

Nov. 29, 1949

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2,489,865

DIRECTIONAL MICROWAVE ANTENNA

Filed July 31, 1944

5 Sheets-Sheet 1

FIG. 1

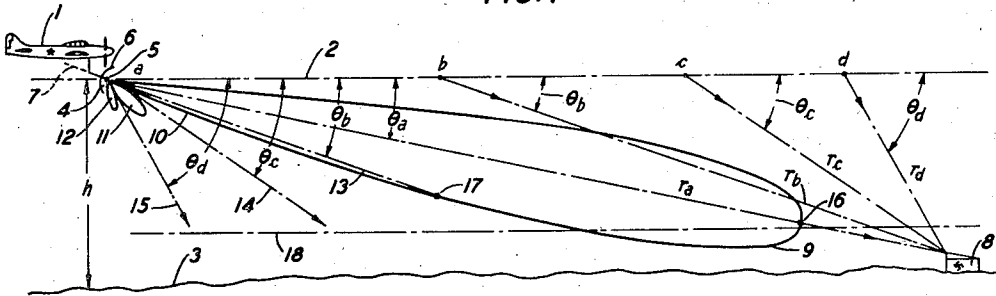


FIG. 2

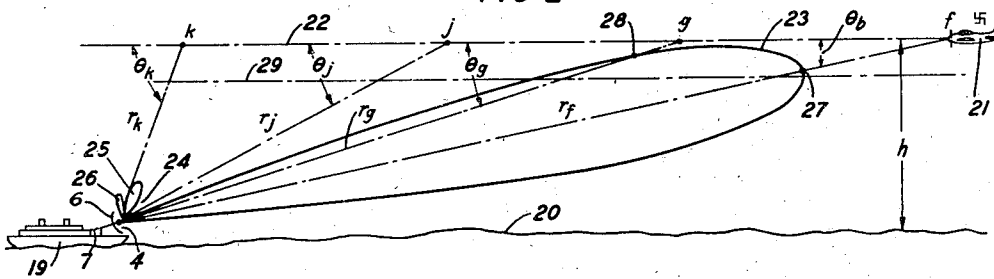


FIG. 3
FRONT VIEW

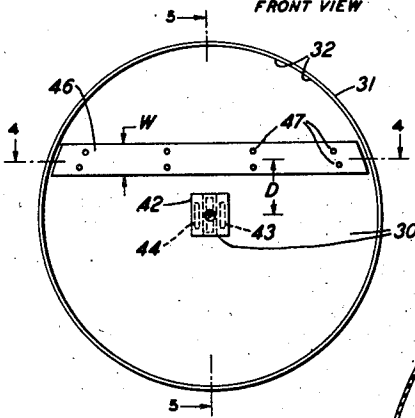


FIG. 4
SECTIONAL PLAN VIEW

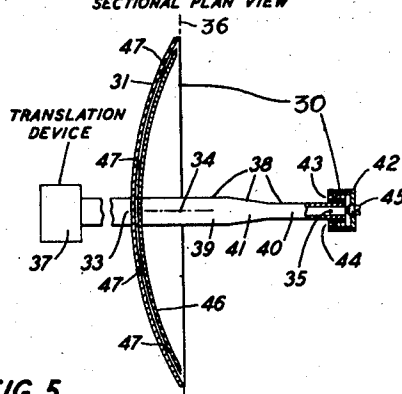
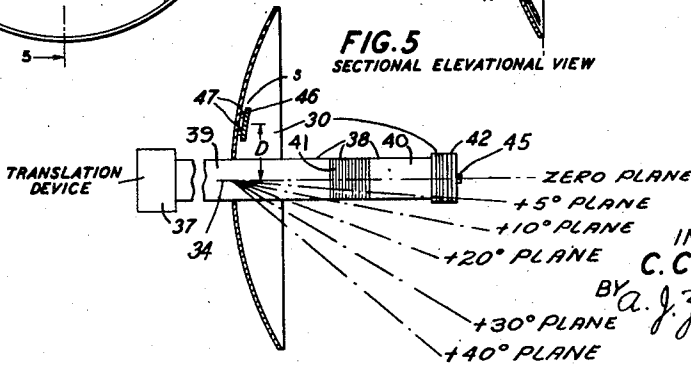


FIG. 5
SECTIONAL ELEVATIONAL VIEW



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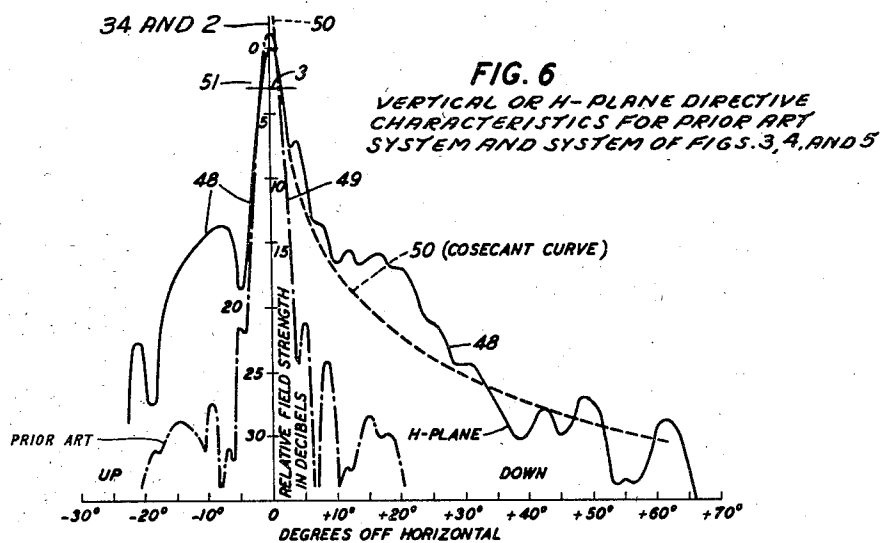
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5 Sheets-Sheet 2



