

March 21, 1961

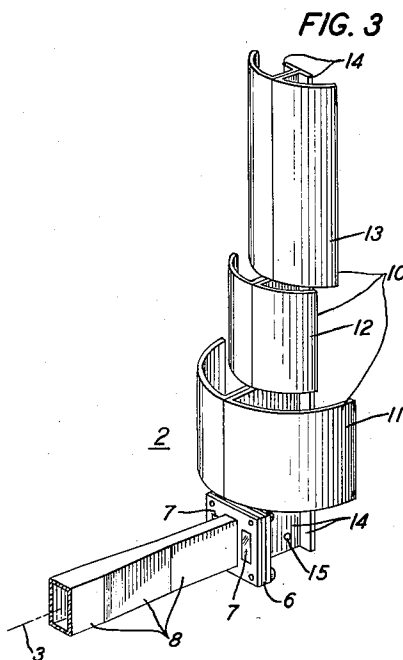
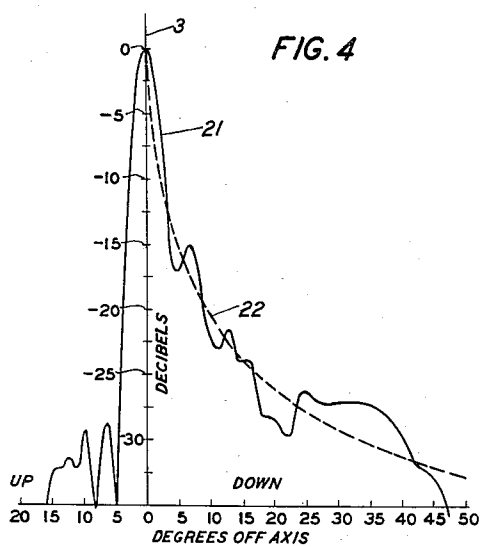
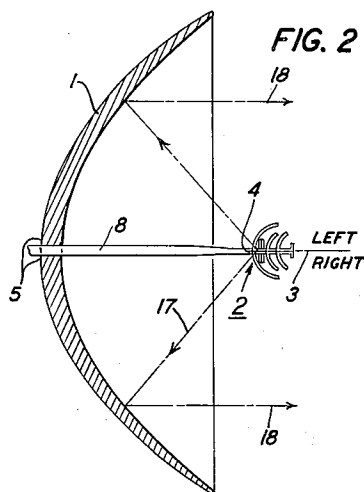
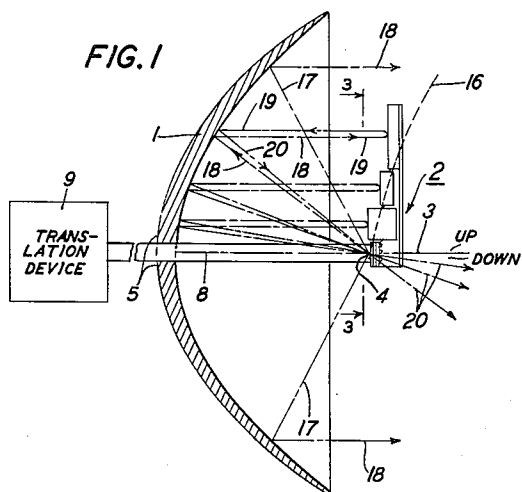
C. C. CUTLER

