Feb. 20, 1951 P. H. SMITH 2,542,844

MICROWAVE DIRECTIVE ANTENNA

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FIG. 2

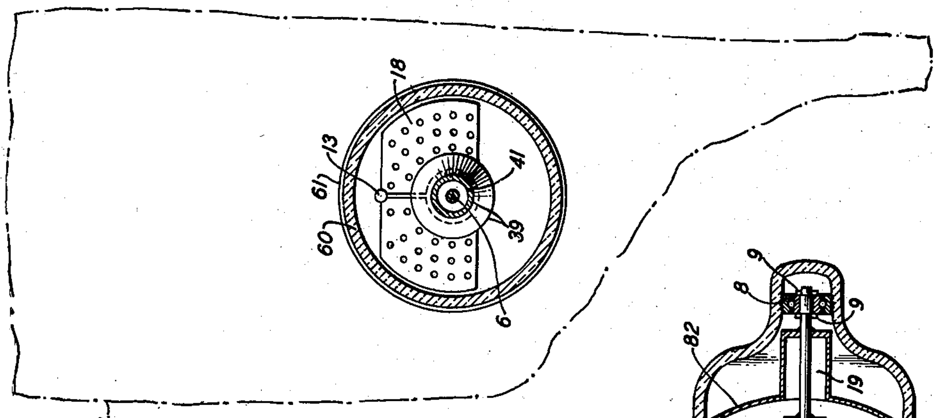

FIG. 8

FIG. 1

FIG. 3

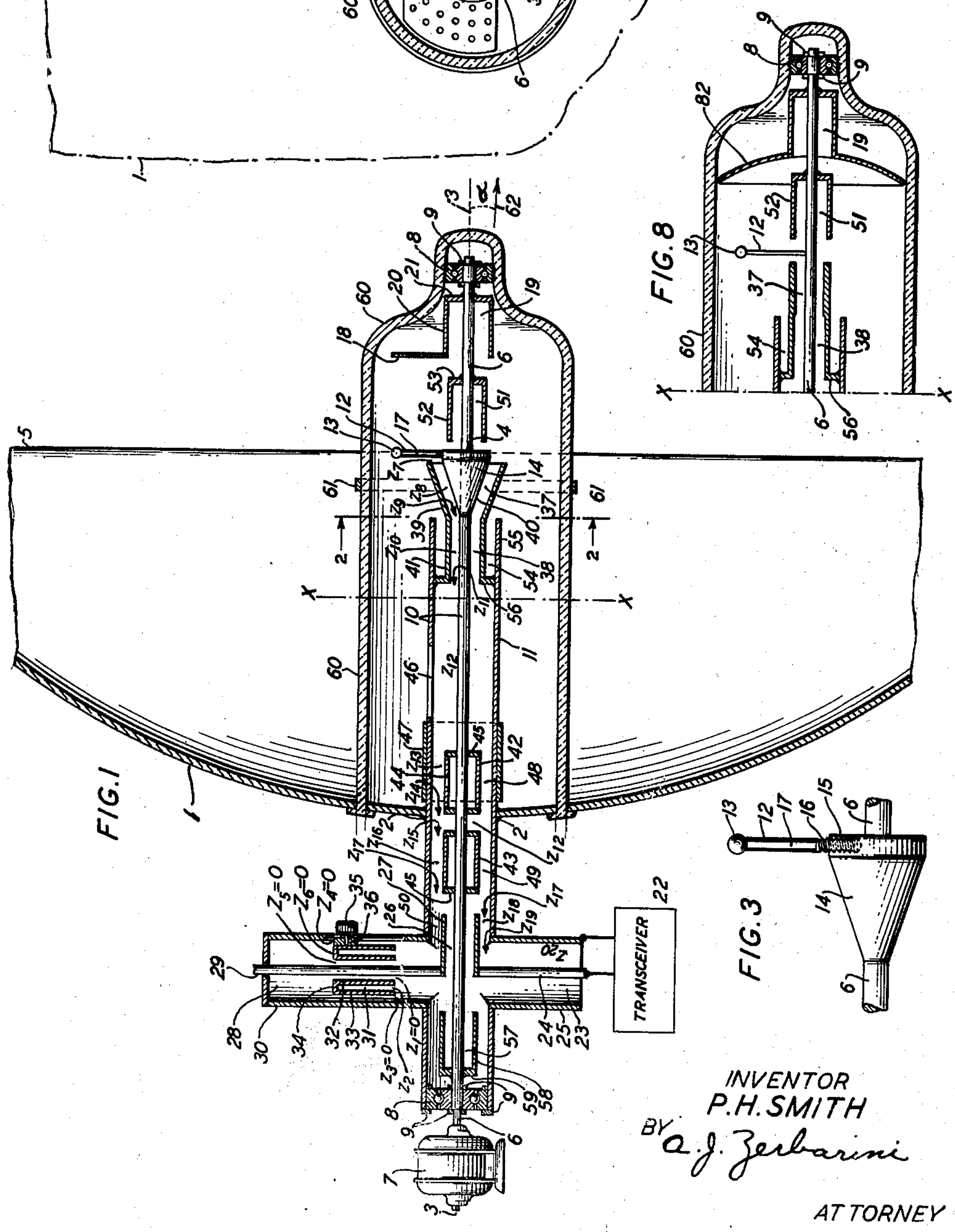

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FIG. 4

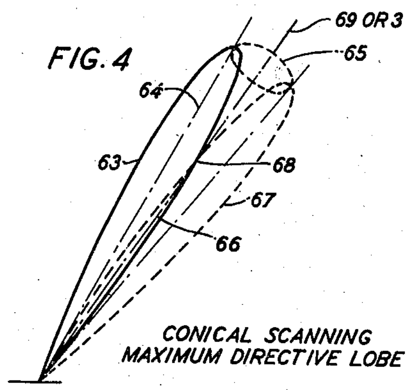


FIG. 5

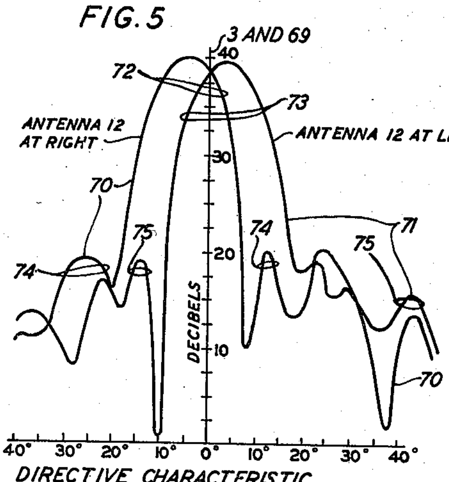
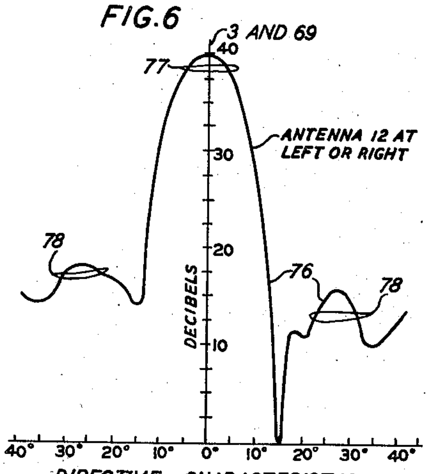


FIG. 6