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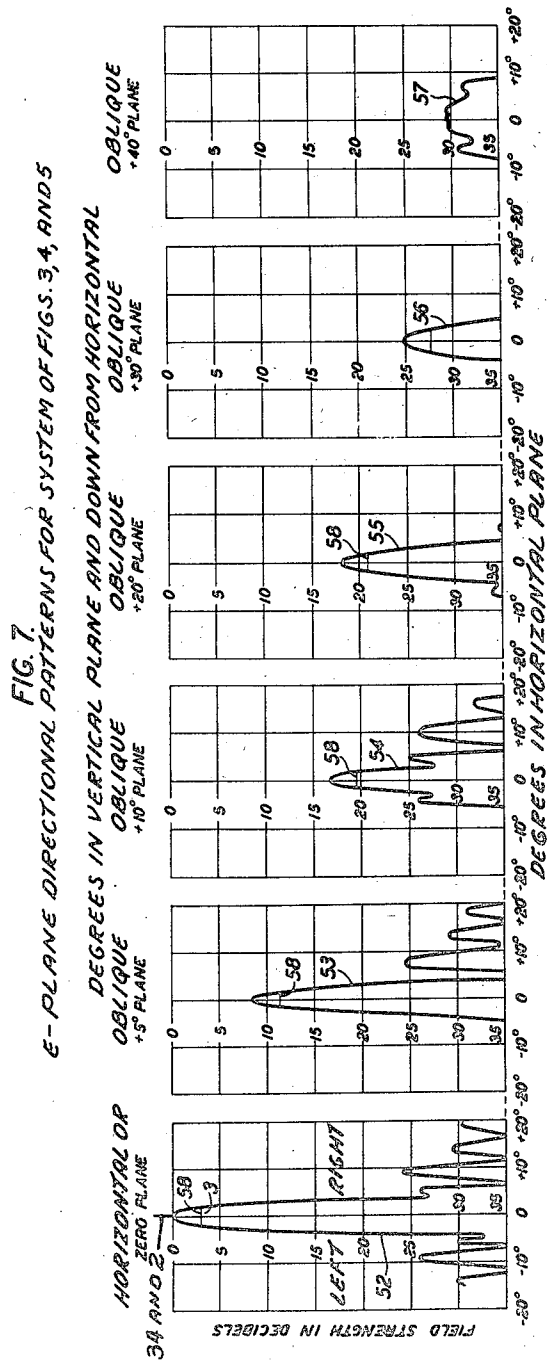
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DIRECTIONAL MICROWAVE ANTENNA

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DIRECTIONAL MICROWAVE ANTENNA