2,976,535

COSECANT SQUARED ANTENNA-REFLECTOR SYSTEMS

Filed March 24, 1949

3 Sheets-Sheet 1



INVENTOR
C. C. CUTLER
BY
A. J. Zerbarini
ATTORNEY

March 21, 1961

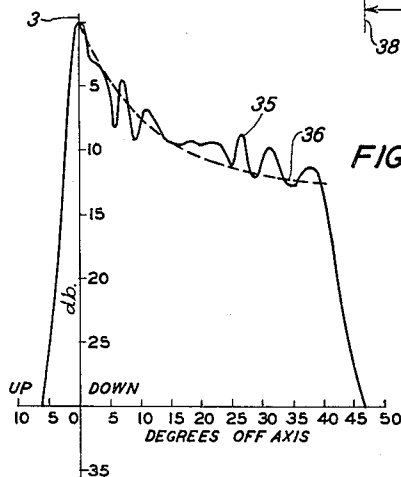
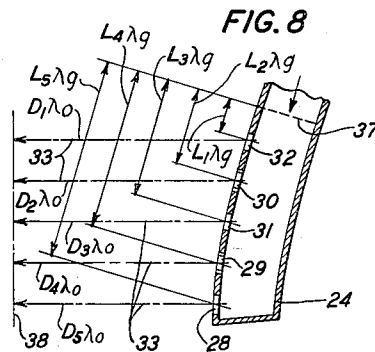
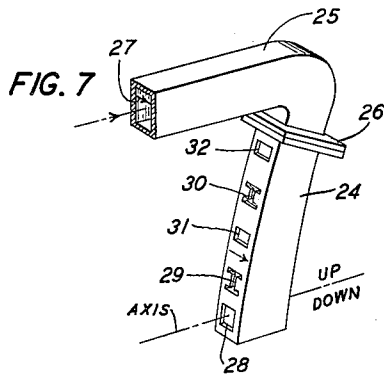
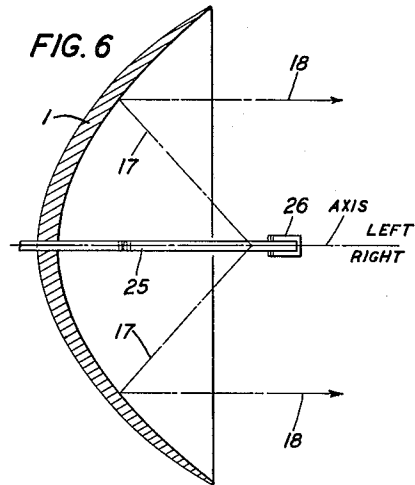
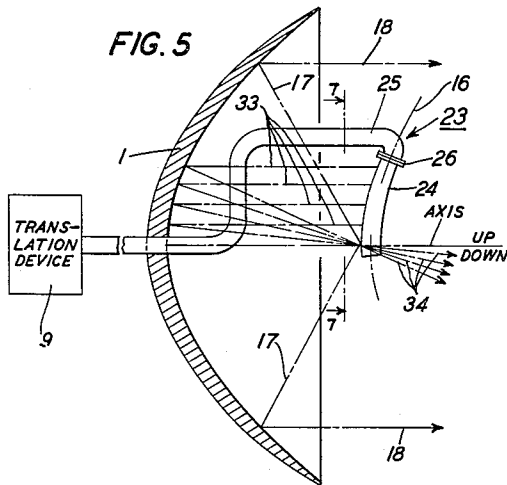
C. C. CUTLER

