

May 27, 1958

M. J. EHRLICH ET AL
METHOD OF FEEDING AND SCANNING A CIRCULARLY
DISPOSED ANTENNA ARRAY

2,836,822

Filed Aug. 10, 1955

3 Sheets-Sheet 1

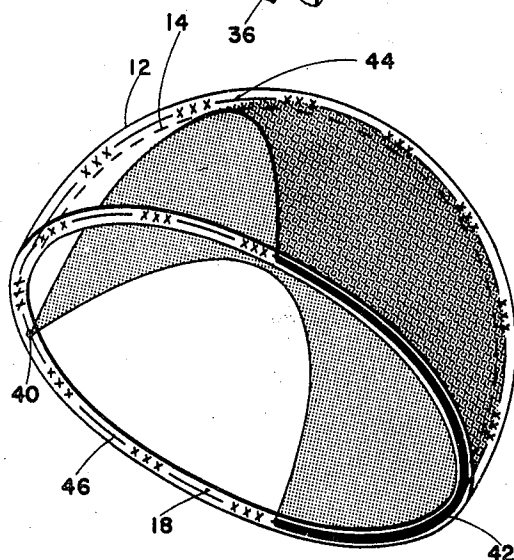
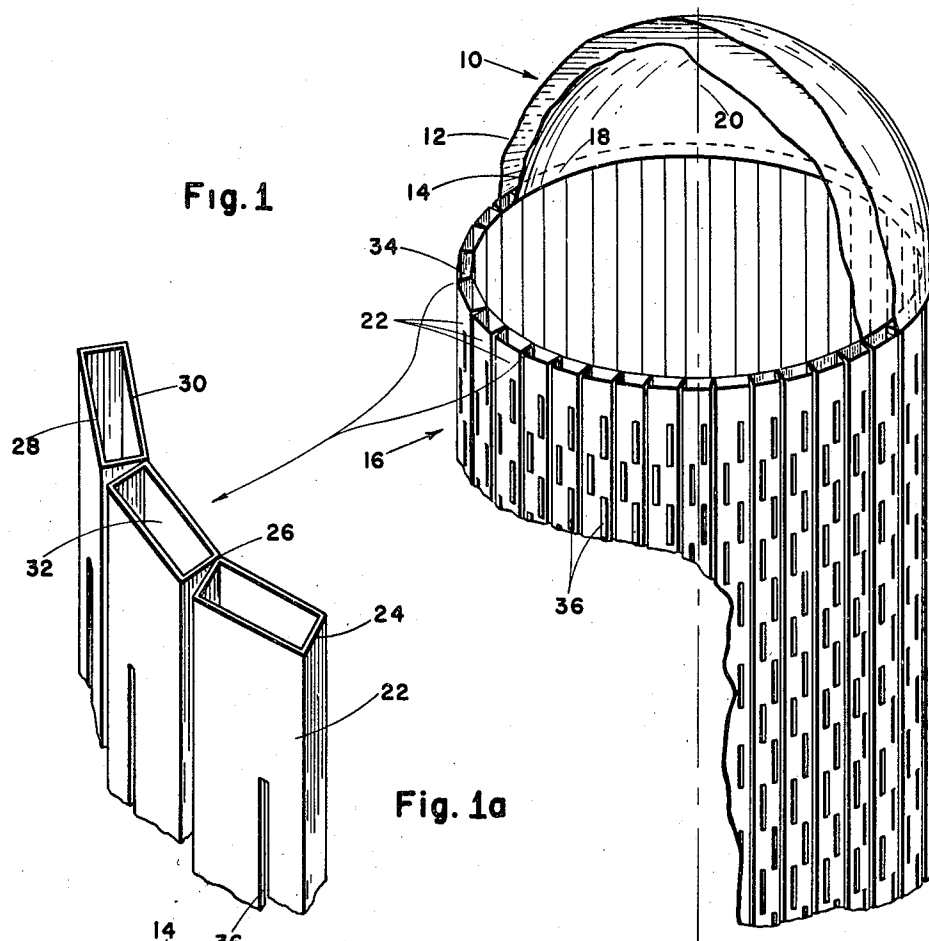