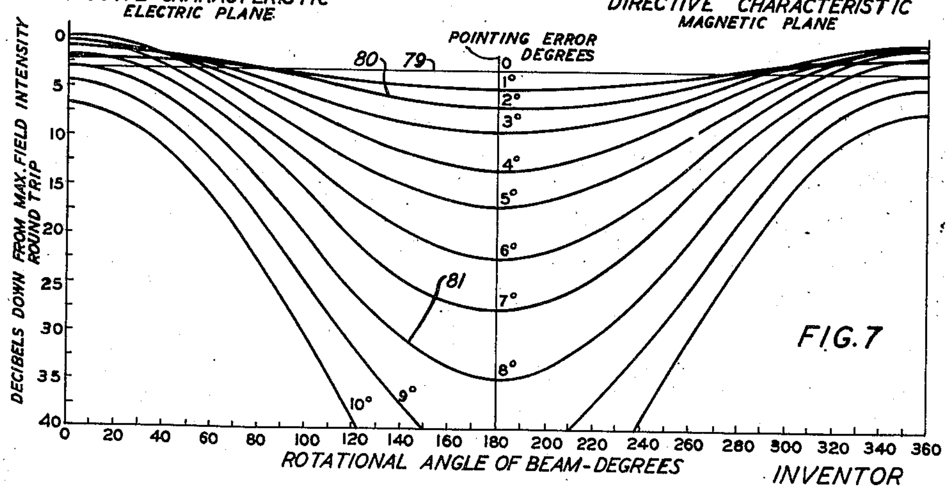


FIG. 7

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MICROWAVE DIRECTIVE ANTENNA

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Application August 14, 1943, Serial No. 498,622

16 Claims. (Cl. 250—33.65)

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This invention relates to directive antenna systems and particularly to microwave conical scanning radar or direction-finding antennas.