2,976,535

COSECANT SQUARED ANTENNA-REFLECTOR SYSTEMS

Filed March 24, 1949

3 Sheets-Sheet 2



INVENTOR
C.C. CUTLER
BY
A.J. Zerbarini
ATTORNEY

March 21, 1961

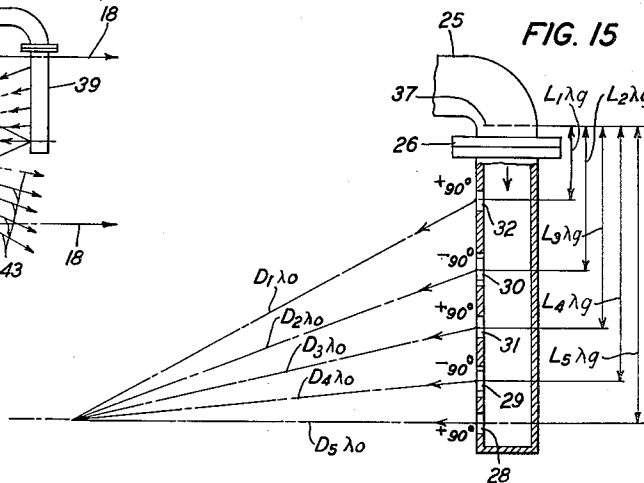
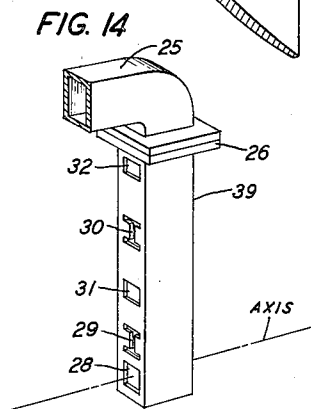
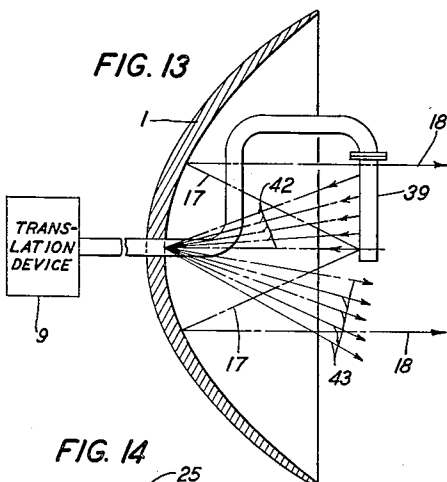
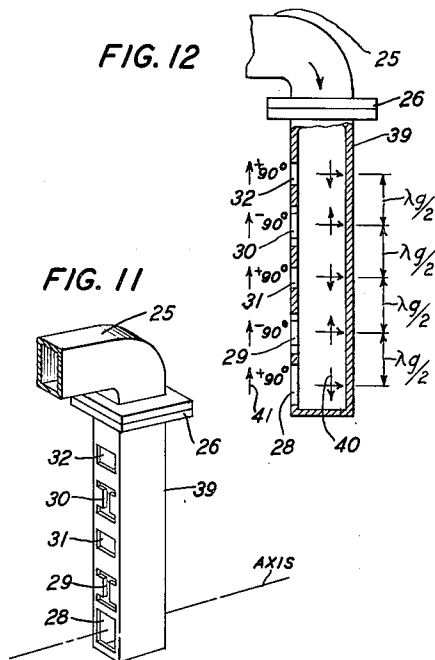
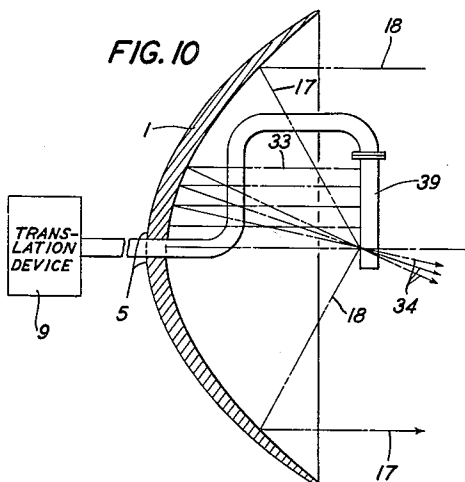
C. C. CUTLER

2,976,535

COSECANT SQUARED ANTENNA-REFLECTOR SYSTEMS

Filed March 24, 1949

3 Sheets-Sheet 3



INVENTOR
C.C. CUTLER
BY
A. J. Zerbarini
ATTORNEY

1

2,976,535

COSECANT SQUARED ANTENNA-REFLECTOR SYSTEMS

Cassius C. Cutler, Gillette, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Mar. 24, 1949, Ser. No. 83,108

10 Claims. (Cl. 343-779)

This invention relates to antenna-reflector systems and particularly to directive cosecant antenna reflector systems.