Fig. 2

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3 Sheets-Sheet 2

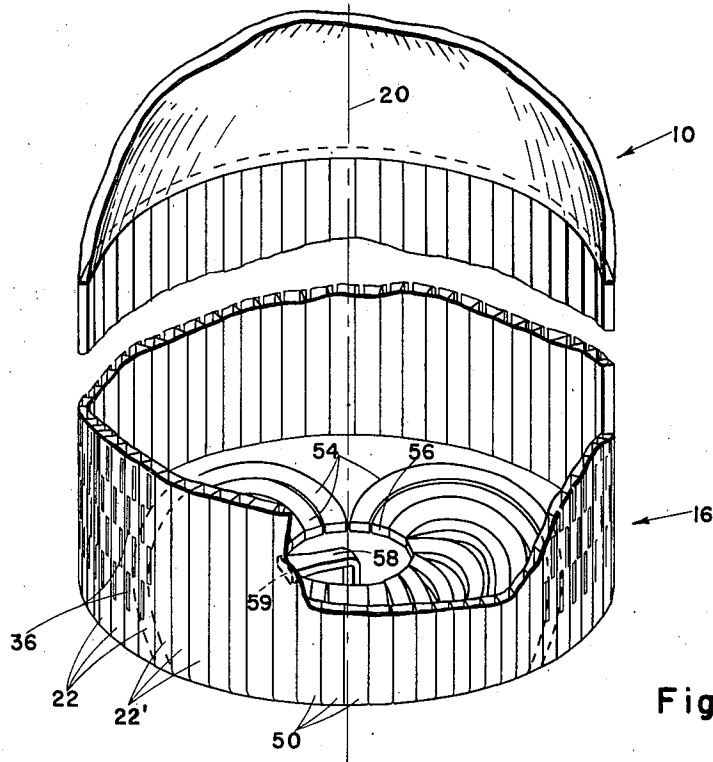


Fig. 3

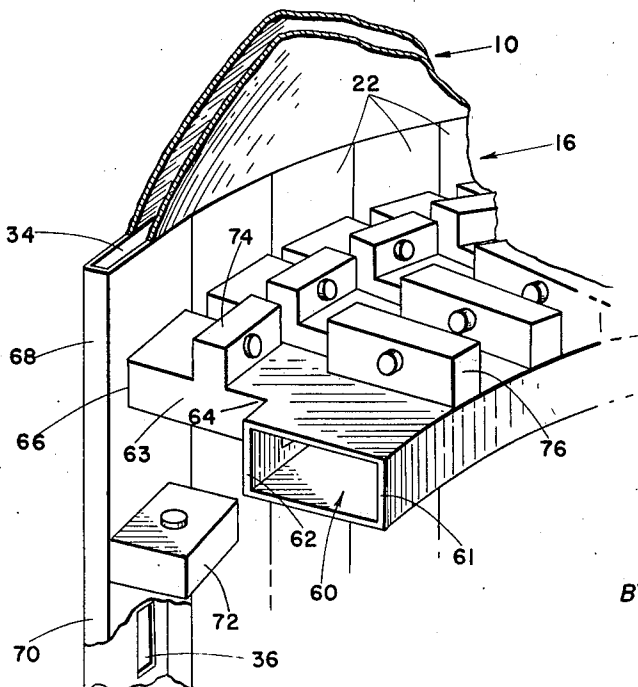


Fig. 4

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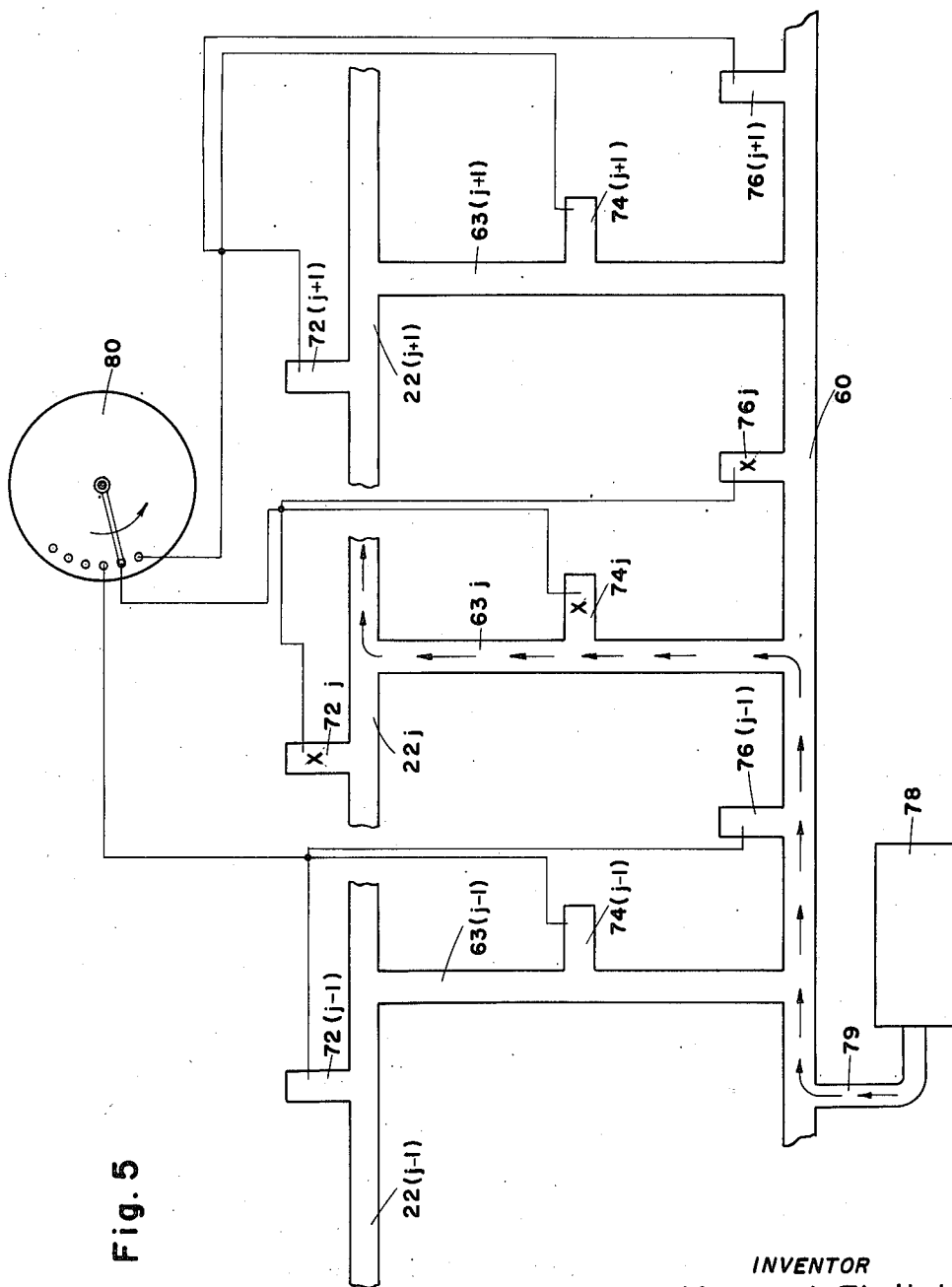


