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CONICAL SCANNING ANTENNA

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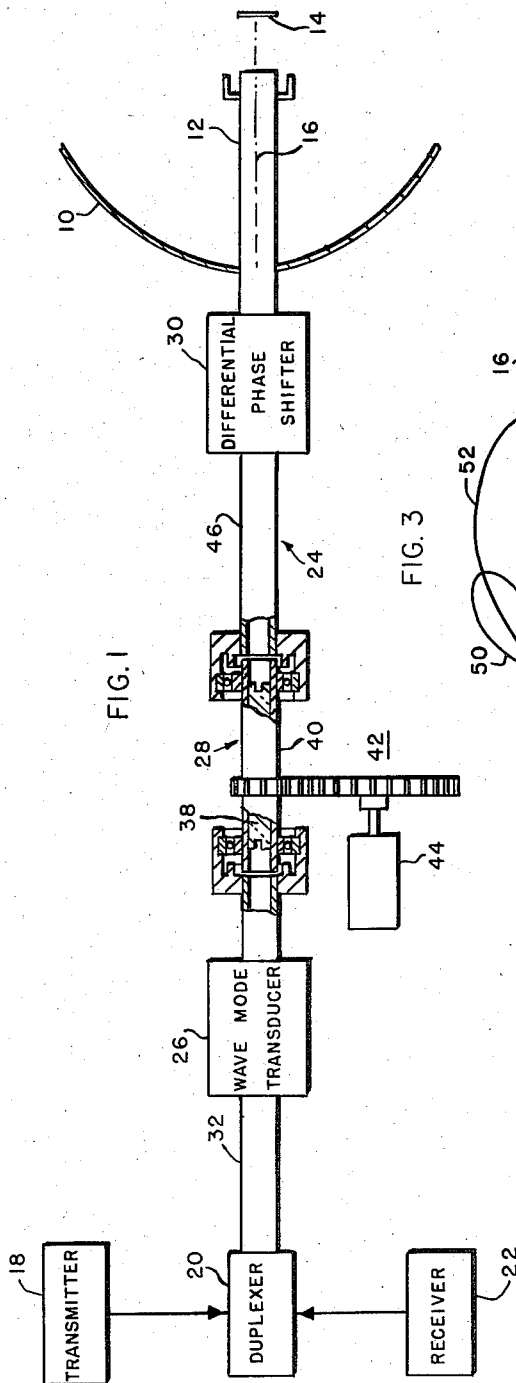


FIG. 1

FIG. 3

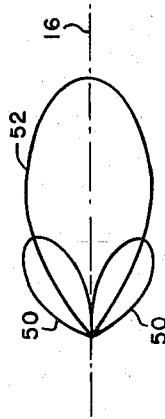


FIG. 4

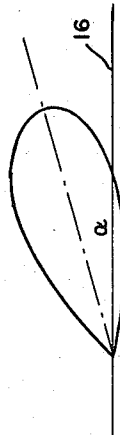


FIG. 5

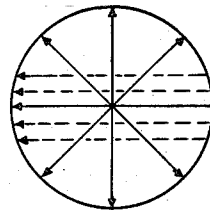


FIG. 2

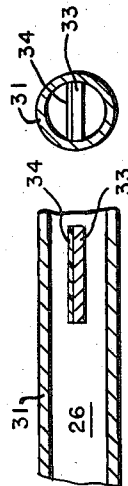
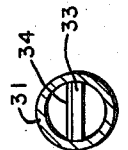


FIG. 2a



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CONICAL SCANNING ANTENNA

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5 Claims. (Cl. 343—756)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

This invention relates to directional microwave antenna systems and more particularly to an antenna system having physical symmetry about an axis but productive of a radiation beam with the direction of maximum radiation at a definite angle with the axis so that when the beam is rotated a conical-shaped scanning will result.

In directional radio systems for locating objects it is important to cause the direction of maximum antenna response to be shifted so as to scan a solid angle or a cone of space. Heretofore, such a conical scanning pattern was achieved by asymmetrically rotating a portion of the antenna structure. One prior art method of conical scanning by mechanical means consists of placing some obstacle in the path of radiation, such as a disc, and rotating the radiating element which has been eccentrically displaced from the axis of the system. Another means utilizes a stationary radiating element with a reflector, such as a paraboloid rotating eccentrically about the radiator. Due to the substantial weight of the antenna structure, such devices must necessarily operate at relatively low rotational speeds and usually require complicated balancing arrangements.

It is therefore an object of the present invention to provide an antenna system productive of a conical-shaped radiation pattern overcoming these limitations.

It is another object of the present invention to provide an antenna system for cooperation with a parabolic reflector for the formation of highly directional conical-shaped radiation pattern.

