United States Patent

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[54] **MULTIPLE BEAM ARRAY ANTENNA**

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[73] Assignee: **Sperry Rand Corporation**

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[52] **U.S. Cl.** **343/754,** 343/756, 343/771, 343/854

[51] **Int. Cl.**.....**H01q 19/06**

[58] **Field of Search** ..343/754, 778, 854, 911 L, 911, 343/756, 771

[56] **References Cited**

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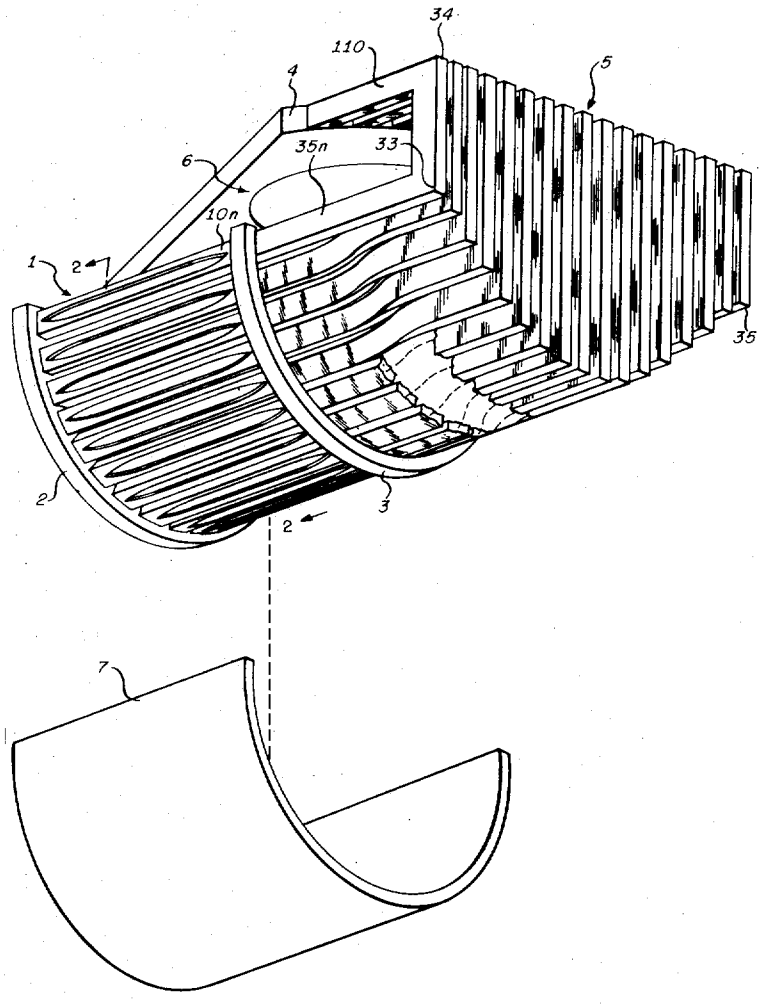
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Primary Examiner—Eli Lieberman
Attorney—S. C. Yeaton

[57] **ABSTRACT**

A high frequency energy array antenna conforming to the contour of a craft comprises a plurality of antenna array elements for providing partial collimation of multiple or scanned radiation or reception patterns. The antenna array cooperatively and selectively operates in energy exchanging relation with a geodesic energy distribution system for further collimation of the multiple or scanning radiation or reception patterns.