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FIG. 11
FRONT VIEW

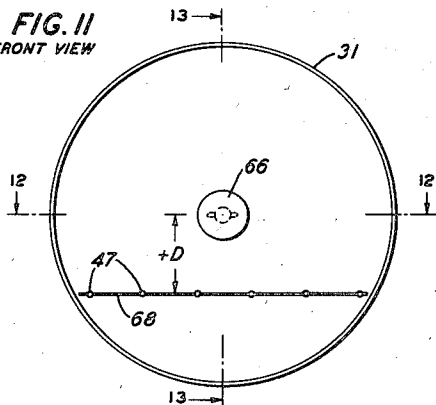


FIG. 12
SECTIONAL PLAN VIEW

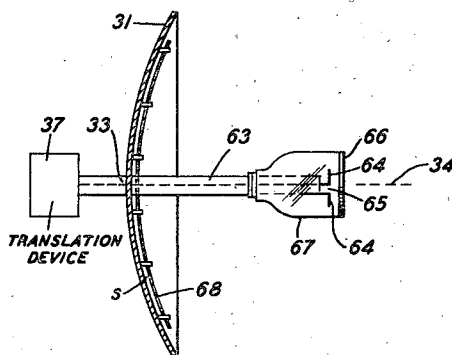
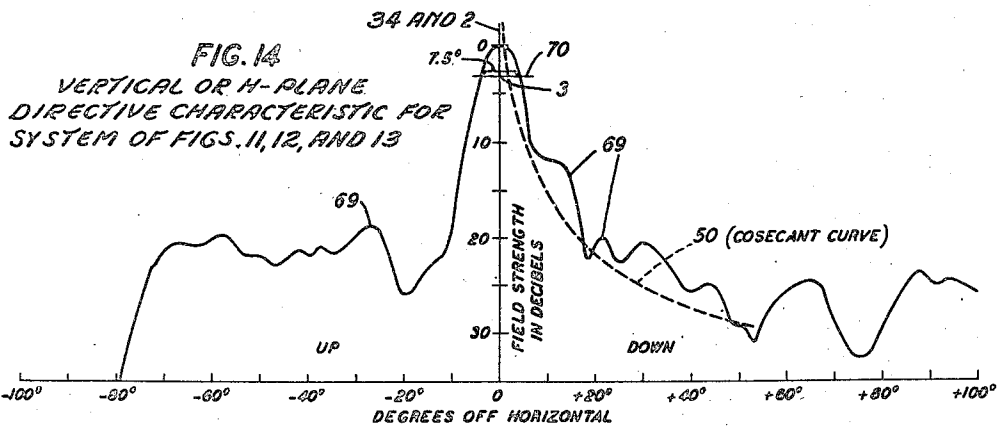
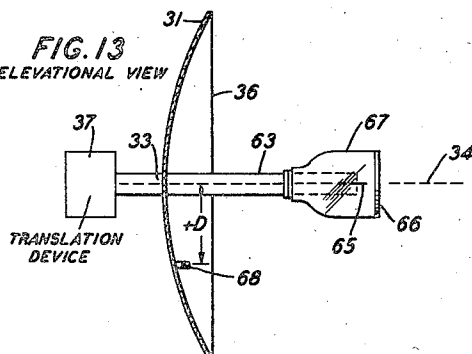


FIG. 13
SECTIONAL ELEVATIONAL VIEW



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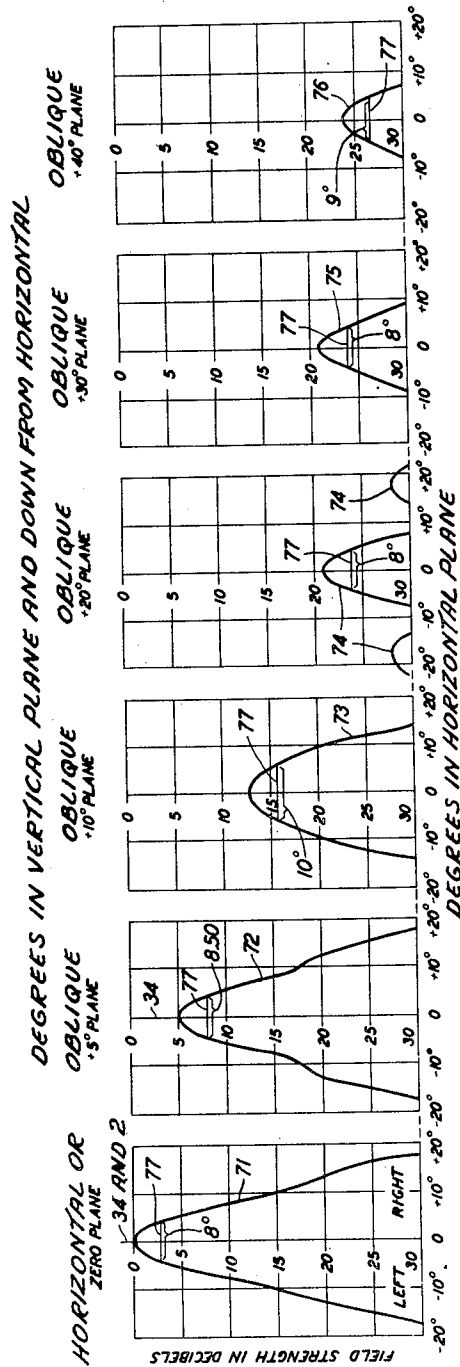
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DIRECTIONAL MICROWAVE ANTENNA

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FIG. 15
E-PLANE DIRECTIONAL PATTERNS FOR SYSTEM OF FIGS. 11, 12, AND 13



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DIRECTIONAL MICROWAVE ANTENNA

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Application July 31, 1944, Serial No. 547,399

6 Claims. (Cl. 250—33.65)

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This invention relates to directional antenna systems and particularly to directional cosecant paraboloidal antenna systems.

As is known, the shape of the electric and magnetic plane directive patterns, and particularly the major lobe patterns, of a "point-beam" antenna comprising a paraboloidal reflector and a focal primary antenna, such as the antenna disclosed in my copending application Serial No. 518,377, filed Jan. 15, 1944, now Patent No. 2,422,184, issued June 17, 1947, are substantially the same. Assuming a point-beam antenna is used in an airborne azimuthal scanning radar on an aircraft flying at a constant altitude, the reflector axis being substantially horizontal or tilted downward, the intensity of the illumination of the ocean surface or a relatively flat ground surface extending ahead of the aircraft is not uniform. Hence the intensities of echoes received from a distant surface target and a nearby surface target, both included in a given vertical plane and therefore having the same azimuthal direction, are substantially different. Also, the echo signal from a single stationary surface target varies, undesirably, as the aircraft approaches the target. The variation in the illumination intensity results from the facts that the lower half of the magnetic plane pattern of the prior art system includes a deep null and a sharp major half lobe, and the illumination intensity is inversely proportional to the distance or range of the earth's surface, as measured along an angular direction from the airborne antenna to the surface. In a converse sense, assuming the point-beam antenna is utilized in a seaborne or land-borne azimuthal scanning radar, the illumination of a horizontal sky plane, in which a hostile aircraft is traveling, is not uniform.

