March 17, 1959 J. L. BUTLER 2,878,471

SCANNING MEANS FOR CONICAL ANTENNA BEAM

Filed Feb. 25, 1955 2 Sheets-Sheet 1

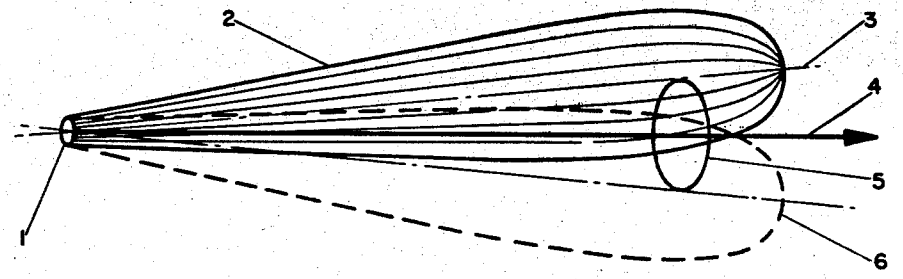


Fig. 1

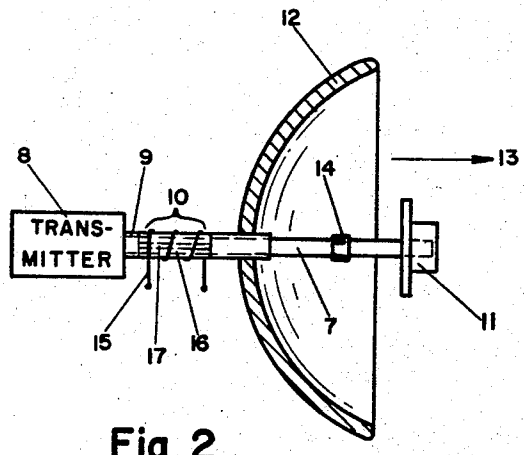


Fig. 2

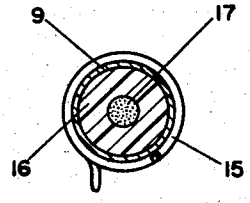


Fig. 3

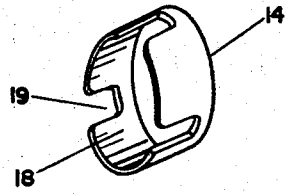


Fig. 4

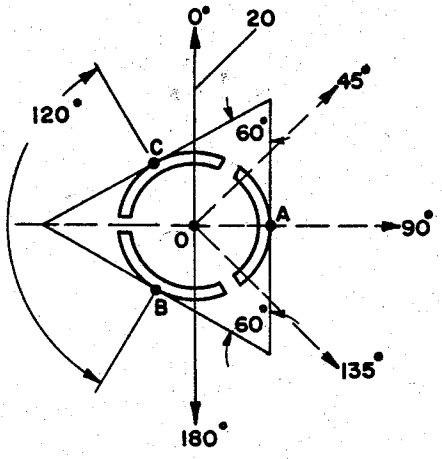


Fig. 5

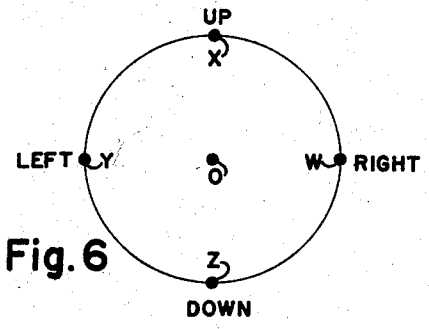


Fig. 6

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March 17, 1959 J. L. BUTLER 2,878,471

SCANNING MEANS FOR CONICAL ANTENNA BEAM

Filed Feb. 25, 1955

2 Sheets-Sheet 2

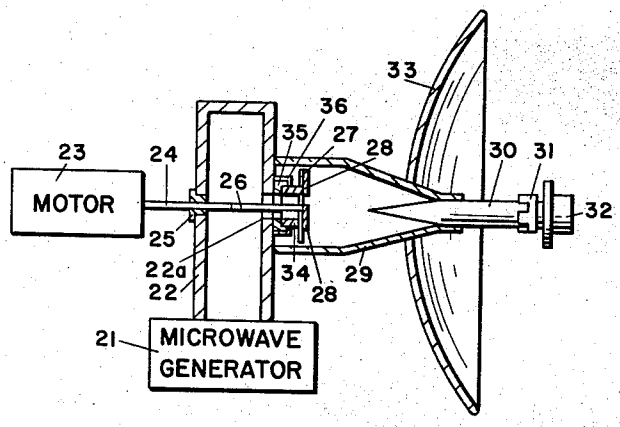


Fig. 7

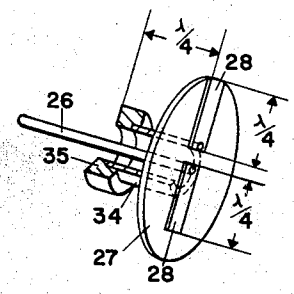


Fig. 8

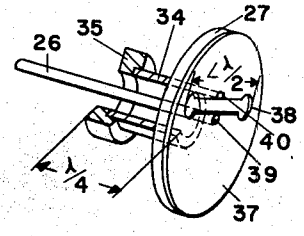


Fig. 9

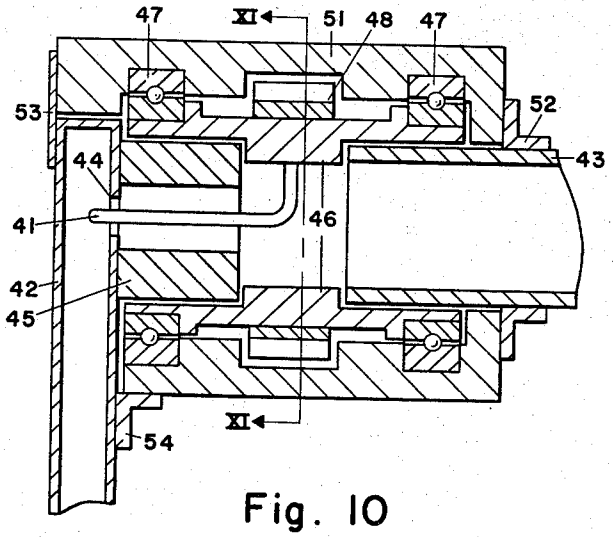


Fig. 10

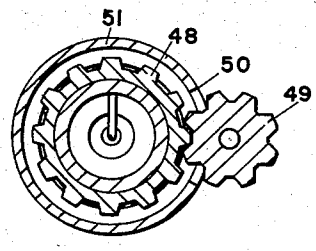


Fig. 11

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United States Patent Office 2,878,471
Patented Mar. 17, 1959

2,878,471

CONICAL SCANNING MEANS FOR ANTENNA BEAM

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Application February 25, 1955, Serial No. 490,649

9 Claims. (Cl. 343—763)

The present invention relates to the art of radiating electromagnetic energy. More particularly, this invention relates to conical scanning systems, such as are used for the directive radiation and reception of high frequency electromagnetic energy in certain systems of radar and guidance control.

In the prior art, various systems have been proposed for developing a conical beam of electromagnetic energy by causing the beam to rotate about the axis of the antenna system. This type of beam rotation is generally known in the art as "conical scanning." It is to be distinguished from the azimuth and elevation scanning functions of the system as a whole.

Conical scanning systems, as employed in the prior art, are characterized by the use of essentially mechanical rotational systems. The rate of conical scanning which is required, in contemplated modern radar techniques, is unattainable by such mechanical systems. A further disadvantage of prior art systems involves their construction techniques which cause shadows in the path of the radiated beam.

This application is a continuation-in-part of my copending application for Letters Patent, Serial Number 432,740, filed May 27, 1954. This continuation-in-part application differs from the earlier filed case primarily in using a rotating radiating element to provide a similar result.

It is, therefore, an object of the invention to provide an improved conical scanning antenna system capable of conical scanning at twice the rate of rotation of input plane-polarized energy.

It is a further object of the present invention to provide an improved ultra high speed conical scanning antenna system.

Other and further objects of the present invention will be apparent from the following description of typical embodiments thereof, taken in connection with the accompanying drawings.

In accordance with the invention, there is provided an antenna system. The system includes a source of electromagnetic energy and a transmission line means including a rotatable radiating element. The transmission line means is connected to the source of electromagnetic energy. Means are provided for rotating the radiating element to effect transmission of the energy with rotation of its electric vector synchronously with the radiating element. The radiating member is provided, having a plurality of polarity-sensitive radiating elements with their centers so disposed to cause the center of rotation to rotate about an axis in response to the energy characterized by the rotating electric vector. Means are provided for directing the rotating vector energy to the radiating elements to provide a conically scanning beam at a scanning frequency higher than the rate of rotation of the rotatable radiating element.

The reflector consists of an electrically conductive reflecting means in the form of a paraboloid. The primary radiator is mounted axially and connected through

the center of the paraboloid. The primary radiator comprises a nonconductive rod forming a dielectric radiator along the surface of which and through which are propagated the energy waves. An electrically conductive tube surrounds part of the rod adjacent one end thereof and provides a guide for the energy wave. Adjacent the opposite end of the rod a reflector is provided having a conductive surface perpendicular to and surrounding the rod. A cylindrical portion at the center of the perpendicular surface surrounds the end of the rod. An annular radiating member is carried by the rod adjacent the perpendicular surface and disposed substantially at the focus point of the paraboloid. The member comprises three radiating elements having their centers radially disposed substantially 120 degrees apart.

The novel antenna system disclosed in this specification is related to systems disclosed in concurrent applications 430,924 and 432,740 by the same inventor. The application 430,924 is directed, in general, to an antenna system utilizing a novel annular radiator. The present application is directed, in general, to an antenna system in which the electric vector of the electromagnetic energy is rotated with respect to a stationary annular radiator by means of a rotating antenna element. The application 432,740 is, in general, directed to the broad concept of obtaining high-speed scanning by utilizing a rotating electric vector in combination with a three element radiating member and, in particular, to the combination of an electromagnetic gyrator to effect rotation of the electric vector with respect to the annular radiator.

In the accompanying drawings:

Fig. 1 is a schematic diagram illustrating conical scanning as provided by the present invention;

Fig. 2 is a side view, partly in section, of a preferred embodiment of the present invention;

Fig. 3 is a cross-sectional vew of the gyrator in Fig. 2 taken at its center;

Fig. 4 is an enlarged, detailed perspective view of a radiating member as used in the embodiment of Fig. 2;

Fig. 5 is a schematic diagram illustrating the operation of the invention;

Fig. 6 is a graph illustrating the operation of the invention;

Fig. 7 is a side view, partly in section and partly enlarged, of another embodiment of the invention;

Fig. 8 is an enlarged isometric view, partly in section, of a detail of the embodiment of Fig. 7;

Fig. 9 is an enlarged isometric view, partly in section, of a modification of Fig. 8;

Fig. 10 is an enlarged side view, partly in section, of another embodiment of the invention; and

Fig. 11 is a sectional view of the embodiment of Fig. 10 taken along the lines XI—XI of Fig. 10.

Referring now in more detail to the drawings and with particular reference to Fig. 1, an antenna system indicated at 1 is illustrated as radiating a beam of electromagnetic energy. The main axis 3 of the beam is caused to rotate about the antenna system axis or boresight 4, as shown. The rotating or circular motion of the beam axis 3 is indicated by the path 5. The extreme lower position of the beam is illustrated by the phantom lines 6. This rotation of the beam thus provides what is known as "conical scanning."

Referring now to Fig. 2, in an antenna system embodying the present invention, a primary radiator comprising a dielectric rod 7 coupled at its opposite ends to a cylindrical wave guide 9 and reflector 11, develops a beam of electromagnetic energy for the system. The rod 7 may be fabricated, for example of polystyrene, having an outer diameter of .625 of an inch. The reflector 11 may be fashioned from aluminum with a reflecting surface 2 inches in diameter. The cylindrical part of the

reflector 11 may be approximately a quarter-wave length long at the operating frequency, for example .2 of an inch at 10 kilomegacycles. The guide 9 may be formed of copper tubing having an outer diameter of .75 of an inch. A transmitter 8 is coupled to the rod 7 through the cylindrical wave guide 9. Part of the guide includes an electromagnetic gyrator as shown at 10. The radiator 7 is connected to a reflector 11 which reflects energy in the direction of a paraboloidal reflector 12. The paraboloid forms the energy into a beam that is radiated in the direction as indicated at 13. A secondary radiator, comprising a metallic annular member 14 having three slots formed therein, is mounted on the rod 7, as shown. The member 14 is located substantially at the focus point of the paraboloid 12.

The gyrator 10, as shown in cross-section in Fig. 3, comprises a coil 15 designed to produce a longitudinal magnetic alternating field in the guide 9 at a frequency, for example, of 100,000 cycles. Within the guide a cylindrical insulator 16 (for example, Rexolite which is a material manufactured by Rex Corporation, West Acton, Massachusetts, and having an outer diameter of .625 of an inch with a .25 of an inch hole passing centrally therethrough) is disposed. Within the .25 of an inch hole is disposed a rod 17 of ferromagnetic material. The term ferromagnetic as used herein includes paramagnetic as distinguished from diamagnetic. The rod 17 may be, for example, 2.4 inches long and .234 of an inch in diameter and composed of ML 1331 ferrite material, such as manufactured by General Ceramics and Steatite Corporation.

Referring now to Fig. 4, the radiating member 14 (formed, for example, of copper of .050 of an inch thickness) comprises three radiating elements 18 a half-wave length long at the operating frequency. The slots 19 are a quarter-wave length deep at the operating frequency, as shown. The slots function electrically like resonant quarter-wave length transmission line sections and, therefore, present a very high impedance across the openings although they are apparently short-circuited at the other end. It is to be noted that the centers of the elements and the slots are respectively disposed substantially 120 degrees apart.

Microwave energy characterized by an electric vector having, for example a horizontal polarization (90 degrees) is coupled to the guide 9 in the well-known manner. A relatively high frequency modulating voltage, for example 100,000 cycles, is applied to the coil 15 to cause an alternating magnetic current to flow longitudinally through the ferrite rod 17. In accordance with the so-called ferromagnetic Farraday effect as applied to microwave energy, the magnetic current parallel to the rod 17 causes the electric vector of the energy passing therethrough to rotate in accordance with the variations of the magnetic current. [See Farraday Effect as outlined by J. H. Rowen in an article entitled, "Ferrite and Microwave Applications," published in the Bell System Technical Journal, volume 32, No. 6, November, 1953.]

The amount of rotation that takes place is also a function of the length and diameter of the ferrite rod. In the preferred embodiment, the electric vector rotates ± 90 degrees, that is to say, 180 degrees clockwise and 180 degrees counter-clockwise in accordance with the maximum amplitudes in opposite polarities of the magnetic field.

Referring now to Figs. 7 and 8, Fig. 7 is a side view of a conically scanning antenna system for the directive radiation and reception of high frequency electromagnetic energy. A microwave generator 21 is coupled to a rectangular wave guide 22 which is terminated in a short-circuit as shown. A motor 23 drives a dielectric shaft 24, such as a quartz rod, which is supported by a metallic bearing 25 in the guide 22. The shaft 24 is mechanically connected to a metallic shaft 26 to drive a rotatable dielectric insulating disc 27 which supports a rotatable radiating element 28 (a center-fed dipole in this embodiment). The dipole antenna is included within the tapered cylindrical wave guide 29 which is coupled through a dielectric radiator 30 to a fixed metallic annular radiator 31 having the same configuration as shown in Fig. 4. A metallic reflector 32 surrounds the end of the dielectric radiator 30. The radiator 31 and the reflector 32 cooperate to illuminate a parabolic reflector 33. The shaft 26 extends into the guide 29 through a circular hole 22*a* in the guide 22 as shown. A coaxial mode transducer utilizes an annular conductor 34 as an outer conductor and the metallic shaft 26 as an inner conductor. One of the quarter-wave elements of the dipole 28 is connected to the outer conductor 34 and the other quarter-wave element is connected to the shaft 26 as shown. The outer conductor 34 is rotatable and is supported by a metallic bearing 35, formed, for example, from graphite impregnated bronze. The bearing 35 is held in place by a flanged ring 36 which is affixed to the outside surface of the guide 22 as, for example, by solder.

In the embodiment of Fig. 9 the disc 27 is shown supporting a rotatable slotted antenna. The antenna is formed from a disc-shaped metallic foil 37, such as copper, which has a capacitively loaded slot 38 formed therein. The configuration of the slot is chosen to be electrically one-half a wave length long at the highest operating frequency, in accordance with well-known principles. The width of the slot must be less than a half-wave length long at the highest operating frequency of the line and in the present embodiment has been chosen to be one-eighth of a wave length wide.

The outer conductor 34 of the coaxial transducer is electrically connected to one side of the slot as indicated at 40. The shaft 26 is connected to the other side of the slot as indicated at 39.

In the embodiment of Fig. 10, a grounded metallic loop 41 provides magnetic coupling from a rectangular wave guide 42 to a cylindrical wave guide 43 through a circular hole 44 in the guide 42 and a coaxial mode transducer utilizing an annular metallic member 45 as an outer conductor and the shaft portion of the loop 41 as an inner conductor as shown. The coupling loop 41 is connected to a rotatable annular conductive member 46 which is suspended by roller bearings 47 as shown. The member 46 is driven by gears 48 and 49. A motor is directly coupled to the gear 49 to rotate the gear 48 which is affixed to the member 46. The gear 49 drives the gear 48 through a slot 50 in the wall of a metallic annular supporting member 51. The member 51 is affixed to the guide 43 with a metallic annular flange member 52 as, for example, by solder. The member 51 is affixed to the guide 42 by means of brackets 53 and 54 which are preferably soldered in place.

Referring now to Fig. 7, plane polarized microwave energy is coupled from the generator 21 and propagated in the guide 22 in typical rectangular wave guide modes (preferably $TE_{0,1}$). The $TE_{0,1}$ mode is converted to the typical coaxial TEM mode by excitation of the coaxial mode transducer. Transmission of the energy characterized by the TEM mode of propagation into the cylindrical wave guide 29 excites the antenna 28 to provide a $TE_{1,1}$ mode of propagation in the guide 29. Rotation of the antenna 28 and the disc 27 is provided by the motor 23 through the shafts 24 and 25. The outer conductor 34 in conjunction with the bearing 36 forms a rotary joint permitting the conductor 34 to rotate with the disc 27 and the antenna 28. Rotation of the antenna 28 effects transmission of the microwave energy characterized by a rotating electric vector synchronously with the antenna 28. The operation of the invention in relation to the effect of the rotating electric vector of the energy incident upon the radiator 31 will be described in greater detail below.

Referring now to Fig. 10, plane polarized energy characterized by the $TE_{0,1}$ mode of propagation in the guide 42 is coupled through the coaxial transducer to excite the grounded loop 41 which radiates into the guide 43,

preferably in the $TE_{1,1}$ mode. The spacing between the guide **43** and the member **46** is much less than one-quarter of a wave length at the highest operating frequency to preserve the cylindrical boundary surfaces defined by the guide **39**. Rotation of the member **46** effects rotation of the loop **41** and hence the electric vector of the propagated energy rotates synchronously with the loop **41**.

The operation of the system can be better understood with particular reference to Figs. 5 and 6. Electromagnetic energy incident upon the member **14** may be assumed then to be characterized by a rotatingly polarized electric vector **20** which rotates clockwise from 0 to 180 degrees and counter-clockwise from 180 to 0 degrees. The energy radiated by the elements A, B and C may be described with reasonable accuracy by assuming the elements to be linear dipoles oriented along lines tangent to their respective centers. A dipole (half-wave length) element radiates a maximum amount of energy when oriented in parallel with the electric vector, and a minimum or substantially zero amount when it is perpendicular to the electric vector. In particular, such an element radiates energy in accordance with the expression:

$$\rho = k \cos^2 \Theta$$

In the above expression ρ equals the electromagnetic energy radiated by the dipole having an electric vector parallel to the electric vector **20**; k is a constant and Θ is the angle between the dipole element and the electric vector **20**. In this case, the dipole elements A, B and C form arcs of a circle and the angles Θ_1 may be taken as the angles between their respective center tangent lines and the electric vector **20**.

Of particular significance in the present invention is the characteristic of the radiating member **14**, whereby a single rotation of the electric vector clockwise from 0 to 180 degrees and from 180 to 0 degrees effects two rotations of the resultant beam of energy, 360 degrees counter-clockwise and 360 degrees clockwise, respectively, as will be shown presently. In Fig. 5 the tangent lines of the respective elements are disposed substantially in the form of an equilateral triangle, as shown; hence, the centers of the radiating elements are radially disposed substantially 120 degrees apart. Varying the radiation of each dipole element causes the resultant beam to be radiated in the direction of the element exhibiting maximum radiation.

In describing the displacement of the resultant beam it is helpful to assume the Cartesian Coordinate System in which the X-axis coincides with the horizontal axis and the Y-axis with the vertical.

The radiation center (RC) of the beam will be a function of the instantaneous radiation of each element and its position. In particular:

$$RC_X = \frac{\sum_{i=A}^{C} \rho_{A} x_A + \rho_{B} x_B + \rho_{C} x_C}{\rho_A + \rho_B + \rho_C}$$

and

$$RC_Y = \frac{\sum_{i=A}^{C} \rho_{A} y_A + \rho_{B} y_B + \rho_{C} y_C}{\rho_A + \rho_B + \rho_C}$$

where x_1 and y_1 equal coordinates of the radiation center of each element and ρ_1 equals the energy radiated by each element respectively.

Since the elements A, B and C are in fixed positions, the values for x_1 and y_1 may be readily calculated. Thus, assuming $x_A = x_{max} = y_{max} = 1$ unit of length:

$$x_B = x_C = -\cos 60° = -.5$$

and

$$y_A = 0, \; y_B = -\sin 60° = -.866$$

and

$$y_C = \sin 60° = 0.866$$

Assuming $k=1$ in the expression for ρ above, the center of radiation of the resultant beam may be defined for the instantaneous positions of the electric vector **20**.

In particular, the positions of the center of radiation of the resultant beam for each 45° position of the vector **20**, as shown in Fig. 5, will be described. Fig. 6 graphically depicts the path of the center of the resultant beam.

When the electric vector **20** is oriented at 0°,

$$\rho_A = \cos^2 \Theta_A = \cos^2 0° = 1$$

$$\rho_B = \rho_C = \cos^2 \Theta_B = \cos^2 60° = .25$$

and

$$\rho_A + \rho_B + \rho_C = 1 + .25 + .25 = 1.5 \text{ units of energy.}$$

Substituting in the expression for RC_X above:

$$RC_X = \frac{1 + (.25 \times -.5) + (.25 \times -.5)}{1.5} = \frac{+.75}{1.5} = .5$$

and

$$RC_Y = \frac{0 + (.25 \times -.866) + (.25 \times .866)}{1.5} = 0$$

From this analysis, it is clear that the beam is offset to the Right as illustrated in Fig. 6 by the point W. Thus, when the electric vector is oriented at 0°, the beam is offset 90°.

When the electric vector **20** is oriented at 45°,

$$\rho_A = \cos^2 45° = .5$$

$$\rho_B = \cos^2 75° = .067$$

$$\rho_C = \cos^2 15° = .933$$

and

$$\rho_A + \rho_B + \rho_C = .5 + .067 + .933 = 1.5 \text{ units of energy}$$

Then:

$$RC_X = \frac{(.5 \times 1) + (.067 \times -.5) + (.933 \times -.5)}{1.5} = 0$$

and

$$RC_Y = \frac{0 + (.067 \times -.866) + (.933 \times .866)}{1.5} = \frac{.75}{1.5} = .5$$

Accordingly, when the electric vector **20** is rotated 45° clockwise, the center of the beam rotates 90° counter-clockwise and is now Up as indicated by the point X in Fig. 6.

When the electric vector **20** is rotated 90° clockwise, $\rho_A = \cos^2 90° = 0$, $\rho_B = \rho_C = \cos^2 30° = .75$. Substituting in the expression for RC above:

$$RC_X = \frac{(.75 \times -.5) + (.75 \times -.5)}{1.5} = -.5$$

and

$$RC_Y = \frac{0 + (.75 \times -.866) + (.75 \times .866)}{1.5} = 0$$

Consequently, when the electric vector **20** is rotated 90° clockwise, the center of the resultant beam rotates counter-clockwise 180° and is now Left as indicated by the point Y in Fig. 6.

When the electric vector **20** is rotated 135° clockwise, $\rho_A = \cos^2 45° = .5$, $\rho_B = \cos^2 15° = .067$, $\rho_C = \cos^2 75° = .933$ and $\rho_A + \rho_B + \rho_C = .5 + .067 + .933 = 1.5$ units of energy. Then:

$$RC_X = \frac{.5(.933 \times -.5) + (.067 \times -.5)}{1.5} = 0$$

and

$$RC_Y = \frac{0 + (.933 \times -.866) + (.067 \times .866)}{1.5} = .5 \text{ units}$$

Hence, the beam is offset Down as indicated by the point Z in Fig. 6, for example, in response to a clockwise rotation of the electric vector of 135°, the beam rotates counter-clockwise 270°.

When the electric vector **20** is rotated 180° the analysis is the same as that for 0° and the beam is offset again to the right, as indicated by the point W. It is to be

noted that the center of the resultant beam rotates counter-clockwise 360°, while the electric vector 20 rotates clockwise 180°. It is obvious, from the above description, that when the electric vector rotates counter-clockwise from 180° back to 0°, the center of the beam rotates clockwise another 360°. If the vector 20 continuously rotates in the same direction, the beam would be characterized by a rotating polarized electric vector, and the resultant beam would rotate at twice the frequency of vector rotation.

In the embodiment of Fig. 2 the conical scanning rate is 200 kilocycles per second (alternate counter-clockwise and clockwise) in response to 100 kilocycles per second frequency of gyration.

It is to be noted that as shown in Figs. 2 and 7, an antenna system embodying the present invention does not require supporting studs and minimizes structure in front of the paraboloid that can cause shadows in the path of the radiated energy.

It will be apparent that the embodiments of the invention illustrated in Figs. 7 through 11 produce conical scanning continuously counter-clockwise where the antenna rotates continuously clockwise. In all other respects the foregoing analysis of the operation of the invention applies to all of the embodiments illustrated.

In an antenna system constructed in accordance with the embodiment of Fig. 7 to operate at a frequency of 10 kilo-megacycles, the rectangular wave guide 22 may have the dimensions of 1 inch by ½ inch; the diameter of the shaft 26 may be .2 of an inch; the hole 22*a* may be .3 of an inch; the diameter of the guide 29 may be 1 inch; the disc 27 may be .8 of an inch in diameter and .020 of an inch thick; the antenna elements 28 may each be .56 of an inch long by .030 of an inch wide and .001 of an inch thick; and the motor may rotate at 6000 R. P. M. to produce conical scanning at 200 cps.

Rotating polarization may also be produced by propagating plane polarized energy through a quarter-wave plate and then propagating through a second quarter-wave plate which is rotated at a rate one-half that of the desired conical scanning frequency. This approach is readily derived from the description of quarter-wave plate devices in the Massachusetts Institute of Technology Radiation Laboratory Series, volume 9, pages 428 to 432 (published by McGraw-Hill Company).

Although the description as noted above has been limited to a discussion of a so-called tripole radiator, that is, the use of three radiating elements that are disposed radially about the axis of the paraboloid, the application of the present invention to devices that vary in transparency with respect to the radiated energy in some manner, or selectively refract the radiated energy in accordance with relative angular positions, are clearly contemplated within the present invention. Such devices are outlined in my copending applications: Serial No. 427,146, filed May 3, 1954; Serial No. 429,633, filed May 13, 1954; and Serial No. 428,933, filed May 11, 1954.

Antenna systems embodying the present invention are capable of literally unlimited scanning rates relative to the frequencies currently contemplated for such systems. Certainly, the conical scanning rates possible with this system exceed the requirements of any detection system known in the prior art.

While there has been hereinbefore described what is at present considered preferred embodiments of the invention, it will be apparent that many and various changes and modifications may be made with respect to the embodiments illustrated, without departing from the spirit of the invention. It will be understood, therefore, that all such changes and modifications as fall fairly within the scope of the present invention, as defined in the appended claims, are to be considered as a part of the present invention.

What is claimed is:

1. An antenna system comprising the combination of a source of microwave electromagnetic energy; a rectangular wave guide terminated in a short-circuit connected to said source; a dielectric radiator; a cylindrical wave guide connecting said dielectric radiator and said rectangular wave guide through a wave-coupling orifice in said rectangular wave guide; a rotatable dipole antenna disposed within said cylindrical wave guide; a rotatable dielectric insulating disc supporting said dipole antenna; a rotatable metallic shaft affixed to said disc and electrically connected to one of the quarter-wave elements of said dipole; an annular conductive member surrounding a part of said shaft and coaxial therewith providing a coaxial mode transducer included within said cylindrical wave guide adjacent said orifice, said annular member being electrically connected to the other quarter-wave element of said dipole; an electric motor for driving said shaft and for rotating said disc and dipole to effect transmission of said energy with rotation of its electric vector synchronously with said dipole; and an annular radiating member responsive to said energy, characterized by said rotating electric vector, supported by said dielectric radiator and having three open-ended slots formed therein with their centers radially disposed substantially 120 degrees apart to provide a conical scanning beam at a scanning frequency twice the rate of rotation of said electric vector.

2. An antenna system comprising the combination of a source of microwave electromagnetic energy; a rectangular wave guide terminated in a short-circuit connected to said source; a dielectric radiator; a cylindrical wave guide connecting said dielectric radiator and said rectangular wave guide through a wave-coupling orifice in said rectangular wave guide; a rotatable capacitively loaded slot antenna disposed within said cylindrical wave guide; a rotatable dielectric insulating disc supporting said slot antenna; a rotatable metallic shaft affixed to said disc and electrically centrally connected to one side of said capacitively loaded slot antenna; an annular conductive member surrounding a part of said shaft and coaxial therewith providing a coaxial mode transducer included within said cylindrical wave guide adjacent said orifice in said rectangular guide, said annular member being electrically centrally connected to the other side of said slot; an electric motor for driving said shaft and for rotating said slot antenna to effect transmission of said energy with rotation of its electric vector synchronously with said slot; and an annular radiating member responsive to said energy, characterized by said rotating electric vector, supported by said dielectric radiator and having three open-ended slots formed therein with their centers radially disposed substantially 120 degrees apart to provide a conical scanning beam at a scanning frequency twice the rate of rotation of said electric vector.

3. An antenna system comprising the combination of a source of microwave energy; a rectangular wave guide terminated in a short-circuit connected to said source; a dielectric radiator; a cylindrical wave guide connecting said dielectric radiator and said rectangular wave guide through a wave-coupling orifice in said rectangular wave guide; a rotatable annular conductive member having an inner diameter the same as said cylindrical guide and coaxial therewith adjacent said rectangular guide; a rotatable metallic coupling loop connected to said rotatable annular member and having a shaft portion disposed along the axis of said cylindrical guide and extending into said rectangular guide through said orifice; a fixed annular conductive member connected to said rectangular guide, said fixed member surrounding a part of said shaft coaxially therewith providing a coaxial mode transducer included within said cylindrical wave guide adjacent said orifice, said coaxial transducer converting $TE_{0,1}$ energy in the rectangular guide to TEM energy within said transducer to enable excitation of said loop providing thereby $TE_{1,1}$ energy in said cylindrical guide;

an electric motor coupled to said rotatable annular conductive member for rotating said loop to effect transmission of said $TE_{1,1}$ energy with rotation of its electric vector synchronously with said loop; and an annular radiating member responsive to said energy, characterized by said rotating electric vector, supported by said dielectric radiator and having three open-ended slots formed therein with their centers radially disposed substantially 120 degrees apart to provide a conical scanning beam at a scanning frequency twice the rate of rotation of said electric vector.

4. In an antenna system, the combination of: a source of electromagnetic energy; transmission line means, including a rotatable, radiating element, connected to said source of electromagnetic energy; means for rotating said radiating element to effect transmission of said energy with rotation of its electric vector synchronously with said radiating element; a radiating member having a plurality of polarity-sensitive radiating elements with their centers so disposed as to cause the center of radiation to rotate about an axis in response to said energy characterized by said rotating electric vector; and means directing said rotating vector energy to said radiating elements to provide a conically scanning beam at a scanning frequency higher than the rate of rotation of said rotatable radiating element.

5. In an antenna system, the combination of: a source of electromagnetic energy; transmission line means, including a rotatable, dipole antenna element, connected to said source of electromagnetic energy; means for rotating said dipole to effect transmission of said energy with rotation of its electric vector synchronously with said dipole; a radiating member having three polarity-sensitive radiating elements so disposed as to cause the center of radiation to rotate about an axis in response to said energy characterized by said rotating electric vector; and means directing said rotating vector energy to said radiating elements.

6. In an antenna system, the combination of: a source of electromagnetic energy; transmission line means, including a rotatable, grounded loop, radiating element, connected to said source of electromagnetic energy; means for rotating said radiating element to effect transmission of said energy with rotation of its electric vector synchronously with said radiating element; a radiating member having three polarity-sensitive radiating elements with their centers so disposed as to cause the center of radiation to rotate about an axis in response to said energy characterized by said rotating electric vector; and means directing said rotating vector energy to said radiating elements to provide a conical scanning beam at a scanning frequency twice the rate of rotation of said rotatable radiating element.

7. In an antenna system, the combination of: a source of electromagnetic energy; transmission line means, including a rotatable, radiating element, connected to said source of electromagnetic energy; means for rotating said radiating element to effect transmission of said energy with rotation of its electric vector synchronously with said radiating element; an annular, radiating member having three polarity-sensitive radiating elements with their centers so disposed as to cause the center of radiation to rotate about an axis in response to said energy characterized by said rotating electric vector; and means directing said rotating vector energy to said radiating elements to provide a conical scanning beam at a scanning frequency twice the rate of rotation of said rotatable radiating element.

8. In an antenna system, the combination of: a source of electromagnetic energy; transmission line means, including a rotatable, dipole antenna element, connected to said source of electromagnetic energy; a rotatable, dielectric disc supporting said dipole to provide mechanical equilibrium; means for rotating said disc and dipole to effect transmission of said energy with rotation of its electric vector synchronously with said radiating element; a radiating member having three polarity-sensitive radiating elements with their centers so disposed as to cause the center of radiation to rotate about an axis in response to said energy characterized by said rotating electric vector; and means directing said rotating vector energy to said radiating elements to provide a conical scanning beam at a scanning frequency twice the rate of rotation of said rotatable radiating element.

9. In an antenna system, the combination of: a source of electromagnetic energy; transmission line means, including a rotatable, slotted antenna element, connected to said source of electromagnetic energy; means for rotating said slotted antenna element to effect transmission of said energy with rotation of its electric vector synchronously with said radiating element; a radiating member having three polarity-sensitive radiating elements with their centers so disposed as to cause the center of radiation to rotate about an axis in response to said energy characterized by said rotating electric vector; and means directing said rotating vector energy to said radiating elements to provide a conical scanning beam at a scanning frequency twice the rate of rotation of said rotatable radiating elements.

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