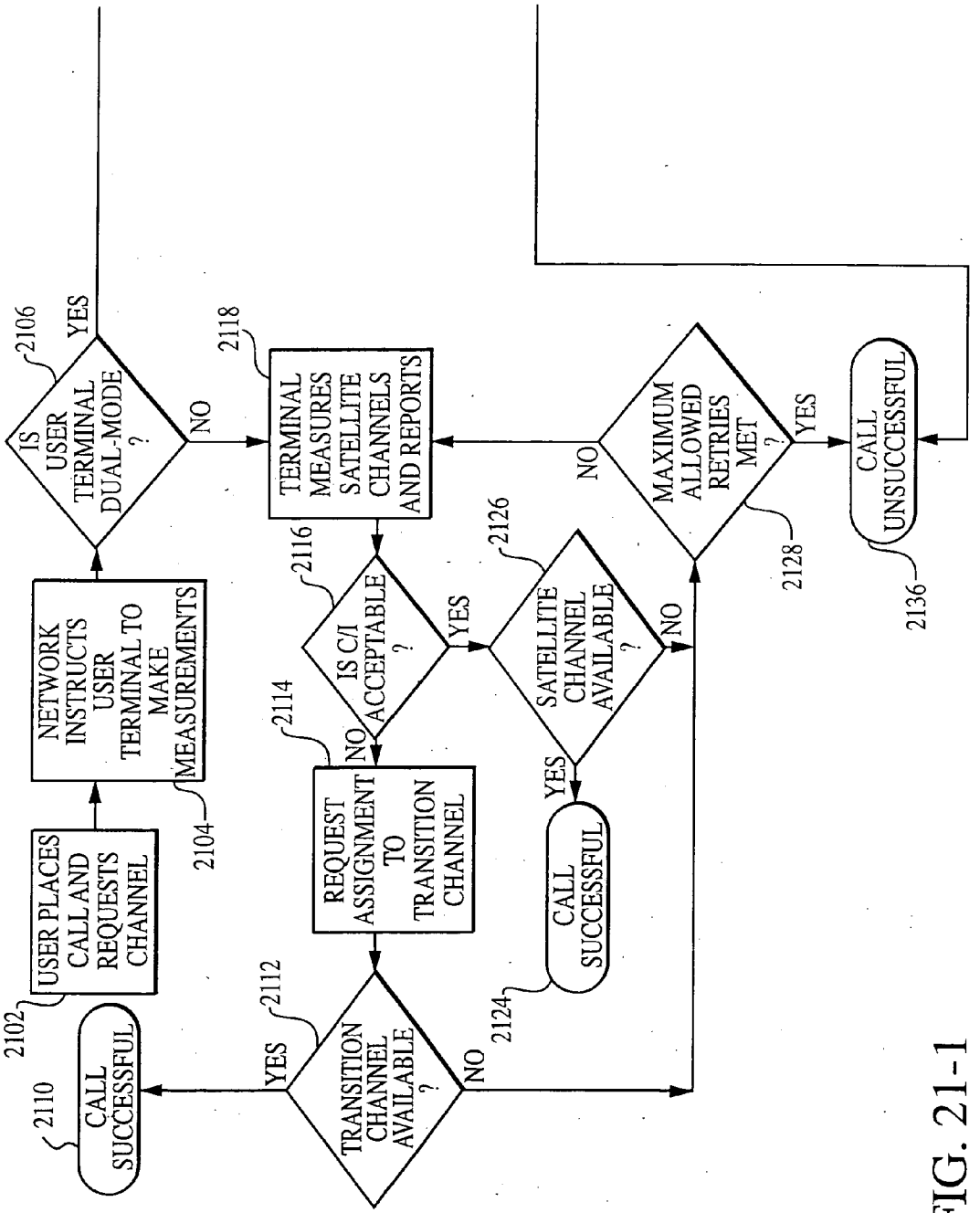


FIG. 21-1

FIG. 21

FIG. 21-1	FIG. 21-2

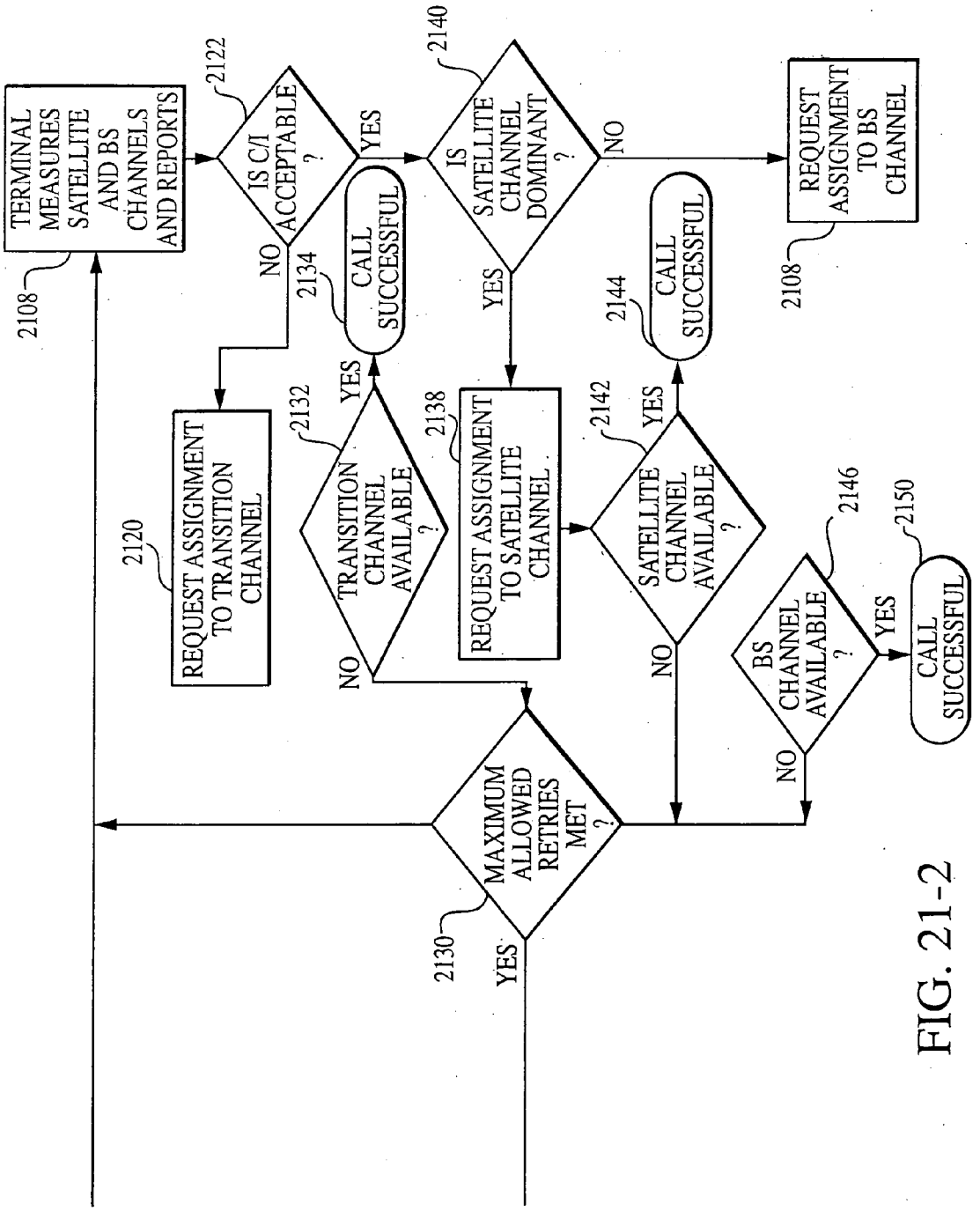

TERMINAL MEASURES SATELLITE AND BS CHANNELS AND REPORTS
2108
IS C/I ACCEPTABLE ?
2122
YES
NO
IS SATELLITE CHANNEL DOMINANT ?
2140
NO
REQUEST ASSIGNMENT TO BS CHANNEL
2108
YES
CALL SUCCESSFUL
2134
REQUEST ASSIGNMENT TO TRANSITION CHANNEL
2120
TRANSITION CHANNEL AVAILABLE ?
2132
YES
NO
REQUEST ASSIGNMENT TO SATELLITE CHANNEL
2138
SATELLITE CHANNEL AVAILABLE ?
2142
YES
NO
CALL SUCCESSFUL
2144
BS CHANNEL AVAILABLE ?
2146
YES
NO
CALL SUCCESSFUL
2150
MAXIMUM ALLOWED RETRIES MET ?
2130
YES

FIG. 21-2

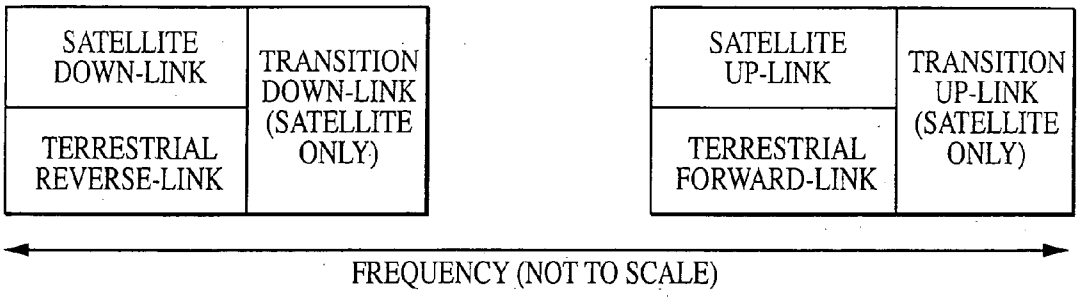

SATELLITE DOWN-LINK
TERRESTRIAL REVERSE-LINK
TRANSITION DOWN-LINK (SATELLITE ONLY)
SATELLITE UP-LINK
TERRESTRIAL FORWARD-LINK
TRANSITION UP-LINK (SATELLITE ONLY)
FREQUENCY (NOT TO SCALE)

FIG. 22

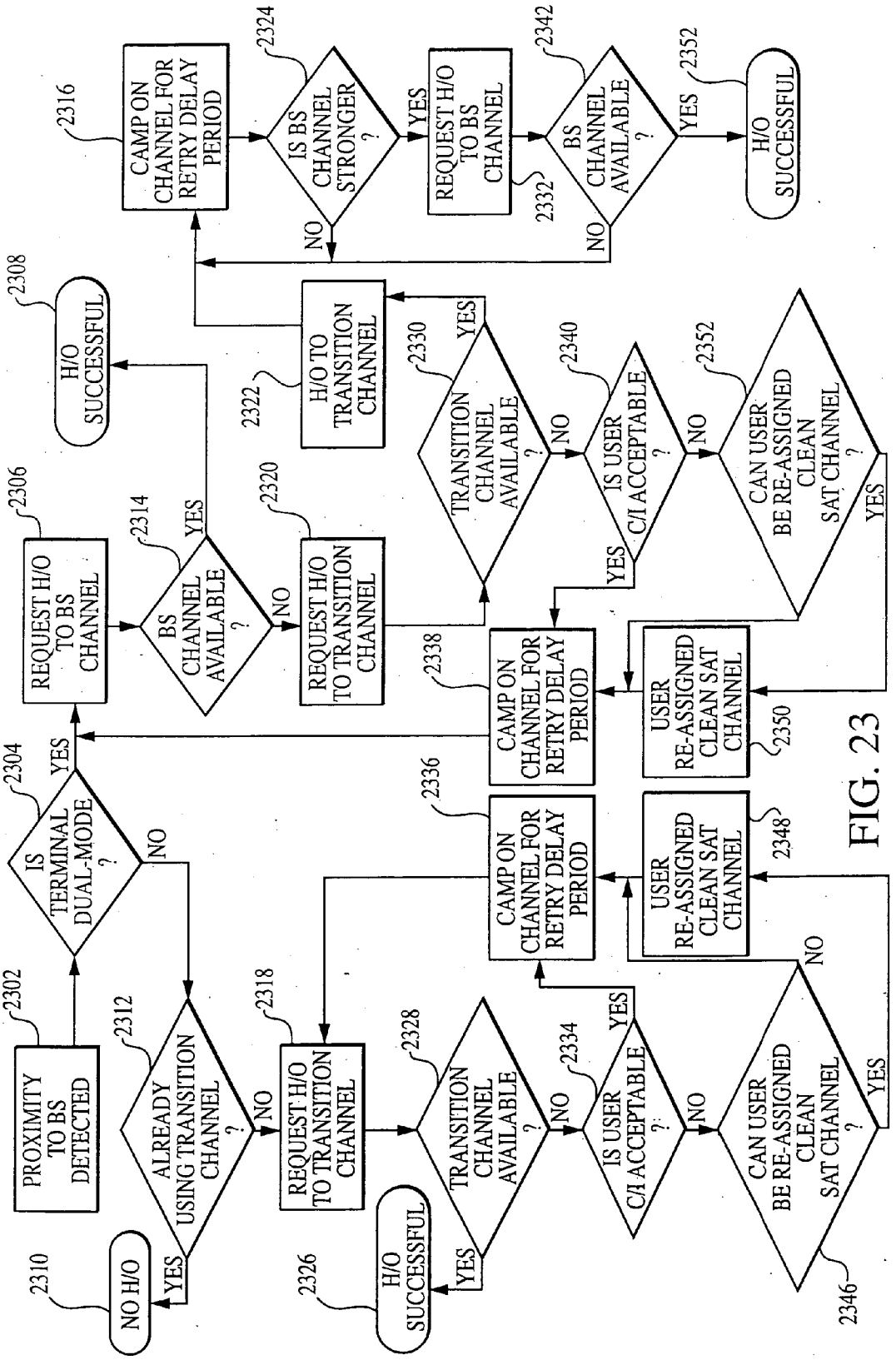

2302
PROXIMITY TO BS DETECTED
2304
IS TERMINAL DUAL-MODE ?
YES
NO
2306
REQUEST H/O TO BS CHANNEL
2308
H/O SUCCESSFUL
2310
NO H/O
2312
ALREADY USING TRANSITION CHANNEL ?
YES
NO
2314
BS CHANNEL AVAILABLE ?
YES
NO
2316
CAMP ON CHANNEL FOR RETRY DELAY PERIOD
2318
REQUEST H/O TO TRANSITION CHANNEL
2320
REQUEST H/O TO TRANSITION CHANNEL
2322
H/O TO TRANSITION CHANNEL
2324
IS BS CHANNEL STRONGER ?
YES
NO
2326
H/O SUCCESSFUL
2328
TRANSITION CHANNEL AVAILABLE ?
YES
NO
2330
TRANSITION CHANNEL AVAILABLE ?
YES
NO
2332
REQUEST H/O TO BS CHANNEL
2334
IS USER C/I ACCEPTABLE ?
YES
NO
2336
CAMP ON CHANNEL FOR RETRY DELAY PERIOD
2338
CAMP ON CHANNEL FOR RETRY DELAY PERIOD
2340
IS USER C/I ACCEPTABLE ?
YES
NO
2342
BS CHANNEL AVAILABLE ?
YES
NO
2346
CAN USER BE RE-ASSIGNED CLEAN SAT CHANNEL ?
YES
NO
2348
USER RE-ASSIGNED CLEAN SAT CHANNEL
2350
USER RE-ASSIGNED CLEAN SAT CHANNEL
2352
CAN USER BE RE-ASSIGNED CLEAN SAT CHANNEL ?
YES
2352
H/O SUCCESSFUL