5 Claims, 9 Drawing Figures



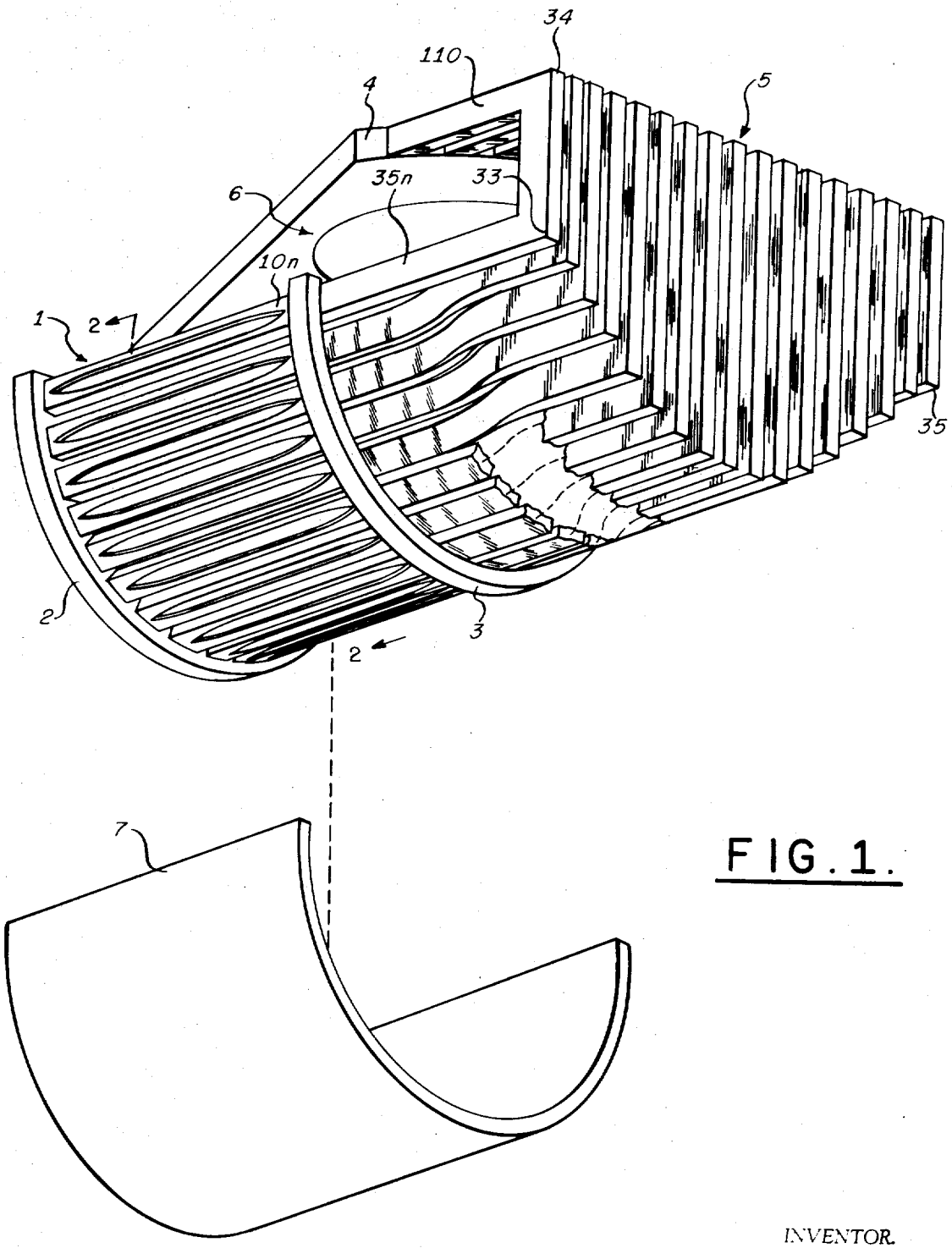


FIG. 1.

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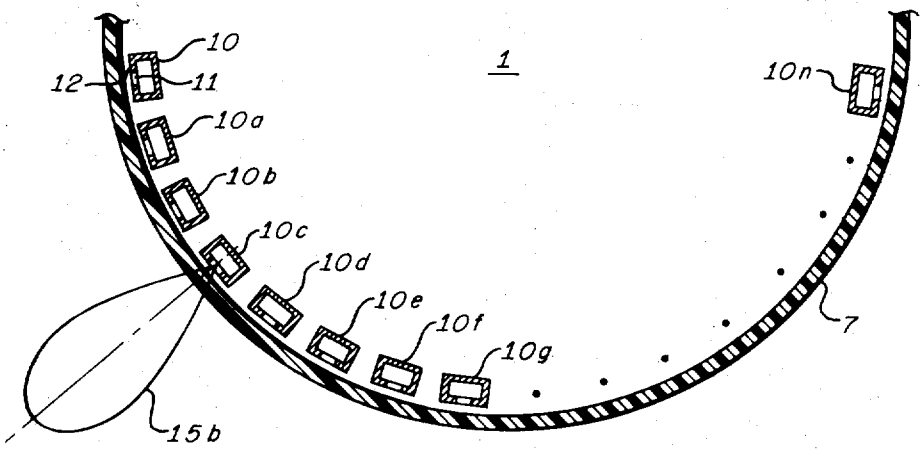


FIG. 2.

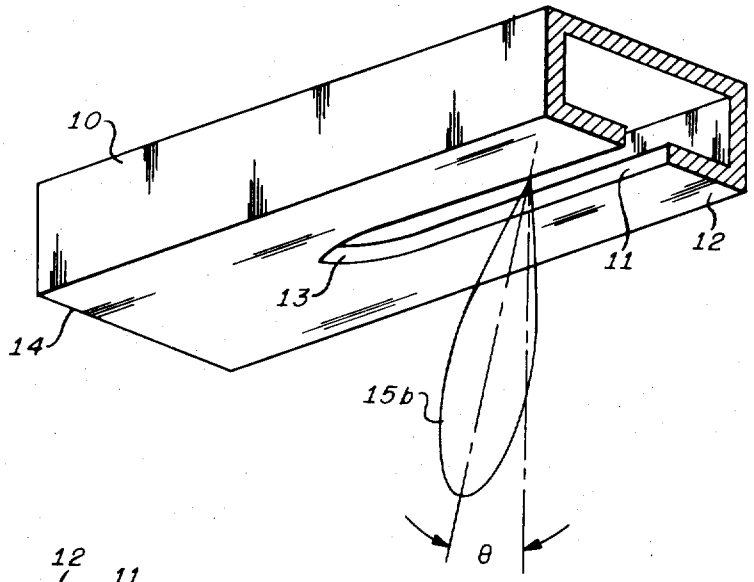


FIG. 3.

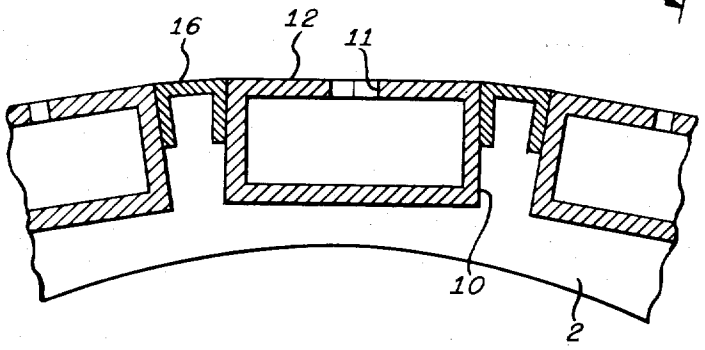
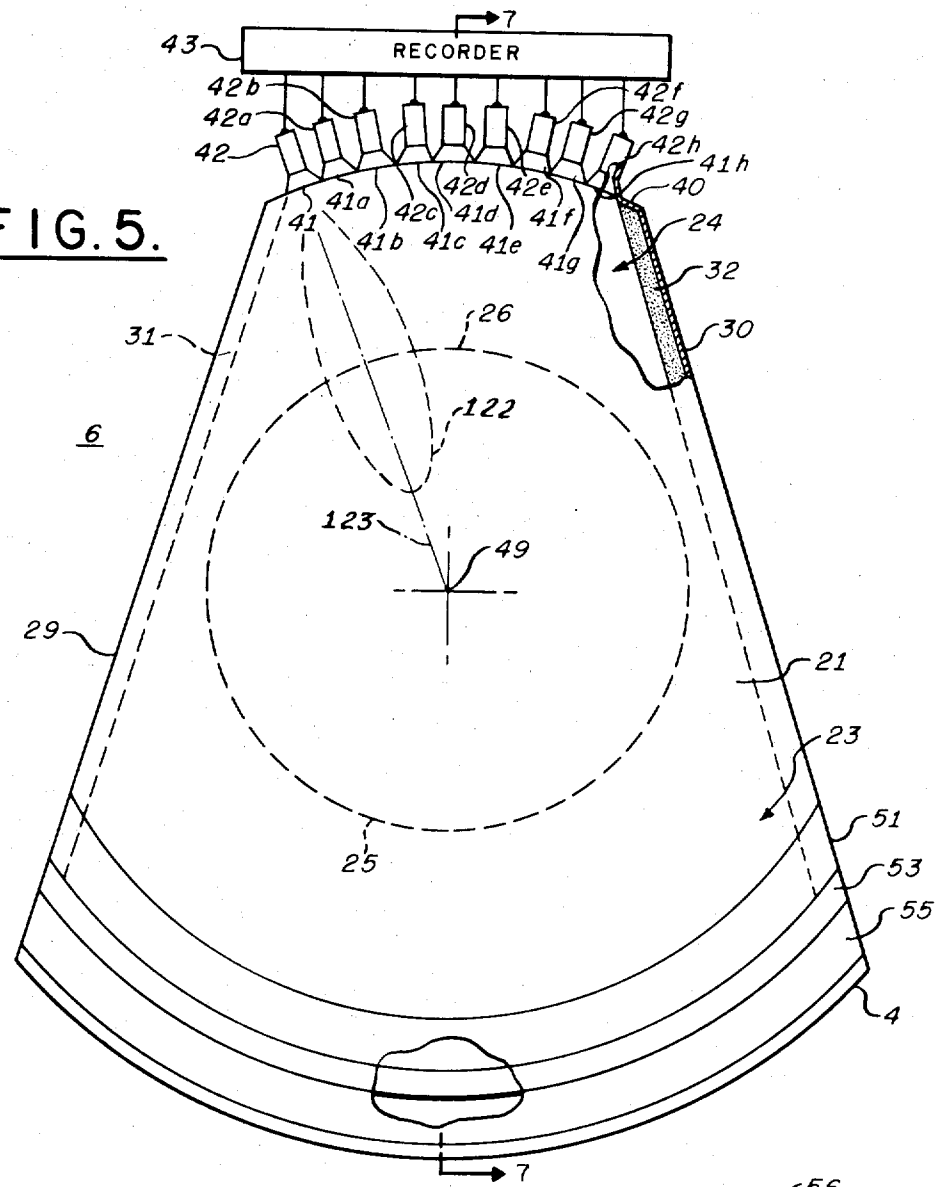