While systems comprising a paraboloidal reflector have been proposed for securing uniform illumination or so-called cosecant coverage of a "target plane" such as the earth's surface or a horizontal sky plane, the systems heretofore suggested are relatively complicated in construction and involve a modification, difficult to make, in the shape of the paraboloidal reflector. Moreover, in general, the prior art systems do not provide an adequate cosecant coverage over a desired elevational angular sector. Accordingly, it now appears desirable to secure, in a radar system, a more satisfactory cosecant pattern in a plane perpendicular to the scanning plane, and to obtain a simple and easily manufactured antenna system having such a pattern.

It is one object of this invention to secure, in an azimuthal scanning radar antenna system,

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uniform illumination of a horizontal target plane which does not contain a radar system.

It is another object of this invention to obtain, in an antenna system comprising a paraboloidal reflector, a cosecant pattern without modifying the paraboloidal reflector.

It is still another object of this invention to secure a skewed or unsymmetrical point beam, utilizing a point beam antenna comprising a standard primary focal antenna member and a conventional or standard secondary reflective member.

In accordance with one embodiment of the invention, a metallic strip or auxiliary reflector is fastened to and spaced from the paraboloidal reflector of the system disclosed in my copending application mentioned above. A design or mean wavelength of approximately three centimeters is used, and the axis of the main or paraboloidal reflector is substantially horizontal. The projection of the strip on the vertical plane is linear and horizontal, and on the horizontal plane it is parabolic or substantially so. The strip has a critical vertical width and extends horizontally across the surface of the main reflector. Also the strip is positioned at a critical distance above the reflector axis and at a critical distance from the main reflector. While the magnetic or electric plane of polarization may be horizontal, usually the electric plane is horizontal and the magnetic plane vertical.

In a different embodiment, especially suitable for high altitude airborne radars, the auxiliary reflector comprises three strips, one above and two below, the axis of the paraboloidal reflector.

In still another embodiment having a design wavelength of approximately ten centimeters, a dipole is employed as the focal primary antenna and a single horizontal wire having a contour as described above is positioned at a critical distance below the main reflector axis.

In operation, considering any of the three embodiments and the vertical plane, the wavelets reflected or reradiated by the auxiliary reflector reinforce in different degrees the wavelets reflected by the paraboloidal reflector along certain desired wide-angle directions extending above, in the case of surface-borne radar, and below in the case of an airborne radar, of the reflector axis; and the wavelets from the auxiliary reflector oppose or less completely reinforce the wavelets reflected by the main reflector in directions on the other side of the reflector axis, whereby a cosecant pattern is secured. Stated differently an asymmetrical vertical plane major lobe pattern having on one side of the lobe axis a cosecant

contour is secured. The effect of the auxiliary reflector on the width of the narrow horizontal plane major lobe pattern is negligible.

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:

Figs. 1 and 2 are explanatory diagrams;

Figs. 3, 4 and 5 are, respectively, front, plan and elevational views of one embodiment of the invention;

Fig. 6 illustrates the directive vertical plane patterns for the system of Figs. 3, 4 and 5 and the prior art point-beam antenna of my copending application; and Fig. 7 illustrates the horizontal plane patterns for the system of Figs. 3, 4 and 5;

Figs. 8, 9 and 10 are respectively front, plan and elevational views of a different embodiment of the invention;

Figs. 11, 12 and 13 are respectively front, plan and elevational views of a third embodiment of the invention; and

Figs. 14 and 15 are, respectively, vertical plane and horizontal plane directive patterns for the system of Figs. 11, 12 and 13.

Referring to Fig. 1, reference numeral 1 denotes an airborne mobile craft flying at a constant altitude h along a horizontal sky plane 2 and over a target plane 3. The airborne craft 1 carries an azimuthal scanning radar antenna 4 comprising a primary focal antenna 5 and a circular paraboloidal reflector 6 having its axis 7 tilted down at an angle related to the maximum target range desired. Numeral 8 designates a hostile surface target or craft located in the target plane 3 of the antenna 4. The angle, in the vertical plane between the horizontal plane or bombing run 2 and the direction, at any instant, to the target 8 is denoted by θ and the distance or range of the target is designated by the reference letter r . The target 8 may, of course, be a land target instead of a seaborne target and the target plane may be the ground surface instead of a sea or ocean surface.