As disclosed in Patent 2,083,242 to W. Runge, British Patent 450,484 and the copending application of C. B. H. Feldman, Serial No. 451,932, filed July 22, 1942, now Patent 2,419,556, issued April 29, 1947, it has been proposed to secure, in a direction-finding system employing ultra short, decimetric or centimetric waves, lobe rotation about a minor lobe axis, that is, conical scanning, by utilizing a dipole and a rotating reflector. While these prior art conical scanning systems may be successfully used, they are not entirely satisfactory, and it now appears desirable to obtain a conical scanning antenna having distinct mechanical and electrical advantages not present in the prior art arrangements.

It is one object of this invention to determine accurately the propagation direction of a radio wave.

It is another object of this invention to secure lobe rotation without utilizing a rotating reflector.

It is another object of this invention to adjust in a conical scanning system, the angle between the principal axis of the maximum antenna lobe and the antenna axis.

It is another object of this invention to obtain a high gain conical scanning antenna.

It is another object of this invention to obtain, in a conical scanning system, a rotating directive characteristic having negligible minor lobes.

It is another object of this invention to utilize, in a conical scanning antenna system, simple light-weight apparatus for producing the lobe rotation.

It is another object of this invention to obtain, in a conical scanning system, truly circular scanning and a constant cone angle in all planes containing the antenna axis.

It is another object of this invention to couple efficiently a rotating coaxial line inner conductor and a stationary coaxial line conductor.

It is another object of this invention to match impedances throughout a system comprising a rotating antenna, a rotating line conductor and a translation device.

It is still another object of this invention to adjust the length of a coaxial line without using sliding contacts.

In accordance with one embodiment of the invention, a quarter wave primary antenna extends perpendicular to the axis of a paraboloidal antenna, the half-dipole being in the focal plane of the reflector and its geometrical mid-point being spaced from the reflector focus. This primary antenna is connected to the far-end terminal of the inner conductor of a coaxial line which extends along the reflector axis and through the reflector apex, and means are provided for rotating the inner conductor whereby the antenna rotates like a wheel-spoke and the antenna mid-point describes a circle about the reflector focus. The near-end of the coaxial line is connected to a translation device such as a radar transceiver, the transceiver being coupled to the rotating inner conductor through a low-impedance rotatable junction. In operation, the semi-dipole illuminates the entire reflector and the principal axis of the maximum lobe of the overall directive characteristic describes in space a circular cone, the axis of which is aligned with the reflector axis. Since the linear antenna rotates, the so-called electric and magnetic planes rotate, and hence, rotary (not circular) polarization is utilized. An auxiliary plane reflector is positioned in front of the quarter-wave primary antenna so as to face the parabolic reflector, for the purpose of increasing the gain of the system. Also, an annular metallic reflector is positioned on the reflector axis between the quarter-wave antenna and the paraboloid reflector, whereby the intensities of the minor lobes are reduced.

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The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawing on which like reference characters denote elements of similar function and on which:

Fig. 1 is a diagrammatic longitudinal cross-sectional view;

Fig. 2 is a diagrammatic transverse cross-sectional view, of the preferred embodiment of the invention;

Fig. 3 is a detail view of the primary antenna included in the preferred embodiment;

Fig. 4 is a theoretical curve;

Figs. 5, 6 and 7 are measured curves used in explaining the invention; and

Fig. 8 is a cross-sectional view of a front concave reflector which may be used in place of the front plane reflector included in the system of Figs. 1 and 2.

