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C. C. CUTLER
DIRECTIVE ANTENNA SYSTEM

2,518,526

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2 Sheets-Sheet 1

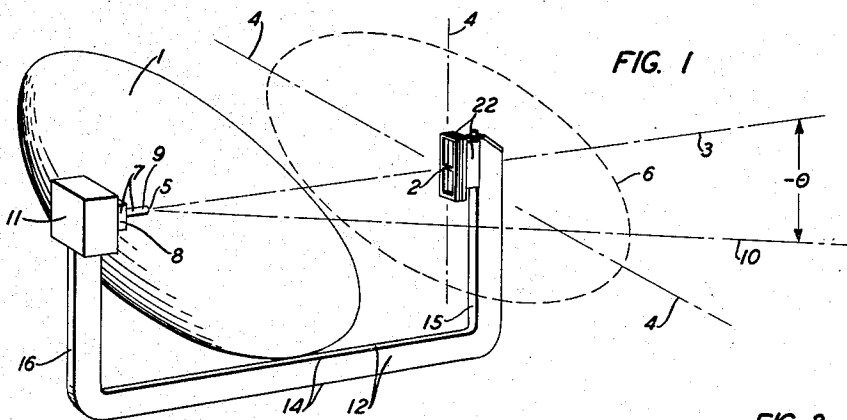


FIG. 1

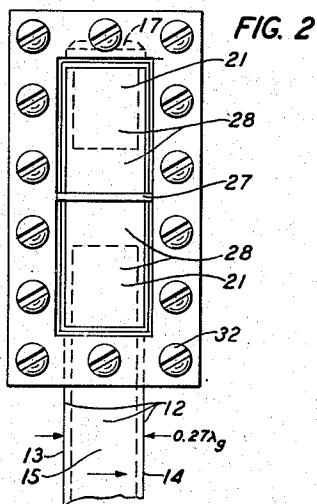


FIG. 2

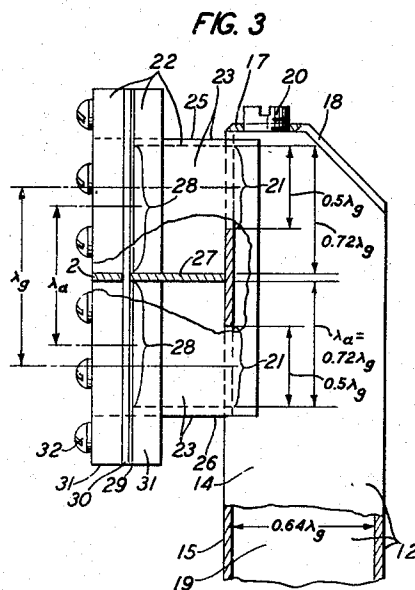


FIG. 3

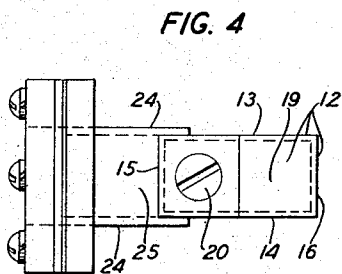
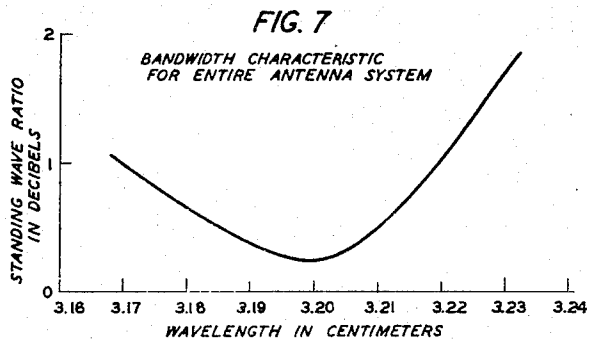