FIG. 4.

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FIG. 5.



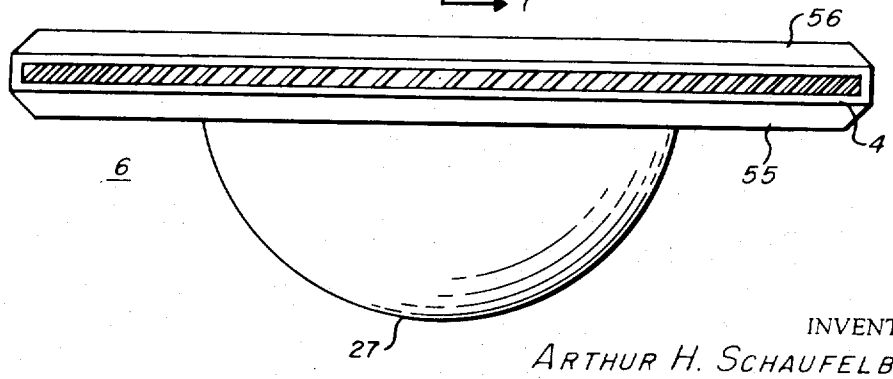


FIG. 6.

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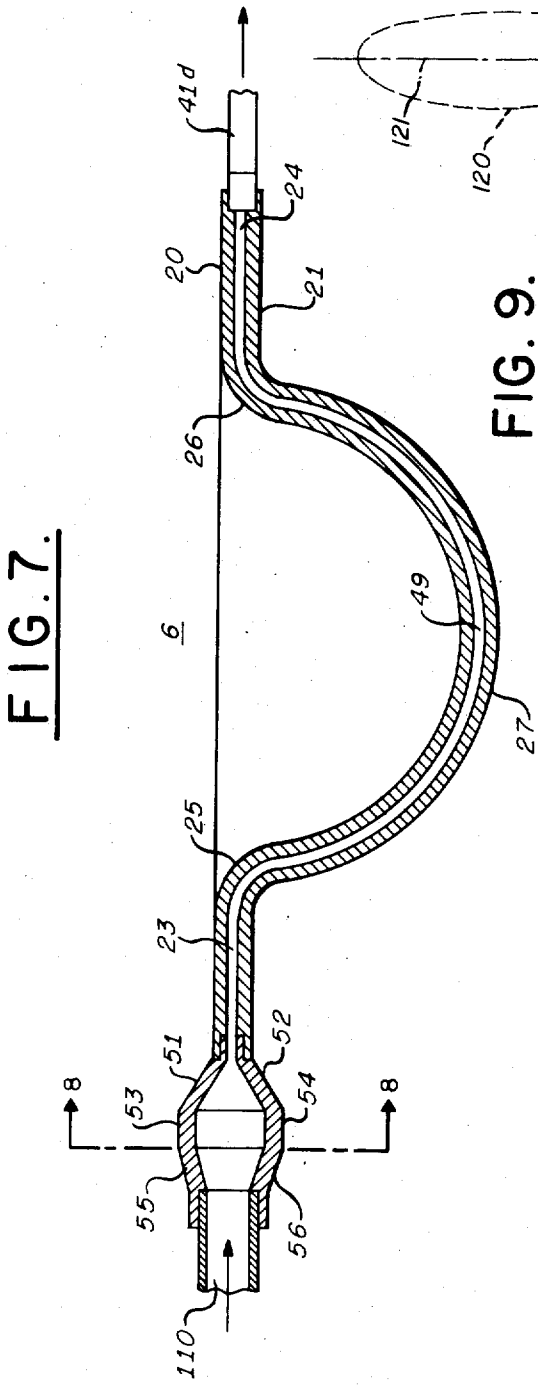


FIG. 7.