As is known, in an antenna system comprising a main paraboloidal reflector and a conventional primary antenna or feed at the reflector focus, a so-called cosecant directive pattern may be obtained by modifying the shape of the main reflector. Also, as is disclosed in my co-pending application, Serial No. 547,399, filed July 31, 1944, which matured into United States Patent 2,489,865, granted November 29, 1949, the cosecant pattern may be obtained by equipping the reflector with one or more properly positioned auxiliary "strip" reflectors. Modifying the paraboloidal reflector or adding thereto auxiliary reflectors involves manufacturing difficulties, and for this and other reasons, it now appears desirable to obtain a cosecant antenna system comprising a conventional paraboloidal reflector and a primary antenna adapted to secure, in conjunction with the main reflector, the desired cosecant field distribution.

It is an object of this invention to obtain a highly satisfactory cosecant directive pattern.

It is another object of this invention to obtain, in an antenna-reflector system, a cosecant pattern utilizing a conventional paraboloidal reflector.

It is still another object of this invention to obtain a simple, inexpensive and easily manufactured cosecant antenna-reflector system.

In accordance with the preferred embodiment of the invention the antenna system comprises a standard paraboloidal main reflector, the axis of the reflector being normally horizontal, a primary antenna therefor comprising a dual-aperture wave guide at the reflector focus, and a plurality of auxiliary reflectors positioned above the focus and having convex reflective surfaces facing the upper half of the main reflector. In operation, the primary antenna illuminates or energizes the entire main reflector. A portion of the energy reflected by the upper half of the main reflector impinges upon the auxiliary reflectors and is redirected to the main reflector and thence in a downward direction through the focus, whereby a cosecant pattern in the vertical plane is obtained. In the horizontal plane the pattern is symmetrical about the reflector axis.

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

Fig. 1 is a side view, Fig. 2 a top view and Fig. 3 a partial perspective view of one embodiment of the invention;

Fig. 4 is a measured cosecant pattern for the embodiment of Figs. 1, 2 and 3;

Fig. 5 is a side view, Fig. 6 a top view, and Fig. 7 a partial perspective view of a different embodiment of the invention;

Fig. 8 is a diagram used for explaining the operation of the embodiment of Figs. 5, 6 and 7;

2

Fig. 9 is a measured cosecant pattern for the embodiment of Figs. 5, 6 and 7;

Fig. 10 is a side view and Fig. 11 a partial perspective view of another embodiment of the invention;

Fig. 12 is a diagram used in explaining the embodiment of Figs. 10 and 11;

Fig. 13 is a side view and Fig. 14 a partial perspective view of still another embodiment of the invention; and

Fig. 15 is a diagram for explaining the operation of the embodiment of Figs. 13 and 14.

Referring to Figs. 1, 2 and 3 the antenna system comprises a main conventional paraboloidal reflector or secondary antenna 1 and a primary antenna 2 of the so-called "rear-feed" wave guide type. The main reflector 1 is concave and has a circular periphery, an axis 3, a point focus 4 and a vertex section or region 5. The primary antenna 2 comprises a head 6 having two antenna orifices 7 facing the reflector 1 and a rectangular wave guide 8 connecting the head 6 to a translation device 9 and passing through the reflector vertex 5. The focus 4 is positioned about midway between the two orifices 7. The device 9 may be a transmitter or a receiver or a combined radar transmitter-receiver commonly known as a transceiver. As described so far the system is the same as that illustrated by Fig. 3 of my Patent 2,422,184, granted June 17, 1947.

In accordance with the present invention an array 10, comprising three convex reflectors 11, 12 and 13, is positioned entirely above the axis 3 of the concave reflector 1, in a manner such that the three convex reflecting surfaces face the concave reflecting surface of the main paraboloidal reflector 1. The three reflectors 11, 12 and 13 are supported by the vertical members 14 which are fastened to each other by the rivets or bolts 15 and attached to the head 6. As illustrated on the drawing, in the vertical plane containing the reflector axis 3 the reflectors 11, 12 and 13 are displaced from each so that they lie approximately along a parabolic curve 16 having a curvature corresponding to that of the main paraboloidal reflector 1. Also, as shown on the drawing, reflectors 11 and 12 have approximately the same height and the height of reflector 13 is greater than that of reflector 11 or 12. Reflectors 12 and 13 have approximately equal horizontal dimensions and the horizontal dimension of reflector 11 is greater than that of reflector 12 or 13. The radii of the cylinders corresponding to reflectors 12 and 13 are approximately equal and the radius of the cylinder corresponding to the reflector 11 is greater than that of the cylinder corresponding to reflector 12 or 13.