The lower half of the vertical plane pattern illustrated in Fig. 1, in polar coordinates, of a prior art point-beam antenna comprises the lower half of the major lobe 9, the null 10 and the minor lobes 11 and 12. For purposes of explanation the width of the major lobe 9 as shown on the drawing is greatly exaggerated, the actual width of a point beam for a prior art antenna being in the order of 3.0 degrees at the half-power point; and, for the same reason, the contour of the entire pattern is somewhat distorted. The reference letters a , b , c and d denote successive representative positions in the sky plane assumed by the mobile craft in approaching the target 8, the angle θ and the range r for these positions being designated θ_a , θ_b , θ_c and θ_d , respectively, and r_a , r_b , r_c and r_d respectively. As the craft 1 moves forward its polar directive pattern also moves forward and the pole or origin of the pattern successively coincides with the positions a , b , c and d . In the interest of simplicity, however, the prior art directive pattern has been illustrated only for position a and lines, denoted by numerals 13, 14 and 15, have been drawn parallel to the lines r_b , r_c and r_d respectively, so as to illustrate the relation between the angular directions θ_b , θ_c and θ_d and the vertical plane pattern. Direction θ_a intersects lobe 9 at point 16 and direction θ_b intersects lobe 9 at point 17 of less intensity. Direction θ_c or line 14 is aligned with the null 10 and

direction θ_d or line 15 is aligned with a minor lobe 11.

As the craft 1, Fig. 1, approaches the target 8, θ increases and r decreases. Assuming the use of a prior art antenna having the pattern 9, 10, 11 and 12, as θ increases the target direction intersects in succession points on the major lobe 9 of successively decreasing intensity, whereby the target illumination, and therefore the echo signal and the intensity of the cathode ray tube target indication, tend to decrease rapidly. As r decreases, however, the target illumination tends to increase, since the field strength or illumination at the target as measured in power units is inversely proportioned to the square of the range and, as measured in volts per meter, is inversely proportional to the range. In other words, the change in illumination, or tendency to change, induced by an increase in θ and the tendency to change occasioned by a decrease in r oppose each other. The shape or contour of the vertical plane directive pattern for the prior art antenna is such, however, that the opposing tendencies do not completely compensate or off-set each other so as to produce a constant target illumination during the approach of craft 1. More specifically the major lobe pattern 9 is too sharp or narrow and the null direction 10 along which little or no radio action occurs is highly undesirable. As will be shown below, for uniform illumination of the target plane, the vertical plane pattern of the antenna should be such that complete compensation is secured and an echo signal obtained which in one sense is independent of the range r .

As is apparent from Fig. 1,

$$\csc \theta = \frac{r}{h} \quad (1)$$

where, as before, θ is the angle between the horizontal and the target direction. But E , the target illumination in volts per meter, is a function of θ , and is inversely proportional to the range. Thus,

$$E = \frac{f(\theta)}{r} \quad (2)$$

or,

$$f(\theta) = E \cdot h \cdot \csc \theta \quad (3)$$

where $f(\theta)$, a function of θ , represents the polar directive characteristic of the antenna. Hence, with h and E constant, the optimum polar characteristic for securing uniform illumination is

$$f(\theta) \sim \csc \theta \quad (4)$$

Consequently, for exact compensation and a uniform illumination of the target plane 3, the lower half of the major lobe pattern, as measured in volts per meter field strength, should have a shape or contour in reasonable conformity with a curve representing $\csc \theta$, or as measured in power units a curve representing the cosecant square function of θ . In Fig. 1, the straight line 13 illustrates the ideal $\csc \theta$ curve in polar coordinates, for the antenna 4; and in Fig. 6 dotted curve illustrates the same ideal curve plotted in rectangular coordinates.

Referring to Fig. 2, the explanatory diagram is in a sense the inverse of that of Fig. 1. Numeral 19 denotes a seaborne craft carrying an azimuthal scanning radar antenna 4, the axis 7 of the antenna reflector 6 being tilted up, relative to the surface 20 of the sea, at an angle related to the maximum target range desired. For a great range the tilt angle is small so that the reflector axis 7 is substantially horizontal.

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Numeral 21 denotes a hostile airborne craft or target approaching at a constant altitude h and in the horizontal sky or target plane 22, the antenna 4. The upper half of the vertical plane pattern for a prior art point-beam antenna includes the upper half of lobe 23, the null 24 and the minor lobes 25 and 26. The craft 21 and directive pattern are assumed to be stationary or relatively so. As the target 22 approaches antenna 4 and assumes in succession the representative positions f, g, j and k, r decreases and θ increases. The successive target directions θ_f and θ_k intersect the major lobe 23 at point 27 and point 28 of less intensity, respectively. The target direction θ_i coincides with the null direction 24 and direction θ_k is aligned with a minor lobe 25. As is apparent from the discussion of Fig. 1, uniform illumination of the target plane 22 is not secured with a prior art antenna having a pattern such as the pattern 23, 24, 25 and 26; and, in the case of a surface-borne azimuthal scanning antenna, the upper half of the major lobe should conform reasonably with the ideal cosecant pattern 29. In Fig. 2, the radar antenna may, of course, be carried by a landborne mobile craft or may be at a fixed radar ground station.

While, for radars requiring uniform target plane coverage, an antenna having a vertical plane cosecant pattern is highly advantageous, it may not be amiss to discuss, before describing the structures embodying the invention, certain limiting factors which should be considered in designing antennas to conform with the cosecant law. Thus, at the zero degree direction coincident with the reflector axis, it is impossible to secure an infinite field strength E as required by the cosecant law. In general, in designing cosecant antennas, (1) the minimum angle θ to which the cosecant law must be followed, (2) the actual field strength desired at a particular intermediate angle θ and (3) the allowable head-on gain reduction from the undistorted or prior art antenna pattern, are factors which are interdependent and must be considered. Thus, as the angle or direction at which the peak of the vertical plane major lobe increases, the gain taken along the major lobe axis called the "head-on" gain, decreases and the gain taken along an intermediate angular direction on the cosecant side of the lobe, for example, the thirty degree direction, increases. For a given size of reflector, the determination of one factor determines the other two.