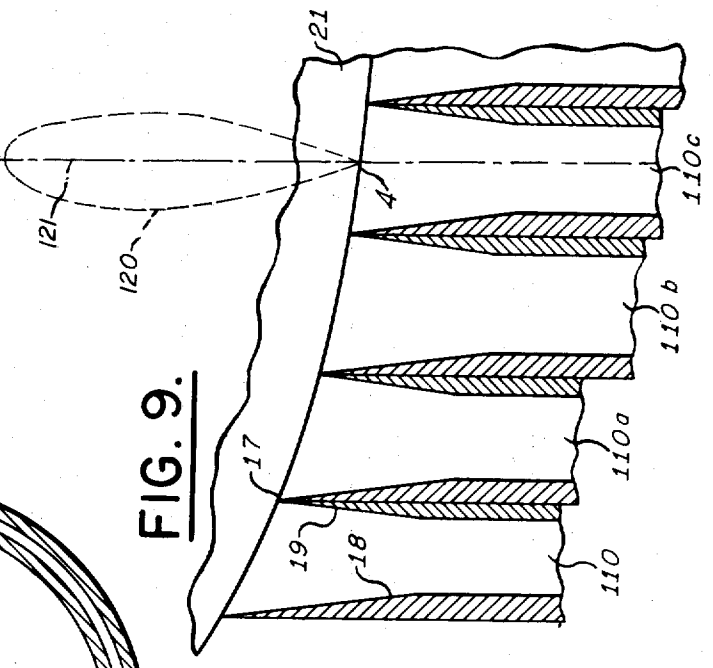


FIG. 9.

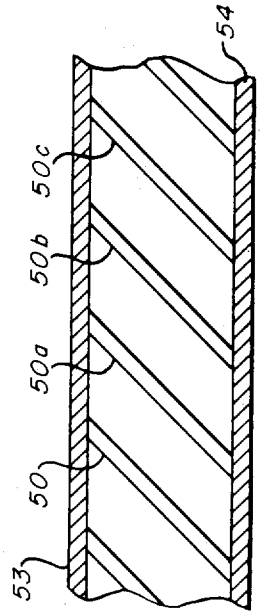


FIG. 8.

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MULTIPLE BEAM ARRAY ANTENNA

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to antenna array systems of the type in which a plurality of cooperating antenna elements provides means for selectively generating multiple or scanning radiation or reception patterns and more particularly relates to such antenna arrays in which the elements thereof inherently provide a degree of collimation of the antenna array pattern and additional means, not directly part of the antenna structure, is provided to afford the total required degree of collimation for the pattern.

2. Description of the Prior Art

Prior art efforts have provided array antennas for various passive and active applications, some having certain particular advantageous attributes, but generally none of these having all of the attributes desired in a versatile antenna array suitable for use with either or both passive or active electronic systems. Some types of such antennas have been inconvenient in configuration for mounting in an airborne craft, the geometries of the craft and of the array antenna being conflicting in nature. Antenna arrays suitable for skin mounting along the fuselage of an aircraft vehicle have also generally been too expensive for practical employment and have often required the use of a major part of the cross section of the craft. Further, such antennas have not generally succeeded for dual mode operation, such as for alternatively providing search and tracking viewing.

Because of inherent characteristics of antenna components and systems employed in the prior art, it has been difficult to provide an antenna array particularly adapted for continuous wide frequency band scanning or viewing of terrain or ocean areas for surveying and for surveillance purposes, such as for warning of the presence of dangerous ice or iceberg conditions.

Mapping and surveillance passive radiometric systems require a wide operational band width. Signal amplitudes, being small and object identifying gradients also small, very low loss, high frequency or microwave (especially millimeter wave length) systems are desired. Prior art proposals have not been successful, in that low loss and sufficient band width have not generally been attained. Where prior art antennas view a sufficiently wide sector, serious deterioration of the beam shape and width is observed, especially at the extremes of the sector scanned or viewed. Beam shape deterioration and wide variation in the location and amplitude of undesired side lobes have been present, in part due to lack of uniform energy phase fronts in various parts of the antenna systems.

SUMMARY OF THE INVENTION

The invention is a multi-element antenna array system adapted both to operation in passive or active electronic systems and having an array antenna conforming to a desired contour, such as the cylindrical contour of an airborne vehicle. Elements of the array, such as slotted transmission line antennas in side-by-side cooperative relation, provide collimation in one plane of the radially extending antenna radiation or reception patterns. According to the invention, a plurality of such radially directive patterns may be simultaneously formed or one or more such patterns may be angularly scanned over a wide sector. The pattern generation mechanism employs a geodesic parallel plate energy guiding system which determines the activities of the antenna patterns and also additionally collimates them in a second plane.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the novel antenna assembly seen from below, and with an element shown in exploded view.

FIG. 2 is a cross section view taken along line 2—2 of FIG. 1 and illustrating a receptivity pattern of a component of the antenna.

FIG. 3 is a perspective view, partly in cross section, of a part of FIG. 2, and illustrating a receptivity pattern of a component of the antenna.

FIG. 4 is a fragmentary cross section view like FIG. 2 of an alternative structure.

FIG. 5 is a plan view seen from below of a part of the structure of FIG. 1, partly in cross section.

FIG. 6 is an end view of the apparatus of FIG. 5.

FIG. 7 is a cross section view taken along the line 7—7 of FIG. 5.

FIG. 8 is an enlarged partly sectioned view of a portion of FIG. 6.

FIG. 9 is a cross section plan view of part of FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention will be discussed with reference to the figures primarily in the form of an embodiment most suitable for use in a passive, high frequency radiometric receiver system. It will be understood, however, that the invention has utility in other types of high frequency systems, including systems such as active radar and communication systems. Such versatility will be seen to be inherent in the invention, since the electromagnetic energy reciprocity propagation law is obeyed by all of its components and, therefore, by the operatively connected sum of them.

Referring to FIG. 1, the novel antenna system comprises several major portions, including a high frequency energy collecting transmission line antenna array 1 seen in the figure as supported at its ends by a framework including the generally arcuate frame or support elements 2 and 3. Details of the structure and operation of the transmission line antenna array 1 remain to be considered in connection with FIGS. 2 and 3.

The novel energy processing system associated with transmission line antenna array 1 extends from the end of the array 1 that is adjacent frame element 3. A first portion thereof comprises an array 5 of closed hollow transmission lines connecting the individual transmission lines of antenna array 1 through the arcuate input 4 of a geodesic wave transmission system 6. Transmission line array 5 serves the purpose of redistributing high frequency energy collected by the curved antenna array 1 so that it appears along a planar array of apertures within arcuate input 4. The energy is not only redistributed thereby, but the array 5 also serves to fold the total structure back relative to itself in a manner making the invention more compact and therefore more convenient for use within, for instance, the

fuselage of an airborne craft. A second portion of the energy processing system includes the geodesic wave transmission system **6**, which will be discussed in further detail with reference to FIGS. **6** to **9**. As will be seen, the modified parallel plate transmission line arrangement of geodesic system **6** aids the antenna array **1** in providing further collimation of the received high frequency energy.