FIG. 4



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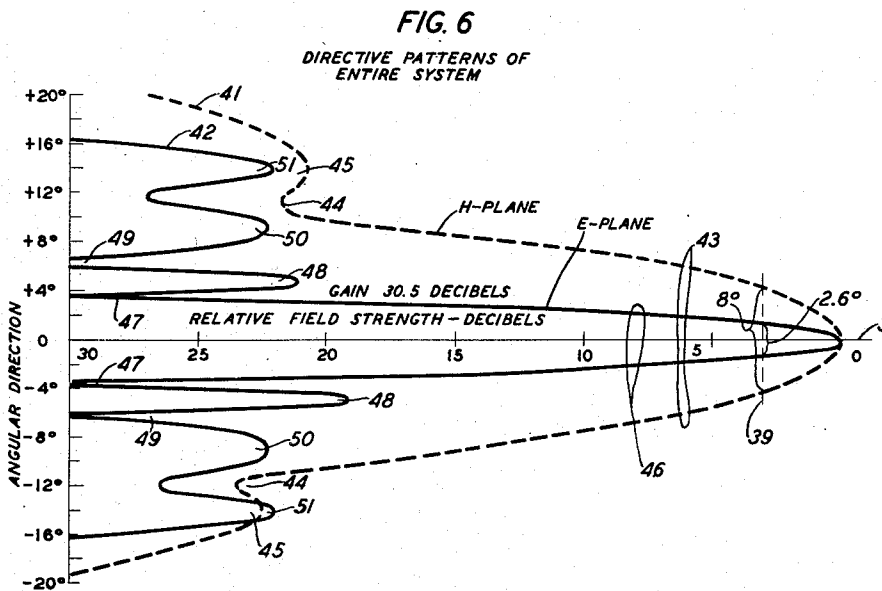
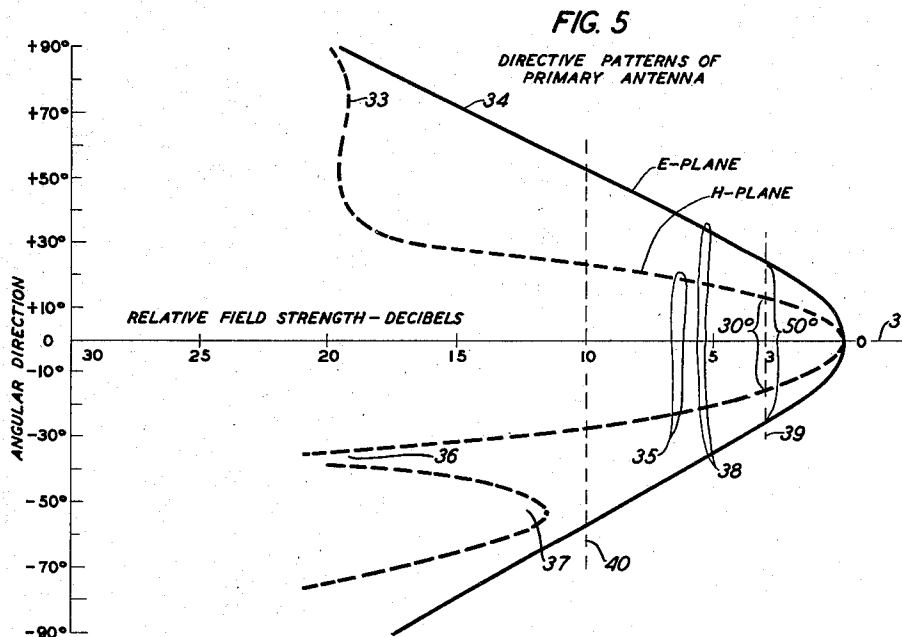
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2 Sheets-Sheet 2



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DIRECTIVE ANTENNA SYSTEM

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3 Claims. (Cl. 250—33.63)

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This invention relates to antenna systems and particularly to microwave directive antenna systems.

As is well known, antenna systems comprising a parabolic reflector and a primary antenna of the "front" or "rear" feed dielectric guide type are widely used in microwave radar systems and microwave communication systems. While, for certain installations, the rear-feed type is preferred, the front-feed type may be employed with advantage in certain other installations. Also, as is known, front-feed and rear-feed parabolic systems have been suggested for securing a "point" beam or a "fan" beam. Thus, Patent 2,434,253 granted to A. C. Beck on January 13, 1948 and the copending application of C. B. H. Feldman, Serial No. 489,740, filed June 5, 1943, now Patent No. 2,482,162, issued September 20, 1949, disclose point-beam systems comprising a fan-beam cylindrical-parabolic reflector and a front-feed fan-beam primary antenna, and Patent 2,409,183 granted to A. C. Beck on October 15, 1946 discloses a fan-beam lobe-switching system comprising a fan-beam paraboloidal reflector and a front-feed point-beam primary antenna. My Patent 2,422,184 granted on June 17, 1947 and my application, Serial No. 546,687, filed July 26, 1944, now Patent No. 2,483,575, issued October 4, 1949, disclose point-beam systems comprising a point-beam paraboloidal reflector and a rear-feed dual-horn point-beam primary antenna, and the last-mentioned application also discloses a fan-beam system comprising a fan-beam paraboloidal reflector and a rear-feed fan-beam dual-horn primary antenna. In general, the point-beam antennas are employed in radar systems in which target detection or target direction finding, in both the azimuthal and elevational scanning planes, is desired; and fan-beam antennas are utilized in radar systems in which target detection or direction finding in only one scanning plane is required. While highly satisfactory results have been obtained with the antenna systems mentioned above, and while the above-mentioned front-feed systems have been used with success, it now appears desirable to secure a fan-beam antenna system comprising a front-feed primary antenna and having distinct advantages over the front-feed fan-beam systems of the prior art.