Referring to Figs. 1, 2 and 3, reference numeral 1 denotes a paraboloidal reflector or secondary antenna, having an apex 2, a principal axis 3, a focus 4 and a focal plane 5. Numeral 6 denotes a shaft extending through apex 2 and aligned with axis 3, the shaft being driven by motor 7 and supported near each end by a bearing 8. Reference numerals 9 denote retaining members for maintaining the bearings 8 in their proper positions. The rotating shaft 6 constitutes the inner conductor of a coaxial line 10 having an outer conductor 11 which does not rotate. Numeral 12 denotes a quarter-wave primary antenna member extending in focal plane 5 in a direction perpendicular to axis 3 and equipped at its far end with an anti-corona knob 13. The antenna 12 is connected to shaft 6 through a solid conical metallic member 14 which is integral with shaft 6 and has a threaded socket 15 for receiving the threaded base 16 of antenna 12 as shown in Figure 3. Hence, the entire quarter-wave antenna 12 and, in particular, its base 13 and its geometrical mid-point 17, are adjustably spaced from the reflector focus 4. Numeral 18 denotes a plane reflector extending perpendicularly to axis 3 and supported through a high impedance or short-circuited quarter-wave line 19 by shaft 6. The high impedance 19 in effect insulates reflector 18 from shaft 6. The line 19 comprises a quarter-wave sleeve member 20, the adjacent tubular surface of inner conductor 6 and an annular end-member 21 which conductively connects one extremity of sleeve 20 to shaft 6. As shown in Fig. 2, reflector 18 has two curved edges and its center point is offset from its center of rotation.

The coaxial line 10 is connected to a translation device 22 through a main coaxial line 23 comprising an inner conductor 24 and an outer conductor 25, the outer conductors 11 and 25 of lines 10 and 23 being directly connected and the inner conductors 24 and 6 of these lines being coupled through a quarter-wave coupling line 26 comprising the quarter-wave sleeve 27 and the corresponding tubular portion of shaft 6. Device 22 may be a transmitter or a receiver or a transceiver. As viewed from either end of line 26, the capacity between the surface of the inner conductor 6 and the inner surface of sleeve 27 is exceedingly large and approaches infinity, since line 26 is a quarter-wavelength long, and the impedance between these surfaces approaches zero. Hence the rotating shaft 6 and the stationary coupling sleeve 27 spaced therefrom are connected through a low impedance at the operating frequency. Reference numeral 28 denotes a stub tuning coaxial line which is connected to line 10 at a point opposite line 23 and which comprises an inner conductor 29 and an outer conductor 30. The conductors 29 and 30 are connected respectively to outer line conductor 11 and sleeve 27. Numeral 31 denotes a plunger which is for all practical purposes air insulated from the line conductors 29 and 30 and which comprise a pair of quarter-wave coaxial sleeves 32 and 33 coaxially included between and spaced from the stub line conductors 29 and 30 and an annular end-piece 34 connecting the sleeves together at one end and also spaced from conductors 29 and 30. Numeral 35 denotes a handle attached to plunger 31 and extending through a longitudinal slot in the outer conductor 30 for permitting longitudinal adjustment of the plunger, and numeral 36 denotes a saddle or supporting member which rides in the slot and slidably secures handle 35 and plunger 31 to the outer coaxial line conductor 30.

As viewed from the junction 26 or "near end" of the stub line 28 the inner surface of sleeve 32 and the corresponding surface of inner line conductor 29 constitute an open-ended quarter-wave line having an input impedance Z_1. The outer surface of sleeve 32, the annular end-piece 34 and the inner surface of sleeve 33 form a short-circuited quarter-wave line having an input impedance Z_2 equal to infinity; and the outer surface of sleeve 33 and the corresponding inner surface of the outer line conductor 30 constitute an open quarter-wave line having an impedance Z_3. Hence, at the input end of the plunger 31, the stub line coaxial conductors 29 and 30 are connected together through three serially connected impedances Z_1, Z_2 and Z_3 and, since one of these impedances, Z_2, is infinity, the stub line is effectively open-circuited and appears to be ended or cut off at this point, regardless of the value of Z_1 and Z_3. By moving the handle 35 the length of the stub line, and therefore its impedance value, may be adjusted. Since the sleeves 32 and 33 and the end piece 34 are, except at the saddle member 36, air-insulated from conductors 29 and 30, sparking during movement of plunger 31 is completely eliminated, the current through saddle 36 being negligible. It may be noted here that, if desired, the plunger 31 may be reversed and utilized to short-circuit a coaxial line. Thus, as viewed from the far end of stub line 28, the impedance connecting the stub line conductors 29 and 30 comprises two open-ended quarter-wave lines having input impedances Z_4 and Z_5, the inputs of these quarter-wave lines being directly connected in series through the annular member 34 which has an impedance Z_6 equal to zero. Since each of these open-ended quarter-wave lines is terminated in an impedance Z_3 or Z_1, which is in series with an impedance Z_2 having a value of infinity, the quarter-wave lines are in effect each terminated in an infinite impedance, so that the input impedances Z_4 and Z_5 are each equal to zero. Hence the conductors 29 and 30 are, at the point adjacent to end-piece 34 and as viewed from the far end of the stub line, connected together or short-circuited through three serially connected impedances each equal to zero.