An additional object is to provide a conical scan with rotating polarization from a duo-mode feed which is mechanically centered on the axis of the antenna structure.

In accordance with the present invention there is provided an antenna structure for producing a narrow beam directive radiation characteristic and for rotating the beam to describe a conical scanning path about the axis of the structure, the axis of the radiation characteristic having a chosen angle relative to the direction axis of the antenna structure. Included in the antenna structure is a wave energy radiation source comprising a circular waveguide axially aligned with the axis of the antenna structure and adapted to propagate wave energy simultaneously in the $TE_{1,1}$ and $TM_{0,1}$ modes. Means having physical symmetry with the axis of the antenna structure are provided for supplying wave energy in both modes to the radiation source and for producing amounts of wave energy in each of the modes in relative amplitude and phase to determine the chosen angle. Also included are means for rotating the plane of polarization of only the $TE_{1,1}$ mode.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing in which:

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Figure 1 shows, partly in section, a typical embodiment of this invention as employed in a radar system;

Figures 2 and 2A illustrate a typical wave mode transducer employed in Figure 1, and

Figures 3-5 are explanatory diagrams.

Referring now to Figure 1 of the drawing, there is shown at 10 a parabolic reflector which is illuminated by a rear feed arrangement, hereinafter referred to as the radiation source, comprising a circular waveguide 12 terminated at the focus of the parabolic reflector and axially aligned with the axis 16 of the parabolic reflector, and a primary reflector 14. For the purpose of this invention, the axis 16 of parabolic reflector 10 is considered to be the axis of the antenna structure. The radiation source is coupled to a radio transmitting and receiving system, the components of which are shown at 18, 20, and 22, by means of a wave energy feed element 24 which includes a wave energy mode transducer or converter 26, a polarization rotating member 28, and a differential phase shifter 30, all interconnected by portions of cylindrical waveguides axially aligned with parabolic axis 16. As shown in Figure 1, the wave energy output of duplexer 20 is coupled to transducer 26 through waveguide 32 adapted to propagate wave energy in the $TE_{1,1}$ mode which is assumed to be the wave energy mode of transmission. For purposes of illustration it will be assumed hereinafter that the antenna system is to be used for transmission although the same analysis will apply to reception. Transducer 26 is adapted to convert the input $TE_{1,1}$ wave energy mode to a duo-mode wave energy output comprising both the $TE_{1,1}$ and $TM_{0,1}$ modes. Such transducers or converters are well known in the art and one preferred type is illustrated in detail in Figure 2. As shown, the transducer 26 consists of a portion of cylindrical waveguide 31 provided with an axially positioned metal fin 33 diametrically disposed in waveguide 31 and positioned so that it is perpendicular to the electric lines of the incoming $TE_{1,1}$ wave energy mode. Superimposed on metallic fin 33 is a dielectric slab 34 of predetermined length and thickness. The metal fin 33 divides the $TE_{1,1}$ mode wave energy field in two and the dielectric slab 34 serves to slow down one-half the field so that it appears out of time phase with the remaining half of the field at the output end of transducer 26 thus generating the duo-mode wave energy comprising the $TE_{1,1}$ and $TM_{0,1}$ modes. The thickness and length of the dielectric slab 34 determine the relative amplitudes of the duo-mode wave energy outputs. The duo-mode output from transducer 26 is applied to polarization rotating member 28 which consists essentially of a dielectric plate 38 mounted in an axially rotatable section 40 of cylindrical waveguide such that rotation of plate 38 has the effect of rotating the plane of polarization of only the $TE_{1,1}$ mode through an angle equal to twice the angle between the plane of polarization and the orientation of plate 38. In the arrangement shown in Figure 1 rotation is accomplished by means of meshed gears 42 and drive motor 44. This type of polarization rotator is well known and is described in detail in United States Patent No. 2,607,849, issued August 19, 1952. It is to be understood, of course, that any other suitable device may be used to rotate the plane of polarization of only the $TE_{1,1}$ mode through 360 degrees.