It is one object of this invention to secure, in a front-feed parabolic antenna system, optimum illumination of the reflector.

It is another object of this invention to obtain, in a front-feed primary antenna system, a fan-

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beam major lobe of optimum shape for illuminating a fan-beam paraboloidal reflector.

It is another object of this invention to secure a highly efficient, high gain, fan-beam antenna system having a wide bandwidth characteristic.

It is another object of this invention to secure, in a high gain microwave antenna system, a directive characteristic including a fan-beam major lobe and negligible minor lobes, utilizing a paraboloidal reflector and a front-feed dielectric guide primary antenna.

It is another object of this invention to secure, in a fan-beam system comprising a movable paraboloidal reflector and a stationary front-feed primary antenna, a directive pattern which remains substantially constant in shape as the reflector axis is moved or tilted relative to its normal horizontal position.

As used herein, the term "parabolic" reflector generically applies to a cylindrical parabolic reflector and a paraboloidal reflector and the term "focus" generically applies to focal point and focal line. The term "wave guide" applies to conventional conductive lines, for example, a coaxial line, and to dielectric guides such as a metallic tube filled with the air dielectric or a solid dielectric. The term "air wavelength" refers to the wavelength as measured in free space, that is, the air medium outside of the guide; and the term "guide wavelength" refers to the wavelength as measured in the dielectric medium forming the guide. The term "directive characteristic" refers to the three dimensional or solid directive diagram and the term "directive pattern" refers to the trace of the directive characteristic on a given plane. The term "beam" refers to the major lobe in a given receiving or transmitting pattern, and the terms E-plane and H-plane refer, respectively, to the plane of electric polarization and the plane of magnetic polarization, of the waves utilized.

In accordance with one embodiment of the invention, a front-feed dual horn primary antenna is associated with a rectangular or quasi-elliptical paraboloid. The dual-horn antenna is attached to a rectangular dielectric guide and positioned at the reflector focus. The guide extends vertically in front of the lower half portion of the reflector and is connected at its near end to a radar transceiver. The E-plane of the waves utilized is horizontal. A pair of rectangular openings or irises spaced vertically a guide wavelength apart are provided at the far end of the vertical guide wall facing the reflector; and these irises constitute the throat apertures of the two

horns, or horn-like guides, comprising the dual horn antenna. The horn mouth apertures are vertically spaced approximately an air wavelength apart and each aperture illuminates, or receives energy from, the entire reflector. The major lobe of the dual horn antenna has a fan-beam shape, the wide beam dimension being horizontal; and the fan-beams of the dual horn primary antenna and of the reflector are perpendicularly related. The gain of the combined system is relatively high. The dimensions of the mouth and throat apertures are critically chosen so that the reflector illumination is graded from a maximum at the vertex to a small value at the reflector periphery, whereby the minor lobes in the directive characteristic of the whole system have negligible intensities.

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

Fig. 1 is a perspective view of one embodiment of the invention;

Figs. 2, 3 and 4 are, respectively, front, side and top views of the front-feed primary antenna included in the embodiment of Fig. 1;

Fig. 5 illustrates the measured E-plane and H-plane directive patterns for the primary antenna included in the embodiment of Fig. 1;

Fig. 6 illustrates the measured E-plane and H-plane directive patterns for the complete system of Fig. 1; and,

Fig. 7 illustrates the measured bandwidth characteristic of the embodiment of Fig. 1.