Fig. 5

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2,836,822

METHOD OF FEEDING AND SCANNING A CIRCULARLY DISPOSED ANTENNA ARRAY

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Application August 10, 1955, Serial No. 527,450

13 Claims. (Cl. 343—754)

This invention relates to antenna arrays, and particularly to antenna arrays providing a beam movable through a large arc.

In applications in which radar or other electromagnetic wave equipment is employed, it is often desired to scan with a fan or pencil beam through a wide angle or an entire circle.

With the stationary circularly disposed antenna arrays heretofore employed, it has been difficult to properly feed the array so as to obtain a narrow beam. The slope of the beam from such an array is determined by the relative phase and amplitude of the illumination contributed by each radiating aperture of the array. A desirable distribution of the illumination is a cophasal planar wave front the amplitude of which decreases from a central maximum along both sides. It has been difficult to provide a proper feed to obtain the desirable distribution of illumination in a manner which permits the scanning of the illumination through a large arc. More specifically, it has been difficult to provide the desirable distribution of illumination in a manner which permits the direction of the normal to the wave front to be readily changed.

It is therefore an object of this invention to provide an improved stationary circular antenna array capable of scanning a beam through all or part of 360 degrees.

It is a further object of this invention to provide an improved circular antenna capable of scanning an essentially cophasal planar wave front whose amplitude decreases on both sides of the normal to the wave front.

It is another object of this invention to provide an improved circular antenna array which can, more simply and efficiently than devices heretofore known, scan through a large arc with a relatively narrow beam.

An antenna array in accordance with the invention may utilize an array of circular cross section capped with a dome-shaped lens, in conjunction with a movable source, to scan a relatively narrow beam through a large arc. In one form the dome-shaped lens may comprise a set of coaxial conducting surfaces equidistantly spaced from a geodesic surface terminating in a geodesic circle forming the rim of the lens. Electromagnetic waves from a point source located on the geodesic circle are refracted over the dome of the lens and emerge as a line source from that part of the geodesic circle lying diametrically opposite to the point source. Each emerging wave in the line source has traversed the same path length, so that the lens provides an essentially cophasal line source parallel to the plane of the geodesic circle. The array of circular cross section acts as a refracting device which guides the emerging waves along a predetermined path to form the desired envelope. In one form the array may comprise a cylindrical arrangement of a number of parallel rectangular waveguides forming a cylindrical shell. The outer surface of the shell is provided with radiation apertures. Because the angle the emerging waves make with the normal to the lens is the same angle as made by the point source, the refraction

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into the cylindrical shell adjusts the amplitudes of the waves in the cylindrical envelope so that the illumination is greatest in the portions of the waveguides diametrically opposite to the point source and diminishes to zero at the diametric extreme of the semicylindrical envelope so formed. Any one of the guides may be used for supplying a point source input to the geodesic circle of the dome-shaped lens. The waves are refracted by passing over the dome and are fed to the guides on the opposite semicircumference. The outer surfaces of the waveguides contain radiating slots which radiate a narrow beam.

To scan the beam through an angle, the wave energy input is moved from one waveguide to the next in rapid succession. The scanning system may in one form employ a mechanical horn rotating within the cylinder defined by the rectangular waveguide. By relative movement between the feed member and the rectangular waveguides, individual ones of the waveguides may be selected for input in succession, thus providing an output scanning beam movable through an arc. Another scanning system may in one form use an auxiliary waveguide which is connected via fast acting switches to all the waveguides making up the cylindrical shell. By feeding this auxiliary guide and by programming the switches, energy is supplied to one waveguide at a time in rapid succession, resulting in an output beam movable through an arc.

Fig. 1 is a three-dimensional view of a cylindrical antenna array in accordance with this invention. Fig. 1A is a cut-out view of Fig. 1.