FIG. 23

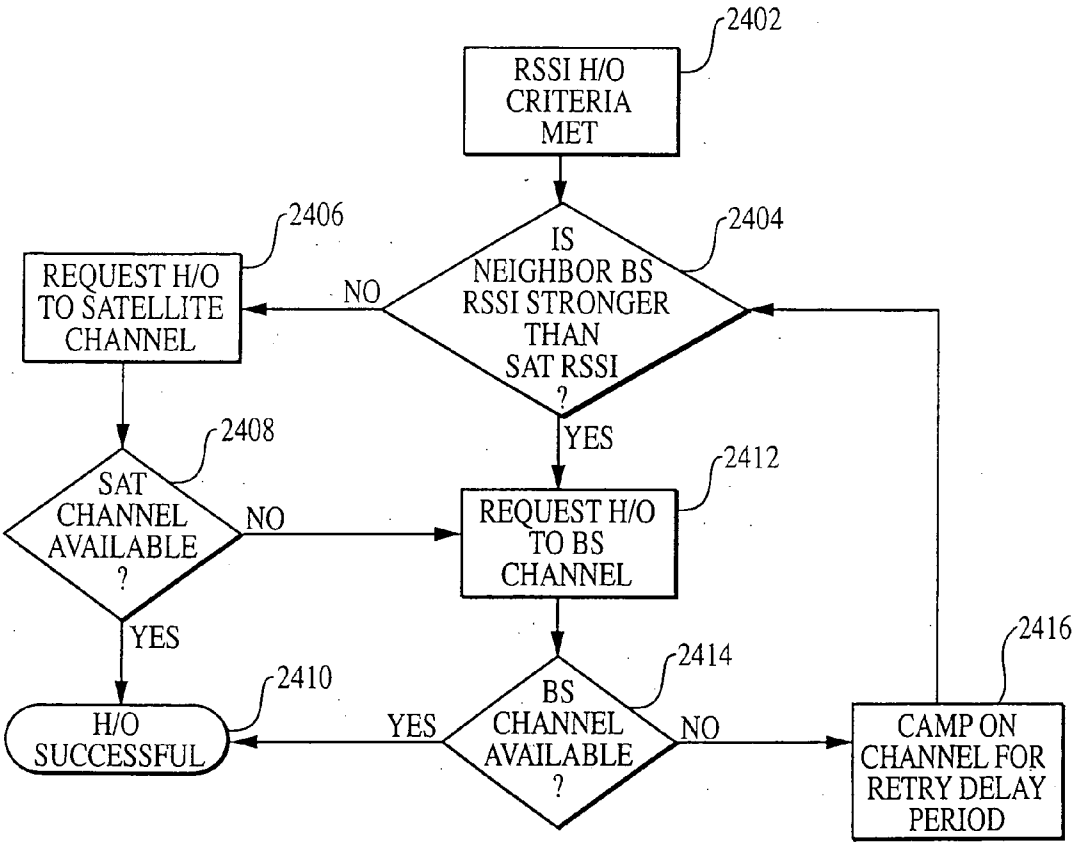

2402
RSSI H/O CRITERIA MET
2404
IS NEIGHBOR BS RSSI STRONGER THAN SAT RSSI ?
NO
2406
REQUEST H/O TO SATELLITE CHANNEL
YES
2408
SAT CHANNEL AVAILABLE ?
NO
YES
2412
REQUEST H/O TO BS CHANNEL
2414
BS CHANNEL AVAILABLE ?
YES
NO
2410
H/O SUCCESSFUL
2416
CAMP ON CHANNEL FOR RETRY DELAY PERIOD

FIG. 24

COORDINATED SATELLITE-TERRESTRIAL FREQUENCY REUSE

RELATED APPLICATION

[0001] This application claims priority from U.S. provisional application Ser. No. 60/222,605 filed on Aug. 2, 2000 and entitled "System and Method of Satellite-Terrestrial Frequency Reuse", from U.S. provisional application Ser. No. U.S. Patent Application No. 60/245,194 filed Nov. 3, 2000 and entitled "Coordinated Satellite-Terrestrial Frequency Reuse", and from U.S. provisional application Ser. No. 60/250,461 filed on Dec. 4, 2000 and entitled "System And Method Of Satellite-Terrestrial Frequency Reuse", each of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention generally relates to frequency assignment, reuse and/or sharing among communications systems having both a terrestrial and a satellite component (dual-mode) and, more particularly, to a satellite-terrestrial communications system and method of operation thereof that provides frequency assignment, reuse and/or sharing between the respective portions of the satellite system and/or terrestrial underlay systems associated therewith, while substantially reducing interference therebetween.

[0004] 2. Background Description

[0005] In satellite-terrestrial systems that reuse the same spectrum, there is a need to efficiently allocate at least a portion of the frequency spectrum of, for example, a first satellite coverage area to, for example, a terrestrial network associated with a terrestrial coverage area. The present invention provides a system and method for efficiently assigning, reusing and/or sharing the spectrum between satellite and/or terrestrial systems in a manner that facilitates efficient frequency spectrum usage, while minimizing interference between the respective satellite and terrestrial systems. The present invention can also be applied to multiple satellite systems as well, in addition to, or instead of, terrestrial systems.

[0006] **FIG. 1** shows a prior art satellite radiotelephone system, as shown in U.S. Pat. No. 6,052,586, incorporated herein by reference. As shown in **FIG. 1**, a satellite radiotelephone system includes a fixed satellite radiotelephone system **110** and a mobile satellite radiotelephone system **130**. The fixed satellite radiotelephone system **110** uses a first satellite **112** to communicate with a plurality of fixed radiotelephones **114***a*, **114***b* and **114***c* in a first communication area **116**.

[0007] Fixed satellite radiotelephone communication system **110** communicates with the plurality of fixed radiotelephones **114***a*-**114***c* using a first air interface **118** (e.g., at C-band). Control of the fixed satellite system **110** may be implemented by a feeder link **122** which communicates with a gateway **124** and the public switched (wire) telephone network (PSTN) **126**.

[0008] The feeder link **122** may include communication channels for voice and data communications, and control channels. The control channels are indicated by dashed lines in **FIG. 1**. The control channels may be used to implement direct communications between fixed radiotelephones, as shown for example between radiotelephones **114***a* and **114***b*. The control channels may also be used to effect communications between a fixed satellite radiotelephone **114***c* and a mobile radiotelephone or a wire telephone via gateway **124** and PSTN **126**. The feeder link **122** may use the same air interface or a different air interface from the first air interface **118**.

[0009] Still referring to **FIG. 1**, mobile satellite radiotelephone system **130** includes a second satellite **132** that communicates with a plurality of mobile radiotelephones **134***a*-**134***d* which are located in a second communication area **136**. Mobile satellite radiotelephone system **130** communicates with mobile radiotelephones **134** using a second air interface **138** (e.g., at L-band or S-band). Alternatively, the second air interface **138** may be the same as the first air interface **118**. However, the frequency bands associated with the two air interfaces will generally be different.

[0010] A feeder link **142** may be used to communicate with other satellite, cellular or wire telephone systems via gateway **144** and PSTN **126**. As with fixed satellite system **110**, the feeder link **142** may include communication channels shown in solid lines and control channels shown in dashed lines. The control channels may be used to establish direct mobile-to-mobile communications, for example, between mobile radiotelephones **134***b* and **134***c*. The control channels may also be used to establish communications between mobile phones **134***a* and **134***d* and other satellite, mobile or wire telephone systems.

[0011] As with the fixed satellite radiotelephone system **110**, the mobile satellite radiotelephone system **130** may employ more than one satellite **132** and will generally communicate with large numbers of mobile radiotelephones **134**. The fixed and mobile satellite radiotelephone system may also use a common satellite.

[0012] Still referring to **FIG. 1**, a congested area may be present in the mobile satellite radiotelephone system **130** where a large number of mobile radiotelephones **134***e*-**134***i* are present. As is also shown in **FIG. 1**, this congested area may be in an overlapping area **128** between first communication area **116** and second communication area **136**. If this is the case, excess capacity from fixed satellite radiotelephone system **110** may be offloaded to mobile satellite radiotelephone system **130**.

[0013] Capacity offload may be provided by at least one fixed retransmitting station **150***a*, **150***b*, that retransmits communications between the fixed satellite radiotelephone system **110** and at least one of the mobile radiotelephones. For example, as shown in **FIG. 1**, first fixed retransmitting station **150***a* retransmits communications between satellite **112** and mobile radiotelephones **134***e* and **134***f*. Second fixed transmitting station **150***b* retransmits communications between the satellite **112** and mobile radiotelephones **134***g*, **134***h* and **134***i*. The fixed retransmitting station need not be located in an overlapping area as long as it can retransmit communications between the fixed satellite radiotelephone system in the first area, and the mobile radiotelephones.

[0014] The fixed retransmitting stations communicate with the satellite **112** using first air interface **118**. However they communicate with the mobile radiotelephones using the

second air interface **138**. Accordingly, from the standpoint of the mobile radiotelephones **134***e*-**134***i*, communication is transparent. In other words, it is not apparent to the mobile radiotelephones **134***e*-**134***i*, or the users thereof, that communications are occurring with the fixed satellite radiotelephone system **110** rather than with the mobile satellite radiotelephone system **130**. However, additional capacity for the mobile satellite radiotelephone system **130** in the congested areas adjacent the fixed retransmitting stations **150** may be provided.

[**0015**] As shown in **FIG. 1**, a mobile radiotelephone can establish a communications link via the facilities of the fixed satellite radiotelephone system, even though the mobile radiotelephone is designed, manufactured and sold as a terminal intended for use with the mobile satellite radiotelephone system. One or more operators may offer both mobile and fixed telecommunications services over an overlapping geographic area using two separate transponders in separate satellites or within the same "hybrid" satellite, with one transponder supporting mobile satellite radiotelephones and the other supporting fixed satellite radiotelephones. As capacity "hot spots" or congestion develops within certain spot beams of the mobile radiotelephone system, the fixed system, with its much higher capacity, can deploy fixed retransmitting stations to relieve the capacity load of the mobile system.

[**0016**] **FIG. 2A** shows a seven-cell frequency reuse pattern which may be used by the mobile satellite radiotelephone system **130**. Within each of the relatively large mobile system cells, each typically being on the order of 400-600 kilometers in diameter, frequencies used by adjacent cells may be locally retransmitted by the retransmitting station at reduced, non-interfering power levels, and reused as shown in **FIGS. 2B and 2C**, thus substantially increasing the effective local capacity.

[**0017**] Accordingly, fixed retransmitting stations, located within the fixed system's footprint or coverage area, receive signals from the fixed satellite and retransmit these signals locally. Frequency translation to bring the signals within the mobile system's frequency band will generally be provided. In the reverse direction, the fixed retransmitting stations receive signals from mobile radiotelephones and retransmit signals from the mobile radiotelephones to the fixed satellite system. Again, frequency translation to bring the signals within the fixed system's frequency band will generally be provided.

[**0018**] The mobile radiotelephones are ordinarily used with the mobile satellite system. Accordingly, the fixed satellite system may need to be configured to support the air interface used by the mobile satellite radiotelephone system.

[**0019**] Alternatively, if different air interfaces are used by the fixed and mobile satellite radiotelephone systems, the fixed retransmitting station can perform a translation from one air interface to the other, for example, by demodulation and remodulation. The fixed retransmitting station then becomes a regenerative repeater which reformats communications channels as well as control channels. However, if the mobile and fixed systems both use substantially the same air interface, then the fixed retransmitting station can function as a non-regenerative repeater.

[**0020**] One embodiment may use the simplest fixed retransmitting station by having the fixed and mobile systems both utilize the same air interface standard. Alternatively, the fixed system is configured to support the mobile system air interface even though the fixed system may be using another air interface for fixed radiotelephone service.

[**0021**] **FIG. 3** is another prior art system as shown in U.S. Pat. No. 5,995,832. **FIG. 3** provides an overview of a communications system **310** showing the functional interrelationships of the major elements. The system network control center **312** directs the top level allocation of calls to satellite and ground regional resources throughout the system. It also is used to coordinate system-wide operations, to keep track of user locations, to perform optimum allocation of system resources to each call, dispatch facility command codes, and monitor and supervise overall system health. The regional node control centers **314**, one of which is shown, are connected to the system network control center **312** and direct the allocation of calls to ground nodes within a major metropolitan region. The regional node control center **314** provides access to and from fixed land communication lines, such as commercial telephone systems known as the public switched telephone network (PSTN). The ground nodes **316** under direction of the respective regional node control center **314** receive calls over the fixed land line network, encode them, spread them according to the unique spreading code assigned to each designated user, combine them into a composite signal, modulate that composite signal onto the transmission carrier, and broadcast them over the cellular region covered.

[**0022**] Satellite node control centers **318** are also connected to the system network control center **312** via status and control land lines and similarly handle calls designated for satellite links such as from PSTN, encode them, spread them according to the unique spreading codes assigned to the designated users, and multiplex them with other similarly directed calls into an uplink trunk, which is beamed up to the designated satellite **320**. Satellite nodes **320** receive the uplink trunks, frequency demultiplex the calls intended for different satellite cells, frequency translate and direct each to its appropriate cell transmitter and cell beam, and broadcast the composite of all such similarly directed calls down to the intended satellite cellular area. As used herein, "backhaul" means the link between a satellite **320** and a satellite node control center **318**. In one embodiment, it is a K-band frequency while the link between the satellite **320** and the user unit **322** uses an L-band or an S-band frequency.

[**0023**] A "node" is a communication site or a communication relay site capable of direct one or two-way radio communication with users. Nodes may include moving or stationary surface sites or airborne or satellite sites.

[**0024**] User units **322** respond to signals of either satellite or ground node origin, receive the outbound composite signal, separate out the signal intended for that user by despreading using the user's assigned unique spreading code, de-modulate, and decode the information and deliver the call to the user. Such user units **322** may be mobile or may be fixed in position. Gateways **324** provide direct trunks that is, groups of channels, between satellite and the ground public switched telephone system or private trunk users. For example, a gateway may comprise a dedicated satellite terminal for use by a large company or other entity. In the embodiment of **FIG. 3**, the gateway **324** is also connected to that system network controller **312**.

[0025] All of the above-discussed centers, nodes, units and gateways are full duplex transmit/receive performing the corresponding inbound (user to system) link functions as well in the inverse manner to the outbound (system to user) link functions just described.

[0026] Referring now to **FIG. 4**, which is another embodiment as shown in U.S. Pat. No. 5,995,832, a block diagram of a communications system **440** which does not include a system network control center **312** is presented. In this system, the satellite node control centers **442** are connected directly into the land line network as are also the regional node control centers **444**. Gateway systems **446** are also available as in the system of **FIG. 3**, and connect the satellite communications to the appropriate land line or other communications systems. The user unit **322** designates satellite node **442** communication or ground node **450** communication by sending a predetermined code. Alternatively, the user unit could first search for one type of link (either ground or satellite) and, if that link is present, use it. If that link is not present, use the alternate type of link.

[0027] The specification of U.S. Pat. No. 5,995,832 states that "[m]easures incorporated in the invention to maximize bandwidth utilization efficiency include the use of code division multiple access (CDMA) technology which provides an important spectral utilization efficiency gain and higher spatial frequency reuse factor made possible by the user of smaller satellite antenna beams. In regard to power efficiency, which is a major factor for the satellite-mobile links, the satellite transmitter source power per user is minimized by the use of forward-error-correcting coding, which in turn is enabled by the above use of spread spectrum code division multiple access (SS/CDMA) technology and by the use of relatively high antenna gain on the satellite."

[0028] The specification of U.S. Pat. No. 5,995,832 also states that "[i]n a system in accordance with the invention, the cluster size is one. That is, each cell uses the same, full allocated frequency band. This is possible because of the strong interference rejection properties of spread spectrum code division multiple access technology (SS/CDMA)." With regard to determining the position of user units **322**, the specification of U.S. Pat. No. 5,995,832 states that "[a]ccurate position determination can be obtained through two-dimensional multi-lateration. Each CDMA mobile user unit's transmitted spreading code is synchronized to the epoch of reception of the pilot signal from its current control site, whether ground or satellite node."

[0029] However, in contrast to the prior art systems described, for example, in **FIGS. 1-4**, the present invention does not utilize in one embodiment frequency translation between fixed and mobile systems. In addition, the present invention provides, for example, a robust satellite-terrestrial frequency assignment and/or reuse scheme in another embodiment. Further, the present invention optionally utilizes a first frequency as a downlink frequency between a satellite and a first fixed and/or mobile user terminal and as an uplink frequency between a second fixed and/or mobile user terminal and a base station, and a second frequency as an uplink between the first fixed and/or mobile user terminal and the satellite and as a downlink between the base station and the second fixed and/or mobile user terminal. Finally, the present invention is not limited, for example, to the use of CDMA technology. Other advantages and features of the invention are described below, that may be provided independently and/or in one or more combinations.

SUMMARY OF THE INVENTION

[0030] It is a feature and advantage of the present invention to provide, for example, a satellite-terrestrial communication system and method of operation thereof that facilitates efficient spectrum assignment, usage, sharing, and/or reuse.

[0031] It is another feature and advantage of the present invention to provide, for example, a satellite-terrestrial communications system and method of operation thereof that minimizes interference between the satellite and terrestrial systems.

[0032] It is still another feature and advantage of the present invention to provide, for example, a satellite-terrestrial communication system and method of operation thereof that enables at least a portion of the frequencies associated with an area of coverage to be utilized by a terrestrial system having overlapping coverage with a second area of coverage.

[0033] It is yet another feature and advantage of the present invention to provide, for example, a satellite-terrestrial communications system and method of operation thereof that enables a terrestrial underlay system associated with a first area of coverage to reuse and/or share in a substantially central portion thereof at least a portion of the frequency spectrum of one or more adjacent areas of coverage of the satellite system.

[0034] It is another feature and advantage of the present invention to provide, for example, a two system communication system wherein frequencies associated with a central portion of a first area of coverage for a first communication system are assigned, reused and/or shared in a second area of coverage associated with a second communication system.

[0035] It is another feature and advantage of the present invention to enable, for example, assignment, reuse and/or reassignment of satellite uplink and downlink channels in a non-paired manner.

[0036] It is another feature and advantage of the present invention to provide, for example, a method by which the size of satellite spot beams and/or terrestrial cell sizes can be determined.

[0037] It is another feature and advantage of the present invention to, for example, invert the frequencies between the satellite system and an underlay terrestrial system, whereby a first frequency is used, for example, as a downlink frequency between a satellite and a first fixed and/or mobile user terminal, and as an uplink frequency between a second fixed and/or mobile user terminal and a base station. In addition, a second frequency is used, for example, as an uplink between the first fixed and/or mobile user terminal and the satellite and as a downlink between the base station and the second fixed and/or mobile user terminal.

[0038] The present invention optionally provides both a terrestrial frequency assignment and/or reuse plan, and a satellite frequency assignment and/or reuse plan.

[0039] In one embodiment of the present invention, a first spot beam or set of spot beams can reuse in a substantially

central portion or pre-designated portion thereof, at least a portion of the frequency spectrum of one or more adjacent or nearby spot beams. The remaining portion of the spot beam is partitioned into, for example, a number of substantially equal sized subareas/subcells (hereinafter "subareas")extending radially from approximately the periphery of the central portion to or substantially to the spot beam boundary. Each of the central portions and the subareas will generally, although not necessarily, comprise one or more terrestrial cells. In addition, the terrestrial cells may cover at least a portion of one or more subareas and/or spot beams. Other configurations of subareas may also be used. The number of subareas is optionally equal to the number of adjacent cells or spot beams. For example, in a cluster size of seven, the center cell or spot beam will comprise a substantially central portion and six substantially equal size subareas, whereas in a cluster size of four, the cells or spot beams will comprise a substantially central portion and three substantially equal sized subareas. Any number of subareas, however, may alternatively be used.

[0040] In another embodiment, the spot beam channels selected for terrestrial assignment and/or reuse are optionally selected beginning with the spot beam(s) farthest or substantially farthest away from the subarea of the spot beam under consideration, and proceeding to the spot beams closest (e.g., adjacent to) the spot beam subarea under consideration. The system and method of the present invention in this embodiment therefore generally maximizes the separation between the satellite frequencies that are reused terrestrially within the terrestrial cells.

[0041] In accordance with another embodiment of the invention, satellite-terrestrial frequency assignment and/or reuse utilizes the inter-spot beam isolation (e.g., the isolation between the various spot beams). Thus, the terrestrial system associated with a particular spot beam and/or one or more subareas within a spot beam and/or one or more terrestrial cells preferably use satellite channels that are not utilized by the spot beam since the spot beam provides an isolation that can be utilized in reducing interference. In other words, one aspect of the present invention takes the co-channel, co-beam interference and "transfers" it to co-channel, adjacent beam interference.

[0042] This feature of the present invention advantageously minimizes interference between adjacent satellites/spot beams and adjacent cells. The transmissions by the terrestrial network(s) will generally, to a certain extent and depending on the local attenuation, be "heard" by the associated satellite.

[0043] It should be understood that the present invention can utilize and/or be deployed with all satellite (e.g., low-Earth orbit (LEO), mid-Earth orbit (MEO), geosynchronous orbit (GEO), etc.) and cellular terrestrial technologies (e.g., time division multiple access (TDMA), code division multiple access (CDMA), Global System for Mobile Communications (GSM), etc.). The present system may also assign, share and/or reuse frequencies of other domestic, foreign, and/or international satellite and/or terrestrial systems, subject to, for example, national, foreign, and/or international government regulatory approval.

[0044] Additional aspects of the present invention relate to determining the size of the satellite spot beam cells and/or terrestrial cells. In accordance with the present invention, satellite spot beams are optionally sized by a 3 dB loss rule. Specifically, spot beam size is optionally determined by locating points that are substantially equidistant from and have approximately a 3 dB loss vis-à-vis a substantially or effective central portion of the spot beam having maximum gain (e.g., where received satellite signal strength is maximum). Spot beams and/or terrestrial cells can also be sized by using for example, a bit error rate. For example, with voice communication, spot beams and/or terrestrial cells can be sized in accordance with a bit error rate in the range of, for example, 10^{-2} to 10^{-3}. For data communications, spot beams and/or terrestrial cells can be sized in accordance with a bit error rate in the range of, for example, 10^{-2} to 10^{-3}. This approach may result, for example, in systems using different protocols and/or air interfaces (e.g., CDMA, GSM) having different sized spot beams and/or terrestrial cells.

[0045] In accordance with the present invention, the size of the substantially central portion of the spot beam where any/all channels of adjacent spot beams can be reused is preferably equal to an area comprising approximately 25% of the spot beam. For example, if circle having radius r is used to approximate the area associated with, for example, a hexagonal shaped spot beam in a seven cell configuration, the central portion will be approximately equal to 0.5 r (of the circle), which corresponds to an area equal to 25% of the circle. Other percentages of the central portion and/or shapes of the cells may alternatively be used.

[0046] In another embodiment of the present invention, the central portion of the first cell is optionally omitted. The spot beams are instead partitioned into a number of substantially equal sized subareas, whereby each subarea can terrestrially reuse adjacent spot beam channels, except for those channels associated with a spot beam adjacent to the subarea.

[0047] Specifically, within any given satellite spot beam, satellite spot beam channels are used for satellite transmissions, whereas the terrestrial transmissions within that spot beam preferably use all satellite channels except those allocated to the present spot beam. That is, within any given satellite spot beam, the frequency channels used in a first spot beam are preferably not used in the underlay terrestrial system associated with the first spot beam.

[0048] For example, an area of coverage by a satellite system may comprise seven spot beams, with each spot beam having nine channels. Thus, the system would have sixty three channels that could potentially be assigned, shared and/or reused between the satellite and the respective underlay terrestrial systems or between satellite systems. The satellite may use, for example, nine (9) of the channels, and the remaining fifty four (54) channels can therefore be allocated to one or more respective underlay terrestrial systems associated with each respective spot beam. In such a system, the nine channels associated with, for example, a first spot beam are preferably not utilized by the underlay terrestrial system associated with the first spot beam. The general concept is to efficiently allocate (e.g., based on demand) the total frequency band (e.g., sixty three channels) between the terrestrial and satellite systems within each of the seven spot beams and each of the respective terrestrial underlay systems associated therewith, while minimizing interference therebetween.

[0049] The system in accordance with the present invention enhances spectrum usage by allocating and/or reusing at least a portion of the spectrum of, for example, at least a first satellite spot beam to an underlay terrestrial system preferably associated with or having overlapping coverage with, for example, at least a second satellite spot beam, a subarea thereof, and/or a terrestrial cell associated therewith. The satellite-terrestrial communications system of the present invention also minimizes interference between each of the respective satellite and terrestrial systems that assign, reuse or share a portion of the spectrum.

[0050] The present invention also provides a system and method for coordinating an assignment and/or reuse plan between satellite spot beams. If one spot beam gets too congested, it can borrow frequency spectrum from one or more other spot beams that have available capacity. The present invention thus provides different ways of assigning and/or reusing the same frequencies, and uses that fact to allow one or more satellite channel sets to be selected for terrestrial reuse within a terrestrial network on a substantially non-interfering basis with the satellite system.

[0051] In general, in accordance with one embodiment of the invention, each satellite channel is subdivided into uplink and downlink portions, and therefore, has respective uplink frequencies and downlink frequencies associated therewith. In a further aspect of the present invention, the uplink frequencies and downlink frequencies associated with a given channel do not have to be assigned pairwise. For example, the uplink frequencies of a first channel associated with spot beam A can be assigned or reused terrestrially in spot beam B, whereas and the downlink frequencies of the first channel associated with spot beam A can be assigned or reused terrestrially in spot beam C. Similarly, channels can also be assigned or reassigned for use in other spot beams and/or other satellite systems. Similarly, the uplink frequencies of a first channel associated with spot beam A can be assigned or reused terrestrially in a first subarea and/or terrestrial cell, for example, of spot beam B. In addition, the downlink frequencies of the first channel associated with spot beam A can be assigned or reused, for example, terrestrially in a second subarea and/or terrestrial cell of, for example, spot beam B. Similarly, channels can also be assigned or reassigned for user in other spot beams.

[0052] It should be understood that the present invention generally works regardless of cluster size, how many spot beams there are, or how many channels there are per spot beam. For example, a fourteen cell repeat pattern or other cell pattern for satellite and/or terrestrial systems could provide additional separation between the terrestrial networks and the satellite networks. However, the allocation of frequencies between the terrestrial network and the satellite network should be managed efficiently. For example, a large repeat pattern satellite and a small repeat pattern terrestrial network may give rise to inefficient use of spectrum on the satellite (unless, for example, there is sufficient excess spectrum), which could render the satellite spectrally limited rather than power limited.

[0053] In this regard, it will be realized that one optional technique that may be practiced with the present invention is increasing the terrestrial frequency reuse cluster size, which generally minimizes the interference between the satellite and terrestrial systems. For example, a traditional GSM type of pattern utilizes four cells with three sectors each. If instead, twenty-four channels, for example, are assigned across the cells, then one site in eight would have the same frequency, as opposed to one site in four having the same frequency (as with the traditional GSM pattern). Thus, the number of instances where the same frequency exists has been halved, and the amount of energy on an individual channel has also been reduced by half. In this example, the interference between the satellite and terrestrial systems would therefore be reduced by approximately 3 dB vis-à-vis the traditional GSM system.

[0054] Finally, an additional aspect of the present invention concerns inverting frequencies to minimize interference between the satellite and terrestrial systems. The frequency inversion technique involves reversing the satellite down-link and satellite up-link frequencies to become the terrestrial up-link ("return-link") and terrestrial down-link ("forward-link") frequencies, respectively, as described below in detail.

[0055] In particular, one embodiment of the present invention provides a method and system for at least one of assigning and reusing frequencies between one or more communication systems. The method preferably comprises the steps of configuring a first satellite spot beam having a first set of frequencies associated therewith. The first spot beam comprises a first substantially central portion and a first plurality of subareas, where each of the first plurality of subareas extend substantially from a periphery of the first substantially central portion to or near a circumference of the first satellite spot beam. Each subarea generally comprises one or more terrestrial cells, although not all subareas are necessarily required to have terrestrial cells associated therewith. A second satellite spot beam is preferably similarly configured. A terrestrial cell is configured within the first satellite spot beam having a third set of frequencies associated therewith. Finally, the method includes the step of at least one of assigning, reusing and borrowing, by the terrestrial system, at least one of a portion of the second set of frequencies and a portion of the first set of frequencies used in the first central portion, responsive to predetermined criteria associated with the third set of frequencies, including at least one of assigning, reusing and borrowing at least one of the second set of frequencies when the second set of frequencies are at least substantially geographically distant from the first satellite spot beam.

[0056] Another embodiment of the present invention provides a method and system for making a telephone call using a satellite-terrestrial communications system that at least one of assigns and reuses frequencies between a first satellite spot beam or spot beams and a second satellite spot beam or spot beams. A user utilizes a mobile terminal to dial a telephone number within an area of a first terrestrial cell located within or associated with a first satellite spot beam. The terrestrial cell has a first set of frequencies associated therewith. The first satellite spot beam comprises a first substantially central or predesignated portion, and a first plurality of subareas, wherein each of the first plurality of subareas extend substantially from a periphery of the first substantially central or predesignated portion to substantially near a circumference of the first satellite spot beam. Each of the subareas may comprise one or more terrestrial cells, which may at least partially overlap with one or more

spot beams and/or subareas. A second spot beam is configured, which can optionally be configured differently than the first spot beam. If the first set of frequencies can not be utilized to establish a connection, then a connection is established between the first mobile terminal and the second terminal by at least one of assigning, reusing and borrowing, by the first spot beam, at least one of the second set of frequencies, responsive to predetermined criteria including at least one of assigning, reusing and borrowing at least one of the second set of frequencies when the mobile terminal is substantially geographically distant from the second satellite spot beam.

[0057] A third embodiment of the present invention provides a method and system for at least one of assigning and reusing frequencies. The method comprises the steps of configuring a first communications area having a first set of frequencies associated therewith. The first communication area preferably comprises a first substantially central or predesignated portion, and a first plurality of subareas, wherein each of the first plurality of subareas extend substantially from a periphery of the first substantially central portion or predesignated area to or substantially near a circumference of the first communications area. Each of the subareas may comprise one or more terrestrial cells, which may overlap with at least a portion of other spot beams and/or subareas. A second communications area is preferably similarly configured. A third communications area, having a third set of frequencies associated therewith, is preferably configured within the first communications area. Finally, the method includes the step of at least one of assigning, reusing and borrowing, by the third communications area, at least one of a portion of the second set of frequencies and a portion of the first set of frequencies used in the first central portion, responsive to predetermined criteria associated with the third set of frequencies, including at least one of assigning, reusing and borrowing at least one of the second set of frequencies when the second set of frequencies are at least substantially geographically distant from the first satellite spot beam.

[0058] A fourth embodiment of the present invention provides a system and method that involves assigning and reusing frequencies between one or more communication systems. A first satellite spot beam is configured having a first set of frequencies associated therewith. The first spot beam preferably comprises a first substantially central portion and a first plurality of subareas, wherein each of the first plurality of subareas extend substantially from a periphery of the first substantially central portion to substantially near a circumference of the first satellite spot beam. A second satellite spot beam is similarly configured. A terrestrial cell, having a third set of frequencies associated therewith, is configured within the first satellite spot beam. Finally, the method involves the step of at least one of assigning, reusing and borrowing, by the second satellite spot beam, at least one of a portion of the third set of frequencies responsive to predetermined criteria, including at least one of assigning, reusing and borrowing at least one of the third set of frequencies associated with the at least one terrestrial cell when the portion is at least substantially geographically distant from the second set of frequencies.

[0059] A fifth embodiment of the present invention also provides a system and method that involves assigning and reusing frequencies between one or more communication systems. A first satellite spot beam is preferably configured having a first set of frequencies associated therewith. The first spot beam comprises a first substantially central portion and a first plurality of subareas. Each of the first plurality of subareas preferably extend substantially from a periphery of the first substantially central portion to or near a circumference of the first satellite spot beam. A second satellite spot beam, having a second set of frequencies associated therewith, is configured. The second spot beam can optionally have a different configuration than the first satellite spot beam. A terrestrial cell, having a third set of frequencies associated therewith, is configured within the first satellite spot beam. Finally, the method involves the step of at least one of assigning, reusing and borrowing, by the terrestrial system, at least one of a portion of the second set of frequencies and a portion of the first set of frequencies used in the first central portion, responsive to predetermined criteria associated with the third set of frequencies, including at least one of assigning, reusing and borrowing at least one of the second set of frequencies when the second set of frequencies are at least substantially distant from the first satellite spot beam.

[0060] A sixth embodiment of the present invention also provides a system and method of at least one of assigning and reusing frequencies between one or more communication systems. A first satellite spot beam is configured having a first set of frequencies associated therewith. The first spot beam preferably comprises a first plurality of subareas, wherein each of the first plurality of subareas extend from a substantially center area of the first satellite spot beam to substantially near a circumference of the first satellite spot beam in a fan-like manner to form the first plurality of subareas. A second satellite spot beam, having a second set of frequencies associated therewith, is configured. The second spot beam can optionally have a different configuration than the first satellite spot beam. At least one terrestrial cell having a third set of frequencies associated therewith is configured within the first satellite spot beam. Finally the method involves the step of at least one of assigning, reusing and borrowing, by the terrestrial system, at least one of a portion of the second set of frequencies and a portion of the first set of frequencies used in the first central portion, responsive to predetermined criteria associated with the third set of frequencies, including at least one of assigning, reusing and borrowing at least one of the second set of frequencies when the second set of frequencies are at least substantially geographically distant from the first satellite spot beam.

[0061] In at least some of the above-described embodiments, the first plurality of subareas are substantially equal sized cells having a first size, and the second plurality of subareas are substantially equal sized cells having a second size. The first and second size may be substantially equal, or different.

[0062] The second set of frequencies, in accordance with at least some of the above-described embodiments, are substantially distant from the first satellite spot beam when they are at least one of assigned, reused and borrowed for use in those first plurality of subareas not sharing a common boundary with the second satellite spot beam. The first set of frequencies, in accordance with at least some of the above-described embodiments, that are used in the first central

portion comprise at least one of those frequency sets respectively associated with satellite spot beams adjacent to or near the first satellite spot beam.

[0063] Further, at least some of the above-described embodiments, optionally assign, reuse and/or borrow frequencies based on prioritization rules such as, for example, the dynamic load and capacity constraints of cells that frequencies are taken from.

[0064] At least some embodiments of the above-described invention utilize a subscriber terminal positioned within the first central portion that can be assigned, reuse and/or borrow use any of the respective set of frequencies associated with the at least one second satellite spot beam. For example, a subscriber terminal positioned within or near the first central portion can be assigned, reuse and/or borrow use any of the respective set of frequencies associated with any spot beams adjacent and/or near the first satellite spot beam.

[0065] Further, at least some embodiments of the present invention include a subscriber terminal positioned within or near a subarea not sharing at least a portion of a common boundary with the second satellite spot beam. Such a subscriber unit can be assigned, reuse and/or borrow any of the second set of frequencies associated with the second satellite spot beam.

[0066] In addition, at least some embodiments of the present invention optionally assign, reuse and/or borrow frequencies based on predetermined criteria such as load balancing, maintaining a reserve of frequencies, and received signal strength interference.

[0067] At least some of the embodiments of the above-described invention optionally include a second terrestrial cell within the second satellite spot beam. The second terrestrial cell optionally has a fourth set of frequencies associated therewith. The second terrestrial cell at least one of assigns, reuses and borrows at least one of the first set of frequencies and the frequencies used in the second central portion, responsive to predetermined criteria associated with the fourth set of frequencies. The predetermined criteria optionally include at least one of assigning, reusing and borrowing at least one of the first set of frequencies when the first set of frequencies are at least substantially geographically distant from the second satellite spot beam.

[0068] The first central portion and the second central portion of at least some of the above-described embodiments optionally comprise approximately twenty five percent of the area covered by the first satellite spot beam and the second satellite spot beam, respectively.

[0069] Further, the first set of frequencies and the second set of frequencies optionally comprise a plurality of paired uplink and downlink frequencies. A downlink frequency of a frequency set can optionally be used in a first subarea of the first spot beam, and a corresponding one of the uplink frequencies can optionally be reused in a second subarea of the first or second spot beam.

[0070] In accordance with at least some of the above-described embodiments, the area of coverage of a spot beam comprises an area having a radius substantially equal to a distance from a center of the spot beam having a substantially maximum signal strength to a distance from the center of the spot beam where the signal strength of the spot beam is attenuated by approximately 3 dB. Further, the number of subareas is optionally equal to a number of spot beams comprising a cluster minus one. Other numbers of subareas can also be utilized.

[0071] Finally, one or more satellites can be used to configure the first and second spot beams. In communicating between a first subscriber terminal and a second subscriber terminal and/or other communication device, a network operations controller is preferably used to facilitate assignment, borrowing and/or reuse of frequencies between spot beams, communication areas, and/or terrestrial cells, central portions of spot beams and/or communication areas, subareas associated with spot beams, communication areas and/or terrestrial cells, and/or terrestrial cells within subareas.

[0072] Finally, an embodiment of the present invention provides a terrestrial communication system that uses satellite uplink and downlink frequencies, where a terrestrial cell site produces a signal at a satellite uplink frequency that is transmitted to a terrestrial terminal unit. The terminal cell site receives a signal at a satellite downlink frequency that was transmitted by the terrestrial terminal unit.

[0073] There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject matter of the claims appended hereto.

[0074] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

[0075] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

[0076] Further, the purpose of the foregoing abstract is to enable the U.S. Patent and Trademark Office and the public generally, and especially the scientists, engineers and practitioners in the art who are not familiar with patent or legal terms or phraseology, to determine quickly from a cursory inspection the nature and essence of the technical disclosure of the application. The abstract is neither intended to define the invention of the application, which is measured by the claims, nor is it intended to be limiting as to the scope of the invention in any way.

[0077] These together with other objects of the invention, along with the various features of novelty which characterize the invention, are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For

a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be made to the accompanying drawings and descriptive matter in which there is illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0078] **FIG. 1** is a prior art diagram of a satellite radiotelephone system;

[0079] **FIGS. 2A, 2B** and 2C are prior art schematic diagrams of frequency reuse in the satellite radiotelephone systems shown in **FIG. 1**;

[0080] **FIG. 3** is a diagram showing an overview of the principal elements of prior art communications system;

[0081] **FIG. 4** is an overview block diagram of another embodiment of the prior art communications system shown in **FIG. 3**;

[0082] **FIG. 5** is an exemplary high level block diagram of a system that can use and/or be used to produce the frequency reuse schemes in accordance with the present invention;

[0083] **FIG. 6** is an exemplary illustration of how a base station can enhance network coverage, particularly in an area having no line of sight path (or reduced line of sight path) with a satellite;

[0084] **FIG. 7** is an exemplary high level block diagram illustrating an integrated satellite-terrestrial system that can use and/or be used to produce the frequency reuse schemes in accordance with the present invention;

[0085] **FIG. 8***a* shows a first exemplary embodiment of frequency reuse within a spot beam where frequencies from any or all surrounding spot beams can be reused in a substantially central portion thereof;

[0086] **FIG. 8***b* shows a first exemplary embodiment of frequency reuse in a seven cell pattern;

[0087] **FIG. 8***c* shows a variation of the first exemplary embodiment wherein the spot beams are depicted as being circular;

[0088] **FIG. 9** illustrates an exemplary method by which spot beam size can be determined in accordance with the present invention;

[0089] **FIG. 10** shows an exemplary way of determining the size of a center area of a spot beam where frequencies from any of one or more adjacent spot beams can be reused;

[0090] **FIG. 11***a* shows a second exemplary embodiment of terrestrial frequency reuse within a satellite spot beam;

[0091] **FIG. 11***b* shows a variation of the second exemplary embodiment wherein the spot beams are depicted as being circular;

[0092] **FIG. 12** shows an exemplary method by which frequencies can be allocated in an area that does not have a full complement of spot beams;

[0093] **FIG. 13** is an exemplary flowchart illustrating a preferred method of reusing frequencies;

[0094] **FIG. 14** is an exemplary flowchart illustrating a method by which frequencies can be assigned when they are equidistant from a cell or subarea to which they are assigned;

[0095] **FIG. 15** is an exemplary flowchart illustrating a method by which frequencies can be dynamically assigned;

[0096] **FIG. 16** is an exemplary flowchart illustrating a method by which frequencies can be preemptively reassigned based on, for example, load balancing and/or capacity issues;

[0097] **FIGS. 17***a* and **17***b* illustrate different exemplary cluster size and channel number combinations that can be used in accordance with the present invention;

[0098] **FIG. 18** shows an exemplary aspect of the present invention pertaining to how uplink and downlink frequencies can be inverted;

[0099] **FIG. 19** shows the interference paths between the satellite, base station, and user terminals;

[0100] **FIG. 20** shows the user of a base station antenna having a null in the geostationary arc;

[0101] **FIG. 21** shows an exemplary method of call initialization;

[0102] **FIG. 22** shows the use of transition channels;

[0103] **FIG. 23** shows an exemplary method of satellite to base-station proximity-initiated hand-off; and

[0104] **FIG. 24** shows an exemplary method of base station-to-satellite and base station-to-base station proximity-initiated hand-off.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

[0105] Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

[0106] As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the invention be regarded as including equivalent constructions to those described herein insofar as they do not depart from the spirit and scope of the present invention.

[0107] **FIG. 5** shows an exemplary high level block diagram of a standard system **500** that can be used to implement the frequency assignment, reuse and/or reassignment, and other features of the present invention. The telemetry, tracking and command (TT&C) facility **502** is used to control and monitor the one or more satellites **516** of the system **500**.

[0108] The terrestrial segment can optionally use, for example, digital cellular technology, consisting of one or more Gateway Station Systems (GSS) **504**, a Network

Operations Center (NOC) **506**, one or more Mobile Switching Centers (MSC) **508**, one or more Base Transceiver Stations (BTS) **514**, and a variety of mobile, portable, and/or fixed subscriber terminals **512**. The subscriber terminals **512** can be equipped with a Subscriber Identity Module (SIM) (not shown) or similar module that identifies the individual subscriber terminal **512**. The subscriber terminals **512** are generally handheld devices that provide voice and/or data communication capability. Subscriber terminals **512** may also have additional capabilities and functionality such as, for example, paging. Equipping the subscriber terminals **512** with a SIM module can allow the user to have access to the system **500** by using any subscriber terminals **512** having a SIM.

[**0109**] The MSC **508** preferably performs the switching functions of the system **500**, and also optionally provides connection to other networks (e.g., Public Data Network (PDN) **516**, and/or Public Switched Telephone Network (PSTN) **518**). BTSs **514** can be used in those areas where the satellite signal is attenuated by, for example, terrain and/or morphological features, and/or to provide in-building coverage. The BTSs **514** and BSCs **510** generally provide and control the air interface to the mobile terminals **512**. It is preferred that the BTSs **514** use a wireless proprietary or standard wireless protocol that is very similar to that of the satellites **516**. The BSC **510** generally controls one or more BTSs **514** and manages their radio resources. BSC **510** is principally in charge of handovers, frequency hopping, exchange functions and control of the radio frequency power levels of the BTSs **514**.

[**0110**] NOC **506** can provide functions such as monitoring of system power levels to ensure that transmission levels remain within tolerances, and line monitoring to ensure the continuity of the transmission lines that interconnect the BSC **510** to the BTS **514**, the MSC **508** to the PDN **516** and the PSTN **518**, and the NOC **506** to other network components. The NOC **506** can also monitor the satellite **516** transponders to ensure that they are maintained within frequency assignment and power allocation tolerances. The NOC also optionally performs priority and preemption to ensure that communication resources are available and/or assigned, reused and/or borrowed in a timely manner to, for example, facilitate calls originating and/or transmitted to a subscriber terminal **512**. To effectuate the dynamic channel assignment and priority and preemption features of the present invention, the NOC generally maintains cognizance of the availability of satellite and/or terrestrial resources and arranges for any necessary satellite reconfiguration and/or assignment and or reuse of frequencies to meet changed traffic patterns. U.S. Pat. Nos. 5,926,745, 5,815,809, 6,112,085, and 6,058,307 are incorporated herein by reference.

[**0111**] The system **500** will also have one or more satellites **516** that communicate with the satellite GSS **504** and the subscriber terminals **512**. A typical GSS **504** will have an antenna to access the satellite. On the uplink transmission path, the GSS **504** will generally have upconverters that can translate the GSS **504** IF frequency to the feeder link frequency. On the downlink transmission path, the received signal is preferably amplified, and feeder link frequencies are translated to the common IF frequency.

[**0112**] **FIG. 6** is an exemplary BTS **514** frequency plan. The nomenclature is provided as follows:

[**0113**] f^{U}_{1a} and f^{D}_{1a}

[**0114**] superscripts U and D indicate uplink and downlink, respectively;

[**0115**] the numeric subscript (e.g., 1) indicates the frequency band; and

[**0116**] the letter subscript (e.g., a) indicates the frequency channel within the frequency band.

[**0117**] The satellite frequency band generally comprises uplink and downlink frequencies, each of which in turn generally comprise a range of separated frequencies (e.g., 1626.5-1660.5 MHz for uplink, and 1525-1559 MHz for downlink). The present invention is not limited, however, to sharing frequencies within a single frequency band assigned and/or designated by, for example, a government regulatory agency. The present system may also therefore, share and/or reuse frequencies of other domestic, foreign, and/or international satellite and/or terrestrial systems, subject to, for example, national, foreign, and/or international government regulatory approval. In addition, as defined in connection with the present invention, a frequency comprises any set of frequencies that have been associated with a particular frequency band, and is not limited to a consecutive set or series of frequencies within a band. Further, a frequency band in alternative embodiments may comprise a logical set of frequencies that may be assigned to different communication systems, carriers, or in other predesignated frequency bands. That is, for example, a frequency band in the present invention may include frequencies that are assigned to other frequency bands, for example, for different purposes.

[**0118**] Conventionally, users communicating on uplink **604** and downlink **602** would use, for example, paired uplink and downlink channels f^{U}_{1a} and f^{D}_{1a}, f^{U}_{2a} and f^{D}_{2a}, f^{U}_{3a} and f^{D}_{3a}, etc. Advantageously,. in the present invention, different channels within the same frequency band are optionally assigned, reused and/or reassigned in a non-pairwise manner. For example, downlink **602** could be using f^{D}_{1a}, whereas uplink **604** could be using f^{U}_{1b}. Similarly, downlink **602** could be using f^{D}_{1c} whereas uplink **604** could be using f^{U}_{1d}. These pairings are illustrative only, insofar as numerous other non-pairwise uplink **604** and downlink **602** combinations are available that can be used, for example, within different terrestrial cells within subareas, within different subareas of a spot beam, and/or between different spot beams.

[**0119**] Further, suppose that f^{U}_{2a} and f^{D}_{2a} are the uplink and downlink frequency bands associated with a second domestic or foreign satellite system. Users of system **500** communicating on downlink **602** and uplink **604** could use, for example, uplink and downlink frequencies f^{U}_{1a} and f^{D}_{2a}, f^{U}_{1c} and f^{D}_{2b}, f^{U}_{1b} and f^{D}_{2c}, etc. In general, the present invention optionally uses one or more uplink and downlink channels that are from different frequency bands and/or associated with a different domestic and/or foreign satellite system.

[**0120**] **FIG. 7** is an exemplary high level block diagram of a GSM system that can use the frequency reuse schemes in accordance with the present invention. As previously noted, the present invention is not limited to use with a GSM

system, and can be deployed with all satellite (e.g., LEO, MEO, GEO, etc.) and cellular terrestrial technologies (e.g., TDMA, CDMA, GSM, etc.).

[0121] An exemplary Home Location Register (HLR) **706** comprises a database that stores information pertaining to the subscribers belonging to the coverage area of a MSC **508**. The HLR **706** also stores the current location of these subscribers and the services to which they have access. In an exemplary embodiment, the location of the subscriber corresponds to the SS**7704** address of the Visitor Location Register (VLR) **702** associated to the subscriber terminal **512**.

[0122] An exemplary VLR **702** contains information from a subscriber's HLR **706** in order to provide the subscribed services to visiting users. When a subscriber enters the covering area of a new MSC **508**, the VLR **702** associated with this MSC **508** will request information about the new subscriber to its corresponding HLR **706**. The VLR **702** will then have enough information in order to ensure the subscribed services without needing to ask the HLR **706** each time a communication is established. The VLR **702** is optionally implemented together with a MSC **508**, so the area under control of the MSC **508** is also the area under control of the VLR **702**.

[0123] The Authentication Center (AUC) **708** register is used for security purposes, and generally provides the parameters needed for authentication and encryption functions. These parameters help to verify the user's identity. Terrestrial cells **816** can also be positioned so that they cover at least a portion of two or more spot beams (e.g., **802**, **804**) and/or two or more subareas (e.g., **820**, **822**)

[0124] **FIG. 8***a* shows a first exemplary embodiment of a frequency sharing and/or reuse scheme in accordance with the present invention. Generally, the capacity of a satellite network utilizing spot beams is directly proportional to the number of times a cluster of spot beams is replicated. Although **FIG. 8***a* shows a cluster size N of seven (7) (i.e., seven spot beams) (**802**, **804**, **806**, **808**, **810**, **812**, **814**), the present invention can equally be practiced with other cluster sizes or numbers. **FIG. 8***a* does not show the terrestrial system underlaying each of the respective spot beams (**802**-**812**), each of which will typically include at least one terrestrial cell **816**.

[0125] The **FIG. 8***a* embodiment advantageously enhances spectrum usage by allocating at least a portion of the spectrum of, for example, at least a first satellite spot beam (e.g., **802**-**812**) to an underlay terrestrial system associated with or having overlapping coverage with, for example, at least a second satellite spot beam (e.g., **814**), while minimizing interference between each of the respective satellite and terrestrial systems that reuse and/or share a portion of the spectrum. The present invention may optionally apply to any combination of systems having overlapping coverage, including terrestrial-terrestrial systems and/or satellite-satellite systems.

[0126] With regard to spot beams **802**-**814**, a superscript T represents a terrestrial system, and the frequencies without a superscript T represent satellite systems. As shown, the terrestrial frequency sets (designated by $(f_3, f_2, f_4, f_1, f_5)^T$, etc.) associated with the spot beam **814** use, are assigned, or reuse in various combinations, f_1, f_2, f_3, f_4, f_5, and/or f_6. For purposes of explaining at least one aspect of the present invention, it is assumed that each spot beam has a frequency set containing nine (9) 200 kHz channels $f_i=\{q_{i,1}, q_{i,2}, q_{i,3}, \ldots, q_{i,9}\}$ for i=1 . . . 7), as discussed with reference to **FIG. 5**. Other quantities of channels and/or associated bandwidths thereof may optionally be used. It is also assumed that there is a spot beam to adjacent spot beam average isolation of, for example, 10 dB, although the present invention is also compatible with, or applies to, different spot beam isolations.

[0127] In this configuration, each spot beam (**802**-**814**) is assigned a set of frequencies that will be used exclusively by, or substantially used by or assigned to, the satellite network f_i. Likewise, the terrestrial network in each spot beam uses a set of frequencies exclusive to, or substantially used by or assigned to, the terrestrial network $(\tilde{f}_i)^T$. For example, the satellite frequencies used in the center spot beam **814** is f_7, and the terrestrial frequencies in this spot beam can include all other frequency sets $\{f_1, f_2, f_3, \ldots, f_6\}=(\tilde{f}_7)^T$. That is, the channels used by center spot beam **814** are preferably not used by the underlay terrestrial system associated with the spot beam **814**. In this manner, the different channels are preferably allocated among the various spot beams (**802**-**814**) and associated underlay terrestrial systems such that any interference between them is minimized. Note that in this configuration the entire spectral allocation is shared or substantially shared between the satellite network and the terrestrial network in each of the seven spot beams **802**-**814**, although other sharing or overlapping coverages are optionally used. Further, while center spot beam **814** has been designated in this embodiment, other spot beams that are not directly center to the spot beam/terrestrial coverage may be selected alternatively.

[0128] Spot beam **814** generally comprises two areas. The first is an area **818** generally central to spot beam **814**, where channels from any or all of spot beams adjacent to spot beam **814** (i.e., spot beams **802**, **804**, **806**, **808**, **810** and/or **812**) can be assigned, borrowed, and/or reused terrestrially. The second area comprises subareas **820**, **822**, **824**, **826**, **828**, and **830**. As shown in **FIG. 8***a*, in areas **820**-**830**, all frequencies can be assigned, borrowed, and/or reused terrestrially, but preferably not those frequencies used in an adjacent spot beam. For example, in subarea **822**, channels associated with spot beams **810**, **808**, **812**, **806**, and **802** can be reused terrestrially. However, as previously noted, channels associated with spot beam **804** are preferably not used in subarea **822**, or any terrestrial cells within subarea **822**.

[0129] If, as previously assumed, each spot beam **802**-**814** has, for example, nine (200 kHz) channels associated therewith, there would be sixty three channels that could potentially be assigned, reallocated and/or reused between the satellite and/or the respective underlay terrestrial systems. The satellite **516** may use, for example, nine (9) of the channels per spot beam of the 7 cell reuse pattern, and the remaining fifty four (54) channels could therefore be allocated to the respective underlay terrestrial systems associated with the spot beams (**802**-**814**). Therefore, each spot beam subarea (**820**-**830**), excluding central area **818**, will have 45 terrestrial channels available. Other division of channels may also be used.

[0130] For example, consider subarea **820**. Since each of f_2, f_3, f_4, f_5 and f_6 has 9 channels, 45 terrestrial channels are

thus available in subarea **820**. Similarly, 45 channels are also available within subareas **822-830**. It should be understood that this example is illustrative, and not limiting, insofar as the present invention generally works regardless of how many spot beams there are or how many channels there are per satellite coverage area and/or terrestrial coverage area.

[0131] Careful frequency planning can help to reduce interference through maximizing satellite-terrestrial frequency reuse distance. To demonstrate this concept, again consider a terrestrial network in the center spot beam in **FIG. 8***a*. Suppose again that the terrestrial network has 45 available RF channels for reuse. Any satellite frequency sets that do not include channels associated with spot beam **814** can be used in the terrestrial network to provide adjacent beam isolation.

[0132] However, a random selection from the pool of 54 frequencies available for terrestrial use may result in areas where the distance between the terrestrial frequencies and satellite frequencies used in the adjacent spot beams is not substantially maximized. Selective assignment of terrestrial frequencies to the immediate area adjacent to each spot beam in accordance with the present invention can result in increased satellite-terrestrial channel reuse distance.

[0133] **FIG. 8***a* shows an exemplary terrestrial frequency allocation that results in increased and possible substantially maximum terrestrial-satellite frequency distance. As shown, in each subarea (**820, 822, 824, 826, 828, 830**), the terrestrial frequency sets have been selected in order to maximize the frequency reuse distance from the satellite frequency sets in adjacent spot beams.

[0134] For example, with regard to subarea **820**, spot beam **808**, having assigned frequency set f_4, is the farthest away. The spot beams with next largest distance are **810** and **806**, having the assigned satellite frequency sets f_3, and f_5, respectively. Finally, spot beams **802** and **804** have the assigned frequency sets f_2 and f_6, respectively. In general, the terrestrial network within each spot beam is preferably sectioned in the same way that has been done for spot beam **814**.

[0135] With regard to frequency channels associated with spot beams **812** and **808** (and spot beams **802** and **806**), frequency channels from spot beam **812** and **808** can be reused in subarea **822** in either order, or even randomly, since they are each substantially equidistant from subarea **822**. Similarly, frequency channels from spot beams **812** and **808** can be used alternately (e.g., reusing a channel from spot beam **808**, reusing a spot beam from channel **812**, and repeating), or even randomly. The order in which frequency channels can be reused and/or reassigned, therefore, is virtually infinite.

[0136] Spot beams **802-814** can be positioned to cover predetermined areas. One or more spot beams **802-814** can also be dynamically configured/reconfigured to cover an area based on, for example, current and/or anticipated loading considerations.

[0137] As will be discussed with regard to **FIGS. 14***a* and **14***b*, increasing terrestrial cluster size within a satellite spot beam can also be utilized to decrease co-channel interference.

[0138] In general, it is therefore preferred that the separation between the terrestrial channels and the satellite channels be maximized which, in turn, generally, tends to minimize the interference between adjacent spot beams (e.g., **802** and **804**) and adjacent subareas (e.g., **820** and **822**). However, even when these objectives are accomplished, the transmissions by the terrestrial network(s) will generally, to a certain extent and depending on the local attenuation, be "heard" by the associated satellite. Therefore, as shown in **FIG. 8***a*, frequency reuse planning must be carefully done preferably along adjacent spot beam boundaries (e.g., **802** and **804**) to ensure that interferences are minimized.

[0139] As described above, the present invention generally utilizes the inter-spot beam isolation (e.g., the isolation between the various spot beams), to reduce interference. In other words, an exemplary embodiment of the present invention takes the co-channel, co-beam and "transfers" it to co-channel, adjacent beam interference.

[0140] Within each spot beam (e.g., **802-814**), the use of satellite frequencies by the terrestrial network results in co-channel/adjacent-beam interference. To utilize the isolation rendered by the availability of the spot beams, satellite terrestrial frequency reuse should preferably be implemented on adjacent spot beams. The resulting co-channel/adjacent beam interference will generally be approximately reduced by the spot beam to adjacent spot beam isolation factor. It should be noted, however, that in a cluster of, for example, seven spot beams, as shown in **FIG. 8***a*, each spot beam **802-812** has six adjacent spot beams that can contribute to the interference received. The advantage of co-channel/adjacent beam technique over co-channel/co-beam technique lay with the fact that not all spot beams have equal service demand. Consequently, the distribution of interference between adjacent spot beams can reduce the average interference in a high service demand beam. Any energy that is being generated by the spot beam channels within a **814** spot beam (e.g., **814**) can be attenuated by the antenna pattern of the spot beam **814** satellite.

[0141] The frequency reuse scheme in accordance with the present invention therefore enables the total frequency band to be efficiently allocated (e.g., based on demand) between the terrestrial and satellite systems within each of the seven spot beams (**802-814**) and each of the respective terrestrial underlay systems associated therewith, while minimizing interference therebetween.

[0142] Consider **FIG. 8***a* from a geographic perspective. As shown, New York city falls within spot beam **802**, as well as terrestrial cell **816**, Philadelphia falls within spot beam **814** and subarea **826**, and Washington, D.C. falls within spot beam **808**. Although terrestrial cells **816** can be located anywhere within the satellite spot beams (**802-814**), they will generally be located in, for example, metropolitan areas (e.g., New York, N.Y.) where satellite coverage may be limited due to, for example, capacity constraints or no line of sight or reduced line of sight between a subscriber terminal **512** and a satellite **516**. This is one illustrative configuration, and is not intended to limit the invention in any way. If desired, spot beams **802-814**, subareas **820-830**, and/or terrestrial cells **816** can optionally be increased, decreased, and/or varied in number, size, and/or arrangement to yield a virtually infinite number of configurations that may be tailored to suit one or more geographic areas.

[0143] In general, the channels associated with one particular spot beam or area of coverage can be reassigned for

satellite and/or terrestrial reuse in conjunction with any other spot beam or area of coverage. If one spot beam (e.g., **814**) gets too congested, it can borrow and/or reuse frequency spectrum from other spot beams (e.g., **802**, **804**, **806**, **808**, **810** and/or **812**) that have available capacity. The frequencies being assigned are thus preferably location dependent upon, for example, the location of the spot beam. Thus, if spot beam **802** has nine frequencies and only three of the nine frequencies are needed for satellite transmission, the remaining six frequencies can dynamically be reassigned to either another system, such as a terrestrial system or other satellite system, or to increase capacity in, for example, an adjacent (i.e., **804**, **812**, and/or **814**) or non-adjacent (i.e., **806**, **808**, and/or **810**) satellite spot beam.