The primary antenna 12 is coupled to line 10 through a pair of serially connected quarter-wave impedance transformers 37 and 38. The transformer 37 comprises the inner surface of the flared quarter-wave tubular conductor 39 and enclosed conical surface 40 of member 14; and the transformer 38 comprises the inner surface of the quarter-wave tubular conductor 41 and the corresponding portion of the shaft or inner line conductor 6. Numeral 42 denotes a slidable quarter-wave sleeve having a transverse slot 44 for permitting adjustment by a screw-driver, and numeral 43 denotes a stationary quarter-wave sleeve, the sleeves 42 and 43 being spaced about a quarter-wavelength. Each of sleeves 42 and 43 is equipped with annular end-pieces 45 which connect the sleeve and conductor 6. Numeral 46 denotes a longitudinal slot in the outer conductor 11 and numeral 47 designates a tubular slidable member for covering slot 46. As is believed to be apparent, the outer surface of sleeve 42 and the corresponding inner surface of the outer line conductor 11 constitute one quarter-wave impedance transformer 48, and the outer surface of sleeve 43 and the corresponding inner surface of the outer conductor 11 constitute another quarter-wave impedance transformer 49. Also, the outer surface of the quarter-wave coupling of sleeve 27 and the associated inner surface of line conductor 11 constitute a quarter-wave impedance transformer 50, the spacing between transformers 49 and 50 being negligible.

The impedance transformers function to match the impedances throughout the transmission system. Thus, the impedance Z_7 of the primary antenna 12 is changed by the flared impedance transformer 37 having a characteristic impedance Z_8, into an impedance Z_9 at the input of transformer 37. The impedance Z_9 is changed by the transformer 38 having a characteristic impedance Z_{10} into an impedance Z_{11} at the input of transformer 38, the impedance Z_{11} being equal to the characteristic impedance Z_{12} of the coaxial line 10. The line impedance Z_{12} is transformed by a quarter-wave line 48 having a characteristic impedance Z_{13} into an impedance Z_{14} at its input end. Since the spacing between sleeves 42 and 43 is a quarter-wavelength, the impedance Z_{14} is changed by the line characteristic impedance Z_{12} into an impedance Z_{15} at the output end of the transformer 49. The impedance Z_{15} is changed by the transformer 49 having a characteristic impedance Z_{16} into an impedance Z_{17} at the input end of transformer 49 and at the output end of transformer 50, the spacing between transformers 49 and 50 being negligible. The impedance Z_{17} is changed by transformer 50 which has a characteristic impedance Z_{18} into an impedance Z_{19}, the impedance Z_{19} being equal to the characteristic impedance Z_{20} of the main coaxial line 23. In one actual embodiment constructed and tested, the values of Z_7 to Z_{20}, inclusive, were respectively 36, 28, 23, 36, 57, 57, 35.5, 22, 145, 24, 5.5, 20, 75 and 75 ohms. The stub line 28 is in practice adjusted to tune out any residual mismatch or reactance at the point where lines 10 and 23 are connected through the coupling sleeve 27.

As illustrated in Fig. 1, line 10 comprising shaft 6 and the outer conductor 11 is equipped with several high impedances of the short-circuited quarter-wave line type, such as impedance 19. Thus, reference numeral 51 denotes a high impedance comprising the quarter-wave sleeve 52, the adjacent quarter-wave portion of shaft 6 and end-piece 53 connecting sleeve 52 and shaft 6. The impedance 51 functions to insulate the portion of shaft 6 associated with reflector 18 from the primary antenna 12. Numeral 54 denotes a high impedance comprising the quarter-wave sleeve 55, annular member 56 and the outer surface of the quarter-wave tubular conductor 41. This impedance resembles the well-known balance-to-unbalance coupling and functions to prevent antenna 12 from establishing standing waves on the outer surface of line conductor 11. Numeral 57 denotes another short-circuited quarter-wave line comprising sleeve 58, annular member 59 and the corresponding portion of shaft 6. Transformer 57 sectionalizes shaft 6 and presents a high impedance to the waves conveyed along the 90-degree bend connecting coaxial lines 10 and 23.