A further major part of the antenna system is the radome **7**, which has a curved or cylindrical shape generally matching the contour of antenna array **1**, and which may be held in place by fasteners (not shown) against the outer surfaces of frame elements **2** and **3**. Alternatively, the radome **7** may replace an appropriate portion of a curved metal surface of an aircraft fuselage and may be fastened to the aircraft in generally the same manner. In any event, radome **7** serves the usual purpose of protecting the antenna system from the effects of the environment outside of the aircraft and may be composed of any of the several materials in common use in aircraft or other radomes. The radome and antenna may be located in a lower part of the aircraft fuselage for surveying the earth's surface, as in surveying for icebergs on the ocean's surface, though other locations may be employed for other purposes.

Referring now to FIGS. **1**, **2**, and **3**, the structure and operation of the high frequency energy collecting transmission line antenna array **1** will be examined. In particular, FIG. **2** illustrates the side-by-side parallel location of the individual wave guide transmission line antenna elements **10**, **10***a*, **10***b*, . . . , **10***n* which make up antenna array **1**. Elements **10**, **10***a* **10***b*, . . . , **10***n* are all of equal electrical lengths and are seen to be located in a curved or cylindrical array, each with an energy receiving slot, such as slot or aperture **11** of wave guide **10**, facing radially outward along the wall of curved radome **7**. For convenience, the energy receiving aperture of each traveling wave antenna element **10**, **10***a*, **10***b*, . . . , **10***n* has been shown as a continuous longitudinal slot **11**, which slots may be located centrally in each broad wall **12** of the antenna wave guide transmission lines. Such traveling wave transmission line antenna devices are well known in the art, having been discussed in several patents to William W. Hansen, including U.S. Pat. No. 2,489,288, issued Nov. 29, 1949. The latter patent and subsequently issued patents illustrate the use of the longitudinal antenna slot **11**, and also illustrate related traveling wave transmission line antennas employing multiplicities of apertures and which may be employed in the present invention. Antennas of the type known as the inductive sheet antenna also have reception patterns similar to those of the slotted guide antenna and have contours which may readily be made to conform to a cylindrical or curved surface.

As seen in FIG. **3**, slot **11** may be supplied with a smoothly narrowing tapered end **13** adjacent the closed end **14** of guide **10** near frame element **3** for diminishing the impedance discontinuity at that end of slot **11**; similar means may be used at the opposite end of slot **11**. The end **14** of wave guide **10** may also be supplied in the well known manner with a matched termination (not shown) for the absorption of reflected energy or of energy otherwise propagated toward end **14**.

Antenna array elements **10**, **10***a*, **10***b*, . . . , **10***n* are positioned by support elements **2** and **3** so that individually they would form individual receptivity patterns about radome **7** as illustrated by the representative pattern **15***b* associated with wave guide antenna **10***b*. Several successive such patterns may, for example, cover as much as 300° or whatever angular range is required for simultaneously viewing radiation from a desired continuous angular extent of the earth's surface to the left and to the right of the vertical. The patterns may be sharpened by providing a continuous substantially smooth surface for the face of the array, as by the use of the conductive inserts **16** shown in FIG. **4**. The patterns, such as pattern **15***b* of FIG. **3**, may fall in a plane inclined relative to the vertical by a predetermined angle θ (the value of θ may be zero). It is to be understood that the patterns shown in FIGS. **2** and **3** represent patterns produced by components of the antenna array.

The orientation of wave guides **10**, **10***a*, **10***b*, . . . , **10***n* with respect to the surface of radome **7** depends upon the electric field polarization desired for reception by antenna array **1**. For example, the orientation shown in FIG. **2** with the broad wall **12** of each guide including slot **11** facing radome **7** produces a receptivity pattern for horizontally polarized energy. For reception of vertically polarized signals, the narrow walls of the wave guides would face radome **7**, and the narrow walls would be equipped with known types of appropriate energy collecting slots or apertures. It is within the scope of the present invention to substitute one polarization for another by appropriately substituting antenna wave guide types. It will be apparent to those skilled in the art that guides having alternating polarization properties may be employed simultaneously or selectively in particularly polarized array sets if appropriate switching arrangements are provided.

The wave guide array arrangement **5** for connecting the antenna array **1** to the geodesic wave transmission system **6** will be more readily visualized if the geodesic system **6** is considered first. Referring to FIGS. **1**,**5**,**6**,**7**, and **8**, apparatus for further collimating and processing the received energy is illustrated. The geodesic system **6** is required because the receptivity pattern of a single slotted antenna, as shown in FIGS. **2** and **3**, is narrow along the axis of antenna array **1** and relatively broad transverse of the array axis. As will be seen, a significant function of the geodesic system **6** is to produce satisfactory collimation of the radiation patterns especially in the plane transverse of the axis of array **1**, so that the total system generates narrow, pencil-beam, receptivity patterns.

Particularly as seen in FIG. **7**, geodesic system **6** basically comprises a wide wave-guiding device including a pair of nesting dome-shaped conducting plates **20** and **21** which are mutually parallel in the sense that their normal separation is substantially constant. The geodesic system is seen to comprise a flat input parallel plate transmission line region **23** which surrounds the base of its nesting dome-shaped portion **27** and is extended past portion **27** to form the flat output parallel plate transmission line region **24**. Vertical side walls **29** and **30** may be used to join conducting plates **20** and **21** and to support them in proper mutually spaced relation. However, flow of high frequency energy, espe-

cially scattered energy, in the vicinity of the interior surfaces of side walls **29** and **30** is largely determined by relatively thick layers of energy absorbing material, as seen at locations **31** and **32**. The absorbing elements **31** and **32** may take the form of layers of sponge foam impregnated with a known high frequency energy absorbing material and fastened to walls **20, 21, 29** and **30** by cementing. The periphery or base of the nesting dome-shaped region **27** is smoothly joined to the flat parallel plate system forming respective input and output regions **23** and **24** by a smoothly curved annular junction region seen in cross section at locations **25** and **26** in FIG. **7**.

Referring particularly to the portion of the apparatus of FIG. **7** including the junction annulus **25,26**, and the nesting dome-shaped portion **27**, it is seen that this part of the FIG. **7** structure forms a true geodesic lens device in the form of a wave guide energy collimating element utilizing cooperating smooth nested high frequency conductor wall surfaces. Of circularly symmetric nature, with respect to the common axis **49** of substantial symmetry it is composed of two curved mutually parallel wall surfaces having constant separation less than one half wave length at the average operating carrier frequency. Only carrier energy in the TEM propagation mode can pass through the geodesic device. Upon excitation, rays of high frequency carrier energy leaving effective substantially point sources at locations spaced from the peripheral annulus **25, 26** of the geodesic lens device pass through it as collimated rays to emerge, still in collimated form, at locations diametrically opposite to the effective point sources. It is seen that such lens operation is reciprocal. Further, because the focal properties of the geodesic lens accrue inherently from an equality of the various physical path lengths in the low-loss medium in portion **27** between the nested dome plates **20** and **21**, the device has broad band operational characteristics, the medium being non-dispersive.

The parallel plate geodesic device **6** may be manufactured by any of several known methods, as will be apparent to those skilled in the art. The domed plates **20** and **21** may be individually machined to the required close tolerances from either an aluminum weldment or from a sand casting. For quantity production, either die casting or spinning may be chosen. After machining, the high frequency current conducting surfaces of plates **20** and **21** are plated by conventional means with a layer of silver to improve conductivity and then with a thin layer of gold to reduce oxidation or other degradation due to chemical attack.

The geodesic system **6** of the invention is further characterized by having a focal line outside of the annular periphery junction **25,26**, of the dome-shaped region **27**. Furthermore, as seen in FIGS. **1** and **5**, the input arc **4** of the parallel plate input region **24** has a radius substantially equal to the radius of the cylindric surface formed by antenna array **1**, and is centered on the geometrical center **49** of device **27**.

It will be seen that each receiver wave guide of antenna array **1** is ultimately to be joined at an input aperture in energy exchanging relation with the arcuate input **4** of the geodesic system **6** of FIG. **5**. FIG. **9** illustrates on a large scale wave guide ends **110**, **110*a***, **110*b***, . . . , **110*n*** respectively corresponding to and cooperating with the antenna wave guides **10**, **10*a***, **10*b***, . . . , **10*n*** of FIG. **2**. Guides **110**, **110*a***, **110*b***, . . . , **110*n*** coact with arcuate input **4** and are arranged parallel to the plane of substantial mirror symmetry **7—7** of the geodesic system (FIG. **5**) with the electric vector direction perpendicular to the plane of FIG. **9** and therefore parallel to the electric vector within geodesic system **6**. As many as sixty wave guide inputs may face the arcuate input **4**, for example; in order to avoid reflections at the ends of the guides, the narrow walls of each are tapered, as at **18** and **19** for guide **110**, so as to form narrow ridges A radiation pattern **120** typical of the several patterns corresponding to guides **110**, . . . , **110*c*** is shown at the end of guide **110*c***, along with the corresponding axis of directivity **121** of pattern **120**. It will be understood that the several axes of directivity of the respective guides **110**, . . . , **1010*c*** are parallel guides, **110**, . . . , **110*c*** being parallel. or points, such as ridge or point **17** common to the walls of contiguous guides **110** and **110*a***.

Referring to FIG. **1**, it is seen that each wave guide section **35**, **35*a***, **35*b***, . . . , **35*n*** extending from a respective slotted antenna wave guide **10**, **10*a***, **10*b***, . . . , **10*n*** undergoes first and second 90° bends before reaching the arcuate input **4**. For example, antenna wave guide **10*n*** is coupled through support element **3** to a wave guide section **35*n*** having 90° bends **33*n*** and **34*n*** for permitting its end **110*n*** to be joined as described in connection with FIG. **9** to the geodesic device **6**. The remaining antenna wave guide elements **10**, **10*a***, **10*b***, . . . , **10*n*-1** of antenna array **1** are similarly attached by individual wave guide sections corresponding to wave guide section **35*n***, each such section having pairs of 90° bends corresponding to the respective bends **33*n*** and **34*n***. To facilitate bending, the guides may be constructed of thin-walled aluminum.

It is seen that the distances between bends respectively corresponding to bends **33*n*** and **34*n*** progressively increase until the center of the array **5** is reached, and then progressively decrease so that wave guide section **35** on the side of the array **5** opposite wave guide section **35*n*** is again dimensionally like wave guide section **35*n***. Because of the curvature of arcuate input **4**, and because all of the wave guide bends **33**, **34**, et cetera, lie in the same plane, it is seen that the distances between arcuate input **4** and the respective bends corresponding to bend **34** progressively decrease until the center of the array **5** is reached, and then progressively increase. Since the contours or curvatures of array **1** and of arcuate input **4** are made equal, it is seen that the distances from support **3** along all wave guides, such as guide **35*n***, to the input **4** are equal. Thus, signals arriving simultaneously at corresponding locations on slot antennas **10**, **10*a***, **10*b***, . . . , **10*n*** always arrive at the same instant of time at arcuate input **4**. It will further be understood by those skilled in the art that contours other than circular may be used for the antenna array **1** and for the arcuate input **4**. Bearing in mind that the signal propagation path lengths between array **1** and arcuate input **4** are to be constant across the wave guide array **5**, it is apparent that other successfully cooperating contours may readily be devised.