In operation, assuming the device 9 is a transmitter, waves having a horizontal electric polarization are supplied by device 9 over guide 8 to the head 6 and then propagated through the two orifices 7 and along diverging paths 17 towards the concave reflector 1. As is known, considering the vertical plane, Fig. 1, the wavelets or rays are redirected by the paraboloidal reflector 1 along paths, such as the paths 18, parallel to the axis 3. A portion of the energy reflected by the upper half of the reflector impinges upon the convex reflectors 11, 12 and 13, and is returned to the upper half of the concave reflector along the parallel paths 19. The returned wavelets are then redirected by the concave reflector along the downwardly pointing directions 20. As a result, the radiation in the vertical plane is unsymmetrical about the reflector axis 3 and, assuming the antenna system is installed on an aircraft, the radiation in directions extending upwards from the axis 3, the so-called "sky" radiation, is relatively small whereas the radiation in directions extending downwards from the axis 3, the so-called "ground" radiation, is relatively large, whereby

a satisfactory cosecant pattern in the vertical plane is obtained. Thus, referring to Fig. 4, the full line curve 21 illustrates a measured vertical of H-plane cosecant pattern for a system constructed in accordance with Figs. 1, 2 and 3. The dash-dash curve 22 illustrates the theoretical or optimum cosecant pattern. In the E or horizontal plane all the wavelets are redirected by the concave reflector 1 along the parallel paths 18 and the pattern is symmetrical about the reflector axis 3. In reception the converse operation is obtained.

Referring to Figs. 5, 6, 7 the primary antenna or "cosecant feed" 23 for the standard reflector 1 comprises a non-square rectangular wave guide 24 having a longitudinal parabolic curvature 16, corresponding to the contour of reflector 1, and a rear-feed bent non-square rectangular wave guide 25 having one end connected to the translation device 9 and the other end connected by the flange assembly 26 to the top end of the parabolic guide 24. The narrow walls of the guides 24 and 25 are parallel to the electric polarization 27 of the waves utilized. A narrow or E-plane wall of the parabolic guide 24 faces the reflector and contains a principal antenna aperture or iris 28, a set of alternate capacitive irises 29, 30 and a set of alternate inductive irises 31, 32. The principal iris 28 is positioned at the focus 4 of reflector 1 and the remaining iris are positioned above the axis 3 of the reflector.

It may be noted here that inductive and capacitive irises are well known in the art. Thus, for example, if an iris is formed inside a non-square rectangular guide by a pair of spaced conductive members extending between and connecting the H-plane or wide walls (perpendicular to the electric polarization) the iris is inductive, whereas if the members extend between, but do not connect, the E-plane walls (parallel to the electric polarization) the iris is capacitive. As shown on the drawing the capacitive iris has an I-shaped opening.

In operation, assuming the device 9 is a transmitter, waves emitted by the principal iris 28 illuminate the entire reflector and are reflected, in both the vertical or H-plane and the horizontal or E-plane along the parallel paths 18. Considering the vertical plane, Fig. 5, wavelets emitted by the subsidiary irises 29, 30, 31 and 32 are cophasal and in phase with the wavelets from the principal iris 28, as explained below, and these wavelets for the most part travel along the parallel paths 33 and, after impinging upon the upper half of the concave reflector 1, are propagated through the focus 4 and along the downward directions 34, whereby in the vertical plane a cosecant pattern is secured, as in the system of Figs. 1, 2 and 3. Thus, the curve 35, Fig. 9, illustrates the measured vertical plane cosecant pattern obtained for a system constructed in accordance with Figs. 5, 6 and 7. The curve 36 of Fig. 9 illustrates the optimum cosecant curve. By reason of the parabolic contour of the guide 24 the energy distribution or illumination of the reflector 1 is the optimum. In the horizontal plane, Fig. 6, the pattern is symmetrical above the reflector axis 3, as in the system of Figs. 1, 2 and 3.