The rotating shaft 6, primary antenna 12 and plane reflector 18 are enclosed in a Plexiglas housing 60 which is attached to the paraboloidal reflector 1 and functions as a support for the bearing 8 at the far end of shaft 6. Numeral 61 denotes an annular or ring reflector coaxially related to shaft 6 and positioned between the primary antenna 12 and the paraboloidal reflector 1.

Referring to Fig. 4 and assuming device 22 is a transceiver, the operation of the radar antenna

system of Figs. 1, 2 and 3 will now be explained. Assuming motor 7 is operating at a constant speed, the mid-points of the quarter-wave primary antenna 12 and the associated plane reflector 18 are rotated about the focal axis 3. Considering the transmitting operation, pulsed centimetric waves are supplied over lines 23 and 10 to the primary antenna 12 and waves polarized in the plane of the rotating half dipole 12 are radiated. The plane of polarization, which contains the linear antenna 12, and the plane perpendicular thereto, both rotate. These planes will be hereinafter termed the "electric" and "magnetic" planes, respectively. The primary antenna functions to illuminate or energize the paraboloidal reflector 1. More particularly, certain of the waves emitted by the primary antenna 12 pass directly to the secondary antenna 1 and, in a manner well understood in the art, these particular waves are redirected in substantially parallel directions making an angle α with the reflector axis 3. Certain other waves emitted by the primary antenna 12 impinge upon the plane reflector 18 and are reflected or directed toward the paraboloidal reflector, these waves being thence propagated or redirected by the paraboloidal reffector in the same common direction as the waves supplied directly to the paraboloidal reflector. The reflector 18 and primary antenna 12 are preferably spaced so as to obtain substantial phase agreement between the set of waves supplied directly and the set of waves supplied indirectly via reflector 18 to the parabolic reflector. Preferably, the spacing should be such that the average difference in the path lengths of these two sets of waves is about a half-wavelength. The plane reflector functions to increase the gain of the system about 2 decibels.

In addition, a certain amount of energy radiated by the primary antenna 12 is absorbed and reradiated, or simply reflected, by the ring reflector 61, the phase and amplitude of this reradiated energy being related to the size of reflector 61 and is position along the parabolic reflector axis 3. Ordinarily, the position of reflector 61 is adjusted so that the phase and propagation direction of the waves radiated thereby are such as to cancel, at least in part, the minor lobes included in the directive characteristic of the antenna system formed by the primary antenna 12 and secondary antenna 1.

The primary antenna 12 and the direction of maximum action for the entire antenna system comprising dipole 12 and reflectors 1 and 18, are ordinarily on opposite sides of the reflector axis 3. Thus, with the primary antenna 12 in the position illustrated in Fig. 1, maximum action occurs in the direction 62. As the primary antenna 12 and the associated plane reflector 18 rotate, the direction 62 describes in space a cone, the angle α of which may be varied to some extent by adjusting the spacing between the primary antenna mid-point 17 and the reflector focus 4. As shown in Fig. 3, the above-mentioned spacing may be changed by adjusting the threaded connection 15, 16 at the base of antenna 12. In Fig. 4 the reference numeral 63 denotes the rotating maximum lobe having a principal axis 64, which is identical to the direction 62 of the maximum action; and numeral 65 designates a circle representing the trace described by the rotating lobe axis 64 on a plane perpendicular to the reflector axis 3. Considered differently, the lobe 63 rotates about the so-called equi-intensity line 66. Numeral 67 denotes the diametrically opposite position for the maximum lobe and numeral 68 denotes the so-called lobe cross-over point.