Referring again to FIGS. **1**, **5**, **6**, and **7**, collimated received energy passing through geodesic system **6** propagates into the flat parallel plate output region **24**

whose outer boundary is formed in part by arcuate wall **40**. Wall **40** is provided with an open region accommodating the apertures of a plurality of contiguous pyramidal or rectangular wave guide horns **41**, **41***a*, **41***b*, . . . **41***n*, arranged along the arc of wall **40** in energy exchanging relation with parallel plate output region **24**. Known types of pyramidal wave guide horns feeding short dielectric rod antennas extending into the parallel plate output region **24** may be substituted for the simple horns or flared wave guides. The locus of the apparent effective point receiver of each of the horns **41**, **41***a*, **41***b*, . . . , **41***n* lies on the aforementioned arcuate focal line of the geodesic system **6**. Accordingly, the axis of each pyramidal wave guide horn **41**, **41***a*, **41***b*, . . . , **41***n* is directed toward the geometrical center **49** of the domed region **27** of the geodesic device. For example, the radiation pattern **123** of horn **41** is directed along axis of directivity **123** passing through locus **49**. The patterns and directive axes associated with horns **41***a*, . . . , **41***h* are similarly directed through locus **49**. The pyramidal horns **41**, **41***a*, **41***b*, . . . , **41***n* are oriented so that the electric vectors propagating therein are normal to the plates **20** and **21**; i.e., the narrow wave guide walls of the horns are generally perpendicular to plates **20** and **21**. In application in a radiometer receiver system, the received energy is collimated into any one of pyramidal or wave guide horns **41**, **41***a*, . . . , **41***n* for detection in associated sensitive broad band detector devices indicated at **42**, **42***a*, . . . , **42***n*. The corresponding several outputs of detectors **42**, **42***a*, . . . **42***n* may be applied to any well known type of radiometric utilization device, such as to multichannel recorder **43**, wherein separate records of the detected signals may be stored on a medium such as paper. The medium may, for instance, be driven past recorder pens at a rate which is a function of time, integrated air speed, or actual distance traveled as derived from a loran navigational receiver system or other aid to navigation. The outputs of the several detectors may also be displayed for visual interpretation, if desired, as in the instance of iceberg detection. A feature of the system in radiometric application lies in the fact that it may be used as a wide-open system in which data from all receiver channels is applied for search alarm purposes, or with a system instantaneously recording data from separate channels simultaneously, or both functions can operate at the same time.

Referring again to FIGS. **5**, **6**, **7**, and **8**, it is possible in a system in which a large number of individual slotted wave guide antennas is to be used, and therefore in which a large number of interconnecting wave guide sections **35** to **35***n* must be used, more readily to accommodate the corresponding large number of wave guide ends **110**, **110***a*, **110***b*, . . . , **110***n* in arcuate input **4** by use of a polarization grating system. Use of a polarization grating adjacent the arcuate input **4** permits rotation of the electric vector of energy flowing into input **4** by 90° and therefore permits the use of wave guide ends **110**, **110***a*, **110***b*, . . . , **110***n* rotated through 90° with respect to the previously discussed orientation. The new orientation, by virtue of the rectangular shape of the guides, permits use of more input wave guide ends for an arcuate input of given extent and therefore of more antenna array elements. The effect of the 90° twist may be compensated, if required, by inserting a second 90° twist elsewhere in the wave guide paths from antenna array **1**, such as in each successive guide portion between ends **33**, **33***a*, . . . , **33***n* and bends **34**, **34***a*, . . . , **34***n*.

The grating is located at the end of the parallel plate input region **23** and takes an arcuate form having the same center of curvature **49** as the arcuate input **4**. It consists essentially of a series of individual short parallelogram wave guides composed of electrically conducting metal plates, such as the plates **50**, **50***a*, **50***b*, . . . , **50***n* seen on an enlarged scale in FIG. **8**, these plates being fabricated of silver and gold plated thin aluminum and being oriented at 45° to plates **20** and **21**. In order to avoid generation of undesired modes in the vicinity of the grating, the parallel plates **20** and **21** are provided with arcuate flares **51** and **52** joined to the arcuate short parallel-plate sections **53** and **54**, centered on locus **49**, within which grating plates **50**, **50***a*, **50***b*, . . . , **50***n* are mounted. The separation of the interior current carrying surfaces of plate sections **53** and **54** may be substantially four times the average system operating carrier wave length.

Past the grating region, the arcuate sections **53** and **54** connect to an inverse arcuate horn section centered on locus **49** and comprised of plates **55** and **56**, this arcuate horn section tapering the propagation space down to the separation required for the signal input wave guides, such as guide **110**.

The metal grating plates **50**, **50***a*, **50***b*, . . . , **50***n* have a normal separation about three quarters of an average carrier wave length, so that an effectively birefringent medium is obtained in the region of the plates wherein the propagation phase velocity of the orthogonal component of the incident high frequency energy parallel to grating plates **50**, **50***a*, **50***b*, . . . , **50***n* is substantially greater than the propagation phase velocity of the component normal to those plates. With a grating guide length of substantially two free space carrier average wave lengths, a net phase rotation for the parallel component of 180° is obtained. Upon recombination of the vectors, the resultant is a vector oriented at 90° with respect to the original polarization.

Operation of the invention as a receiver device is generally apparent from the foregoing discussion of its structure and attributes. It will be understood that the device may also be employed for transmission, and a discussion of its operation when radiating energy may further make clear its operation as a receiver system. The invention may be employed in scanning transmitter system or where multiple radiation pattern generation is to be accomplished in a single plane. Referring to FIG. **5**, the output horns **41**, **41***a*, . . . , **41***n* now become horns excited, for instance, by a pulsed, high frequency transmitter or transmitters. Appropriate duplexer and receiver channels may also be connected to each of the several horns. The horns may be excited in succession, such as by use of a single rotating scanning horn or by use of an organ-pipe or related scanner switching system.

Energy injected into the geodesic system **6** by any one or more of horns **41**, **41***a*, . . . , **41***n* and polarized normal to plates **20** and **31** will enter the flat parallel plate portion **24** of the geodesic system **6**. Here, the energy is collimated as previously described and will appear at the arcuate wall **4**. For example, if all seven

of the horns 41, 41*a*, . . . , 41*n* shown in FIG. 5 are simultaneously excited, there will appear in the flat parallel plate portion 23 of the geodesic device seven collimated narrow over-lapping beams of radiation. Certain ones of the series of wave guide ends 110, 110*a*, 110*b*, . . . , 110*n*, which are arranged to accommodate energy with its electric vector perpendicular to plates 20 and 21, are excited in proportion to their respective illuminations by the seven beams. Since there are many more guide ends 110, 110*a*, 110*b*, . . . , 110*n* than there are beams, many may have little or no excitation.