The duo-mode output from polarization rotator 28 is applied to waveguide 12 of the radiation source through differential phase shifter 30 which is adapted to shift the phase of the $TM_{0,1}$ wave energy mode with respect to the $TE_{1,1}$ wave energy mode such that the wave energy modes are in quadrature phase relationship at the radiation source. Phase shifter 30 may comprise an appropriate length of waveguide 46 or any other suitable well known phase shifter. To further control the amplitude and phase of the $TM_{0,1}$ mode a radio frequency choke

is mounted on waveguide 12. Phase shifter 30 is necessary because of the well known phenomenon that, upon radiation, the beam radiated by the $TM_{0,1}$ wave energy mode undergoes a 90-degree differential phase shift with respect to beam radiated by the $TE_{1,1}$ mode. This relationship is apparent from the equations presented on pages 337 and 338 of volume 12, "Microwave Antenna Theory and Design" of the Massachusetts Institute of Technology Radiation Series (1949). Hence, the quadrature relationship of the modes at the radiation source achieved by phase shifter 30 will cause the beams from the two modes to combine in space to form a resultant beam which is lobed in the E plane of the $TE_{1,1}$ mode. The lobing results from the well known phenomena that while the $TE_{1,1}$ mode has even symmetry about a central vertical plane, the $TM_{0,1}$ mode has odd symmetry about a central vertical plane, so that the $TM_{0,1}$ mode actually comprises two lobes which are 180° out of phase. If one $TM_{0,1}$ lobe is considered positive, the other $TM_{0,1}$ lobe is negative. This result is apparent from Equation 13 on page 338 of the above-mentioned volume 12 of the MIT Radiation Series. These positive and negative $TM_{0,1}$ lobes will either add to or subtract from the $TE_{1,1}$ mode to provide the conical scan lobing pattern.

To better understand the operation of my invention, reference is made to Figures 3-5. In Figure 3 there is shown at 50 and 52, the beam lobes generated by the $TM_{0,1}$ mode and $TE_{1,1}$ mode respectively. It is to be assumed that both lobes are in space phase and that the magnitudes of the outputs of both modes is such that the axis of the resultant lobe is displaced from the axis 16 of the antenna structure by a predetermined angle α as shown in Figure 4. In Figure 5, the E vectors of the $TE_{1,1}$ mode are represented by the dotted lines and the E vectors of the $TM_{0,1}$ mode are represented by the solid lines. As the polarization of lobe 52 is rotated by means of polarization rotating member 28, the vectors of the $TE_{1,1}$ mode will add with the positive and negative vectors of lobe 50 to produce a conical scan.

While there have been described what is at present considered to be the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In combination with an antenna structure having a parabolic reflector and a wave energy radiation source at the focus of said reflector for producing a narrow beam directive radiation characteristic of prescribed beam width, means for rotating said characteristic to describe a conical scanning path about the axis of said parabola comprising a circular waveguide coupled to said radiation source and adapted to propagate wave energy simultaneously in the $TE_{1,1}$ and $TM_{0,1}$ wave energy modes,

means for producing a relative phase difference of 90 degrees between said modes at said radiation source whereby said wave energy modes are in space phase relationship, and means for rotating the plane of polarization of only the wave energy of the $TE_{1,1}$ mode whereby the beam formed by said $TM_{0,1}$ wave energy combines in space with said rotated beam to form said conical scanning path.

2. In combination with an electromagnetic transmission system adapted to generate wave energy in the $TE_{1,1}$ mode, an antenna structure for producing a narrow beam directive radiation characteristic, the axis of said characteristic having a prescribed angle relative to the axis of said structure, comprising means for converting said $TE_{1,1}$ mode wave energy to duo-mode wave energy including both the $TE_{1,1}$ and $TM_{0,1}$ modes, means for simultaneously propagating wave energy in said $TE_{1,1}$ and $TM_{0,1}$ modes, a wave energy radiation source coupled to said propagating means, means for producing a relative phase difference of 90 degrees between said wave energy modes at said radiation source whereby said modes are in space phase relationship, and means for rotating the plane of polarization of only the wave energy of the $TE_{1,1}$ mode whereby the beam formed by said $TM_{0,1}$ wave energy combines in space with said rotated beam to rotate said radiation characteristic in a conical path about said axis.

3. In combination, a source of $TE_{1,1}$ mode wave energy, a parabolic reflector having a source of radiation at its focus, a wave energy feed element interconnecting said wave energy source and said radiation source, said feed element comprising means for converting said $TE_{1,1}$ mode wave energy to wave energy including both said $TE_{1,1}$ wave energy mode and a $TM_{0,1}$ wave energy mode, means for producing a relative phase difference of 90 degrees between said wave energy modes at said source whereby the two wave energy modes are in space phase relationship, and means for rotating the plane of polarization of only the wave energy of said $TE_{1,1}$ mode whereby the beam formed by said $TM_{0,1}$ wave energy combines in space with said rotated $TE_{1,1}$ beam to produce a directive radiation characteristic describing a conical path about the axis of the parabolic reflector.

4. The combination in accordance with claim 3 wherein said radiation source and said reflector are stationary.

5. The antenna structure in accordance with claim 3 wherein the wave energy radiation source and the reflector are non-rotatable and stationary.

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