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Wang

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(54) **SYSTEM AND METHOD FOR CONTINUOUS BROADCAST SERVICE FROM NON-GEOSTATIONARY ORBITS**

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This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/012,621**

(22) Filed: **Jan. 24, 2011**

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(63) Continuation of application No. 12/069,346, filed on Feb. 8, 2008, now Pat. No. 7,877,089, which is a continuation of application No. 09/702,218, filed on Oct. 30, 2000, now Pat. No. 7,369,809.

(51) **Int. Cl.**
H04B 7/185 (2006.01)

(52) **U.S. Cl.**
CPC ***H04B 7/18523*** (2013.01); ***H04B 7/18521*** (2013.01)

(58) **Field of Classification Search**
CPC H04B 7/18523; H04B 7/18578
USPC 455/12.1, 427, 3.02, 13.1, 13.2, 436, 455/437, 430, 429, 428, 440, 13.3, 3.01
See application file for complete search history.

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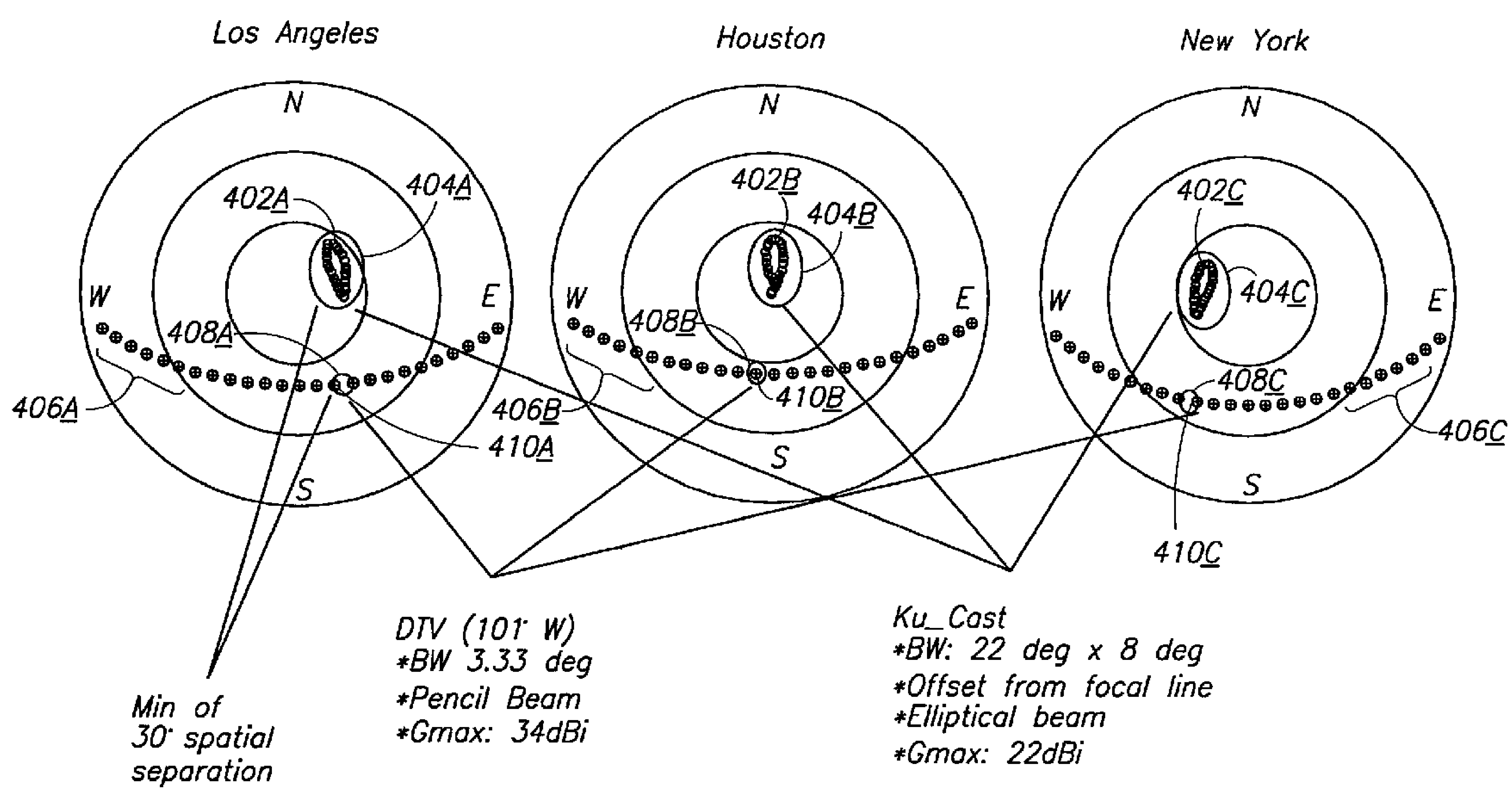
Primary Examiner — John J Lee

(57) **ABSTRACT**

A method, apparatus for providing at least near continuous broadcast services to one or more terrestrial receiver stations is disclosed. The system comprises a plurality of satellites, each satellite in an inclined, elliptical geosynchronous orbit, each satellite providing a portion of the at least near continuous broadcast service to the terrestrial receiver. In one embodiment, the system also comprises a receiver station having a legacy antenna modified so as to include a sensitivity pattern substantially matched to the track of the apparent position of the satellites actively broadcasting information to the receiver stations. The present invention is also embodied in a method for receiving at least near continuous broadcast service from at least one of a plurality of satellites at a time, each satellite in an inclined, elliptical, geosynchronous orbit.