The wavelets from the five irises 28, 29, 30, 31 and 32 are rendered cophasal by judiciously positioning these irises so that the time, consumed by a wavelet in traveling from a given point or reference position of the wave front 37, Fig. 8, in the guide 24 through the associated iris to the vertical plane 38 perpendicular to the reflector axis 3, is equal to the time consumed by a wavelet in traveling from the wave front reference position 37 through the adjacent iris to the wave front reference position 38 minus a full cycle, that is, 360 degrees, the 90 degree phase delay or advance in each iris being, of course, taken into consideration. In Fig. 8, the distances from the wave front reference position 37 in the guide to the five irises are designated by the letter L with subscripts 1 to 5, respectively, as shown, the wavelength in the guide λ_g being added to the designa-

tions to indicate that throughout each of these distances, the energy has the wavelength λ_g . Similarly, the distances from each of the five irises to the reference plane 38 are designated by the letter D with subscripts 1 to 5 for the five irises, respectively, as shown, the wavelength in free space λ_0 being added to the designations to indicate that throughout each of these distances, the energy has the wavelength λ_0 . More particularly, the time, T_1 , in degrees for the wavelet passing through the inductive iris 32 and traveling from the front 37 to the plane 38, may be represented

$$T_1 = \left[\frac{L_1}{\lambda_g} + \frac{D_1}{\lambda_0} \right] 360 + 90 \quad (1)$$

where:

λ_g is the wavelength in centimeters in guide 24,

λ_0 is the wavelength in centimeters in free space,

L_1 is the distance in centimeters from the wave front 37 to the iris 32,

D_1 is the distance in centimeters from the iris 32 to the plane 38, and

(+90) represents the degrees of phase delay passing through the inductive iris 32.

The adjacent iris 30 is spaced from the iris 32 a distance such that the time, T_2 , for the wavelet passing through iris 30 and traveling from the front 37 to the plane 38 is

$$T_2 = \left[\frac{L_2}{\lambda_g} + \frac{D_2}{\lambda_0} \right] 360 - 90 \quad (2)$$

where:

L_2 is the distance from front 37 to iris 30,

D_2 is the distance from iris 30 to the plane 38, and

(-90) represents the degrees of phase advance produced by the capacitive iris 30.

Now, in order to produce cophasal wavelets at the plane 38 we have

$$T_1 + 360 = T_2 \quad (3)$$

From (1), (2) and (3) we have

$$\frac{L_2}{\lambda_g} - \frac{L_1}{\lambda_g} = \frac{1}{2} + \frac{D_1}{\lambda_0} - \frac{D_2}{\lambda_0} \quad (4)$$

or

$$L_2 - L_1 = \frac{\lambda_g}{2} + \frac{(D_1 - D_2)\lambda_g}{\lambda_0} \quad (5)$$

Letting S_{12} represent the spacing between the mid-points of irises 30 and 32 and R_{12} the difference between the lengths of the paths D_1 and D_2 , we have

$$S_{12} = \frac{\lambda_g}{2} + R_{12} \frac{\lambda_g}{\lambda_0} \quad (6)$$

Similarly for irises 31 and 30

$$S_{23} = \frac{\lambda_g}{2} + R_{23} \frac{\lambda_g}{\lambda_0} \quad (7)$$

where S_{23} is the distance between the mid-points of irises 31 and 30 and R_{23} is the difference between the lengths of the paths D_2 and D_3 . In a similar manner the positions of the irises 29 and 28 may be determined.

The system of Figs. 10, 11 and 12 is the same as that of Figs. 5, 6 and 7 except that a linear feed guide 39 is used in place of the parabolic feed guide 24. As shown in Fig. 12 the adjacent capacitive and inductive irises are spaced a half guide wavelength apart, whereby all of the outgoing wavelets are cophasal. The arrows 40 illustrate the phases of the wavelets inside the guide at the iris locations and the arrows 41 illustrate the similar phases of the outgoing wavelets. The operation in both planes is the same as that of the system of Figs. 5, 6 and 7 except that the distribution produced by the linear feed 39 is not as satisfactory as that produced by the

5

parabolic feed guide 24. In the horizontal plane a symmetrical pattern is secured.

The system of Figs. 13, 14 and 15 is the same as that of Figs. 10, 11 and 12 except that the irises 28, 29, 30, 31 and 32 of guide 39 are spaced so as to focus the wavelets in the region of the vertex 5 of the reflector 1, as shown by the paths 42, whereby the vertex region functions in a sense as a plane reflector and the downward radiation is enhanced as illustrated by the arrows 43. In a manner similar to that explained in connection with Fig. 8, the irises 28, 29, 30, 31 and 32 are judiciously positioned so as to secure the focussing effect. Thus, referring to Fig. 15, the Equations 1 to 7 given above apply when D_1 , D_2 , D_3 , D_4 and D_5 denote the distances in centimeters from the vertex 5 to the irises 28, 29, 30, 31 and 32, respectively. By virtue of the focussing effect described above a cosecant pattern is obtained in the vertical plane. In the horizontal plane a symmetrical pattern is secured. In Fig. 15, the paths in the guide are designated L with subscripts 1 to 5, inclusive, and the paths in free space are designated D with subscripts 1 to 5, inclusive, and the wavelengths λ_g and λ_0 are indicated in the same manner as explained in connection with Fig. 8, above.

Although the invention has been explained in connection with certain embodiments it is not to be limited to the described embodiments since other apparatus may be successfully utilized in practicing the invention.

What is claimed is:

1. An antenna-reflector system for producing a cosecant directive pattern comprising a paraboloidal reflector, a primary antenna therefor comprising a wave guide extending longitudinally across the front of said reflector and having a plurality of irises facing said reflector said wave guide being positioned substantially on one side only of the axis of said reflector.

2. A system in accordance with claim 1, said guide having a parabolic longitudinal curvature corresponding to the parabolic curvature of said reflector.

3. A system in accordance with claim 1, said guide being linear and the spacing between adjacent irises being a half guide wavelength.

6

4. A system in accordance with claim 1, said guide being linear and the spacing between adjacent irises being a function of the guide wavelength and the difference in the distances between said focal point of said reflector and said irises.

5. A system in accordance with claim 1, said irises being located along a line, one set of alternate irises having an inductive reactance and the other set of alternate irises having a capacitive reactance.

6. A system in accordance with claim 1, said guide having a parabolic curvature, the spacing between adjacent irises being a function of the guide wavelength and the difference in the distances from said irises to a plane perpendicular to the axis of said reflector.

7. An antenna-reflector system for producing a cosecant directive pattern comprising a paraboloidal reflector and a primary antenna therefor, said primary antenna comprising a wave guide closed at one end extending across the front of said reflector, said primary antenna having a main iris near the closed end of said wave guide, said main iris being positioned on the axis of said reflector, said primary antenna having a plurality of secondary irises at progressively increasing distances from the closed end of said wave guide, all of said irises facing said reflector.

8. A system in accordance with claim 7, said guide having a parabolic longitudinal curvature corresponding to the curvature of said reflector.

9. A system in accordance with claim 7, said guide being linear and the spacing between adjacent irises being a function of the guide wavelength and the difference in the distances between said focal point of said reflector and said irises.

10. A system in accordance with claim 7, said irises being located along a line, one set of alternate irises having an inductive reactance and the other set of alternate irises having a capacitive reactance.

References Cited in the file of this patent

UNITED STATES PATENTS

1,771,148	Sprague	July 22, 1930
2,342,721	Boerner	Feb. 29, 1944
2,436,380	Cutler	Feb. 24, 1948