Referring to Figs. 1, 2, 3 and 4, reference numeral 1 denotes a quasi-elliptical paraboloidal reflector having a focal point 2, an axis 3, a latus rectum 4 and a vertex 5. The quasi-elliptical reflector, considered alone, is disclosed and claimed in my copending application Serial No. 546,687 mentioned above. The projection of the periphery of the reflector on the plane perpendicular to axis 3 and including the latus rectum 4 is an ellipse 6. In Fig. 1, the axis 3 and the latus rectum plane containing the ellipse 6 and focal point 2, are horizontal and vertical, respectively. Reference numeral 7 denotes a tilting mechanism comprising a gear or cam box 8 and a rod 9 attached to the vertex 5 of reflector 1 and associated with the box 8. The mechanism 7 may be utilized, if desired, for the purpose of manually or automatically tilting reflector 1 downwardly so that its axis is aligned, for example, with a direction 40 making an angle $-\theta$ with the horizontal position of axis 3.

Reference numeral 11 denotes a translation device, such as a radar transceiver, and numeral 12 designates a rectangular dielectric guide connected at its rear end to device 1. The guide 12 comprises two wide metallic side walls 13, 14, a rear narrow wall 15 facing the reflector, a front narrow wall 16, a top horizontal end wall 17, a top inclined end wall 18 and the air dielectric 19. Numeral 20 denotes an adjustable tuning plug inserted in the top end wall 17. The guide 12 extends vertically in front of the lower half portion of reflector 1 and perpendicular to the long dimension of the elongated reflector 1. Near the top of guide 12 two rectangular irises 21 are provided in the rear narrow wall 15, the centers of the irises being spaced vertically, and along the longitudinal dimension of guide 12, a guide wavelength λ_g apart.

Numeral 22 designates a dual horn primary an-

tenna or "head" attached to guide 12 and comprising two short air-filled dielectric guides 23. The rectangular guides 23 are electrically open at both ends and comprise two vertical metallic side walls 24, the top metallic wall 25, the bottom metallic wall 26 and the common center metallic wall or partition 27. The wall 27 is of sheet metal and has a negligible thickness. Numerals 28 denote the rectangular mouth apertures of the horn-like guides 23, the centers of these apertures being spaced vertically, and therefore along the short dimension of the elongated reflector 1, and air wavelength, λ_a , apart. The irises 21 of guide 12 constitute the throat apertures of the horn-like guides 23. In the case of each short guide 23, the transverse horizontal dimensions of the mouth and throat apertures are substantially equal, whereas the longitudinal vertical dimension of the mouth aperture is greater than the corresponding dimension of the throat aperture. Numeral 29 denotes a thin mica window which covers the two mouth apertures 28 and which, together with the apertured rubber gasket 30, is included between the two brass plates 31. The window assembly 29, 30 and 31 is fitted to the mouth end of the dual horn antenna 22 and is securely held together by means of the bolts 32.

In operation, horizontally polarized microwaves supplied by the transmitter in the transceiver 11 are conveyed over guide 12 to the two horn-like guides 23 and emitted toward reflector 1 by the two antenna apertures 28. Assuming the reflector axis is horizontal, the wavelets impinging upon the reflector 1 are redirected along the general direction of the axis 3. More specifically, the wave components arriving in guide 12 at the irises 21 are cophasal since the irises are a guide wavelength apart, and the wave components projected into space by the mouth apertures are also cophasal, since the mouth apertures are an air wavelength apart. Hence the two horn-like guides constitute a two element broadside array, the direction of greatest radio action of the array being perpendicular to the vertical array axis and aligned with the horizontal reflector axis 3. In reception the converse operation obtains by reason of the reciprocity theorem.

Referring to Fig. 5, reference numerals 33 and 34 denote, respectively, the measured H-plane and E-plane directive patterns of the dual-horn primary antenna 22, obtained at a design or mean guide wavelength λ_g equal to 3.2 centimeters. The H-plane pattern includes the major lobe 35, the null or dip 36 and the minor lobe 37; and the E-plane pattern includes, in the ± 90 degree angular range, only the major lobe 38. At the half power point 39, three decibels down from the peak value, the widths of the H-plane and E-plane major lobe patterns are, respectively, about 30 and 50 degrees. Hence, the primary antenna 22 produces a horizontal fan-beam, the wide and narrow beam dimensions being parallel to the long and short dimensions of the quasi-elliptical reflector 1.