Those of wave guide sections 35, 35*a*, . . . , 35*n* which are consequently excited transfer the energy from the geodesic system 6 to associated elements of the wave guide antenna array 1. Since all propagation paths are equal, the collimated phase conditions in the geodesic device 6 are preserved at the inputs to the antenna elements 10, 10*a*, 10*b*, . . . , 10*n* of array 1. Because the antenna elements 10, 10*a*, . . . , 10*n* of array collimate the radiated energy in the longitudinal direction, the output of array 1 consists of seven over-lapping pencil radiation patterns in a transverse plane because of the cooperative collimation action of the geodesic system 6. It is seen that the maximum possible number of overlapping radiation patterns instantaneously formed in space is equal to the maximum number of horns 41, 41*a*, 41*b*, . . . , 41*n* that are instantaneously excited; the number of slotted wave guide antennas is not the determinant.

Likewise, it is seen that operation of the system as a receiver system depends upon the cooperative collimation effects of the elements of antenna array 1 and of the geodesic device 6. Any external signals directed toward the seven receptivity patterns of the antenna array 1 excite appropriate slotted line wave guides 10, 10*a*, 10*b*, . . . , 10*n* at various energy levels and propagate through equal-length corresponding paths within the array 5 of transmission lines to the arcuate aperture 4 of geodesic system 6. Signals flowing from the many wave guide ends 110, 110*a*, . . . , 110*n* at arcuate input 4 flow over equal length paths through the geodesic device 6 and are further collimated because of the directive properties of device 6 and of the horns 41, 41*a*, 41*b*, . . . , 41*n*. The signals sampled by any given horn, such as horn 41*b*, will generally be a composite of signals collected by several of the slotted antenna elements of antenna array 1.

In the general case, the number of antenna elements 10, 10*a*, 10*b*, . . . , 10*n* depends upon the extent of the largest angular sector to be viewed by the antenna system. It is also related to other factors, such as the radius of the geodesic lens dome and the radius of the antenna array 1 (substantially that of the craft fuselage). The number of horns 41, 41*a*, 41*b*, . . . , 41*n* once the angular sector to be viewed is selected, is dictated by the effective beam widths of the radiation patterns to be produced.

From the foregoing, it is seen that the invention provides a versatile antenna array system of convenient design for permanent location, for example, in survey types of aircraft and which can be installed in an aircraft in any of several locations along the fuselage. Thus, it can readily be placed in a location not needed for any primary flight function of the vehicle and not requiring any extensive or awkward modification of the aircraft structure. It can be placed in a location such that the radiometer output is easily accessible to the radiometer operator.

In addition to the above convenience, the novel array antenna accommodates itself to employment in active or passive systems as a sensitive device for selectively producing uniformly shaped multiple reception or transmission patterns or for scanning such patterns without serious shape deterioration at large scan angles. Substantially complete collimation of the antenna patterns is afforded by the low-loss, wide band scanning or beam forming geodesic portion of the system in cooperation with the directive antenna array system.

While the invention has been described in its preferred embodiment, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departure from the true scope and spirit of the invention in its broader aspects.

I claim:

1. Apparatus having focal properties for collimation and transfer of high frequency energy comprising:
- spaced conducting wall means having nesting dome-shaped surfaces with a common axis of substantial symmetry and defining therebetween a geodesic energy propagation means,
- opposed parallel plate transmission line means in direct energy exchanging relation with said geodesic energy propagation means,
  - each said opposed parallel plate transmission line means having an arcuate open end remote from said geodesic energy propagation means,
- said geodesic energy propagation means, said parallel plate transmission line means, and said arcuate ends forming a composite energy propagation structure having a plane of substantial mirror symmetry,
- first transmission line means in energy exchanging relation at a first of said arcuate ends with said parallel plate transmission line means,
  - said first transmission line means comprising a plurality of hollow wave guide means each having an aperture located at said first of said arcuate ends and each having an axis of directivity at said ends substantially parallel to said plane of substantial mirror symmetry,
    - each said hollow wave guide means having contiguous walls tapered to a common ridge at said aperture, and
- second transmission line means in energy exchanging relation at a second of said arcuate ends with said parallel plate transmission line means.

2. Apparatus as described in claim 1 wherein said second transmission line means comprises a plurality of hollow wave guide means each having a flared aperture located at said second of said ends and each having an axis of directivity at said ends directed substantially to intersect said common axis of substantial symmetry of said geodesic energy propagation means.

3. Apparatus as described in claim 2 wherein one of said opposed parallel plate transmission line means contains, adjacent its arcuate end, grating means for modifying the plane of polarization of high frequency energy passing therethrough.

4. Apparatus having focal properties for collimation and transfer of high frequency energy comprising:

spaced conducting wall means having nesting dome-shaped surfaces with a common axis of substantial symmetry and defining therebetween a geodesic energy propagation means,

opposed parallel plate transmission line means in direct energy exchanging relation with said geodesic energy propagation means,

each said opposed parallel plate transmission line means having an arcuate open end remote from said geodesic energy propagation means and being further defined by wall means substantially perpendicular to said parallel plates for supporting high frequency energy absorbing material extending within said parallel plate transmission line means,

said geodesic energy propagation means, said parallel plate transmission line means, and said arcuate ends forming a composite energy propagation structure having a plane of substantial mirror symmetry,

first transmission line means in energy exchanging relation at a first of said arcuate ends with said parallel plate transmission line means, and

second transmission line means in energy exchanging relation at a second of said arcuate ends with said parallel plate transmission line means.

5. Apparatus having focal properties for collimation and transfer of high frequency energy comprising:

spaced conducting wall means having nesting dome-shaped surfaces with a common axis of substantial symmetry and defining therebetween a geodesic energy propagation means,

opposed parallel plate transmission line means in direct energy exchanging relation with said geodesic energy propagation means,

each said opposed parallel plate transmission line means having an arcuate open end remote from said geodesic energy propagation means,

said geodesic energy propagation means, said parallel plate transmission line means, and said arcuate ends forming a composite energy propagation structure having a plane of substantial mirror symmetry,

first transmission line means in energy exchanging relation at a first of said arcuate ends with said parallel plate transmission line means,

second transmission line means in energy exchanging relation at a second of said arcuate ends with said parallel plate transmission line means,

an array of transmission line antenna elements, said array having a contour matching that of said first arcuate end, and

means for individually connecting said transmission line antenna elements to said first transmission line means so dimensioned that the signal propagation paths from any of said antenna elements to said first arcuate end are substantially equal.

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