Fig. 2 is a three-dimensional view of a dome-shaped lens employed in practicing this invention.

Fig. 3 is a three-dimensional view of a cylindrical antenna array including an arrangement for effecting a 90-degree mechanical scan.

Fig. 4 is a fragmentary three-dimensional view of a portion of a feeding arrangement using electrically controlled microwave switches for obtaining 360-degree scanning of a cylindrical antenna array.

Fig. 5 is an illustrative diagram showing particulars of the feed and switch arrangement of the arrangement of Fig. 4.

An arrangement constructed in accordance with this invention, referring now to Fig. 1, may employ a dome-shaped lens 10 comprised of two coaxial conductive shells 12 and 14 which are conductively connected to a cylindrical array of waveguides 16. The medium separating the outer conductive shell 12 and the inner conductive shell 14 may be air, as shown, or any other uniform dielectric medium. Both of the shells 12 and 14 are surfaces of revolution and are spaced coaxial with and equidistant from one another. The shells 12 and 14 terminate in a peripheral feed aperture circle 18 which is the annular space between the rim of the outer and the inner shell and which lies in a plane transverse to the lens axis 20.

The cylindrical array 16 comprises a set of rectangular similar waveguides 22 arranged with one another to form a cylindrical shell having a circular cross section. The narrow sides 24 of the waveguides 22 abut one another along the edge 26 shown in the cut-out Fig. 1A, so that the broad faces 28 and 30 form the outer and inner surfaces, respectively, of the cylindrical array 16. The open ends 32 of the waveguides 22 lie in a plane transverse to the axis 20 of the cylindrical array. The center line 20 is the lens axis as well as the array axis. The opposite faces 28 and 30 of the waveguides 22 define a substantially annular space hereafter termed the aperture feed circle 34 of the cylindrical array 16. The aperture feed circle 34 is coextensive with the aperture feed circle 18 of the dome-shaped lens 10. The rectangular

waveguides 22 making up the cylindrical array 16 are provided with radiation elements such as the narrow slots 36 which are cut into the broad walls 28. The number of slots cut into each waveguide and the position of those slots with respect to one another determine the cross-sectional shape of the beam in a plane passing through the center line 20. Beam shaping by varying the geometric arrangement of apertures is well known to those skilled in the art.

In order to explain the factors which determine the geometry of the inner and outer shells 12 and 14, respectively, a brief description of the theory of operation of the lens is here provided.

The lens shown in Fig. 2 and made up of an outer shell 12 and an inner shell 14 is a device for converting a point source 40 located in the aperture feed circle 18 into a semicircular line source 42 in the plane of the aperture feed circle 18 and opposite the point source 40. The line source 42 so obtained is cophasal. It is this last mentioned property which determines the shape of the dome-shaped lens. To this end a geodesic surface 44 so constructed to be the mean surface of the lens and terminates in a geodesic circle 46 in the plane of the feed aperture circle 18. From the definition of a geodesic surface it follows that waves propagated from any point on the feed aperture circle along a path lying in the hypothetical surface to any other point on the feed circle along the geodesic and which thereafter are refracted into the plane of the feed circle emerge in phase with one another. These waves, when collimated, will form a plane wave front. The collimation is achieved by a refracting medium such as the cylindrical shell shown in Fig. 1. One type of lens which might be employed is the so-called Rinehart-Luneberg lens which achieves this focusing action by a variation in the physical path length as is done here. Such a lens is shown and described in an article entitled "A Solution of the Problem of Rapid Scanning for Radar Antennae," by R. F. Rinehart in the *Journal of Applied Physics*, vol. 19, September 1948, p. 860. Another type of lens which will produce a cophasal wave front from a point source is the Luneberg lens which accomplishes this result by a variation in the electrical path length by using a non-uniform dielectric medium.

In the operation of the cylindrical antenna array, referring again to Fig. 1, microwave energy is introduced into one of the rectangular waveguides 22 to be propagated toward the aperture feed circle 18 to form a close approximation of a point source. Methods of feeding are described below in connection with Figs. 3 and 4. The energy from the point source is distributed by the lens 10 so that the waveguides 22 lying on the opposite circumference of the cylindrical array 16 receive energy. The energy received by the waveguides 22 is cophasal. The cophasal wave front is propagated through the waveguides 22 and radiated by the apertures 36. The resulting pattern of radiation is essentially a plane wave front moving normal to the antenna axis. Because of the interaction between the radiating apertures, a narrow search beam is formed.

If the source point is moved by switching microwave energy from one waveguide 22 to an adjacent waveguide 22 the plane wave front changes direction correspondingly to be at all times diametrically opposite to the energizing waveguide 22.