In reception, the echo pulsed waves reflected by the target are directively collected by the antenna system and supplied over lines 10 and 23 to the receiver in the transceiver 22, the receiving action being the converse or reciprocal of the transmitting action. Assuming the target is on the cone axis 69, Fig. 4, which coincides with the reflector axis 3, the echo pulses have a constant intensity corresponding to the cross-over point 68. If the target is off the axis 69, the amplitude of the received echo pulsed waves varies sinusoidally, the frequency of the detected waves being dependent on the conical scanning rate and, therefore, on the speed of motor 7. With the target off the axis the amplitude of the echo waves is a measure of the degree of the pointing error, that is, the angular deviation of the target from the reflector axis. The phase of the detected current, as compared to the phase of a current from a reference generator, is indicative of the radial direction, relative to the reflector axis, of the target. In one actual embodiment, a reference generator driven by motor 7 in synchronism with the antenna beam and a cathode tube indicator are utilized for ascertaining the amplitude and phase of the echo waves and, therefore, for ascertaining the "pointing error" of the antenna. The direction and amount of displacement of a dot pattern from the center of the cathode-ray tube screen represent the pointing error.

Figs. 5 and 6 illustrate, respectively, the measured electric plane and magnetic plane directive curves for a system constructed in accordance with the invention and illustrated by Figs. 1, 2 and 3. Thus, referring to Fig. 5, reference numeral 70 denotes the characteristic obtained with the primary antenna 12 at the right of the reflector axis 3 and numeral 71 designates the characteristic obtained with the linear antenna 12 at the left of the axis 3. It will be noted that the maximum lobe 72 of curve 70 is at the left and the maximum lobe 73 of the curve 71 is at the right of the cone axis 69. Also it will be noted that, by reason of the use of the ring reflector 61, the minor lobes 74 of curve 70 and the minor lobes 75 of curve 71 are negligible, the minor lobes for each curve being for the one-way trip approximately 20 decibels down from the maximum value of the maximum lobe. For the round trip, that is, from the transceiver to the target and return, the minor lobes are down 40 decibels. Referring to Fig. 6, numeral 76 denotes the magnetic plane characteristic having a maximum lobe 77 and the negligible minor lobes 78, the maximum lobe 77 being aligned with the reflector axis 3 and the cone axis 69. Stated differently, in a plane perpendicular to the linear antenna 12, the directivity is the same with the "spoke" antenna 12 pointing first in a given radial direction and then in the opposite direction.

Fig. 7 illustrates a set of "error" curves for the system constructed and tested as described above, the curves each being representative of different amounts (but not directions) of pointing error. The error curves were obtained by rotating the antenna maximum lobe while maintaining the target fixed at a point on the circle 65 in Fig. 4. As illustrated by the curves of Fig. 7, with the target off the axis, the received intensity varies as a function of the beam rotation, that is, the envelope of the received current is related to the rotating speed of the quarter-wave antenna 12.

Also the amplitude of the varying received current is a function of the error angle. Thus, with an angular pointing error of 2 degrees, a received current represented by curve 80 is obtained and with a pointing error of 8 degrees a current represented by curve 81 is obtained, the amplitudes of each current being proportional to the amount of the pointing error. With the target aligned with the reflector axis 3, that is, with the pointing error equal to zero degrees, a series of echo waves of constant envelope intensity is received as shown by the flat curve or envelope 79.

If desired, the plane reflector 18 of Fig. 1 may be replaced by a different type of reflector, such as a concave reflector or a dipole reflector. In one embodiment actually constructed and tested, and comprising a relatively large paraboloidal reflector, a front reflector of the spherical type was utilized and the flared or conical member 14 was omitted, the antenna 12 being directly attached to the rotating shaft 6. Figs. 1 and 8 illustrate this embodiment, the structure shown in Fig. 8 being substituted for that shown at the right of the line X—X in Fig. 1. In Fig. 8, reference numeral 82 denotes the spherical type reflector. This reflector rotates with shaft 6 but may be made stationary, if desired. The reflector 82 is isolated from shaft 6 by the high impedance circuit comprising quarter-wave line 19, while the direction 62 of action for the entire system is ordinarily on the opposite side of the reflector axis from the primary antenna 12. the action of the spherical reflector is sometimes such that the direction of maximum action and the primary antenna may be on the same side of the reflector axis 3.

Although the invention has been explained in connection with certain specific embodiments, it is to be understood that it is not to be limited to the embodiments described inasmuch as other apparatus may be successfully utilized in practicing the invention.

What is claimed is:

1. In combination, a paraboloidal reflector, an antenna element positioned in the focal plane of said reflector and having one end or terminal at the reflector focus, substantially, and means for rotating said element about said terminal and reflector focus.

2. In combination, a paraboloidal reflector, a linear primary antenna positioned in the focal plane and having one terminal at the focus, and means for rotating said primary antenna about said terminal and focus.

3. In combination, a parabolic reflector, a primary antenna element positioned in the focal plane of the reflector, a ring reflector included between said parabolic reflector and said primary antenna and symmetrically related to the axis of the parabolic reflector.

4. In combination, a parabolic reflector having a focus and a principal axis, an auxiliary reflector facing said parabolic reflector, a linear primary antenna positioned between said reflectors and spaced from said focus, said auxiliary reflector and primary antenna extending perpendicularly to said axis and means for rotating said primary antenna and auxiliary reflector about said axis.

5. In combination, a parabolic reflector, a coaxial line comprising an inner and an outer conductor extending through said reflector, the inner conductor being aligned with the reflector axis, a linear quarter-wave primary antenna posi-

tioned in the reflector aperture, and connected to said inner conductor, means for rotating said inner conductor and a translation device connected to said line.

6. A combination in accordance with claim 5, the mid-point of said primary antenna being adjustably spaced from said inner conductor and the reflector focus.

7. A combination in accordance with claim 5, a quarter-wave high impedance included between said primary antenna and said outer conductor.

8. A combination in accordance with claim 5, an auxiliary reflector positioned in front of said primary antenna, a high impedance, said auxiliary reflector being connected through said impedance to said inner conductor .

9. A combination in accordance with claim 5, an auxiliary reflector positioned in front of said primary antenna and connected to said inner conductor and a high impedance comprising a portion of said inner conductor included between said primary antenna and said auxiliary reflector.

10. In an antenna system comprising a reflector having the shape of a surface of revolution about its directive axis, a directive antenna member located on said axis at substantially the focal point of said reflector, and means for exciting said antenna member, means for causing radiation from said antenna at an angle with respect to said axis, and means for rotating said antenna member about said axis with respect to said reflector.

11. In combination, a parabolic reflector having a focus and a principal axis, an auxiliary reflector facing said parabolic reflector, a linear primary antenna positioned between said reflectors and spaced from said focus, said auxiliary reflector and primary antenna extending perpendicularly to said axis and means for rotating said primary antenna about said axis.

12. In an antenna system comprising a reflector having the shape of a surface of revolution about its directive axis and having a focal point on said axis, a concentric transmission line extending through said reflector and along said axis, the central conductor thereof extending beyond said focal point of said reflector, a radiating element attached at one end thereof to said central conductor near said focal point and extending therefrom transversely to said axis unsymmetrically with respect thereto and arranged for excitation from said transmission line, and a second reflector attached to said center conductor at a point beyond said focal point to reflect waves from said element toward said first reflector, and means to rotate said central conductor, radiating element, and second reflector as a unit to rotate the beam produced by said system about said axis.

13. In an antenna system comprising a reflector having the shape of a surface of revolution about its directive axis and having a focal point on said axis, a transmission line extending through said reflector and along said axis to said focal point, a radiator located near said focal point eccentrically with respect to said axis and connected for excitation from said transmission line, and means to rotate said radiator about said axis.

14. In an antenna system comprising a reflector having the shape of a surface of revolution about its directive axis and having a focal point on said axis, a coaxial transmission line extending through said reflector and along said axis to the focal point thereof, a radiating element mechanically and conductively connected at one end thereof to the central conductor of said line and extending transversely thereto, and means to rotate said central conductor thereby to rotate said radiating element about said axis to rotate the field pattern produced by said radiating element and reflector about said axis.

15. In an antenna system comprising a reflector having the shape of a surface of revolution about its directive axis and having a focal point on said axis, a concentric transmission line extending through said reflector and along said axis, a radiating element attached to a central conductor of said transmission line near said focal point and extending therefrom transversely to said axis unsymmetrically with respect thereto and arranged for excitation from said transmission line, a second reflector at a point beyond said focal point to reflect waves from said element toward said first reflector and means to rotate said central conductor and radiating element as a unit to rotate the beam produced by said system about said axis.

16. In an antenna system comprising a reflector having the shape of a surface of revolution about its directive axis and having a focal point on said axis, a coaxial transmission line extending through said reflector and along said axis to the focal point thereof, a radiating element mechanically and conductively connected to the central conductor of said line and extending therefrom unsymmetrically with respect to said axis and means to rotate said central conductor thereby to rotate said radiating element about said axis to rotate the field pattern produced by said radiating element and reflector about said axis.

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