In general, the echo signals should be the same, for a given value of h , within a given maximum range. If the sensitivity of the antenna and the effective target cross-section are known, the following equation may be used to calculate the desired pattern

$$P = \left[(4\pi)^{3/2} \frac{h^2 \csc^2 \theta}{\lambda \Delta} \sqrt{\frac{P_m}{P_n}} \right]^{1/2} \quad (5)$$

where

P = the power gain, one way

h = altitude

λ = wavelength

Δ = effective collision cross-section

P_m = minimum peak power detectable

P_n = peak power transmitted

R = maximum desired range

θ = angle between target direction and horizontal reflector axis

For navigation over land, a view of the general background of land return is sometimes advan-

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tageous and the following equation, obtained empirically for present 3 centimeter radar systems, may be used to calculate the cosecant characteristic for an antenna designed to secure satisfactory background echoes

$$P = \left[(1.2) (10)^{\frac{h^2 \csc^2 \theta}{\lambda}} \sqrt{\frac{P_m}{P_n}} \right]^{1/2} \quad (6)$$

In addition to the factors discussed above, the lower limit of useful level, as measured on the vertical decibel scale, Fig. 6, at any angle θ is, because of the difficulty of controlling the amplitude of the pattern at very low levels, about six decibels above the uncontrollable minor lobe level at the same angle θ . At such low levels, interference between the desired radiation or cosecant major lobe and the unavoidable minor lobes may cause a reduction in resolution and render the control of the shape of the resulting pattern difficult. Ordinarily, in determining the illumination coverage desired, it is necessary to balance the desirability of short range coverage against reduction in long range performance resulting from a reduction in the antenna gain. In general, in designing cosecant antennas, as the close range performance is increased, that is, extended toward zero miles, the antenna gain is reduced to some extent and, as a result, the maximum range is reduced to a certain extent.

Referring now to Figs. 3, 4 and 5, reference numeral 30 denotes a cosecant antenna comprising a paraboloidal reflector 31 having a circular perimeter 32, a vertex 33, an axis 34, a focal point 35 and a latus rectum plane 36. Numeral 37 denotes a translation device, such as a radar transceiver, which is connected to one end of the rectangular wave guide 38 comprising the end sections 39 and 40 and the impedance matching section 41. The guide extends through the vertex 33 of reflector 31 along the axis 34 to a point near the focus 35. Numeral 42 denotes a primary antenna or head having two apertures 43, 44 facing the reflector 31 and a tuning plug 45. The plane of electric polarization of the waves transmitted and received by the system is assumed to be horizontal. The antenna reflector and associated head 42 or, more accurately, the reflector axis 34 is rotated for azimuthal scanning, the axis 34 being substantially horizontal or, as explained above, tilted in the vertical plane. As described so far the system of Figs. 3, 4 and 5 is exactly the same as that disclosed in my above-mentioned copending application.

In accordance with the invention, an auxiliary reflector 46 is included between the main reflector 31 and its focus 35 and attached to the surface of the reflector 31 by means of the stud members 47 which may be conductive or non-conductive. The strip 46 has a width w and extends, as shown in Fig. 4, completely across the reflector surface. It is parallel to the horizontal scanning plane and is positioned at a distance D above the reflector axis 34. In more detail, the projection of the bottom or top edge of the strip reflector 46 on the vertical plane is linear and parallel to the assumed plane of electric wave polarization. In the horizontal plane, Fig. 4, the front and rear edges of the strip reflector 46 may, if desired, each coincide with a parabolic curve having its focus at the focus 35 of the main reflector 31, and the small spacing s between the main reflector 31 and the auxiliary reflector 46 may vary accordingly. In practice, however, it has been found that this refinement is not essential and for the

purpose of facilitating manufacture, the strip reflector 46 may be uniformly spaced at a small constant average distance s from the main reflector 31, the bottom edge being slightly closer to the main reflector than the top edge.

In operation the wavelets emitted by the dual aperture head 42 are reflected by the main reflector 31 and are reradiated or reflected by the auxiliary reflector 46. The phases and amplitudes of the two sets of reflected wavelets are such that the wavelets interfere or oppose in certain vertical plane directions and reinforce in other vertical plane directions; and a resultant vertical plane pattern is obtained. In practice, the critical position D , plus or minus, the critical width w and the critical spacing s for securing a vertical plane pattern, one-half of which approaches the ideal cosecant curve, are determined experimentally. In reception, the converse operation obtains.