Before the description of several feed switching systems, however, several other structures which may be employed for the refracting purpose of the cylindrical waveguide arrangement will be discussed. A particularly suitable refracting system is the set of waveguides arranged to form a cylinder as described in conjunction with Fig. 1. In another form the system might employ a hollow cylinder having a cross section equal to the feed aperture circle of the dome-shaped lens and providing partitions parallel to a generatrix of the cylinder,

the distance between the partitions being determined by the propagation characteristics of the energy to be radiated. In still another form the refracting medium might comprise a set of waveguides forming a cylinder as shown in Fig. 1, with each waveguide having a 90-degree axial twist at some point below the aperture feed circle of the antenna array. The radiation apertures in such an arrangement remain in the wall defining the outer surface of the array. In another arrangement the cylindrical form might be replaced by the frustum of a circular cone or by the frustum of a paraboloid.

To make the arrangement described in Fig. 1 a scanning circular antenna array, a feed switching system is provided which permits the rapid switching of the source point from one waveguide to the next. As described, such switching produces a scanning action of the plane wave front. The switching of the source point can be accomplished by mechanical or electrical means or a combination thereof. The proper choice of a switching mechanism will depend, as is well known to those skilled in the art, on the scan rate, the space requirements and the angle through which the beam is required to scan.

A feed switching system which mechanically switches the source point through a 90-degree circumferential section of the aperture feed circle of the refracting medium and thereby produces a 90-degree scan is shown in Fig. 3. In this feed switching system a first quarter of all the waveguides comprising the refracting medium are used exclusively for feeding the dome-shaped lens while the remainder of the waveguides receive their energy from the lens and serve exclusively as radiators. The waveguides serving only for feeding are not provided with radiation apertures.

Referring now to Fig. 3, a plurality of waveguides 22 lie in a 270-degree sector of the refracting medium and are provided with radiation apertures 36. As shown, the waveguides 22 do not include terminating members, but non-reflective terminations may be used if desired.

A plurality of feed waveguides 22' occupy the remaining 90-degree sector of the refracting medium and are not provided with radiation apertures. Each feed waveguide 22' includes a 90-degree waveguide bend 50 to which is coupled a curved waveguide portion 54 here called a branch feed waveguide. The remaining open ends of these branch feed waveguides 54 are arranged to form a branch feed circle 56. As can be seen from Fig. 3, the curvature of the branch feed waveguides 54 is determined by the geometry of the system. One end of each branch feed waveguide 54 is coupled to the 90-degree bend 50 and the other end defines a small segment of the branch feed circle 56. Therefore, the branch feed waveguides 54 extend the feed waveguides 22' to the branch feed circle 56 and lie in a plane and adjacent to one another.

A feed horn 58 having its aperture 59 in the plane of the branch feed circle 56 is rotatable about the axis of the branch feed circle 56. The feed horn 58 is operatively associated with the ends of the branch feed waveguides 54 lying in the branch feed circle 56, and supplies energy to the branch feed waveguides 56 in sequence, thereby moving the source point through a 90-degree sector of the refractive medium upon one revolution about its own axis. The scan rate of this feeding system is the same as the angular velocity of the horn and is therefore capable of wide ranges of adjustment. Note that instead of providing one 90-degree sector with microwave energy, two 45-degree sectors or three 30-degree sectors may similarly be employed.

A feed switching system which electronically switches the source point through the complete aperture feed circle of the refractive medium and thereby produces a 360-degree scan is shown in Fig. 4, together with the lens 10 and the cylindrical refracting medium 16. In this electronic feed switching system, all waveguides 22 comprising the refracting medium 16 are employed for

feeding the dome-shaped lens 10 at one instant and for feeding the radiators 36 at the next. Each waveguide 22 thereby serves a dual purpose, namely, to feed the lens and to feed the radiating aperture 36. All waveguides 22 are therefore provided with radiation apertures unlike the mechanical feed switching system of Fig. 3. In the electronic feed switching system shown, each waveguide 22 is divided into an upper portion 68 for feeding the dome-shaped lens 10 and a lower portion 70 and containing the radiation aperture 36. The lower portion 70 is separated from the upper portion by an array switch 72.

The electronic feed switching system as shown in Fig. 4 comprises essentially a main feed waveguide 60 forming a flat ring of rectangular cross section. The narrow faces 61 and 62 of the main feed waveguide 60 are the inner and the outer surfaces, respectively, of a cylinder. The branch feed waveguides 63, couple the waveguides 22 to the main feed waveguide 60. The coupling is an H-plane T-junction 64 between the branch feed waveguide 63 and the main feed waveguide 60, and an E-plane T-junction 66 between the branch feed waveguide 63 and the waveguide 22. The junction 66 defines the division of the waveguide 22 into its upper portion 68 and its lower portion 70. The array switch 72 in the waveguide 22 is normally open and provides a switch between the branch feed waveguide 63 and the radiation apertures 36. Located between each junction 64 and the junction 66 is a branch feed switch 74, normally open. The branch feed switch 74 presents, if open, an infinite impedance at both of the junctions 64 and 66 so that they effectively separate the main feed waveguide 60 from the waveguide 22. The main feed switch 76 is located inside the main feed waveguide 60 between adjacent branch feed waveguides 63 and is normally open to permit the unobstructed propagation of the wave energy through the main feed waveguide 60.