12 Claims, 9 Drawing Sheets



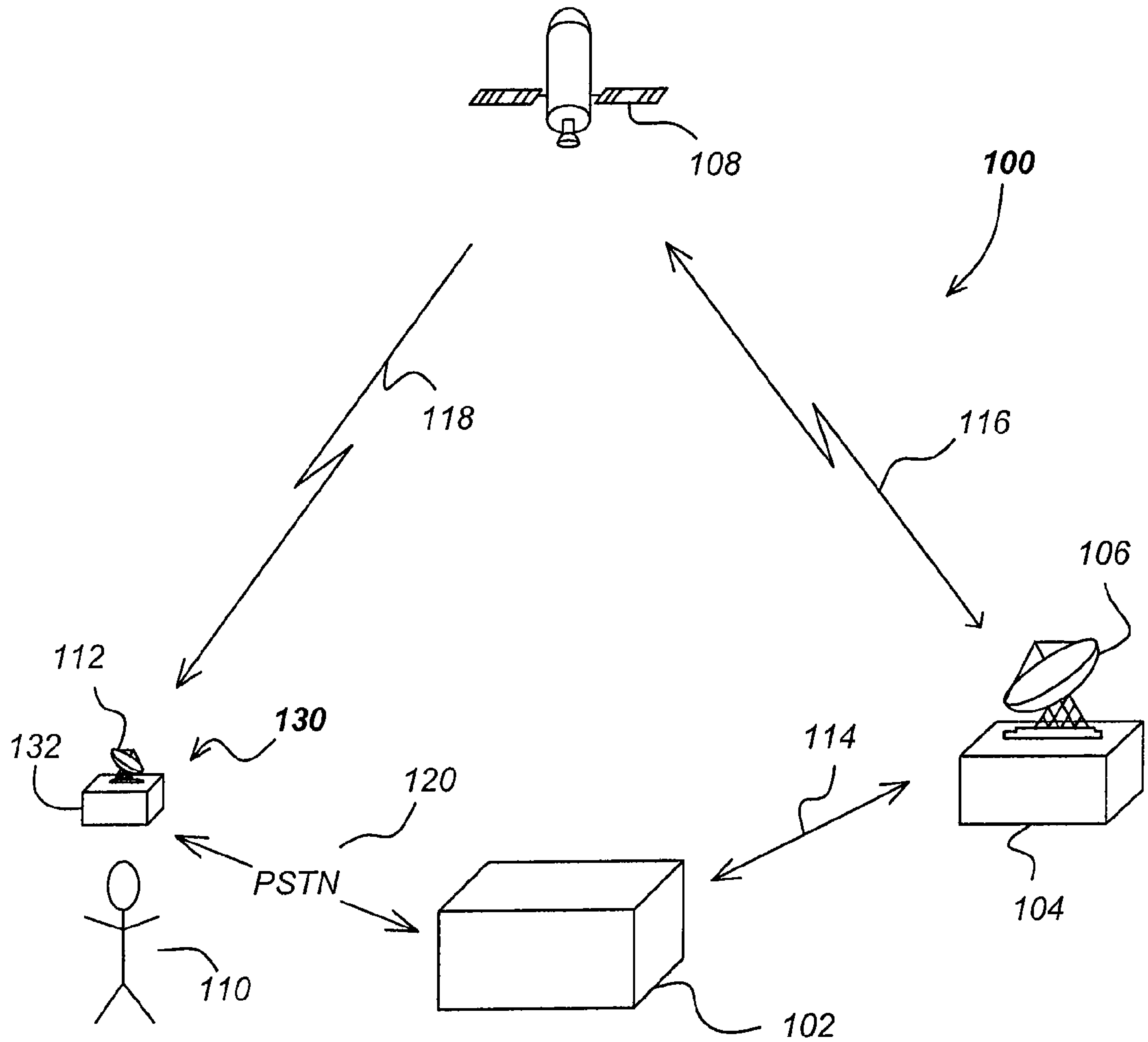


FIG. 1

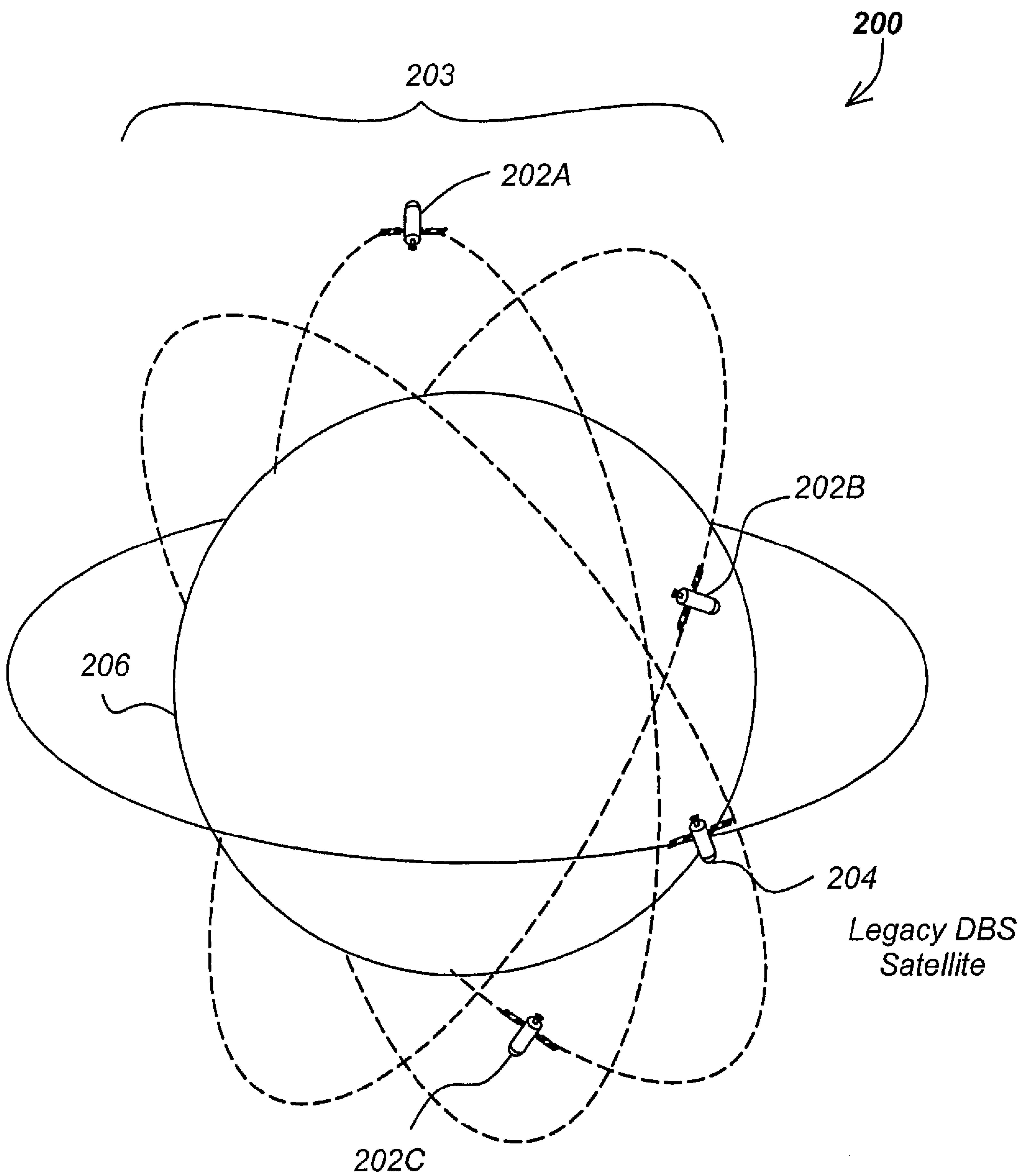


FIG. 2

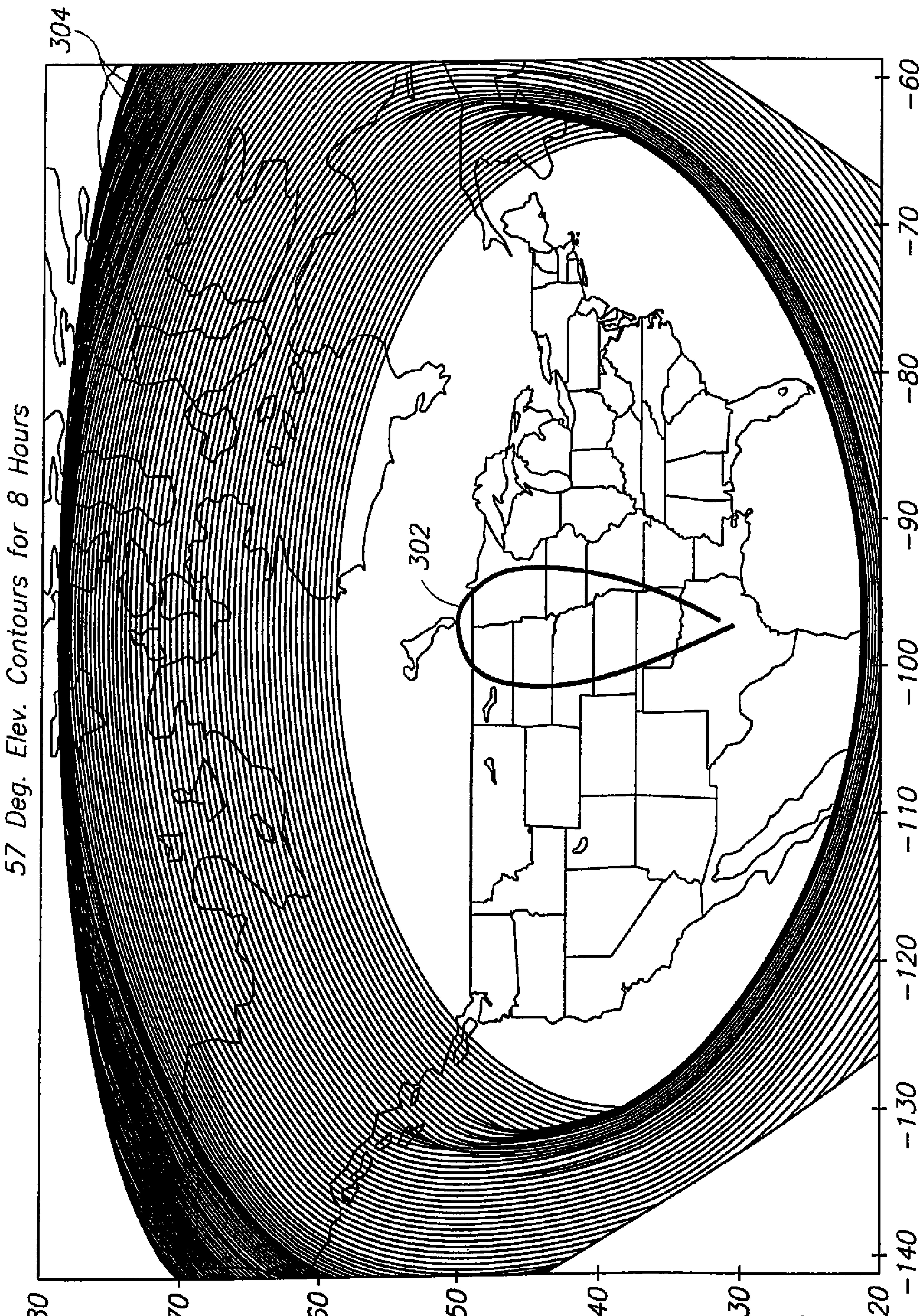

57 Deg. Elev. Contours for 8 Hours
304
302
Longtitude
Latitude
−140 −130 −120 −110 −100 −90 −80 −70 −60
20 30 40 50 60 70 80