[**0144**] At some point, the spot beam **808** channels that are reused terrestrially within spot beam **814** will interfere with the spot beam **808** satellite transmissions. However, any potential interference can be minimized by managing the frequency reuse and the size of these networks.

[**0145**] As discussed above, it is preferred that those frequencies associated with a spot beam furthest away be reused first, and that those frequencies associated with a spot beam closest (i.e., adjacent) to the spot beam which will reuse the frequency be used last. Again referring to subarea **822** and/or any terrestrial cells having at least partially overlapping coverage therewith, it is therefore preferred that channels from spot beam **810** be reused first, then channels from spot beams **808** and **812** be reused, and then channels from spot beams **802** and **806** be reused. An alternative or in addition, frequencies may be reassigned responsive to the congestion load in adjacent or nearby cells such that substantially equidistant cells are selected based on lower congestion or capacity rate, and even cells that are closer may alternatively be selected over cells that are further away based on congestion, load and/or capacity constraints.

[**0146**] In highly populated areas where terrestrial coverage can present great spectral efficiency over the satellite coverage, the terrestrial cell site density will be high. Accordingly, the interference generated in these cell sites will also be high. In such circumstances, it is advantageous to trade part of the satellite frequency spectrum of the spot beam (and even part of adjacent spot beams) to the terrestrial network. Such a trade off results in lower co-channel interference levels. As an example of a frequency borrowing technique, consider the example discussed in the previous section where each of the terrestrial networks have been configured with 45 RF channels and the satellite network in the corresponding spot beam has been configured with nine (9) RF channels. To reduce the interference by increasing the cluster size, three (3) channels from the satellite network can be reassigned to the terrestrial network resulting in 48 channels for reuse terrestrially and six (6) channels for the corresponding satellite spot beam.

[**0147**] The channels within spot beam **808**, for example, can also be used as a terrestrial frequency in, for example, spot beam **814**. It is preferred that the channels in spot beam **808** are used in five of the six subareas, and/or respective terrestrial cells associated therewith, of spot beam **814** (i.e., subareas **820**, **822**, **824**, **828** and **830**). As shown in **FIG. 8***a*, it is also preferred that the channels of spot beam **808** not be used in subarea **826** (i.e., in the subarea that is contiguous with and directly adjacent to the spot beam **808**). However, in alternate embodiments, depending on load and/or capacity issues, directly adjacent cells may also be utilized for frequency assignment and/or reuse.

[**0148**] **FIG. 8***b* shows a first exemplary embodiment of frequency reuse in a seven cell pattern. As discussed with regard to **FIG. 8***a*, the frequencies assigned, borrowed and/or reused are preferably taken from the spot beam furthest away from the assigned, reusing, or borrowing subarea and/or terrestrial cell(s) associated therewith.

[**0149**] **FIG. 8***c* shows a variation of the first exemplary embodiment shown in **FIG. 8***a*. In **FIG. 8***c*, spot beams **803**, **805**, **807**, **809**, **811**, **813**, and **815** are depicted as being circular, and respectively correspond to spot beams **802**, **804**, **806**, **808**, **810**, **812**, and **814** shown in **FIG. 8***a*. Similarly, subareas **850**, **852**, **854**, **856**, **858**, and **860** respectively correspond to subareas **820**, **822**, **824**, **826**, **828**, and **830** shown in **FIG. 8***a*. In **FIG. 8***c*, subareas **850-860** have a different shape than subareas **820-830** shown in **FIG. 8***a*, and generally extend from the center portion **818** to the dashed line of the respective adjacent subcell that partially overlaps with the area of coverage of spot beam **815**. Aspects of the present invention discussed in connection with **FIG. 8***a* pertaining to frequency borrowing, assignment and reuse are also generally applicable to **FIG. 8***c*.

[**0150**] **FIG. 9**. shows an exemplary method by which the size of satellite spot beams (**802-814**) can be determined. Specifically, as shown in **FIG. 9**, cell size (e.g., cell diameter) can be determined as being approximate to the distance corresponding to a 3 dB loss. That is, an exemplary radius of a satellite spot beam (**802-814**) in accordance with the present invention is preferably determined as being approximately equal to the distance over which maximum signal strength decreases by approximately 50%. Therefore, assuming that satellite **516** can generate, for example, seven spot beams having substantially equal power, the radius of each spot beam (**802-814**) is determined from a point of maximum gain to the points having approximately a 3 dB loss. Other signal strength decrease percentages and/or techniques for determining the size and shape of the satellite cells, and/or center areas may optionally be used.

[**0151**] **FIG. 10** shows an exemplary method by which a substantially central area **818** is determined. Specifically, in accordance with the present invention, we have determined that channels from all adjacent spot beams (**802-814**) can be reused in an area **818** that is equal to approximately 25% of the area of spot beam **814**. Insofar as an infinite number of line segments, each having a different distance and radius, can be drawn from center **819** of spot beam **814** to one of its adjacent sides (e.g., segment **850**, **854**), there can be an infinite number of substantially equal areas within a spot beam (**802-812**) where channels from all adjacent spot beams can be reused. In accordance with one embodiment, we have determined that the maximum radius will correspond to a radius extending from the center or substantially the center of spot beam **814** (at **819**) to point **850** (or **854**), and a minimum area will correspond to a radius extending from the center of spot beam **815** (at **819**) to point **852**, which bisects segment **850**, **854**. Other methods of determining the size and/or shape of area **818** may also be used, and area **818** may be of any shape including, for example, rectangular, hexagonal, and the like.

[**0152**] **FIG. 11***a* shows a second exemplary embodiment of frequency reuse within a satellite spot beam. Although

FIG. 11*a* differs from **FIG. 8***a* in that **FIG. 11***a* does not have a central area **818** as shown in **FIG. 8***a*, terrestrial cells along the interior boundaries of spot beam **814** may nevertheless utilize all frequencies (f_1-f_6). Other aspects of the invention pertaining to, for example, frequency assignment, reuse and/or borrowing discussed in connection with the **FIG. 8***a* embodiment are generally applicable to the embodiment shown in **FIG. 11***a*. That is, the embodiment shown in **FIG. 11***a* advantageously enhances spectrum usage by allocating at least a portion of the spectrum of, for example, at least a first satellite spot beam (e.g., **1102-1112**) to an underlay terrestrial system preferably associated with or having overlapping coverage with, for example, at least a second satellite spot beam (e.g., **1114**), while minimizing interference between each of the respective satellite and terrestrial systems that reuse and/or share a portion of the spectrum. **FIG. 11***a* may also optionally apply to any combination of systems having overlapping coverage, including terrestrial-terrestrial systems and/or satellite-satellite systems. In addition, frequencies may be reassigned responsive to the congestion load in adjacent or nearby spot beams, subareas, and/or terrestrial cells such that, for example, substantially equidistant spot beams and/or subareas are selected based on lower congestion or capacity rate, and even subareas that are closer may alternatively be selected over subareas that are further away based on congestion, load and/or capacity constraints.

[**0153**] **FIG. 11***b* shows a variation-of the second exemplary embodiment shown in **FIG. 11***a*. Spot beams **1103**, **1105**, **1107**, **1109**, **1111**, **1113**, and **1115** are depicted as being circular, and respectively correspond to spot beams **1102**, **1104**, **1106**, **1108**, **1110**, **1112**, and **1114** shown in **FIG. 11***a*. Similarly, subareas **1150**, **1152**, **1154**, **1156**, **1158**, and **1160** respectively correspond to subareas **1120**, **1122**, **1124**, **1126**, **1128**, and **1130** shown in **FIG. 11***a*. In **FIG. 11***b*, subareas **1150-1160** have a different shape than subareas **1120-1130** shown in **FIG. 11***a*. In **FIG. 11***b*, subareas generally extend from the center or substantially the center of spot beam **1115** to the dashed line of the respective adjacent subcell having partially overlapping coverage with spot beam **1115**.

[**0154**] Further, in areas where spot beams overlap (e.g., **1170**, **1172**, **1174**, **1176**, **1178**, and **1180**), there may be increased interference due to the overlapping coverage of the respective spot beams. In subareas **1150-1160**, all frequencies associated with adjacent spot beams **1103-1113** could be used. This could depend, for example, on the need for spectrum terrestrially and frequency separation distance. For example, in subarea **1150**, although frequencies f_4, f_3, f_5, f_2 and f_6 are first preferably borrowed, assigned and/or reused terrestrially, f1 may also be borrowed, assigned and/or reused terrestrially. If any of the f_1 frequencies are borrowed, assigned or reused terrestrially in subarea **1150**, it is preferred that, in order to reduce interference, they be borrowed, assigned or reused in one or more terrestrial cells near the center of spot beam **1115**. However, the f_1 frequencies can also be used in a terrestrial cell **1132** near area **1170** but within subcell **1152**. Other aspects of the present invention discussed in connection with **FIG. 11***a* pertaining to frequency borrowing, assignment and reuse are also generally applicable to **FIG. 11***b*.

[**0155**] As shown in **FIG. 12**, satellite spot beams at the edge of the service area (**1202**, **1204**, **1206**, **1208**, **1210**) do not have the full complement of six neighbors. As such, the terrestrial network within the areas covered by this type of spot beams will have slightly different configuration. **FIG. 12** shows an exemplary terrestrial network frequency plan for such a spot beam.

[**0156**] Spot beam **1210**, having assigned frequency channels f_7, has only three adjacent spot beams **1202**, **1204**, **1206**. Spot beams with frequency channels f_2, f_3, and f_4 are missing from the cluster. As a result, the f_2, f_3, and f_4 frequency channels can be assigned to all subareas (**1212**, **1214**, **1216**, **1218**, **1220**, **1222**) of spot beam **1210**. The remaining terrestrial frequency assignments for subareas **1212-1222** follow the procedure described above with regard to **FIG. 8***a*, with the exception of subarea **1220**. In subarea **1220**, there are two choices for one frequency channel assignment, f_5 and f_1, either of which can be assigned to subarea **1220**. This is because both f_1, and f_5 are equidistant from subarea **1220**. Accordingly, assignment of frequencies can be based on load and/or capacity issues in the spot beams with frequencies f_1 and f_5, as well as other methods of determining which of the spot beams with frequencies f_1 and f_5 are preferred.

[**0157**] **FIG. 13** is an exemplary flowchart illustrating a process of assigning and/or reusing frequencies. In step **1302**, spot beams are divided into a number of subareas. Different sized and/or different shaped cells may alternatively be used. In accordance with one embodiment of the present invention, the spot beam may also have an optional central portion **818** as shown in **FIG. 8***a*. A determination is then made at step **1304** as to whether underlay terrestrial frequencies are required in the spot beam. If not, the process ends at step **1306**.

[**0158**] If terrestrial frequencies are required, then a determination is made at step **1308** as to whether frequencies are required in a central portion of the spot beam. If yes, then frequencies of other spot beams can be used in the central portion of the spot beam at step **1310**, whereafter the method proceeds to decision step **1312**. If frequencies are not required in a central portion of the spot beam, then at decision step **1312** a determination is made as to whether terrestrial frequencies are required in any of the subareas. If yes, then at step **1314** frequencies are reused from the most distant spot beams relative to each required subarea (as previously discussed with regard to and indicated in **FIG. 8***a*). At decision step **1316**, a determination is made whether additional frequencies are required. If so, the process returns to decision step **1308**. If not, the process ends at step **1306**.

[**0159**] **FIG. 14** is an exemplary flowchart illustrating a method by which frequencies can be assigned when they are equidistant from a cell or subarea to which they are assigned. At decision step **1402**, a determination is made whether the cell or coverage area to which the frequencies are to be assigned, reused and/or shared is substantially equidistant from the cell or coverage area from which they are taken. If not, the frequencies associated with a cell or coverage area furthest away from the coverage area to which the frequencies are to be assigned, reused and/or shared are preferably used, as discussed with regard to **FIG. 13**. the process then ends at step **1406**.

[**0160**] If the cell or coverage area to which the frequencies are to be assigned, reused and/or shared is substantially equidistant from the cell or coverage area from which they are taken, at decision step **1408** a time interval for which the

frequencies can be borrowed can optionally be utilized. If a time interval is selected at decision step **1408**, the time interval may consider, for example, historical usage patterns when evaluating excess capacity of equidistant cells at step **1412**. For example, with regard to **FIG. 12**, spot beams **1202** and **1208** are equidistant from subarea **1220**. If, for the time period under consideration, spot beam **1208** has a historically higher usage than spot beam **1202**, frequencies can first be borrowed from spot beam **1202**. Other factors such as signal to interference ratio, and signal strength can also be used in determining the order in which frequencies are assigned, reused and/or shared. If a time interval is not used, then, at step **1412**, the assignment, reuse and/or sharing determination is preferably based on, for example, current loading considerations. As discussed with regard to step **1412**, other factors such as signal to interference ratio, and signal strength can also be used in determining the order in which frequencies are assigned, reused and/or shared. At step **1414**, frequencies are assigned, reused or borrowed such that the probability that each cell from which frequencies are taken has substantially the same probability that frequencies will not be exhausted therein. When a time interval is selected at step **1410**, step **1414** will generally take into consideration historical usage, as discussed above. When a time interval is not chosen, probabilities will generally be evaluated based upon, for example, current usage.

[**0161**] **FIG. 15** is an exemplary flowchart illustrating a method by which frequencies can be dynamically assigned. At step **1502**, frequency usage is monitored within each spot beam and/or subarea. When, as determined at decision step **1504** that there are incoming calls, a determination is made at decision step **1506** whether sufficient channels are available. If so, then frequencies are allocated in accordance with existing channel assignments. If sufficient channels are not available, then, at step **1510**, frequencies are assigned, reused and/or shared to provide sufficient bandwidth. As discussed with regard to **FIG. 14**, one criteria by which frequencies can be assigned, reused and/or shared can be based on substantially equalizing the probability that each cell from which frequencies are borrowed frequencies will not be exhausted. As indicated at decision step **1512**, channels can again be reassigned if, for example, interference levels are not acceptable. At step **1514**, calls are allocated to channels in accordance with updated channel assignments, after which the process either returns to step **1502** or terminates, as determined at decision step **1516**.

[**0162**] **FIG. 16** is an exemplary flowchart illustrating a method by which frequencies can be preemptively reassigned based on, for example, load balancing and/or capacity issues. At step **1602**, frequency usage is monitored within each spot beam and/or subarea. When, as determined at decision step **1604** that there are incoming calls, a determination is made at decision step **1606** whether sufficient channels are available. If so, then at step **1608** frequencies are allocated in accordance with existing channel assignments. If sufficient channels are not available, then, at step **1610**, a time interval is selected. At step **1612**, and based upon the time interval selected at step **1610**, frequencies are assigned, reused and/or shared to provide sufficient bandwidth. As discussed with regard to **FIG. 14**, one criteria by which frequencies can be assigned, reused and/or shared, based on a selected time interval, can be that of substantially equalizing the probability that each cell from which frequencies are borrowed frequencies will not be exhausted. This, in turn, can be based, for example, on historical usage patterns for the affected area(s) and/or selected time interval. As indicated at decision step **1614**, channels can again be reassigned at step **1612** if, for example, interference levels are not acceptable. At step **1616**, calls are allocated to channels in accordance with updated channel assignments, after which the process either returns to step **1602** or terminates, as determined at decision step **1618**.

[**0163**] As shown in **FIGS. 17***a* and **17***b*, one technique and alternative embodiment that may be practiced with the present invention is increasing the cluster size. This will generally minimize the interference between the satellite and terrestrial systems.

[**0164**] **FIG. 17***a* shows a traditional GSM type of pattern of four cells with three sectors each. If instead, as shown in **FIG. 17***b*, twenty-four channels are assigned across the cells, then one site in eight has the same frequency, as opposed to one site in four having the same frequency as with the traditional GSM pattern of **FIG. 17***a*. Thus, the number of instances where the same frequency exists has been halved, and the amount of energy on an individual channel has also been reduced by approximately half. In this example, the interference between the satellite and terrestrial systems would be reduced by approximately 3 dB vis-à-vis the traditional GSM system.

[**0165**] Cross network interference occurs when a channel is utilized both in the terrestrial network and in the satellite network, either in the co-beam configuration or in the adjacent-beam configuration. The severity of such interference depends on the power received by the competing network. In particular, the terrestrial networks use or reuse an RF channel or channels many times in an area covered by a given satellite spot beam or beams. Each occurrence of this channel gives rise to increased co-channel interference for the satellite network.

[**0166**] In the case of the co-beam configuration, the co-channel interference can be approximated by MI, where M is the number of times a channel is reused and I is the interference power of one source. For the adjacent-beam configuration the co-channel interference from one adjacent beam can be approximated by αMI , where α accounts for the fraction of power leaked from the adjacent beam. Thus, in both co-beam and adjacent beam configuration, the co-channel interference is directly proportional to the number of times a particular frequency is reused terrestrially.

[**0167**] Again with regard to **FIGS. 17***a* and **17***b*, by increasing the cluster size for the terrestrial network, the reuse of a particular frequency is reduced. To illustrate the point, consider a terrestrial network as shown in **FIG. 17***a* that has 12 available RF channels for reuse with a cluster size of four and three sectors per cell site. In each terrestrial cluster, the skyward energy from one sector will or may interfere with all satellite co-channels in the adjacent spot beams (in the same spot beam for co-beam configuration). **FIG. 17***b* shows a terrestrial network with 16 cell sites (48 sectors), each RF channel is repeated four times in this network. In this same 16 site network, if twenty-four RF channels are used, for example, in a cluster of 8, then the number of co-channel sectors is reduced from 4 to 2. In general, this type of tradeoff between bandwidth and interference can be employed with the present invention to reduce co-channel interference.

[0168] The frequency inversion technique, as shown in **FIGS. 18***a* and **18***b*, involves reversing the satellite down-link (F_1) and satellite up-link (F_2) frequencies to become the terrestrial up-link ("return-link") and terrestrial down-link ("forward-link") frequencies, respectively. As a result, there will be two possible interference paths, as shown in **FIG. 19**: (1) between the satellite **516** and base stations **1802**, as return-link to down-link interference on F_1, and as up-link to forward-link interference on F_2; and (2) between the satellite user terminals **1804** and terrestrial user terminals **1806**, as down-link to return-link interference on F_1, and as forward-link to up-link interference on F_2. The system and method according to the present invention eliminates or substantially reduces both of these possible interferences, as will be described herein. It should be understood that the system may comprise one or more base station antennas (and associated base stations) and one or more satellites, although only one of each are shown in **FIG. 19**. It should also be understood that the system may comprise one or more satellite handsets and one or more base station handsets, although only one of each are shown in **FIG. 19**.

[0169] As shown in **FIG. 20**, interference between the satellite **516** and base stations **1802** (i.e., return-link to down-link and up-link to forward-link interference) is substantially reduced or eliminated, preferably by using a base station antenna having a substantially reduced gain in the geostationary arc (i.e., the elevation angle above the horizon from a base station to the satellite). Unlike a user terminal **1804**, **1806**, which is mobile and may be oriented differently from user to user, a base station **1802** does not move and therefore forms a substantially fixed angular relationship with respect to the satellite. Within North America, the geostationary arc typically varies from approximately 30° to 70°, depending, for example, on the latitude of the base station. To fully take advantage of this fact, it is preferred that the base station antenna pattern have a null, and therefore significantly reduced gain, in the geostationary arc portion of its vertical pattern. As an analogy, one could consider the satellite to be in a "blind spot" with respect to the base station. The additional signal attenuation achieved from this technique substantially reduces or eliminates interference between the satellite and terrestrial base stations. This technique will facilitate terrestrial coverage and at the same time substantially reduce or eliminate interference to the satellite system.

[0170] To further enhance the performance of the system, a technique for optimally or substantially optimally locating and orienting base stations will preferably be used, to advantageously utilize the horizontal gain pattern of the antenna. The benefits of using this technique, for example, are that frequency reuse will be maximized or substantially maximized, thereby enhancing the overall capacity of the system, and further reducing or eliminating interference.

[0171] In addition to the increased isolation provided by the vertical antenna pattern, additional isolation can be obtained from the horizontal antenna pattern. For example, preferably by configuring base stations such that the azimuth to the satellite is off-bore or between sectors, several additional dB of isolation can typically be achieved. By keeping this configuration standard for, say, a cluster of base stations, frequency reuse for the terrestrial system can generally be increased.

[0172] Interference between satellite user terminals **1804** and terrestrial user terminals **1806** is typically a problem when the units are in relatively close proximity to one another. It is preferred that such interference be substantially reduced or eliminated by, for example, first detecting close proximity before the assignment of a radio channel (i.e., during call initialization), and secondly by providing a hand-off to a non-interfering channel if close proximity occurs after the assignment of a radio channel. The call initialization method shown in **FIG. 21** allows for real-time or near real-time operation of this technique.

[0173] The technique provides optimum or substantially optimum radio resource allocation so that the coexistence of single-mode terminals (satellite mode) and dual-mode terminals can be accomplished. In order for this to work, it is preferred that a relatively small group of channels, called "transition channels", as shown in **FIG. 22**, be reserved for single-mode terminals. The single-mode terminals preferably use transition channels while inside base station coverage. It is also preferred that dual-mode terminals also use the transition channels under certain circumstances, as will be described in detail herein.

[0174] As shown in **FIG. 21**, when a user places a call at step **2102**, the user terminal will request a traffic channel from the network. It is preferred that, at step **2104**, the network instruct the terminal to make a series of measurements. If the terminal is single-mode, as determined at decision step **2106**, it will, at step **2118**, preferably scan satellite channels for signal strength and interference. If interference levels are acceptable, as determined at decision step **2116**, and if a satellite channel is available, as determined at decision step **2126**, then the terminal will preferably be assigned that channel at step **2124**. If a satellite channel is not available, the terminal will preferably retry a fixed number of times, as determined at decision step **2128**, starting from the measurements, before the call is determined to be unsuccessful at step **2136**. If interference levels are unacceptable, the terminal will preferably request a transition channel at step **2114**. If a transition channel is available, as determined at decision step **2112**, then the terminal will preferably be assigned that channel at step **2110**. If a transition channel is not available, the terminal will preferably retry a fixed number of times starting from the measurements, before the call is determined to be unsuccessful at step **2136**.

[0175] If, as determined at decision step **2106**, the terminal is dual-mode, it will preferably scan both satellite and base station channels for signal strength and interference at step **2108**. If interference levels are unacceptable as determined at decision step **2122**, the terminal will preferably request a transition channel at step **2120**. If a transition channel is available as determined at decision step **2132**, then the terminal will preferably be assigned that channel at step **2134**. If a transition channel is not available, the terminal will preferably retry a predetermined number of times, as determined at decision step **2130**, starting from the measurements, before the call is determined to be unsuccessful at step **2136**. If interference is acceptable, the terminal will preferably request the system (i.e., satellite or base station) with the dominant signal, as determined at decision step **2140**. If the terminal requests a satellite channel at step **2138**, and one is available as determined at decision step **2142**, then the terminal will preferably be assigned that channel at

step **2144**. If a satellite channel is not available, the terminal will preferably retry a fixed number of times starting from the measurements, as determined at decision step **2130**, before the call is determined to be unsuccessful at step **2136**. If the terminal requests a base station channel at step **2148**, and one is available as determined at decision step **2146**, then the terminal will preferably be assigned that channel at step **2150**. If a base station channel is not available, the terminal will preferably retry a fixed number of times starting from the measurements, as determined at decision step **2130**, before the call is determined to be unsuccessful at step **2136**. It should be obvious to those skilled in the art that many variations of the **FIG. 21** are available that would accomplish. the call initialization objective. For example, the specific sequence of steps may be altered or re-ordered, such that the overall functionality is substantially the same or similar. For example, the determination whether the user is in dual-mode may be juxtaposed after measuring satellite and base station channels.

[**0176**] **FIG. 23** shows an exemplary method of satellite to base-station proximity-initiated hand-off. As shown in **FIG. 23**, as a user terminal approaches a base station at step **2302**, it will preferably alert the network of its proximity. If, as determined at decision step **2304**, the terminal is single-mode, then one of two things can generally happen. If, for example, the single-mode terminal is being served by a transition channel, as determined at decision step **2312**, then hand-off is not required **2310**. If, for example, the single-mode terminal is being served by a satellite channel, then a request to hand-off to a transition channel is preferably made at step **2318**. If a transition channel is available as determined at decision step **2318**, then the hand-off procedure preferably takes place at step **2326**. If a transition channel is not available, then the terminal preferably checks if its current interference level is acceptable at decision step **2334**. If interference is acceptable, then the terminal preferably camps on the satellite at step **2336**, preferably for a pre-specified period of time before another request to hand-off to a transition channel is made. If interference is not acceptable, the terminal preferably determines if another satellite channel is available for use at decision step **2346**. If not, then the terminal preferably camps on the channel at step **2336**. If so, the terminal is preferably re-assigned to a new satellite channel at step **2348**, which it camps on at step **2336**, preferably for a pre-specified period of time before another request to hand-off to a transition channel is made at step **2318**.

[**0177**] If the terminal is dual-mode, then a request to hand-off to a base station channel is preferably made at step **2306**. If, as determined at decision step **2314**, a base station channel is available, then the hand-off procedure preferably takes place at step **2308**. If a base station channel is not available, then a request to hand-off to a transition channel is preferably made at step **2320**. If, as determined at decision step **2330**, a transition channel is not available, then the terminal preferably checks, at decision step **2340**, if its current interference level is acceptable. If interference is acceptable, then the terminal preferably camps on the channel at step **2338**, preferably for a pre-specified period of time before another request to hand-off to a base station channel is made at step **2306**. If interference is not acceptable, the terminal preferably determines at decision step **2352**, if another satellite channel is available for use. If not, then the terminal preferably camps on the satellite at step **2338**. If so, the terminal is preferably re-assigned to a new satellite channel at step **2350**, which it preferably camps on for a pre-specified period of time at step **2338** before another request to hand-off to a base station channel is made at step **2306**.

[**0178**] If the first attempt to hand-off to a transition channel was successful, then the terminal preferably camps on this channel at step **2316**, preferably for a pre-specified period of time before comparing the signal levels of the transition channel and base station at decision step **2324**. If the base station is not stronger by a pre-specified margin, then the terminal preferably camps on the transition channel at step **2316**, preferably until the base station channel becomes the stronger channel. If the base station is stronger by a pre-specified margin, then a request to hand-off to a base station channel is preferably made at step **2332**. If, as determined at decision step **2342**, a base station channel is available, then the hand-off procedure preferably takes place at step **2356**. If a base station channel is not available, then the terminal preferably camps on the transition channel at step **2316**, preferably for a pre-specified period of time before comparing the signal levels of the transition channel and base station again. It should be obvious to those skilled in the art that many variations of the **FIG. 23** are available that would accomplish the satellite to base station hand-off objective. For example, the specific sequence of steps may be altered or re-ordered, such that the overall functionality is substantially the same or similar.

[**0179**] **FIG. 24** shows an exemplary method of base station-to-satellite and base station-to-base station proximity-initiated hand-off. As shown in **FIG. 24** at step **2402**, as a dual-mode terminal moves away from the base station it is served by, it will eventually take appropriate measures upon sensing a stronger channel, either from the satellite, another base station, or a system or device associated therewith. If, as determined at decision step **2404**, a satellite channel is stronger than a neighboring base station channel, then a request to hand-off to a satellite channel is preferably made at step **2406**. If, as determined at decision step **2408**, a satellite channel is available, then the hand-off procedure preferably takes place at step **2410**. If a satellite channel is not available or if a neighboring base station channel is stronger than a satellite channel, then a request to hand-off to a base station channel is preferably made at step **2406**. If, as determined at decision step **2414**, a base station channel is available, then the hand-off procedure preferably takes place at step **2410**. If a base station channel is not available, then the terminal preferably camps on its current channel at step **2416**, preferably for a pre-specified period of time before making measurement comparisons again at decision step **2404**. It should be obvious to those skilled in the art that many variations of **FIG. 24** are available that would accomplish the base station-to-satellite and base station-to-base station hand-off objectives. For example, the specific sequence of steps may be altered or re-ordered, such that the overall functionality is substantially the same or similar.

[**0180**] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the

exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention. While the foregoing invention has been described in detail by way of illustration and example of preferred embodiments, numerous modifications, substitutions, and alterations are possible without departing from the scope of the invention defined in the following claims.

1-154. (canceled)

155. A wireless communications system comprising:

a space-based system configured to conduct traffic channel communications with radioterminals in a first service region using a set of satellite frequencies; and

a ground-based system configured to communicate with radioterminals in a second service region adjacent and/or overlapping the first service region and to limit use of the set of satellite frequencies for radioterminal traffic channel communications to a subset of the set of satellite frequencies.

156. A wireless communications system according to claim 155, wherein the set of satellite frequencies comprises frequencies in a band of satellite frequencies, and wherein the subset of the set of satellite frequencies comprises a sub-band of the band of satellite frequencies.

157. A wireless communications system according to claim 155, wherein the ground-based system is further configured to conduct traffic channel, control channel and/or signaling communications with radioterminals using frequencies outside of the set of satellite frequencies.

158. A wireless communications system according to claim 155, wherein the space-based system and/or the ground-based system selectively reuse frequencies of the set of satellite frequencies on a geographic basis.

159. A wireless communications system according to claim 155, wherein the space-based system is configured to preferentially conduct traffic channel, control channel and/or signaling communications with radioterminals using the set of satellite frequencies used by the ground-based system.

160. A wireless communications system according to claim 155, wherein the set of satellite frequencies comprises a first subset, and further comprising a controller configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to a second subset of the set satellite frequencies that is not used by the ground-based system.

161. A wireless communications system according to claim 160, wherein the controller is configured to preferentially assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to the second subset of the set of satellite frequencies.

162. A wireless communications system according to claim 160, wherein the controller is configured to transition traffic channel, control channel and/or signaling communications of a radioterminal with the space-based system between the first and second subsets of the set of satellite frequencies responsive to a measure of interference.

163. A wireless communications system according to claim 160, wherein the controller is configured to limit traffic channel, control channel and/or signaling communications of a single-mode radioterminal to the second subset of the set of satellite frequencies when the single-mode radioterminal is positioned in a cell of the ground-based system.

164. A wireless communications system according to claim 160, wherein the controller resides at the ground-based system, at the space-based system and/or at a radioterminal.