The three sets of switches 72, 74 and 76 comprising a set of array switches, a set of branch feed switches and a set of main feed switches, may be regarded as broken up into three new sets, each set comprising one array switch, one branch feed switch and one main feed switch associated with a particular waveguide 22. In this way, each waveguide 22 of the circular array 16 has associated with it an identical set of three switches.

The operation of the electronic feed switching system may be better understood by reference to Fig. 5. There shown is a transceiver unit 78 coupled to the main feed waveguide 60 by means of a waveguide 79 in the usual manner such as an E-plane T-junction or an H-plane T-junction and supplying wave energy to the antenna array. Fig. 5 also shows schematically three waveguides 22 each with its associated array switch 72, branch feed waveguide 63 and branch feed switch 74 and coupled to the main feed waveguide 60 with its associated switches 76. The three waveguides 22 are here for descriptive purposes identified as the $(j-1)$, (j) , and $(j+1)$ waveguides. The j th feed waveguide, namely, 22 (j) is chosen to act as the primary feed waveguide feeding energy to the lens 10. Then the waveguide 22 $(j-1)$, and the waveguide 22 $(j+1)$, respectively, are the two neighboring waveguides 22. The set of switches associated with 22 (j) are, respectively, 72 (j) , 74 (j) and 76 (j) . The switches associated with the neighboring waveguide 22 $(j+1)$ and 22 $(j-1)$ are similarly 72, 74 and 76 having the subscripts $(j+1)$ and $(j-1)$, respectively. An electronic commutator 80 sequentially energizes the sets of switches 72, 74, 76, so that only one set of switches receives energy from the commutator 80 at any particular time, during which time none of the other sets 72, 74, 76, is energized. The switches 72 (j) , 74 (j) , 76 (j) , associated with the j th waveguide 22 are shown energized in Fig. 5 (denoted by an X in the switch). Microwave energy from the main feed wave-

guide 60 is propagated along the guide 60 until the energy encounters the junction immediately preceding the main feed switch 76 (j) . The switch 76 (j) is positioned such that when energized it presents an infinite impedance at that junction, preventing further propagation of the energy along the main feed waveguide 60. At the same time, switch 74 $(j-1)$ is open and in this position presents an infinite impedance at both its extremities. Therefore, no energy is propagated along the branch feed waveguide 63 $(j-1)$. Branch feed switch 74 (j) , however, is energized, thereby removing the infinite impedance presented by the branch feed waveguide 63 (j) and permitting passage of the energy through branch feed waveguide 63 (j) into the upper portion of waveguide 22 (j) . Waveguide 22 (j) terminates at the feed aperture circle 18 of the lens 10 and feeds energy as a point source to the lens 10. The array switch 72 (j) also is energized and is positioned to present an infinite impedance at the junction of the branch feed waveguide 63 (j) and the lower portion of waveguide 22 (j) . Thus, the array switch 72 (j) diverts all of the energy to the aperture feed circle 18.

The waveguides 22 located on the diametrically opposite semicircumference to waveguide 22 (j) will now act as radiating elements. The branch feed switches 74 of the waveguides acting as radiators are not energized and are positioned so that they present an infinite impedance at the junction made by branch feed waveguides 63 with the waveguides 22. Therefore, the energy received by waveguide 22 from the lens 10 cannot enter the branch feed waveguides 63 and the total energy is directed to encounter the radiation apertures 36. Also, the array switches 72 which are normally not energized, are positioned so that, unless energized, they permit the unobstructed passage of microwaves from the upper portion of the waveguides 22 to the lower portions containing the radiation apertures 36.

The above description of the preferred embodiment of the electronic feed switching system is but representative of the invention and is not to be interpreted in a limiting sense, since many possible modifications of this feed switching system may be made within the scope of the appended claims. The switches described can be AT switches or ATR switches or other microwave switches. The commutator referred to as performing the sequencing operation of energized sets of switches may be replaced by an electric scanning programmer incorporating a primary electron beam switch tube. Furthermore, by means of convenient auxiliary programming units, it is possible to accomplish the scanning of the microwave beam through one or more sectors of all or part of 360 degrees.

What is claimed is:

1. An antenna array comprising: a lens composed of two conducting shells defining a figure of revolution about the lens axis, the opposite surfaces of said shells being equispaced from the mean geodesic surface of said lens; two coaxial conducting cylinders forming a cylindrical shell, each cylinder being coupled to a different one of the shells of said lens and forming a coaxial system therewith, the outer surface of said cylindrical shell including a plurality of radiating apertures and separation members forming equispaced radial septa and dividing said cylindrical shell into longitudinal waveguides conducting wave energy along said cylindrical shell in a direction parallel to the axis of said system, and wave energy feed means coupled to said waveguides.

2. An antenna array comprising: a plurality of waveguides disposed substantially parallel to one another and together defining a cylindrical shell, said waveguides having radiation apertures disposed along the outer wall of said cylindrical shell; a dome-shaped lens having a rim coupled to said cylindrical shell at one end thereof, and forming a cap thereon, said lens refracting wave energy over the dome of said lens, and feed means coupled to said antenna array and adapted to provide a point source

of wave energy at said rim, whereby wave energy from said point source is dispersed into a substantially semicircular line source diametrically opposite to said point source.