FIG. 3

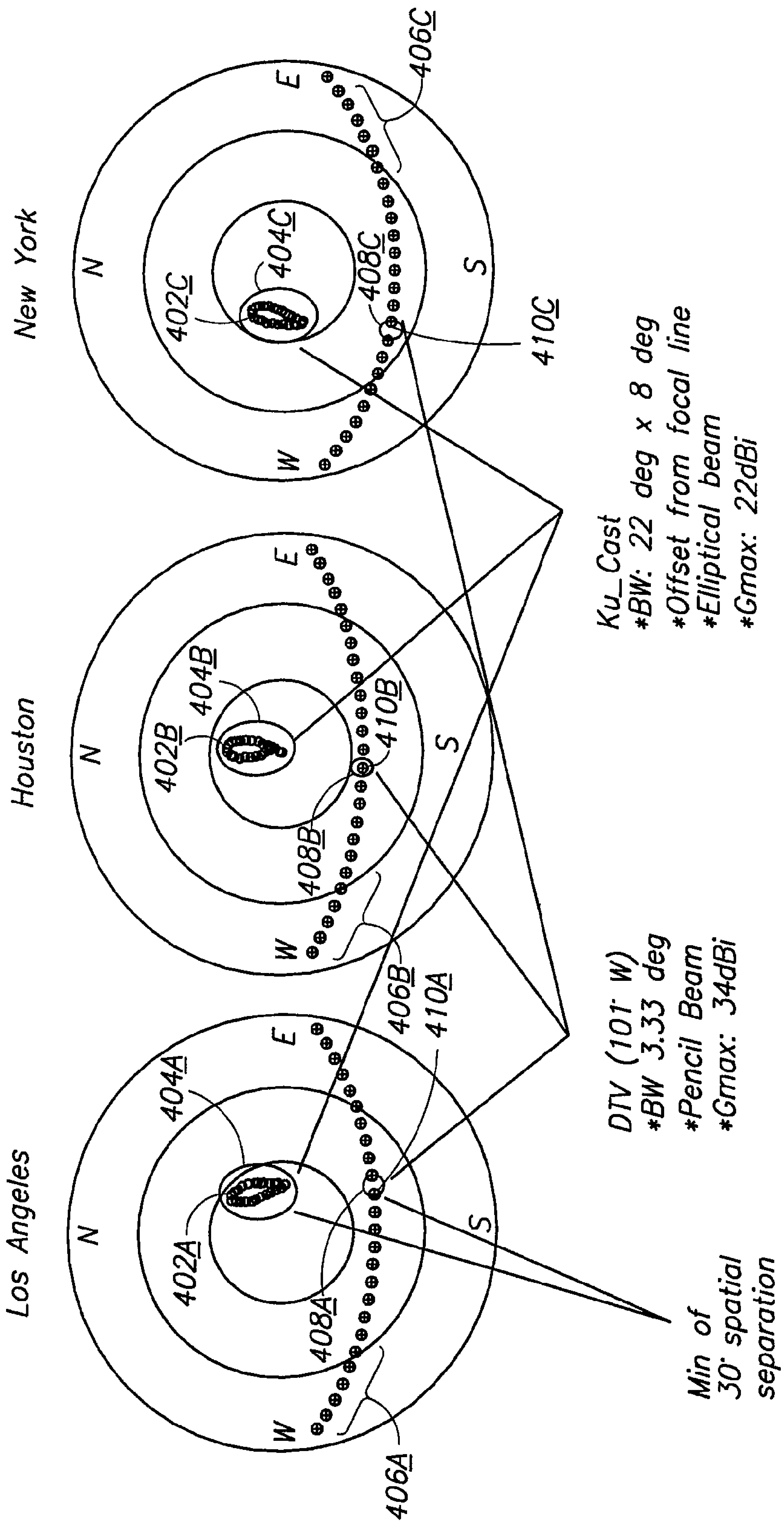

Los Angeles
Houston
New York
N
S
E
W
402A
404A
406A
408A
410A
402B
404B
406B
408B
410B
402C
404C
406C
408C
410C
Ku_Cast
*BW: 22 deg x 8 deg
*Offset from focal line
*Elliptical beam
*Gmax: 22dBi
DTV (101° W)
*BW 3.33 deg
*Pencil Beam
*Gmax: 34dBi
Min of
30° spatial
separation

FIG. 4

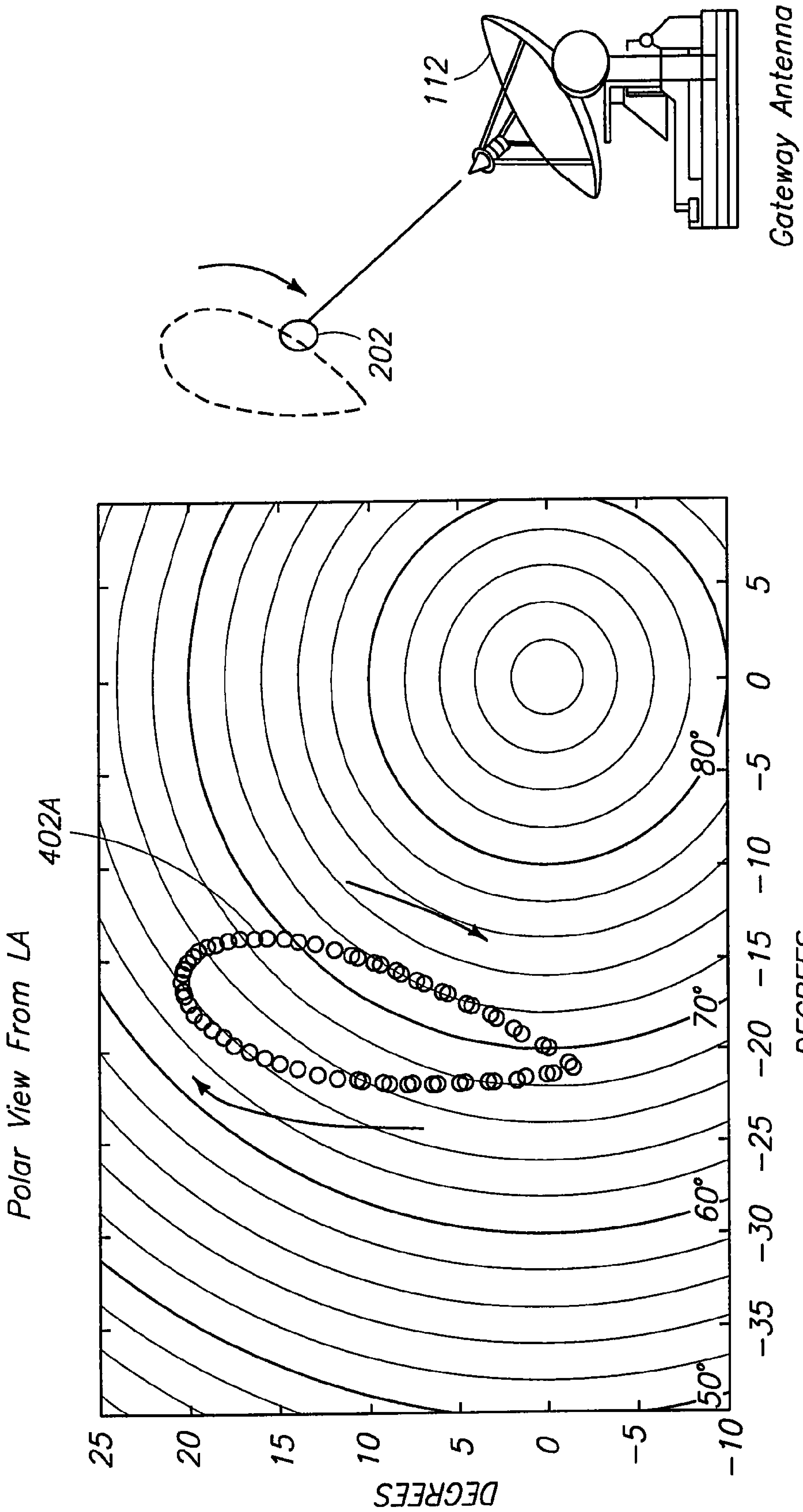

112
Gateway Antenna
202
Polar View From LA
402A
80°
70°
60°
50°
DEGREES
5
0
-5
-10
-15
-20
-25
-30
-35
DEGREES
25
20
15
10
5
0
-5
-10

FIG. 5

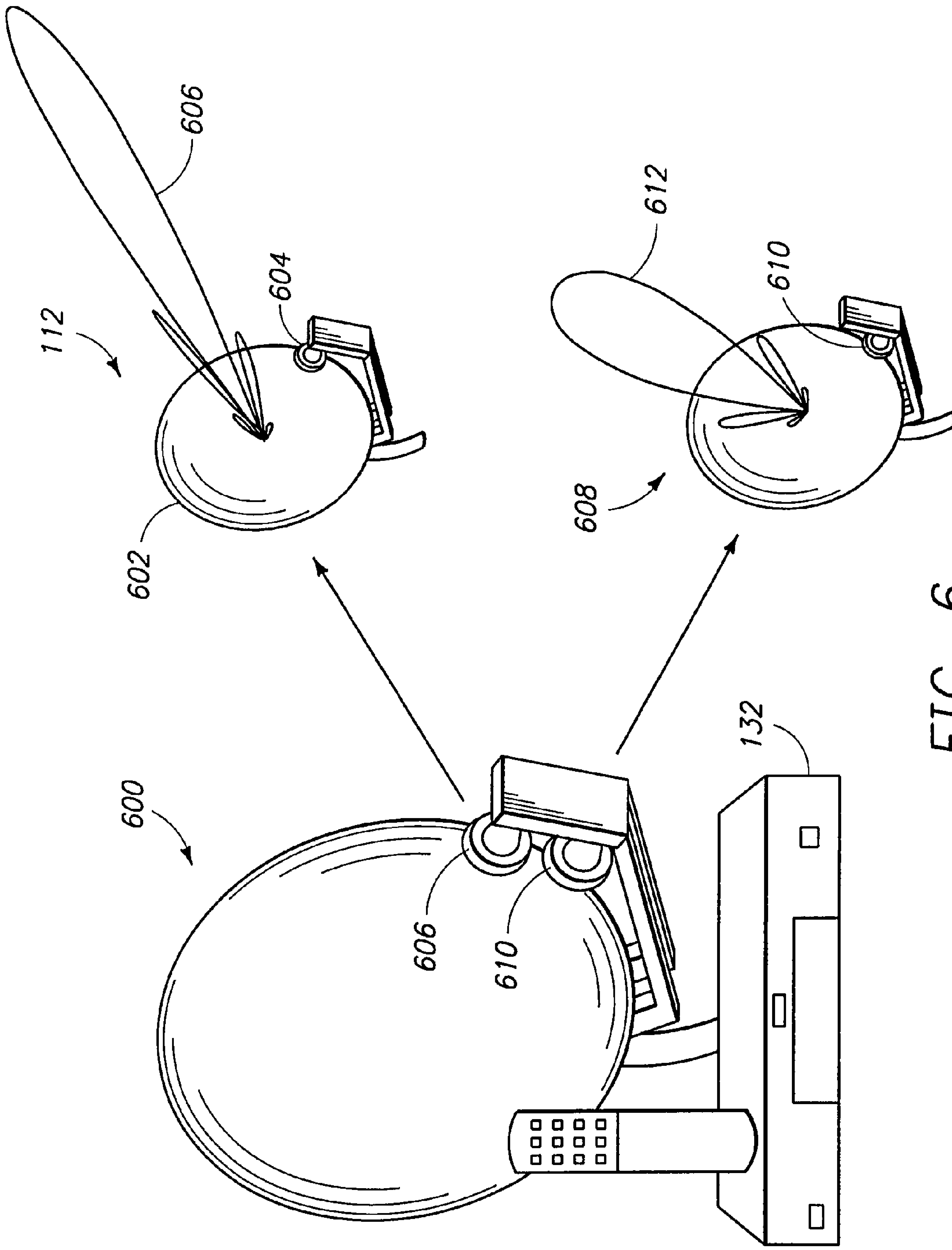


FIG. 6

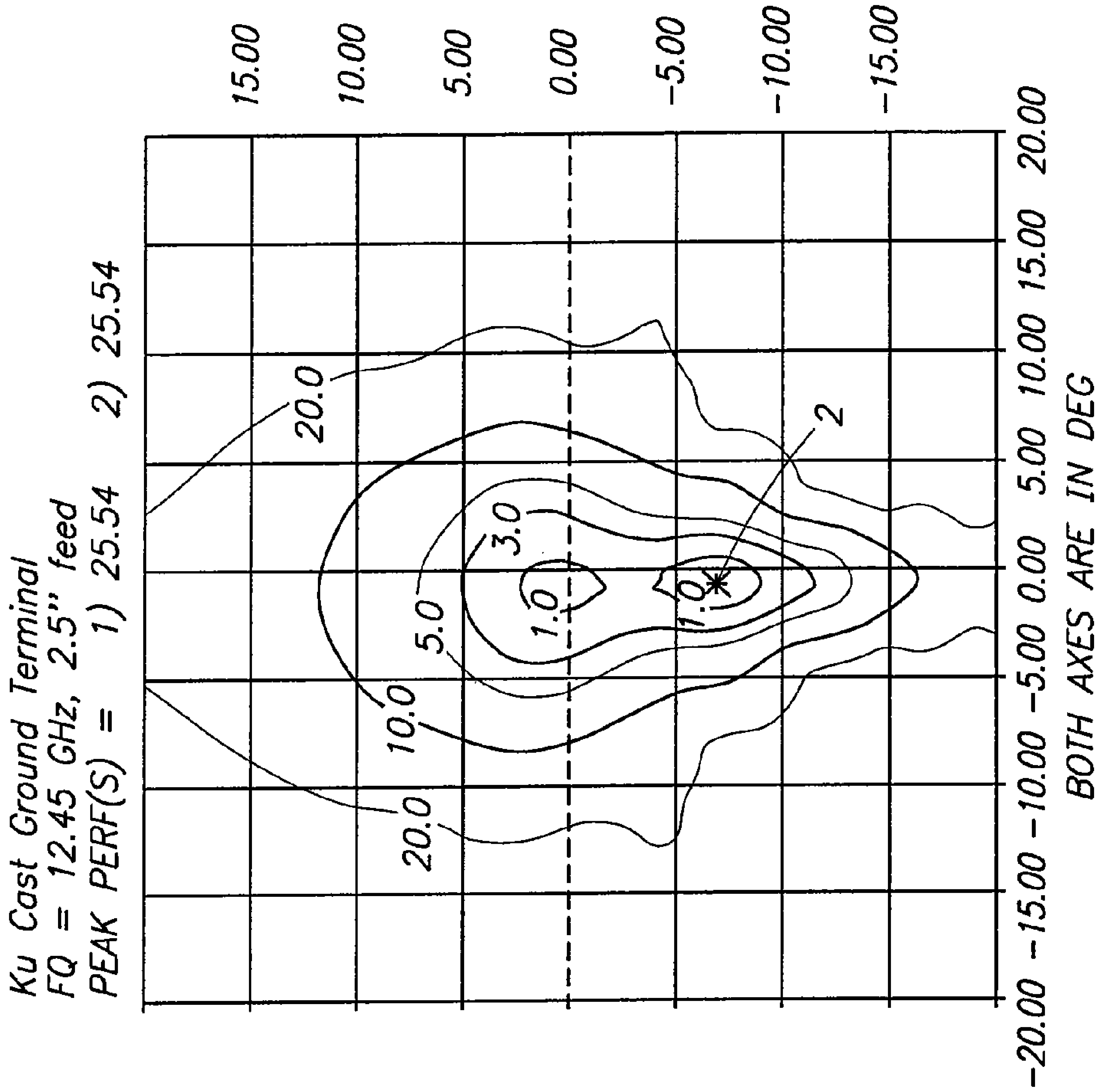

Ku Cast Ground Terminal
FQ = 12.45 GHz, 2.5" feed
PEAK PERF(S) = 1) 25.54 2) 25.54
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00 -15.00 -10.00 -5.00 0.00 5.00 10.00 15.00 20.00
20.0
10.0
5.0
3.0
1.0
1.0
2
20.0
BOTH AXES ARE IN DEG

FIG. 7B

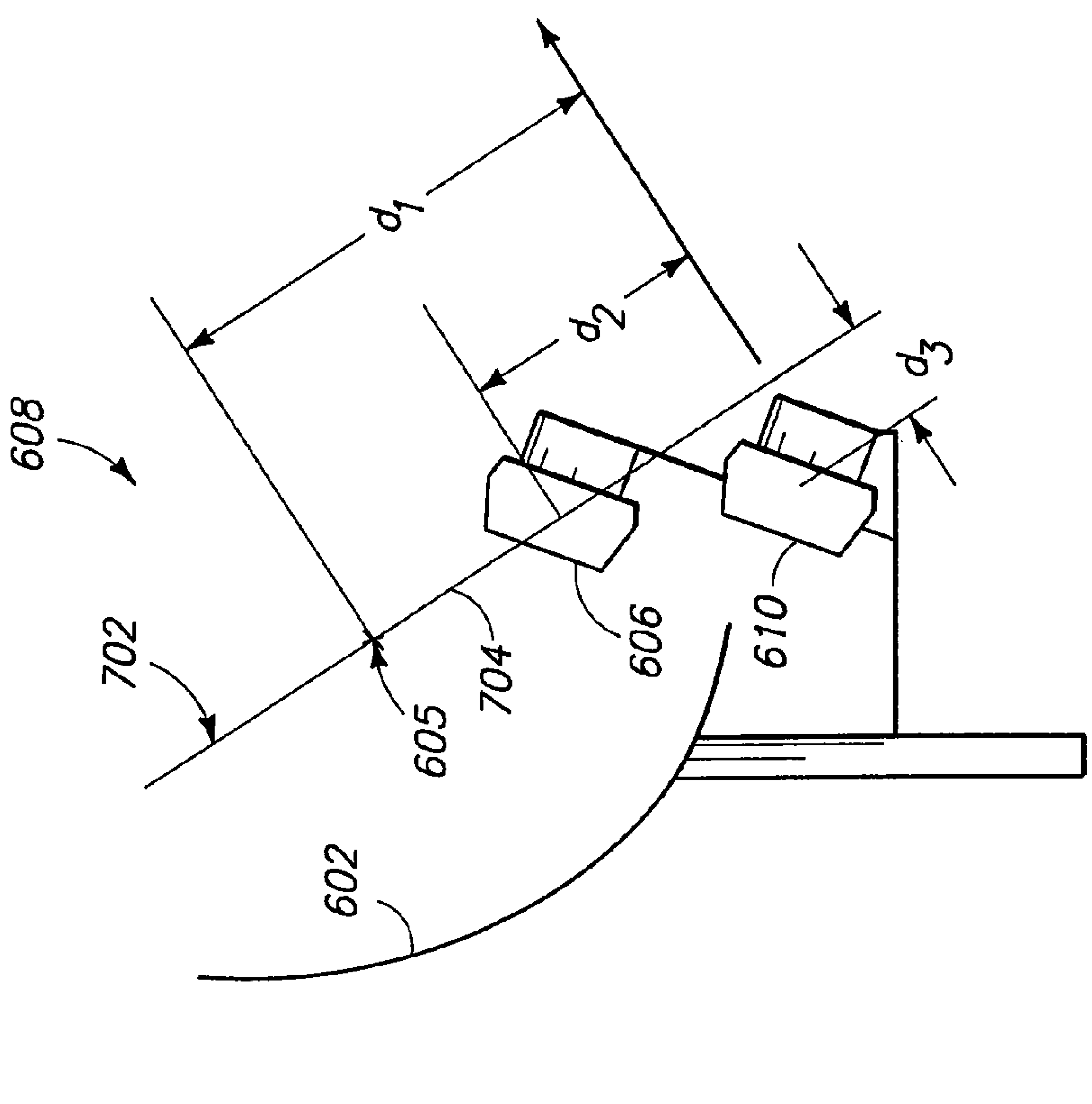

608
d1
d2
d3
702
605
704
606
610
602

FIG. 7A

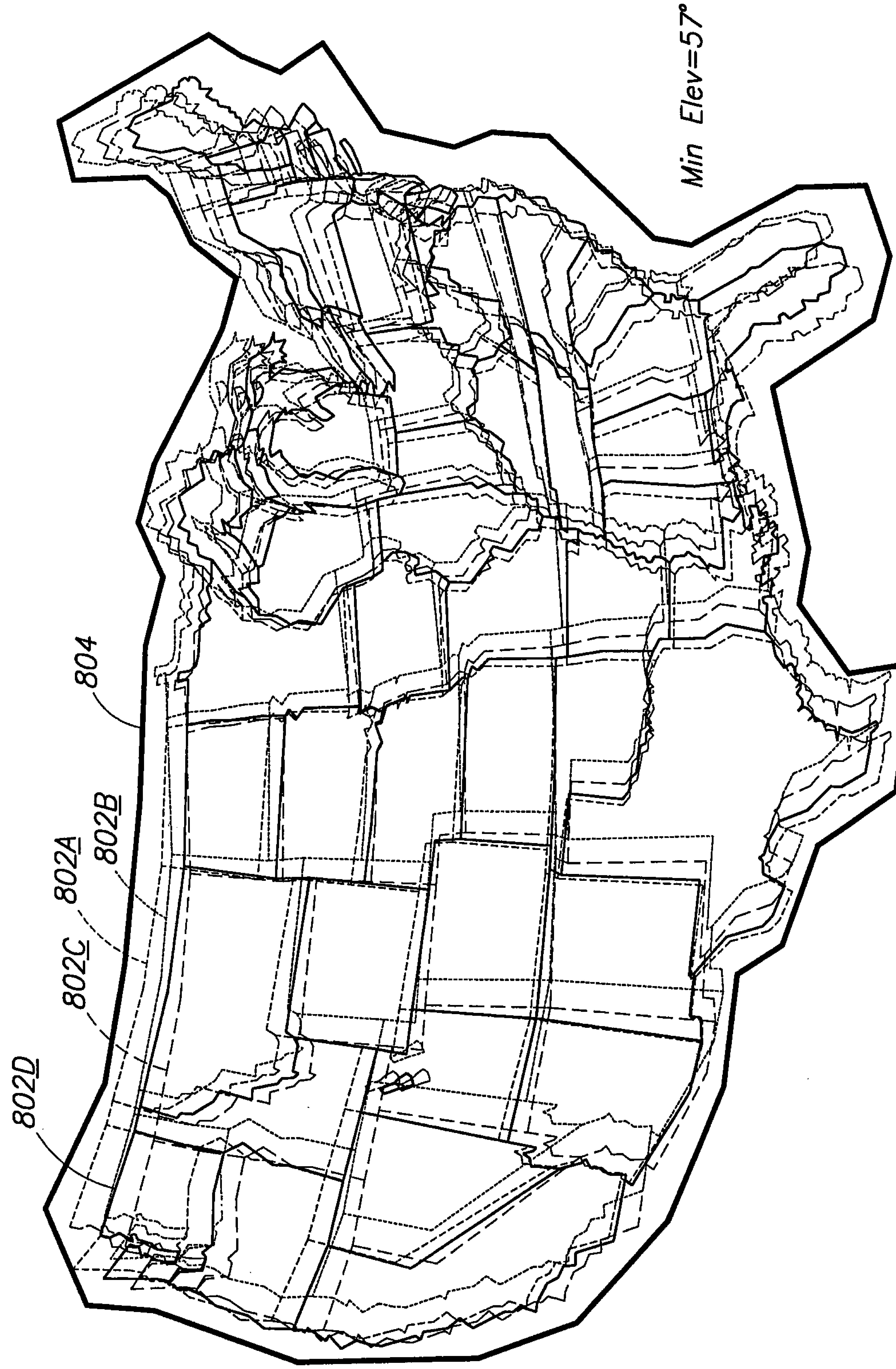


FIG. 8

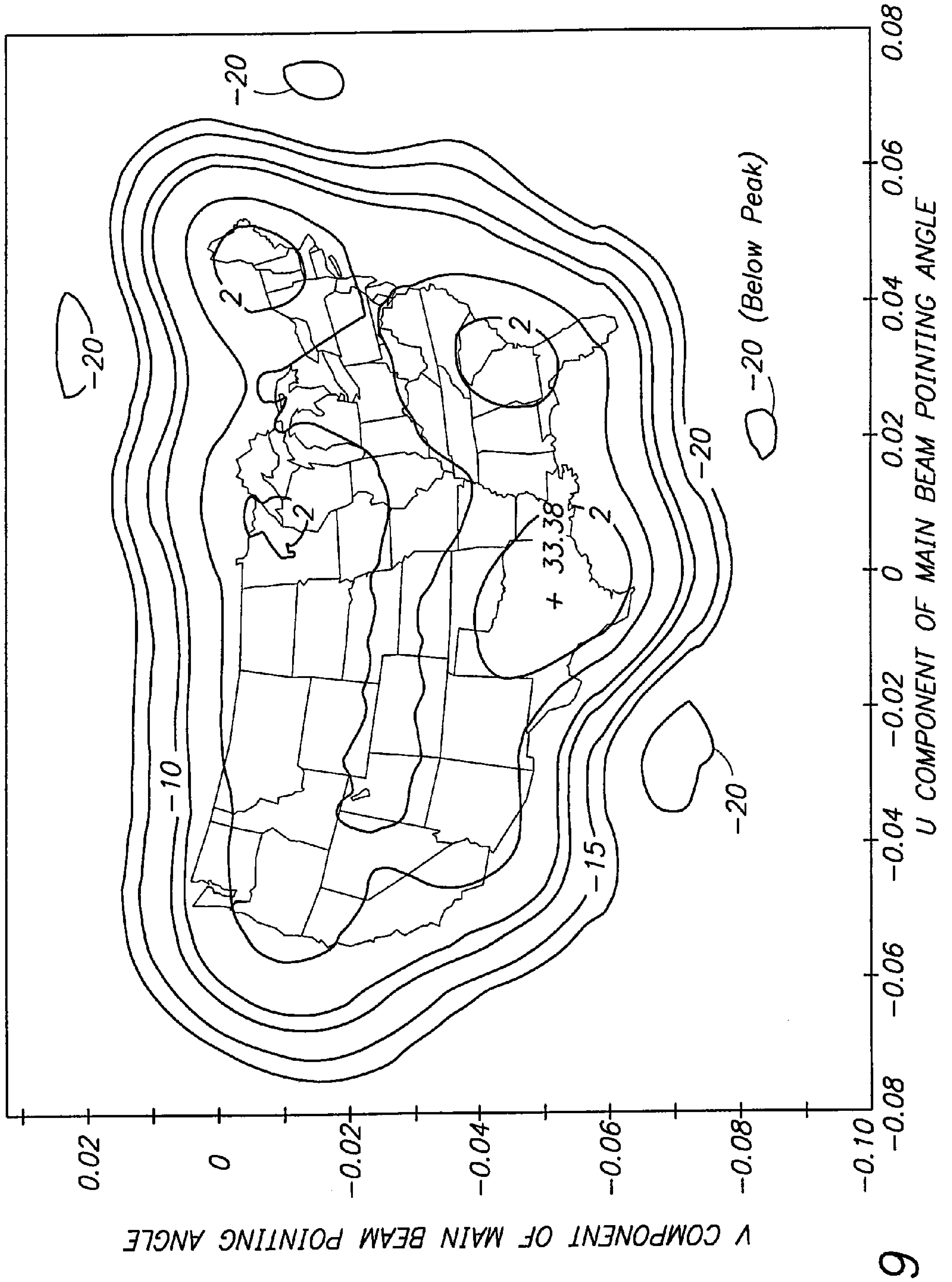

V COMPONENT OF MAIN BEAM POINTING ANGLE
U COMPONENT OF MAIN BEAM POINTING ANGLE
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.10
−0.08
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
−20 (Below Peak)
−20
−20
−20
−20
−10
−15
2
2
2
2
+ 33.38

FIG. 9

SYSTEM AND METHOD FOR CONTINUOUS BROADCAST SERVICE FROM NON-GEOSTATIONARY ORBITS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 12/069,346, entitled "LOW COST DESIGN TO DOUBLE NUMBER OF CHANNELS FOR DIRECT BROADCAST SATELLITE SERVICES," filed Feb. 8, 2008, by Arthur W. Wang, issued as U.S. Pat. No. 7,877,089, which is a continuation of U.S. patent application Ser. No. 09/702,218, entitled "LOW COST DESIGN TO DOUBLE NUMBER OF CHANNELS FOR DIRECT BROADCAST SATELLITE SERVICES", filed Oct. 20, 2000, by Arthur W. Wang, issued as U.S. Pat. No. 7,369,809, both of which applications are incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to systems and methods for providing satellite broadcast services, and in particular to a low cost system for increasing channel capacity in a satellite broadcast network.

2. Description of the Related Art

The past decade has seen the development of Direct Broadcast Satellite (DBS) services for providing video, audio, data, and other program material to subscribers. The electromagnetic spectrum allocated for DBS in the United States has been limited to 500 MHz. This constraint limits the maximum number of channels that existing DBS service can offer from one geostationary orbit (GSO) slot, since each video channel typically occupies about 2-6 MHz of bandwidth, depending on the data rates. This shortage of spectrum/channels becomes worse with the emerging demand for High Definition TV (HDTV) which requires much higher bandwidth per channel than traditional video channels. The shortage of spectrum and channels is made even more apparent with the recent approval for DBS operators to provide local programming. There are an estimated 200 or more local TV station spreading over the domestic markets, and DBS operators will not be able to cover all cities through their existing fleet of satellites, if the demand on extending channel numbers continue to grow.

One possible solution is to use another GSO orbital slot for DBS services. However, using another GSO slot is not a permanent solution, because the 9 degree orbit slot spacing requirement for satellites broadcasting at DBS frequencies allow only few slots for given service regions (e.g. the continental United States, or CONUS) and these orbital slots are almost all taken.

Another possible solution is to use different or additional frequency bands to transmit the additional information. Unfortunately, this solution requires that each subscriber's receiver include additional circuitry to detect and demodulate the information on the additional frequency bands. Further, this solution faces the formidable task of overcoming the regulatory process to acquire the required spectrum.

What is needed is a system and method for providing high bandwidth DBS services that augment current DBS systems in a non-interfering way. The present invention satisfies that need.

SUMMARY OF THE INVENTION

To address the requirements described above, the present invention discloses a method and apparatus for providing at least near continuous broadcast services to one or more terrestrial receiver stations. The system comprises a plurality of satellites, each satellite in an inclined, elliptical geosynchronous orbit, each satellite providing a portion of the at least near continuous broadcast service to the terrestrial receiver. In one embodiment, the system also comprises a receiver station having a legacy antenna modified so as to include a sensitivity pattern substantially matched to the track of the apparent position of the satellites actively broadcasting information to the receiver stations. The present invention is also embodied in a method for receiving at least near continuous broadcast service from at least one of a plurality of satellites at a time, each satellite in an inclined, elliptical, geosynchronous orbit.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

FIG. **1** is a diagram illustrating an overview of a video distribution system;

FIG. **2** is a diagram showing one embodiment of a satellite constellation of an enhanced video distribution system using the principles of the present invention;

FIG. **3** is a diagram illustrating the ground track of the orbit of a satellite in the augmenting satellite constellation;

FIG. **4** is a diagram presenting a polar fish-eye view of the apparent position of the augmented satellite constellation over an 8-hour period;

FIG. **5** is a diagram presenting a polar view of the satellite track from a location in CONUS;

FIG. **6** is a diagram showing an augmented receiver station design;

FIG. **7**A is a cross sectional diagram of an augmented receiver station antenna;

FIG. **7**B is a plot of a teardrop-shaped sensitivity pattern of the antenna depicted in FIG. **7**A;

FIG. **8** is a plot of CONUS contours seen from an active satellite at boundary points in the satellite's apparent position within the active period; and

FIG. **9** illustrates a sample satellite transmission beam shaped to follow the outer contour of CONUS.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the following description, reference is made to the accompanying drawings which form a part hereof, and which is shown, by way of illustration, several embodiments of the present invention. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

Video Distribution System

FIG. **1** is a diagram illustrating an overview of a video distribution system **100**. The video distribution system **100** comprises a control center **102** in communication with an uplink center **104** via a ground or other link **114** and an integrated receiver/decoder (IRD) **132** at terrestrial receiver station **130** via a public switched telephone network (PSTN) or other link **120**. The control center **102** provides program material to the uplink center **104**, coordinates with the receiver station **130** to offer subscribers **110** pay-per-view (PPV) program services, including billing and associated decryption of video programs.

The uplink center **104** receives program material and program control information from the control center **102**, and using an uplink antenna **106**, transmits the program material and program control information to a geostationary satellite **108**. The satellite **108** receives and processes this information, and transmits the video programs and control information to the IRD **132** and a communicatively coupled receiver station antenna **112** at the receiver station **130** via downlink **118**. The IRD **132** receives this information using a communicatively coupled subscriber antenna **112**.

The video distribution system **100** can comprise a plurality of satellites **108** in order to provide wider terrestrial coverage, to provide additional channels, or to provide additional bandwidth per channel. In one embodiment of the invention, each satellite comprises 16 transponders to receive and transmit program material and other control data from the uplink center **104** and provide it to the subscribers **110**. However, using data compression and multiplexing techniques the channel capabilities are far greater. For example, two satellites **108** working together can receive and broadcast over 150 conventional (non-HDTV) audio and video channels via **32** transponders.

While the invention disclosed herein will be described with reference to a satellite based video distribution system **100**, the present invention may also be practiced with terrestrial-based transmission of program information, whether by traditional broadcasting means, cable, or other means. Further, the different functions collectively allocated among the control center **102** and uplink center **104** as described above can be reallocated as desired without departing from the intended scope of the present invention.

Although the foregoing has been described with respect to an embodiment in which the program material delivered to the subscriber is video (and audio) program material such as a movie, the foregoing method can be used to deliver program material comprising purely audio information or data as well.

The foregoing video distribution system **100** provides continuous broadcast services using geostationary satellites **108**. Since the apparent position of the satellites in the sky does not move, inexpensive stationary ground antennae can be used to receive the broadcast signal. However, as described above, the number of channels available in such a system is limited by the allocation of broadcast bandwidth and the number of geostationary satellite orbital slots. The present invention provides the additional broadcast bandwidth with a satellite constellation that is compatible with existing DBS broadcast systems.

There are typically three configurations that allow a terrestrial receiver station **130**, whether mobile or stationary, to communicate the satellites **108**. First, the receiver station **130** may point in a fixed direction at a geostationary satellite (e.g. legacy satellite **204**), whose apparent position in the sky remains stationary over time. Second, the receiver station **130** may be equipped with antennae **112** and other equipment that allows tracking a non-geostationary satellite (such as a low earth orbit or mid earth orbit satellite) as the apparent position of the satellite moves in the sky over time. Third, the receiver station **130** may have an omni-direction antenna. Unfortunately, all of these configurations have drawbacks. The drawback of the first configuration is that they are generally usable only with geostationary satellites, and orbital slots for geostationary satellites are a precious commodity. One drawback of the second configuration is that is requires expensive receiver station **130** equipment. One drawback of the second configuration is that it requires expensive receiver station **130** equipment. One drawback of the second configuration is that it is difficult to use for two way communications between the receiver station **130** and the satellite **108**, and the low gains inherent with omnidirectional antennae place greater demands on the receiver and transmitter subsystems of the satellite **108** and IRD **132**.

Enhanced Video Distribution System

FIG. **2** is a diagram showing one embodiment of a satellite constellation of an enhanced video distribution system **200** using the principles of the present invention. The enhanced video distribution system comprises one or more legacy satellites **108** in a geostationary orbit around the Earth **206**, and an augmenting satellite constellation **203** of three or more satellites **202**A-**202**C (hereinafter alternatively referred to as satellite(s) **202**) which are in inclined, substantially elliptical, geo-synchronous orbits with objective service at or near the center of CONUS. Each satellite **202** provides an active period of about 8 hours of broadcast service per day. The constellation **203** is phased so that when an active satellite **202** (which is currently providing the broadcast service) is no longer able to do so, the broadcast service function is handed over to the next satellite **202** entering the region over the service area. Since there is always at least one active satellite **202** available, continuous, 24 hours a day coverage is provided. In one embodiment, the orbital parameters for the augmenting satellite constellation **203** are shown in Table I below:

TABLE I

Longitude	97	degrees West
Period	86164.09	Seconds
Inclination	50	degrees
Eccentricity	0.13	
Altitude at Perigee	30305	Km
Altitude at Apogee	41268	Km
Phase difference between adjacent orbital planes	120	degrees

FIG. **3** is a diagram illustrating the ground track **302** of the orbit of the satellite **202** specified in Table I, centered at the geographical center of CONUS for an 8-hour period when the satellite is providing broadcast services to a subscriber. The outside rings **304** show 57 degree elevation contours at 10 minute intervals within the active period. Note that all of CONUS (all 48 states) are covered within the 57 degree elevation angle. The ground track **302** of the orbit of the satellite **202** is a closed loop in a (reversed) teardrop shape. This eliminates sudden shifts in the apparent position of the active satellite (as the task of transmitting the broadcast signal is shifted from a first satellite (e.g. **202**A) to a second satellite (e.g. **202**B) in the constellation) and thus allows an IRD **132** with a fixed (non tracking) receiver station antenna **112** to receive uninterrupted service from the satellite constellation.

The enhanced video distribution system **200** of the present invention has several advantages over the systems described above. The receiver station **132** maintains relatively high gain and a fixed antenna configuration, yet is still capable of communicating with non-GSO satellites. The augmenting constellation **203** is designed to minimize the apparent motion of the constellation **203** member satellites **202** in the sky so that the sensitivity pattern of a stationary receiver station antenna **112** is sufficient to receive the broadcast signal from at least one of the augmenting constellation **203** satellite **202** members at any given time.

The augmenting satellite constellation **203** of the video distribution system **100** provides not only an optimized coverage for receiver stations **130** within CONUS but also minimizes the footprint of the apparent satellite position over time. This allows the use of receiver station antennae **112** which offer relatively high gain and low beamwidth. Further, the augmenting satellite constellation **203** presents apparent satellite positions that are sufficiently disposed away from the apparent positions of GSO satellites. This allows the video distribution system **100** to operate with existing GSO distribution systems without interference. Finally, as will be discussed later, the teardrop shape of the apparent position of the active satellite **202** over time during the active period substantially coincides with a teardrop sensitivity pattern of the receiver station antennae.

FIG. **4** is a diagram presenting polar fish-eye views of the apparent position of the satellite **202** members of the augmenting satellite constellation **203** over an 8-hour period, for three representative cities within CONUS (Los Angeles, Houston, and New York). As is shown, the shape of the track of the apparent position of the satellite **402**A-**402**C (hereinafter alternatively referred to as satellite tracks **402**) in the sky over time is consistently teardrop shaped. Further, the satellite tracks **402** exhibit a wide spatial separation away from the apparent position of the satellite **202** apparent position of existing GSO satellites. In particular, FIG. **4** shows that the minimum angular separation satellite tracks **402** and a representative DBS satellite in a GEO orbit (101 degrees West) at least thirty degrees. This design achieves a balance between the requirements of high elevation angle and simplicity of antenna pointing.

FIG. **4** also shows the sensitivity pattern (essentially, the beamwidth) for the receiver station antenna **112** for existing DBS services **408**A-**408**C. Since the geostationary satellites of the existing DBS service are effectively motionless in the sky, the beamwidth **408**A-**408**C (hereinafter alternatively referred to as beamwidth **408**) of the receiver station antennae **112** used to receive signals from the legacy satellite(s) **204** is only approximately 3.33 degrees, and the gain of the receiving station antenna is approximately 34 dBi. The satellites **202** of the augmenting satellite constellation **203**, however do not retain a fixed apparent position in the sky, but rather move about. Consequently, the beamwidth **404**A-**404**C (hereinafter referred to as beamwidth **404**) of the receiver station antennae **112** used to receive signals from the satellites **202** in the augmenting constellation **203** is wider. In one embodiment, the beamwidth approximately 22 degrees by 8 degrees, and can elliptically or teardrop shaped. Since the receiver station antennae **112** is used to cover a greater portion of the sky, the gain of the antenna is lower than that which is used to receive signals from the legacy satellites. In one embodiment, the gain is approximately 22 dBi. Hence, the overall gain of the receiver station antennae **112** is nominally about 12 dB less than standard DBS receiver station antennae. This lower gain can be accommodated by using multiple spot beams from the satellites **204**, by increasing the transmitter power, by increasing the size of the reflector of the antenna at the receiver station, or by similar methods.

Tracking Antennae for Gateway or High Data Rate Receiver Station Applications

While the augmenting constellation **203** of the present invention obviates the need for the use of receiver station antennae **112** that can track a satellite **108** across the sky, the ability of the receiver antenna **112** to track a satellite across the sky can still be valuable for some applications. For example, in typical broadcast applications, the size of the receiver station antenna **112** is kept small to ease installation difficulties. This negatively affects the gain of the receiver station antenna **112**, and the power of the signal transmitted from the satellite **108** is adjusted to take this into account. However, where two way communications between the receiver station **130** (essentially rendering it a receiver/transmitter station or gateway) and the satellite are desired (e.g. for high-bandwidth Internet and data transfer applications), the smaller size of the receiver station antenna **112** can be problematic, because it negatively affects the strength of the signal transmitted from the receiver station **130**. In such situations, it may be advantageous for the antenna at the gateway to track satellites **108** across the sky during service.

The augmenting satellite constellation **203** is designed so that when an active satellite **202** is about to finish its service, its apparent position in the sky relative to the receiver station **130** substantially overlaps with another satellite **202** in the constellation **203** rising and about to enter active service. This allows the receiver station antenna **112** to continue ground tracking without re-steering or experiencing temporary data drop-outs, thus saving the time for tracking and handover.

FIG. **5** is a diagram presenting a polar view of the satellite track **402**A from a location in CONUS (e.g. Los Angeles). The receiver station antenna at the gateway **112**G tracks the active satellite **202** during service, following an essentially teardrop path in a clockwise direction. When the active satellite **202** is about to complete service, the next satellite **202** in the constellation **203** is at or near the same apparent position along the satellite track **402**A. Small discrepancies between the apparent location of the active satellite **202** and the rising satellite **202** are not problematic, so long as the beamwidth of the gateway antenna **112**G is sufficient to encompass both the active satellite **202** and the rising satellite **202** at the same time. The high predictability of the satellite track **402** also allows for simplified gateway antenna **112**G design, and the ability to predict where the rising satellite **202** should appear when handoff is necessary.

An important feature of the constellation **203** of the present invention is that it creates satellite tracks **402** that are essentially closed-loop. For a specific orbital period (and hence, service period for each satellite **202**) there is only one constellation **203** that can be defined. The constellation **203** described above not only offers the closed loop satellite track **402** feature that simplifies receiver antenna **112** design, it also meets the required elevation angle for servicing subscribers **110** in CONUS and maintains an adequate separation angle from satellites in geostationary orbits.

Dual Capability Receiver Station

One significant advantage of the present invention is that it can be applied to existing receiver station **130** designs. This allows service capacity to be essentially doubled with minor modifications of existing hardware to add an additional receiving head or LNB and providing an intelligent switch.

FIG. **6** is a diagram showing an augmented receiver station **600** design. A baseline receiver station antenna **112** comprises a reflector **602** which is nominally about 45 cm in diameter and a first LNB **604** powered by the IRD **132** via a cable connection. This configuration results in a baseline antenna sensitivity pattern **606**. This configuration results in an approximate gain of 34 dBi, and is used to communicate with the satellites in geostationary orbit (GSO) satellites). The augmented receiver station antenna **608** further comprises a second LNB **610** offset from the first LNB **604**, resulting in a second antenna sensitivity pattern **612** which is non-symmetric and covers the movement of the satellites in the augmenting satellite constellation **203** when each of the augmenting satellites **202** are in the active period. This configuration has an approximate gain of 22 dBi, and is used to communicate with the (NGSO) satellites in the augmenting satellite constellation **203**. Signals are received via the first LNB **604** and the second LNB **610** according to a switch controlled by the IRD **132**.

The reduced gain inherent in the augmented receiver station (22 dBi versus 34 dBi) may be compensated for by increasing the output of the signal from the satellites in the augmenting constellation.

The foregoing can be implemented with a simple clip on LNB head, or a minor replacement to legacy LNBs. To maximize performance, the location of the second LNB **610** can be varied according to the geographical location of the subscriber **110**.

FIG. **7**A is a cross sectional diagram of an augmented receiver station antenna **608**. The reflector **602** of the antenna **608** can be characterized by a focal plane **702**, representing the locus of points at the focus of the parabolic reflector **602**. A vertically oriented focal line **704** and a focal point **605** at the along the centerline **603** of the parabolic reflector **602** can be defined on the focal plane **702**. In the embodiment illustrated in FIG. **7**A, the second LNB **610** is offset a first distance d_1 from the focal point **605** of the parabolic reflector, offset a first distance d_2 from the location of the first LNB **606** along the focal line **704** and offset a distance d_3 perpendicularly away from the focal line **704**. In one embodiment, d_1 is approximately seven inches, and d_3 is approximately four inches. This design generates the reverse teardrop-shaped sensitivity pattern shown in FIG. **7**B, and covers the movement of the active satellite **202** in the augmenting satellite constellation **203**. Hence, by matching the sensitivity pattern of the antenna **608** with the apparent motion of the active satellite **202**, a receiver station can be constructed that does not require active tracking of the satellite. While the foregoing shows an implementation using two separate LNBs, the present invention may be practiced using a single integrated LNB.

In addition to facilitating the design of a simplified receiver station, the augmenting satellite constellation **203** also achieves the highest elevation for coverage focusing at CONUS. Impact of the apparent motion of the satellites **202** is now discussed.

FIG. **8** is a plot of four CONUS contours **802**A-**802**D as seen from the active satellite **202** at four boundary points in the satellite's apparent position within the 8-hour active period. If the satellite **202** can steer its beam to minimize the gain degradation due to movement, then the shapes of CONUS, after new steering by aiming to the center of the desired coverage area, will be covered through a general shape marked by the outside contour **804**. Any point at the CONUS within this 8-hour active period, the receiving station can see at the least one satellite **202** at a minimum elevation of 57°. Since these satellites **202** are in a non-circular orbits (nominal eccentricity of 0.13) the satellites also change altitude during the active period, but this change of altitude does not cause major contours. Hence, the design of the spacecraft **202** antenna is similar to that of legacy satellite **204**.

FIG. **9** illustrates sample satellite transmission beam shaped to follow the outer contour **804** shown in FIG. **8**. Spot beams (which can offer local programs to regional areas) may also be utilized.

As can be seen, the present invention can be implemented while minimizing changes to existing user equipment through add-on receiver station **130** components, and the augmenting satellite constellation **203**. The system requires only two additional hardware components to double the reception capacity provided to the receiver station **130**: an add-on kit for the receiving antenna **112**, and an intelligent switch to select the signal received from the legacy satellites **104** by the first LNB **606** from the augmenting satellites **202** by the second LNB **610**. The intelligent switch may be integrated with other antenna components or with the RD **132**.

As described above, an important advantage of the present invention is that it allows the antennae, converters, and set top boxes used by current GSO satellites to be used for additional capacity without interference. In addition to these advantages, the present invention allows the augmenting satellite constellation **203** to share the electromagnetic spectrum with the legacy satellites **204**. The satellites **202** in the augmenting satellite constellation **203** achieve a minimum 30° spatial separation to avoid the signals from the legacy satellites **204**. When a member satellite **202** of the augmenting satellite constellation **203** flies through lower latitude regions during the non-active period, the satellite ceases the transmission of signals in the shared spectrum to avoid harmful interference with legacy satellite **204** transmission. The satellite **202** remains in a stand-by mode until it leaves the lower latitude regions and becomes active. The spatial separation away from legacy satellites **204** (at least 30°) provides large (−30 dB) antenna discrimination, which prevents interference.

The present invention can be used to provide additional bandwidth to nearly any broadcast service provided by satellites in geostationary orbits. The augmenting satellite constellation **203** provides improved capacity, improved reception (due to the higher elevation), and reduced cost (since management and other ground functions can be shared with other GSO systems).

Conclusion

The foregoing description of the preferred embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto. The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

What is claimed is:

1. A system for providing at least near continuous broadcast service to a terrestrial receiver, comprising:

a plurality of satellites, each satellite in an inclined, elliptical, geosynchronous orbit, each satellite providing a portion of time of the at least near continuous broadcast service to the terrestrial receiver;

wherein the plurality of satellites augments at least one legacy satellite in a geostationary orbit providing service to the terrestrial receiver; and

wherein a track of the apparent position of each of the satellites relative to the terrestrial receiver when the satellite is providing its position of the at least near continuous broadcast service is substantially closed loop.

2. The system of claim **1**, wherein the terrestrial receiver comprises an antenna having a sensitivity characteristic substantially corresponding to the track of the apparent position of each of the satellites.

3. The system of claim **1**, wherein the track of the apparent position of each of the satellites substantially corresponds to a sensitivity pattern of an antenna at the terrestrial receiver.

4. A system for providing at least near continuous broadcast service to a terrestrial receiver, comprising:

a plurality of satellites, each satellite in an inclined, elliptical, geosynchronous orbit, each satellite providing a portion of time of the at least near continuous broadcast service to the terrestrial receiver;

wherein the plurality of satellites augments at least one legacy satellite in a geostationary orbit providing service to the terrestrial receiver; and

wherein a track of the apparent position of each of the satellites relative to the terrestrial receiver when the satellite is providing its portion of the at least near continuous broadcast service is substantially teardrop-shaped.

5. A method of providing at least near continuous broadcast service to a terrestrial receiver, comprising the steps of:

providing a signal having a portion of the continuous broadcast service from at least one of a plurality of satellites at a time, each satellite in an inclined, elliptical, geosynchronous orbit; and

providing service from at least one legacy satellite in a geostationary orbit,

wherein a track of the apparent position of the each of the satellites relative to the terrestrial receiver when the satellite is providing its portion of the at least near continuous broadcast service is substantially closed loop.

6. The method of claim 5, wherein the terrestrial receiver comprises an antenna having a sensitivity characteristic substantially corresponding to the track of the apparent position of each of the satellites.

7. The method of claim 5, wherein the track of the apparent position of each of the satellites substantially corresponds to a sensitivity pattern of an antenna at the terrestrial receiver.

8. A method of providing at least near continuous broadcast service to a terrestrial receiver, comprising the steps of:

providing a signal having a portion of the continuous broadcast service from at least one of a plurality of satellites at a time, each satellite in an inclined, elliptical, geosynchronous orbit; and

providing service from at least one legacy satellite in a geostationary orbit;

wherein a track of the apparent position of the each of the satellites relative to the terrestrial receiver when the satellite is providing its portion of the at least near continuous broadcast service is substantially teardrop-shaped.

9. A method of receiving at least near continuous broadcast service at a terrestrial receiver, comprising the steps of:

receiving a signal having a portion of the continuous broadcast service from at least one of a plurality of augmenting satellites at a time, each augmenting satellite of the plurality of satellites being in an inclined, elliptical, geosynchronous orbit; and

receiving broadcast service from at least one legacy satellite in a geostationary orbit;

wherein a track of the apparent position of the each of the augmenting satellites relative to the terrestrial receiver when the augmenting satellite is providing its portion of the at least near continuous broadcast service is closed loop.

10. The system of claim 9, wherein the terrestrial receiver comprises an antenna having a first sensitivity characteristic corresponding to the track of the apparent position of each of the augmenting satellites and a second sensitivity characteristic corresponding to the at least one legacy satellite.

11. The system of claim 9, wherein the track of the apparent position of each of the augmenting satellites corresponds to a sensitivity pattern of an antenna at the terrestrial receiver.

12. A method of receiving at least near continuous broadcast service at a terrestrial receiver, comprising the steps of:

receiving a signal having a portion of the continuous broadcast service from at least one of a plurality of augmenting satellites at a time, each augmenting satellite of the plurality of satellites being in an inclined, elliptical, geosynchronous orbit; and

receiving broadcast service from at least one legacy satellite in a geostationary orbit;

wherein a track of the apparent position of the each of the augmenting satellites relative to the terrestrial receiver when the augmenting satellite is providing its portion of the at least near continuous broadcast service is teardrop-shaped.

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