165. A wireless communications system according to claim 160, wherein the controller is configured to preferentially assign a radioterminal to the ground-based system or to the space-based system.

166. A wireless communications system according to claim 160, wherein the controller is configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications to the space-based system or the ground-based system responsive to an input to the ground-based system, space-based system, radioterminal and/or to a location of a radioterminal.

167. A wireless communications system comprising:

a space-based system configured to communicate with at least one first and/or second radioterminal using frequencies of a first and/or second portion of a satellite frequency band; and

a ground-based system configured to communicate with the at least one second radioterminal using frequencies of the second portion of the satellite frequency band,

wherein the first and second portions of the satellite frequency band do not overlap.

168. A wireless communications system according to claim 167 wherein the space-based system and/or the ground-based system selectively reuse frequencies of the satellite frequency band on a geographic basis.

169. A wireless communications system according to claim 167 wherein the space-based system is configured to preferentially communicate with a radioterminal using frequencies of the first and/or second portion of the satellite frequency band.

170. A wireless communications system according to claim 167 further comprising a controller that preferentially assigns radioterminal communications of the space-based system and the ground-based system to the first and second portions of the satellite frequency band, respectively, or that preferentially assigns radioterminal communications of the space-based system and the ground-based system to the second portion of the satellite frequency band.

171. A wireless communications system according to claim 170 wherein the controller resides at least in part in the space-based system, a radioterminal and/or the ground-based system.

172. A wireless communications system according to claim 170 wherein the controller preferentially establishes communications between a radioterminal and the ground-based system.

173. A wireless communications system according to claim 170 wherein the controller preferentially establishes communications between a radioterminal and the space-based system.

174. A wireless communications system according to claim 170 wherein the controller is responsive to an input of a user of a radioterminal, an input of an operator of the space-based and/or ground-based system, a location of the

radioterminal, a signal received by the radioterminal and/or a signal received by the space-based and/or ground-based system.

175. A wireless communications system according to claim 167 wherein the space-based system is configured to preferentially communicate with a radioterminal using frequencies of the second portion of the satellite frequency band.

176. A ground-based system for providing radioterminal communications in conjunction with a space-based system that is configured to conduct traffic channel communications with radioterminals in a first service region using a set of satellite frequencies, the ground-based system configured to communicate with radioterminals in a second service region adjacent and/or overlapping the first service region and to limit use of the set of satellite frequencies for radioterminal traffic channel communications to a subset of the set of satellite frequencies.

177. A ground-based system according to claim 176, wherein the set of satellite frequencies comprises frequencies in a band of satellite frequencies, and wherein the subset of the set of satellite frequencies comprises a sub-band of the band of satellite frequencies.

178. A ground-based system according to claim 176, further configured to conduct traffic channel, control channel and/or signaling communications with radioterminals using frequencies outside of the set of satellite frequencies.

179. A ground-based system according to claim 176, configured to selectively reuse frequencies of the set of satellite frequencies on a geographic basis.

180. A space-based system configured to provide radioterminal traffic channel communications in a first service region using a set of satellite frequencies in conjunction with a ground-based system configured to communicate with radioterminals in a second service region adjacent and/or overlapping the first service region, wherein the ground-based system is limited to use of a subset of the set of satellite frequencies for radioterminal traffic channel communications.

181. A space-based system according to claim 180, wherein the set of satellite frequencies comprises frequencies in a band of satellite frequencies, and wherein the subset of the set of satellite frequencies comprises a sub-band of the band of satellite frequencies.

182. A spaced-based system according to claim 180, wherein the space-based system selectively reuses frequencies of the set of satellite frequencies on a geographic basis.

183. A space-based system according to claim 180, configured to preferentially conduct traffic channel, control channel and/or signaling communications with radioterminals using the set of satellite frequencies used by the ground-based system.

184. A space-based system according to claim 180, wherein the set of satellite frequencies comprises a first subset, and further comprising a controller configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to a second subset of the set satellite frequencies that is not used by the ground-based system.

185. A space-based system according to claim 184, wherein the controller is configured to preferentially assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to the second subset of the set of satellite frequencies.

186. A space-based system according to claim 184, wherein the controller is configured to transition traffic channel, control channel and/or signaling communications of a radioterminal with the space-based system between the first and second subsets of the set of satellite frequencies responsive to a measure of interference.

187. A spaced-based system according to claim 184, wherein the controller is configured to limit traffic channel, control channel and/or signaling communications of a single-mode radioterminal with the space-based system to the second subset of the set of satellite frequencies when the single-mode radioterminal is positioned in a cell of the ground-based system.

188. A space-based system according to claim 184, wherein the controller is configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system and/or the ground-based system responsive to an input to the ground-based system and/or the space-based system, an input to a radioterminal, and/or a location of the radioterminal.

189. A space-based system configured to communicate with at least one first and/or second radioterminal using frequencies of a first and/or second portion of a satellite frequency band in conjunction with a ground-based system that communicates with the at least one second radioterminal using frequencies of the second portion of the satellite frequency band, wherein the first and second portions of the satellite frequency band do not overlap.

190. A space-based system according to claim 189, configured to selectively reuse frequencies of the satellite frequency band on a geographic basis.

191. A space-based system according to claim 189, further comprising a controller that preferentially assigns radioterminal communications of the space-based system to the first and/or second portion of the satellite frequency band.

192. A space-based system according to claim 191 wherein the controller is responsive to an input of a user of a radioterminal, an input of an operator of the space-based and/or ground-based system, a location of the radioterminal, a signal received by the radioterminal and/or a signal received by the space-based and/or ground-based system.

193. A ground-based system for communicating with radioterminals in conjunction with a space-based system that is configured to communicate with at least one first and/or at least one second radioterminal using frequencies of a first and/or second portion of a satellite frequency band, the ground-based system configured to communicate with the at least one second radioterminal using frequencies of the second portion of the satellite frequency band, wherein the first and second portions of the satellite frequency band do not overlap.

194. A ground-based system according to claim 193 wherein the ground-based system selectively reuses frequencies of the satellite frequency band on a geographic basis.

195. A ground-based system according to claim 193, further comprising a controller that preferentially establishes communications between a radioterminal and the ground-based system.

196. A ground-based system according to claim 195 wherein the controller is responsive to an input of a user of a radioterminal, an input of an operator of the space-based

and/or ground-based system, a location of the radioterminal, a signal received by the radioterminal and/or a signal received by the space-based and/or ground-based system.

197. A wireless communications method comprising:

conducting traffic channel communications between a space-based system and radioterminals in a first service region using a set of satellite frequencies; and

conducting traffic channel communications between a ground-based system and radioterminals in a second service region adjacent and/or overlapping the first service region, including limiting traffic channel communications between the ground-based system and radioterminals in the second service region to a subset of the set of satellite frequencies.

198. A method according to claim 197, wherein the set of satellite frequencies comprises frequencies in a band of satellite frequencies, and wherein the subset of the set of satellite frequencies comprises a sub-band of the band of satellite frequencies.

199. A method according to claim 197, further comprising conducting traffic channel, control channel and/or signaling communications between the ground-based system and radioterminals using frequencies outside of the set of satellite frequencies.

200. A method according to claim 197, further comprising selectively reusing frequencies of the set of satellite frequencies on a geographic basis in the space-based system and/or the ground-based system.

201. A method according to claim 197, further comprising preferentially conducting traffic channel, control channel and/or signaling communications between the space-based system and radioterminals using the subset of satellite frequencies used by the ground-based system.

202. A method according to claim 197, wherein the set of satellite frequencies comprises a first subset, and further comprising selectively assigning radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to a second subset of the set satellite frequencies that is not used by the ground-based system.

203. A method according to claim 202, wherein selectively assigning radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to a second subset of the set satellite frequencies that is not used by the ground-based system comprises preferentially assigning radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to the second subset of the set of satellite frequencies.

204. A method according to claim 202, further comprising transitioning traffic channel, control channel and/or signaling communications of a radioterminal with the space-based system between the first and second subsets of the set of satellite frequencies responsive to a measure of interference.

205. A method according to claim 202, further comprising limiting traffic channel, control channel and/or signaling communications of a single-mode radioterminal to the second subset of the set of satellite frequencies when the single-mode radioterminal is positioned in a cell of the ground-based system.

206. A method according to claim 202, further comprising preferentially assigning a radioterminal to the ground-based system or to the space-based system.

207. A method according to claim 202, wherein selectively assigning radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to a second subset of the set of satellite frequencies that is not used by the ground-based system comprises selectively assigning radioterminal traffic channel, control channel and/or signaling communications of the space-based system and/or the ground-based system responsive to an input to the ground-based system and/or the space-based system, an input to a radioterminal, and/or a location of a radioterminal.

208. A wireless communications method comprising:

communicating between a space-based system and at least one first and/or at least one second radioterminal using frequencies of a first and/or second portion of a satellite frequency band; and

communicating between a ground-based system and the at least one second radioterminal using frequencies of the second portion of the satellite frequency band,

wherein the first and second portions of the satellite frequency band do not overlap.

209. A method according to claim 208, further comprising selectively reusing frequencies of the satellite frequency band on a geographic basis in the space-based system and/or the ground-based system.

210. A method according to claim 208, further comprising preferentially communicating between the space-based system and a radioterminal using frequencies of the first and/or second portion of the satellite frequency band.

211. A method according to claim 208, further comprising preferentially assigning radioterminal communications of the space-based system and the ground-based system to the first and second portions of the satellite frequency band, respectively, or preferentially assigning radioterminal communications of the space-based system and the ground-based system to the second portion of the satellite frequency band.

212. A method according to claim 208, further comprising preferentially communicating between the space-based system and a radioterminal using frequencies of the second portion of the satellite frequency band.

213. A method according to claim 208, further comprising preferentially establishing communications between a radioterminal and the ground-based system.

214. A method according to claim 208, further comprising preferentially establishing communications between a radioterminal and the space-based system.

215. A method according to claim 208, further comprising assigning radioterminal communications of the space-based system and/or the ground-based system responsive to an input of a user of a radioterminal, an input of an operator of the space-based and/or ground-based system, a location of the radioterminal, a signal received by the radioterminal and/or a signal received by the space-based and/or ground-based system.

216. A wireless communications system comprising:

a space-based system configured to conduct control channel and/or signaling communications with radioterminals in a first service region using a set of satellite frequencies; and

a ground-based system configured to communicate with radioterminals in a second service region adjacent and/or overlapping the first service region and to limit use of the set of satellite frequencies for radioterminal control channel and/or signaling communications to a subset of the set of satellite frequencies.

217. A wireless communications system according to claim 216, wherein the set of satellite frequencies comprises frequencies in a band of satellite frequencies, and wherein the subset of the set of satellite frequencies comprises a sub-band of the band of satellite frequencies.

218. A wireless communications system according to claim 216, wherein the ground-based system is further configured to conduct control channel and/or signaling communications with radioterminals using frequencies outside of the set of satellite frequencies.

219. A wireless communications system according to claim 216, wherein the space-based system and/or the ground-based system selectively reuse frequencies of the set of satellite frequencies on a geographic basis.

220. A wireless communications system according to claim 216, wherein the space-based system is configured to preferentially conduct traffic channel, control channel and/or signaling communications with radioterminals using the set of satellite frequencies used by the ground-based system.

221. A wireless communications system according to claim 216, wherein the set of satellite frequencies comprises a first subset, and further comprising a controller configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to a second subset of the set satellite frequencies that is not used by the ground-based system.

222. A wireless communications system according to claim 221, wherein the controller is configured to preferentially assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to the second subset of the set of satellite frequencies.

223. A wireless communications system according to claim 221, wherein the controller is configured to transition traffic channel, control channel and/or signaling communications of a radioterminal with the space-based system between the first and second subsets of the set of satellite frequencies responsive to a measure of interference.

224. A wireless communications system according to claim 221, wherein the controller is configured to limit traffic channel, control channel and/or signaling communications of a single-mode radioterminal to the second subset of the set of satellite frequencies when the single-mode radioterminal is positioned in a cell of the ground-based system.

225. A wireless communications system according to claim 221, wherein the controller resides at the ground-based system, at the space-based system and/or at a radioterminal.

226. A wireless communications system according to claim 221, wherein the controller is configured to preferentially assign a radioterminal to the ground-based system or to the space-based system.

227. A wireless communications system according to claim 221, wherein the controller is configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications to the space-based system or the ground-based system responsive to an input to the ground-based system, space-based system, radioterminal and/or to a location of a radioterminal.

228. A ground-based system for providing radioterminal communications in conjunction with a space-based system that is configured to conduct control channel and/or signaling communications with radioterminals in a first service region using a set of satellite frequencies, the ground-based system configured to communicate with radioterminals in a second service region adjacent and/or overlapping the first service region and to limit use of the set of satellite frequencies for radioterminal control channel and/or signaling communications to a subset of the set of satellite frequencies.

229. A ground-based system according to claim 228, wherein the set of satellite frequencies comprises frequencies in a band of satellite frequencies, and wherein the subset of the set of satellite frequencies comprises a sub-band of the band of satellite frequencies.

230. A ground-based system according to claim 228, further configured to conduct traffic channel, control channel and/or signaling communications with radioterminals using frequencies outside of the set of satellite frequencies.

231. A ground-based system according to claim 228, configured to selectively reuse frequencies of the set of satellite frequencies on a geographic basis.

232. A space-based system configured to provide radioterminal control channel and/or signaling communications in a first service region using a set of satellite frequencies in conjunction with a ground-based system configured to communicate with radioterminals in a second service region adjacent and/or overlapping the first service region, wherein the ground-based system is limited to use of a subset of the set of satellite frequencies for radioterminal control channel and/or signaling communications.

233. A space-based system according to claim 232, wherein the set of satellite frequencies comprises frequencies in a band of satellite frequencies, and wherein the subset of the set of satellite frequencies comprises a sub-band of the band of satellite frequencies.

234. A spaced-based system according to claim 232, wherein the space-based system selectively reuses frequencies of the set of satellite frequencies on a geographic basis.

235. A space-based system according to claim 232, configured to preferentially conduct traffic channel, control channel and/or signaling communications with radioterminals using the set of satellite frequencies used by the ground-based system.

236. A space-based system according to claim 232, wherein the set of satellite frequencies comprises a first subset, and further comprising a controller configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to a second subset of the set satellite frequencies that is not used by the ground-based system.

237. A space-based system according to claim 236, wherein the controller is configured to preferentially assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system to the first subset of the set of satellite frequencies and/or to the second subset of the set of satellite frequencies.

238. A space-based system according to claim 236, wherein the controller is configured to transition traffic channel, control channel and/or signaling communications of a radioterminal with the space-based system between the first and second subsets of the set of satellite frequencies responsive to a measure of interference.

239. A spaced-based system according to claim 236, wherein the controller is configured to limit traffic channel, control channel and/or signaling communications of a single-mode radioterminal with the space-based system to the second subset of the set of satellite frequencies when the single-mode radioterminal is positioned in a cell of the ground-based system.

240. A space-based system according to claim 236, wherein the controller is configured to selectively assign radioterminal traffic channel, control channel and/or signaling communications of the space-based system and/or the ground-based system responsive to an input to the ground-based system and/or the space-based system, an input to a radioterminal, and/or a location of the radioterminal.

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