3. An antenna array comprising: a plurality of waveguides disposed parallel to one another and together defining a cylindrical shell, said waveguides having radiation apertures disposed along the outer wall of said cylindrical shell; a dome-shaped lens having an aperture feed circle, the aperture feed circle of said lens being coupled to a first end of said cylindrical shell and in registry with the waveguides defining said shell, and feed means coupled to said antenna array to provide a point source of wave energy at said aperture feed circle, said lens converting said point source into a semicylindrical cophasal line source diametrically opposite to said point source on said aperture feed circle.

4. An antenna array comprising: a plurality of waveguides disposed parallel to one another and together defining a cylindrical shell, at least some of said waveguides having radiation apertures disposed along the outer wall of said cylindrical shell; a dome-shaped lens having an aperture feed circle, the aperture feed circle of said lens being coupled to one end of said cylindrical shell and in registry with the waveguides defining said shell, said lens converting a point source of electromagnetic energy on its aperture feed circle into a semicylindrical cophasal line source diametrically opposite to said point source on said aperture feed circle; and means coupled to said cylindrical shell for energizing individual ones of said waveguides with input energy in sequence.

5. An antenna array comprising: a plurality of parallel waveguides defining a cylindrical shell, at least some of said waveguides having radiation apertures disposed along the outer wall of said cylindrical shell; a dome-shaped lens coupled to and forming a cap on one end of said shell, said lens, in response to input energy from any one waveguide at the coupling to said cylindrical shell, feeding a section of said waveguides diametrically opposed to the input waveguide; and means coupled to said cylindrical shell for energizing in sequence individual ones of said waveguides.

6. A cylindrical antenna array comprising: a plurality of identical waveguides disposed parallel to one another to form a shell of circular cross section, said waveguides having radiation apertures disposed along the outer wall of said shell, said shell having an input end and an output end, a dome-shaped lens being formed by an inner and an outer surface of revolution, said surfaces being coaxial and equispaced from one another, the distance between said inner and said outer surface being such as to support the propagation of the dominant mode of electromagnetic energy to be radiated by said array, the termination of said lens lying in a plane perpendicular to the axis of said surface of revolution, said lens being connected to said output end of said shell portion to form a cap coaxial therewith; and means connected to said input end of said cylindrical portion for energizing said waveguides with wave energy progressively.

7. A cylindrical antenna array comprising: a plurality of rectangular waveguides disposed coextensively and parallel to one another to form a cylindrical shell portion, at least some of said waveguides having radiation apertures in the outer wall of said shell portion, said shell portion having an input end and an output end, a dome-shaped lens being formed by an inner and an outer surface of revolution, said surfaces being coaxial and equispaced from one another, the distance between said inner and said outer surfaces being substantially equal to the wall thickness of said cylindrical portion, the termination of said lens lying in a plane perpendicular to the axis of said surface of revolution and forming two concentric rings equal in diameter to the cross section of said cylindrical shell portion, said lens being connected to said output end of said cylindrical shell portion to form

a cap coaxial therewith, and means connected to said input end of said cylindrical portion for switching wave energy progressively into adjacent, individual ones of said waveguides.

8. A cylindrical antenna array comprising: a plurality of waveguides disposed coextensively and parallel to one another to form a cylindrical shell, at least some of said waveguides having radiation apertures in the outer wall of said cylindrical shell, said cylindrical shell having an input and an output section; means for successively switching microwave energy from any one of said waveguides to the adjacent waveguide, said means being electrically coupled to the input section of said cylindrical shell; and distribution means connected to the output section of said cylindrical shell, said distribution means providing a refraction path along a geodesic surface with the output section of said cylindrical shell defining the geodesic circle, such that wave energy supplied by said switching means to one of said waveguides is dispersed and distributed as a cophasal line source to the waveguides comprising a sector of said cylindrical shell lying diametrically opposite to the such waveguide.

9. An antenna array comprising: a cylindrical shell defined by a plurality of parallel rectangular waveguides, at least some of said waveguides having apertures in the surfaces defining the outside of said cylindrical shell; a convex microwave lens, the base of which is in registry with and electrically coupled to an end of said cylindrical shell; said lens dispersing energy from a concentrated source on the base of said lens to an extended source on the diametrically opposed part of the base by refraction between the lens surfaces; coupling means connected to said cylindrical shell for providing a concentrated source at any of a plurality of points on said base when energized; and input energy feed means for selectively energizing said coupling means.