Referring to Fig. 6, reference numeral 48 denotes a measured vertical or H-plane space factor pattern obtained for an airborne system such as that illustrated by Figs. 3, 4 and 5 and having a design wavelength of 3.2 centimeters. Reference numeral 49 denotes the measured vertical plane pattern corresponding to curve 94 of Fig. 20 of my above-mentioned copending application for the prior art system. In the actually constructed and tested system of the invention, the diameter of the main reflector opening was 29 inches corresponding to 23 wavelengths and its focal length was 10.5 inches. The dimensions w , D and s were approximately 2.5 inches, 6.0 inches and 0.3 inch, respectively, the bottom edge of the strip 46 being slightly closer to the reflector 31 than the top edge. At the design wavelength of λ equal to 3.2 centimeters, the dimensions given above for w , D and s correspond, respectively, to 1.99λ , 4.76λ and 0.238λ . Numeral 50 denotes the ideal cosecant pattern which extends to infinity at zero degrees and which provides a uniform illumination of the target plane. It will be observed that the lower or positive half of the measured pattern 48 for the antenna of the invention conforms, substantially, with the ideal cosecant pattern 50 for downwardly pointing angles or directions as large as $+50$ degrees. Note that the zero or reference point on the vertical decibel scale, Fig. 6, is higher for pattern 49 than for pattern 48. In a sense the effect of the auxiliary reflector 46 is to distort, in a desired manner, a portion of the prior art pattern 49. Stated differently, the auxiliary reflector functions to shift, in the vertical plane, a portion of the power at the peak or zero angle, and the immediately adjacent angles of the major lobe pattern to the larger angular directions on one side of the zero direction and in this manner operates to produce the cosecant pattern, with a small reduction as explained previously, in the head-on gain. The half power width 51, taken three decibels down, of lobe 48 is about 3 degrees, as in the prior art system. It should be pointed out that the patterns 48 and 49 are substantially, but not strictly, comparable since in the prior art system the reflector diameter is, as described in the copending application, 30 inches and the focal length is 10.6 inches. Note that for the 3.2 centimeter system of Figs. 3, 4 and 5, the cosecant half portion of the lobe pattern 48 and the strip reflector 46 are on opposite sides of the axis 34 of the main reflector 31.

Referring to Fig. 7, reference numeral 52 designates the measured zero degree horizontal or E-plane pattern of the system illustrated by Figs.

3, 4 and 5 and tested at 3.2 centimeters, as described above. Numerals 53, 54, 55, 56 and 57 denote the E-plane patterns taken in the oblique $+5$ degree plane, $+10$ degree plane, $+20$ degree plane, $+30$ degree plane, and $+40$ degree plane shown in Fig. 5. These oblique planes extend perpendicular to the vertical plane, Fig. 6, and contain, respectively, the $+5$, $+10$, $+20$, $+30$ and $+40$ degree directions of Fig. 6. The half power width 58 of the zero degree major lobe pattern 52 is 3 degrees, and, since the half power width 51 of the vertical plane major lobe 48, Fig. 6, is 3 degrees, a point beam is secured. At decibel levels or points considerably below the half power levels, 58 and 51, the major lobe of the H-plane pattern 48 is much wider, by reason of the cosecant characteristic, than the major lobe of the E-plane pattern 52, so that in one sense the beam has a special fan shape. To illustrate, at 22.5 decibels down, the width of the major lobe of the vertical pattern 48, Fig. 6, is about 44.5 degrees whereas the corresponding width of the major lobe of pattern 52, Fig. 7, is about 8 degrees. In other words, the auxiliary reflector 46 does not affect, materially, the horizontal pattern, but does change the vertical plane pattern; and this highly desired effect is secured by positioning the auxiliary reflector 46 parallel to the azimuthal scanning plane.

In addition, the horizontal or scanning plane resolution realized with the antenna of the present invention is fairly satisfactory. More specifically, each of the half power lobe widths 58, Fig. 6, in the patterns 53, 54, 55 and 56 obtained respectively for the positive or "down" planes $+5$, $+10$, $+20$ and $+30$ degrees, is not over twenty-five per cent greater than the half power lobe width 58 in pattern 52 obtained for the zero degree plane, or for the half power lobe width of a prior art system not containing the auxiliary reflector 46. In short, assuming the axis of the main reflector is horizontal, the effective horizontal width of the beam, which for the zero or horizontal plane is relatively small, does not increase materially, that is, not more than a quarter of the half power width in the zero or horizontal plane, as the angle in the vertical plane between the aforesaid zero plane and the downwardly extending oblique plane increases. Since the half power width 58 for any pattern is inversely proportional to the horizontal or scanning plane resolution, the resolution for the system of Figs. 3, 4 and 5 does not decrease more than twenty-five per cent as the angle of the oblique plane increases from zero down to $+30$ degrees.

Referring to Figs. 8, 9 and 10, the system illustrated is the same as that of Figs. 3, 4 and 5, except that the auxiliary reflector 59 comprises three metallic strips 60, 61 and 62, each similar in construction and contour to the strip reflector 46 of Figs. 3, 4 and 5. The strip 60 is positioned above, and the two strips 61 and 62 below, the reflector axis 34. As in the system of Figs. 3, 4 and 5, the width w , the position $\pm D$ and the spacing s are, in practice, adjusted to secure the desired cosecant half pattern. In general, the system of Figs. 3, 4 and 5 is more suitable than the system of Figs. 8, 9 and 10 for use in a low altitude airborne radar and the system of Figs. 8, 9 and 10 is preferred for use in a high altitude airborne radar, the reason being that the three-strip auxiliary reflector 59 intercepts more of the energy emitted by the primary antenna head 42, and therefore reflects more energy into the cosecant portion of the vertical plane directive pat-

tern. In short, referring to Fig. 1, the more energy directed downwardly into the cosecant portion of the pattern, the higher the aircraft may fly and still establish sufficient field strength on the target plane 3. If desired any plurality, within a practical limit and including two, of strips may be employed.

Referring to the 10-centimeter system illustrated by Figs. 11, 12 and 13, reference numeral 63 denotes a coaxial line which passes through the vertex 33 of the reflector 31. Numeral 64 designates a horizontal dipole located at the reflector focus 65 and connected to line 63 and numeral 66 designates a disc reflector adjacent the dipole 63, the dipole and disc reflector 66 being enclosed by the plastic insulator housing 67. Numeral 68 denotes a reflector rod or wire positioned at a distance $+D$ below the reflector axis 34 and extending horizontally. The wire or auxiliary reflector 68 is attached to the reflector 31 by means of the spacers 47.

In operation, Figs. 11, 12 and 13, the wavelets radiated by dipole 64 are propagated directly and via the disc reflector 66 toward the main reflector 31 and the wire or auxiliary reflector 68. The waves reflected by the main reflector 31 and the wire reflector 68 oppose, as in the system of Figs. 3, 4 and 5, in certain vertical plane directions and reinforce in certain other vertical plane directions, whereby, the lower half of the vertical plane pattern substantially agrees with the cosecant curve.

Referring to Fig. 14, reference numeral 69 denotes a vertical or H-plane pattern measured at an operating frequency of 3300 megacycles for a system such as that illustrated by Figs. 11, 12 and 13. In the system tested, the opening and focal length of reflector 31 were 29 and 10.6 inches, respectively. The spacing s between the wire 68 and the reflector 31 was about 1 inch and the distance $+D$ was about 6 to 7 inches. The lower or positive half of the pattern 69 agrees substantially for angular directions up to about 50 degrees with the ideal cosecant curve 50. The width at the half power or three decibel point 70 on the major lobe is about 7.5 degrees. Note that in contrast to the system of Figs. 3, 4 and 5, the auxiliary reflector 68 and the cosecant half portion of the pattern 69 are on the same side of the axis 34 of the main reflector 31.

Referring to Fig. 15 reference numerals 71, 72, 73, 74, 75 and 76 designate the E-plane patterns, taken respectively in the zero or horizontal and the $+5$, $+10$, $+20$, $+30$ and $+40$ degree downwardly extending oblique planes containing the 0, $+5$, $+10$, $+20$, $+30$ and $+40$ degree directions, Fig. 14, for the system tested at 3300 megacycles. The half power width 77 for pattern 71 is about 8 degrees and is not materially different for the patterns 72, 73, 74, 75 and 76. Also the half power width 70 of the H-plane pattern 69, Fig. 14, and the E-plane half power width 77 of the E-plane pattern 71, Fig. 15, are about the same.

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

What is claimed is:

1. In an antenna system, a paraboloidal main reflector having a focus and an axis, an auxiliary reflector comprising a metallic strip positioned entirely in front of and throughout its length adjacent to said main reflector, said auxiliary reflector being positioned entirely on one side of said axis, and a primary antenna at or near said focus.

2. A system in accordance with claim 1, said axis being horizontal and the bottom edge of said auxiliary reflector being horizontal and positioned above said axis.

3. A system in accordance with claim 1, said axis being horizontal and the top edge of said auxiliary reflector being horizontal and positioned below said axis.

4. In an antenna system, a main reflective member having an axis and a focus, a primary antenna member positioned at or near said focus, an auxiliary reflective member entirely included between said main reflective member and said primary antenna member and spaced uniformly from the main reflective member, the entire auxiliary reflective member being spaced from said axis.

5. In combination, a paraboloidal reflective member having a horizontal axis and a focus, a primary antenna therefor at or near the focus and an auxiliary reflective member, the projection of said auxiliary member on a horizontal plane being substantially parabolic, said reflective members having focal lengths several wavelengths long and substantially the same parabolic curvatures said auxiliary member being asymmetrically positioned relative to said axis and included entirely between a minor portion of the face or surface of said paraboloidal member and said focus, whereby an asymmetrical directive pattern is secured.

6. In an azimuthal scanning radar antenna system, a main paraboloidal reflector having a horizontal axis, a focal primary antenna, and an auxiliary reflector spaced uniformly from the main reflector surface and extending horizontally, said auxiliary reflector being included between said main reflector and said primary antenna and spaced entirely from said axis, the distance between said auxiliary reflector and said primary antenna being greater than the distance between said two reflectors, the reflective surface of said auxiliary reflector being small relative to that of the main reflector, one-half of the vertical plane pattern of said system having a contour substantially in accordance with a cosecant curve.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,771,148	Sprague	July 22, 1930
2,118,419	Scharlau	May 24, 1938
2,170,028	Kohl	Aug. 22, 1939

FOREIGN PATENTS

Number	Country	Date
668,231	Germany	Nov. 28, 1938