In addition, by reason of the critical dimensions of the throat and mouth apertures 28, 21 of the dual-horn antenna, the contours of the fan-beam in the E and H planes are such that the taper or variation in the illumination of a reflector having a focal length of $8.5\lambda_g$, a long or major axis dimension of $23.0\lambda_g$ and a short or minor axis dimension of $8.0\lambda_g$, is the optimum. Thus, the illumination at the vertex is a maximum, where-

as at the periphery it is about 10 decibels below maximum, that is, negligible. In other words, only the portion of the fan-beam shown above the -10 decibel point, denoted by reference line 40, is effective in illuminating the elongated reflector 1. The minor lobe 37, it will be noted, is about 11.5 decibels down and therefore of small consequence in so far as the illumination of reflector 1 is concerned. In the tested system, the transverse dimensions of the throat and mouth apertures 21, 28 was about $0.27\lambda g$ and the longitudinal dimensions of the throat and mouth apertures were about $0.5\lambda g$ and $0.72\lambda g$. The wide transverse dimension of guide 12 was $0.64\lambda g$.

Referring to Fig. 6, reference numerals 41 and 42 denote the measured E-plane and H-plane patterns of the combined system comprising reflector 1 and the primary antenna 22, taken at the mean wavelength λg equal to 3.2 centimeters. The H-plane pattern 41 includes a major lobe 43, the dips 44 and the first minor lobes 45, and the E-plane pattern includes the major lobe 46, the first nulls 47, the first minor lobes 48, the second nulls 49 and the higher order minor lobes 50 and 51. The half power widths of the H-plane and E-plane major lobe patterns, are, respectively, 8.0 and 2.6 degrees, so that the system 1, 22 has a vertical fan-beam perpendicularly related to the fan-beam of the primary antenna 22. The measured gain of the system is about 30.5 decibels, as measured along the reflector axis 3.

The curve 52, Fig. 7, illustrates the measured bandwidth characteristic of the complete system, taken over the 3.17-3.23 centimeter bands. As shown by this curve, the complete antenna system 1, 22 is substantially matched to the main guide 12 over the band and, in the central portion of the band, the characteristic is relatively flat, as is desired.

The antenna system 1, 22 described above is especially suitable for use in an aircraft radar employed for azimuthal scanning and for scanning the ground target plane. As previously indicated the reflector 1 may be tilted downwardly for the purpose of scanning the earth's surface in front of and below the aircraft. When the reflector is tilted relative to the primary antenna, the measured gain decreases nearly linearly as the tilt angle, $-\theta$, increases and at -25 degrees tilt the gain is about 2 decibels below the gain obtained with the axis 3 horizontal. At the -25 degree tilt angle, the beam deflection is -43 degrees. Also, the E-plane pattern remains fairly constant in shape as the reflector 1 is tilted or moved from the zero degree position down to, for example, the -25 degree position.

Thus, in accordance with the invention, a front-feed dual-horn primary antenna is provided for securing optimum illumination of an elongated reflector whereby, in a quasi-elliptical paraboloidal antenna system, a high gain and a highly useful fan-beam are obtained.

Although the invention has been explained in connection with a specific embodiment, it is to be understood that it is not to be limited to the embodiment described inasmuch as other apparatus

may be employed in successfully practicing the invention.

What is claimed is:

1. In combination, a main air-filled dielectric guide connected to a translation device and having a metallic longitudinal wall, a pair of parallel dielectric horn guides having coplanar non-square rectangular mouth apertures and coplanar non-square rectangular throat apertures, the centers of said mouth apertures being spaced an air wavelength apart, said throat apertures being located in said wall and the centers of said throat apertures being spaced longitudinally a guide wavelength apart, said air and guide wavelengths being substantially different, and said mouth and throat apertures having substantially different long dimensions.

2. A broadside microwave antenna array comprising a main dielectric guide having in one longitudinal wall a pair of non-square rectangular irises, a pair of dielectric horn guides attached to said main guide and having coplanar non-square rectangular mouth apertures, said irises constituting the throat apertures of said horn guides, the centers of said irises being spaced farther apart than the centers of said mouth apertures, the long dimension of each iris being one-half a guide wavelength and the long dimension of each mouth aperture being approximately an air wavelength, an air wavelength being equal to 0.72 guide wavelength, and a translation device connected to said main guide.

3. A broadside microwave antenna array comprising a pair of dielectric horn guides having parallel axes and coplanar rectangular mouth apertures, each of said apertures having a long dimension equal to 0.72 guide wavelength, a main dielectric guide extending perpendicular to said axes and having in one longitudinal wall a pair of longitudinally spaced rectangular irises constituting the throat apertures of said horn guides, each of said irises having a long dimension equal to 0.5 guide wavelength, the centers of said irises being farther apart than the centers of said mouth apertures, and a translation device connected to said main guide.

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