10. A cylindrical antenna array for scanning a beam through an angular sector comprising: a plurality of identical rectangular waveguides grouped into an energizing sector and a radiating sector, and together forming a cylindrical shell, said energizing sector being equal in angular magnitude and oppositely disposed to the angular sector through which the beam scans, the waveguides of said radiating sector having radiation apertures in the outer surface of said cylindrical shell, said cylindrical shell having an input end and an output end, a dome-shaped lens comprising two conducting cap members defining inner and outer surfaces of revolution, said surfaces being coaxial and equispaced from one another, the distance between said inner and said outer surfaces being substantially equal to the wall thickness of said cylindrical portion, the termination of said lens forming two concentric rings equal in diameter to the cross section of said shell, and being conductively coupled to the output end of said cylinder shell to form a cap coaxial therewith; a set of feed waveguides, each having an input and an output end, each of the output ends of said feed waveguides being coupled to a different one of the waveguides making up the energizing sector of said cylindrical shell, the input ends of said waveguides being arranged about the periphery of a feed circle; and a feed horn rotatably mounted about the feed circle axis, said horn being operatively associated with said input ends of said feed waveguides, whereby energy from the horn is fed successively on rotation of said horn to individual ones of said feed waveguides.

11. A cylindrical antenna array comprising: a plurality of identical rectangular waveguides disposed coextensively and parallel to one another to form a cylindrical shell, said waveguides having radiation apertures in the outer wall of said cylindrical shell, said cylindrical shell having an input end and an output end, a dome-shaped lens being formed by an inner and an outer surface of revolution, said surfaces being coaxial and equispaced from one another, the distance between said

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inner and said outer surfaces being substantially equal to the wall thickness of said cylindrical shell portion, the termination of said lens lying in a plane perpendicular to the axis of said surface of revolution and forming two concentric rings equal in diameter to the mean outer and the mean inner diameter of said cylindrical portion, said lens being connected to said output end of said cylindrical portion to form a cap coaxial with said cylindrical portion, and electronic switch coupled to said input end for switching wave energy progressively from one of said waveguides to the next.

12. A cylindrical antenna array for electronically scanning a narrow microwave beam through 360 degrees comprising: a plurality of rectangular array waveguides grouped together parallel to one another to form a cylindrical shell, said cylindrical shell having a radiation portion and a feeding portion disposed along the longitudinal axis thereof, radiation apertures contained in the outer surface of the radiation portion of said shell; a dome-shaped lens comprising two conducting cap members defining inner and outer surfaces of revolution, said surfaces being coaxial and equispaced from one another, the distance between said inner and said outer surfaces being substantially equal to the wall thickness of said cylindrical portion, the termination of said lens forming two concentric rings equal in diameter to the cross section of said shell, and being conductively coupled to the feeding portion of said cylindrical shell to form a cap coaxial therewith; a continuous main feed waveguide; a set of branch feed waveguides, each of said branch feed waveguides connecting said main feed waveguide to a different one of said array waveguides and defining the separation of the shell into said radiation portion and said feeding portion; a first set of electronic microwave switches coupled to a different one of said array waveguides at a point between said radiation apertures and the junction with said branch feed guides; a second set of electronic microwave switches each coupled to a different one of said branch feed waveguides; a third set of electronic microwave switches coupled to said main feed waveguide between the junctions made by a different adjacent pair of said branch feed waveguides with said main feed waveguide, and means coupled to said switches for energizing said electronic microwave switches in a predetermined manner.

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13. A cylindrical antenna array for electronically scanning a narrow microwave beam through 360 degrees comprising: a plurality of rectangular array waveguides grouped together parallel to one another to form a cylindrical shell, said cylindrical shell having a radiation portion and a feeding portion disposed along the longitudinal axis thereof, radiation apertures contained in the outer surface of the radiation portion of said shell; a dome-shaped lens comprising two conducting cap members defining inner and outer surfaces of revolution, said surfaces being coaxial and equispaced from one another, the distance between said inner and said outer surfaces being substantially equal to the wall thickness of said cylindrical portion, the termination of said lens forming two concentric rings equal in diameter to the cross section of said shell, and being conductively coupled to the feeding portion of said cylindrical shell to form a cap coaxial therewith; a continuous main feed waveguide; a set of branch feed waveguides, each of said branch feed waveguides connecting said main feed waveguide to a different one of said array waveguides and defining the separation of the shell into said radiation portion and said feeding portion; a first set of electronic microwave switches coupled to a different one of said array waveguides and positioned between said radiation apertures and the junction with said branch feed guides, said first set of switches in the normal state permitting energy propagation through said array waveguides; a second set of electronic microwave switches each coupled to a different one of said branch feed waveguides, said second set of switches in the normal state offering an open circuit to energy propagated through said array waveguide and through said main feed waveguide; a third set of electronic microwave switches coupled to said main feed waveguides between the junctions made by a different adjacent pair of said branch feed waveguides with said main feed waveguide, said third set of switches in the normal state permitting the propagation of microwave through said main feed waveguide; and commutator means coupled to said switches for energizing said electronic microwave switches in a predetermined manner.

No references cited.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,836,822

May 27, 1958

Morris J. Ehrlich et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 22, for "so constructed" read -- is constructed --;
line 45, for "antenan" read -- antenna --; line 53, for "circumeference"
read -- circumference --; column 8, line 55, for "cylinder" read
"cylindrical --; column 10, line 34, for "waveguides" read -- waveguide --.

Signed and sealed this 22nd day of July 1958.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents