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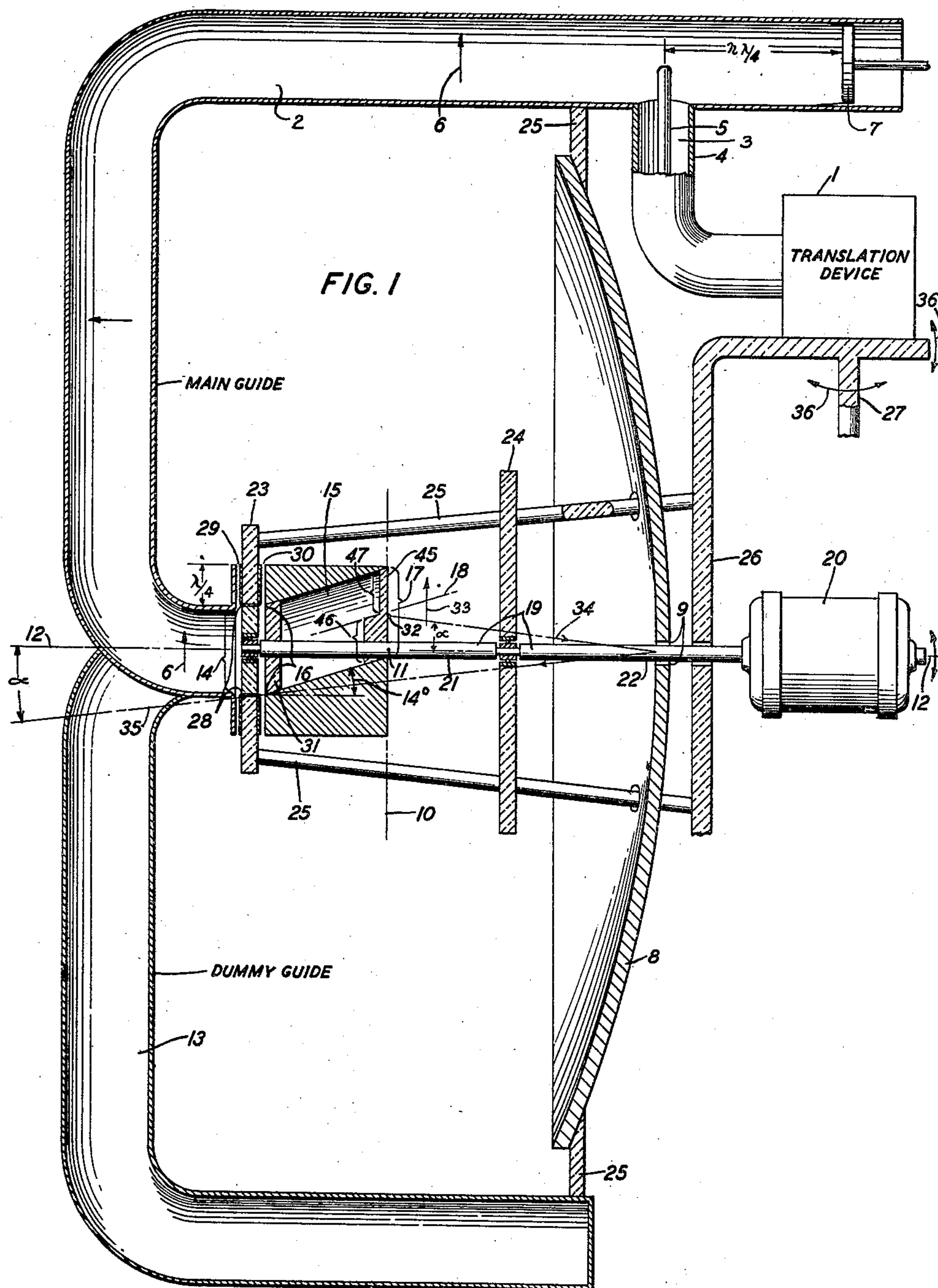
M. C. BISKEBORN ET AL

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MICROWAVE RADAR DIRECTIVE ANTENNA

Filed Nov. 22, 1943

3 Sheets-Sheet 1



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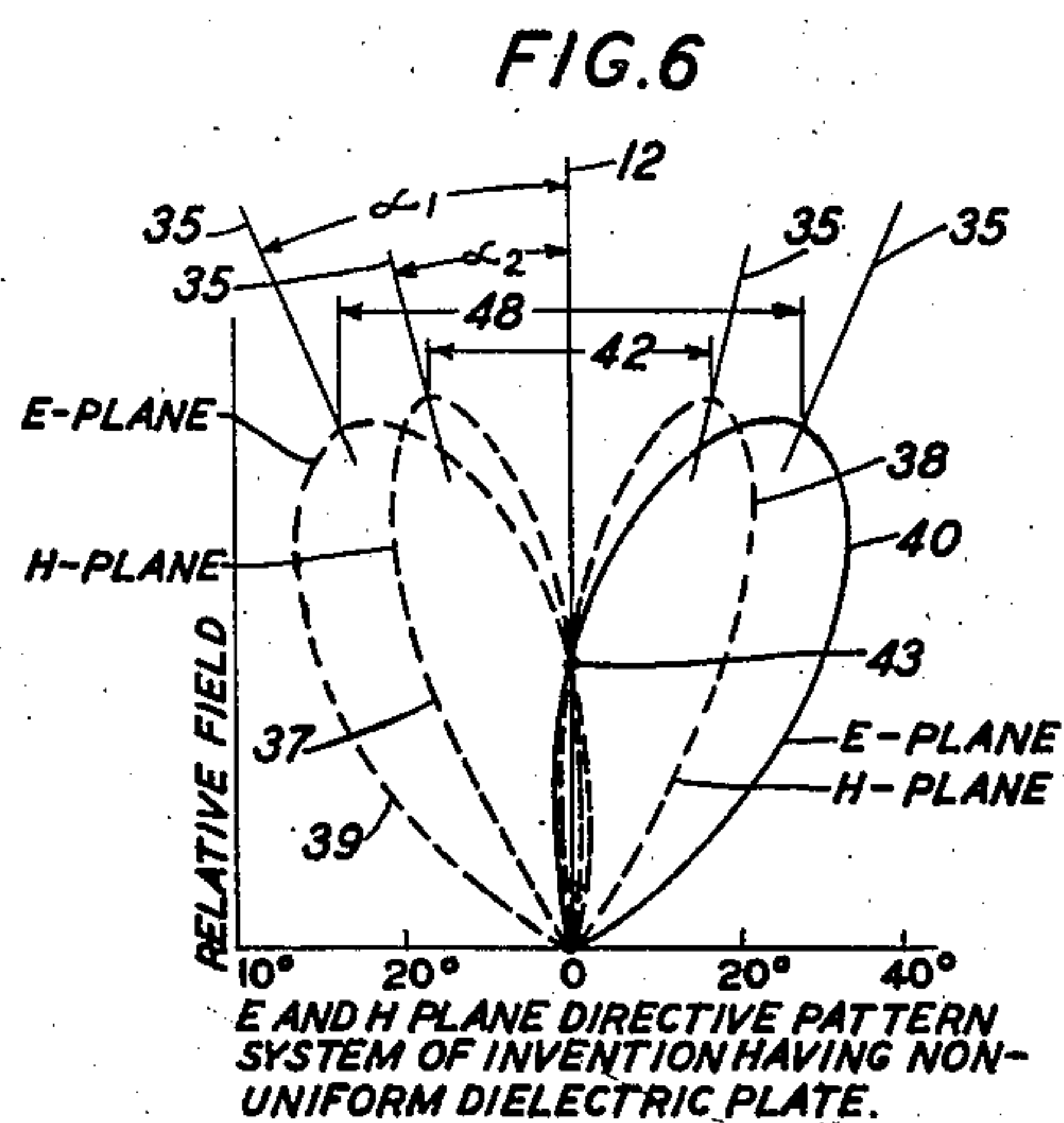
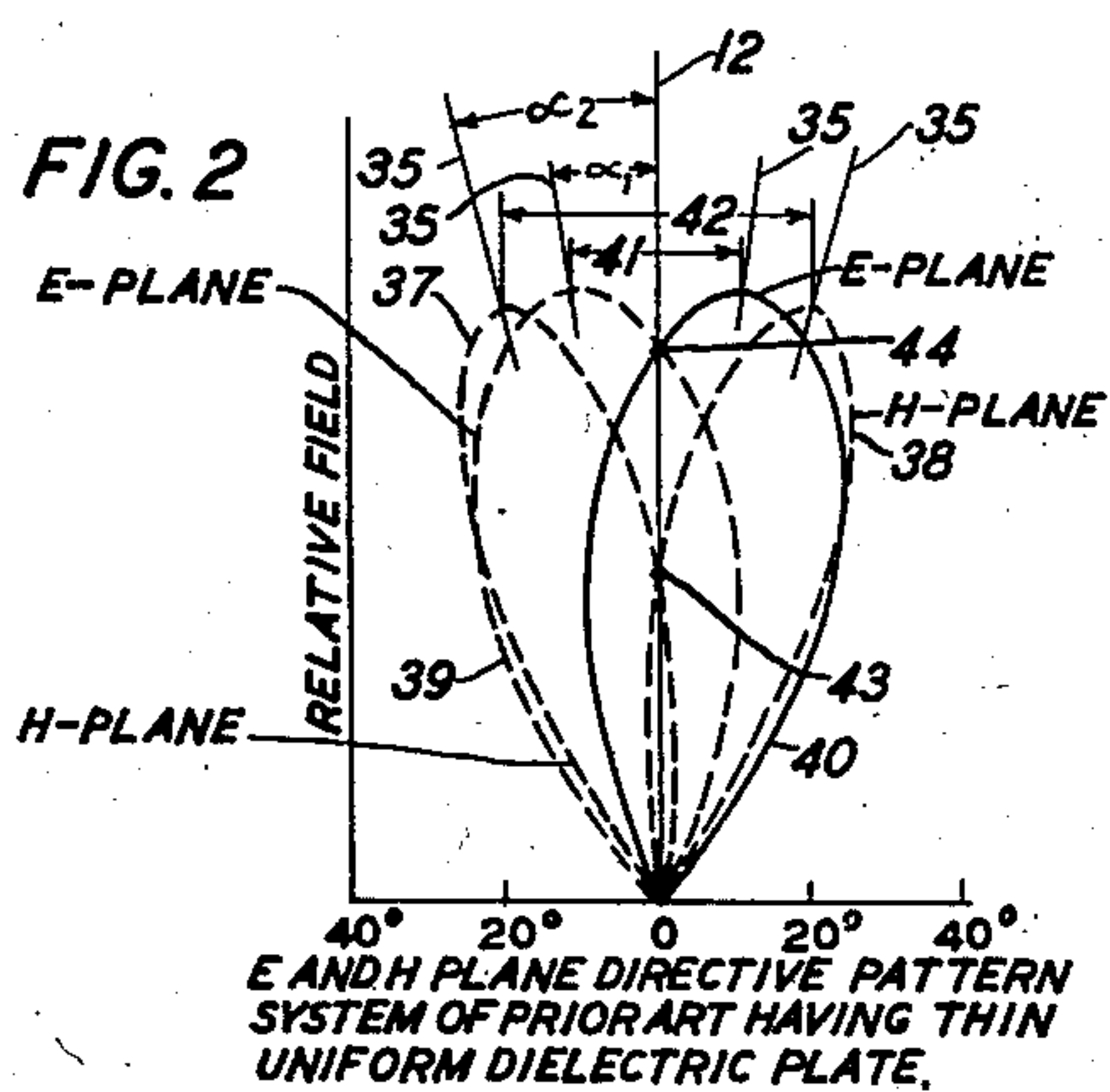
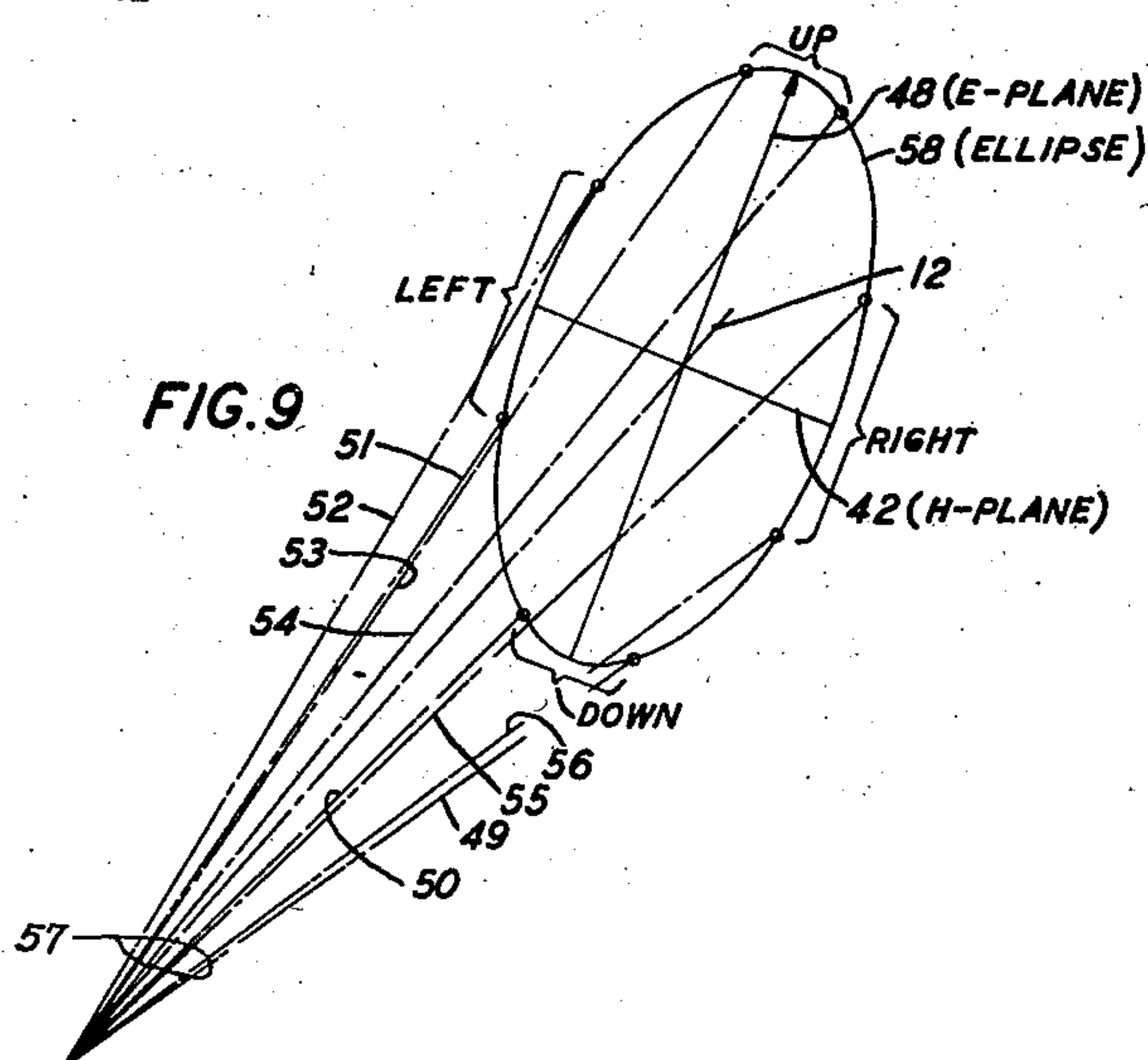
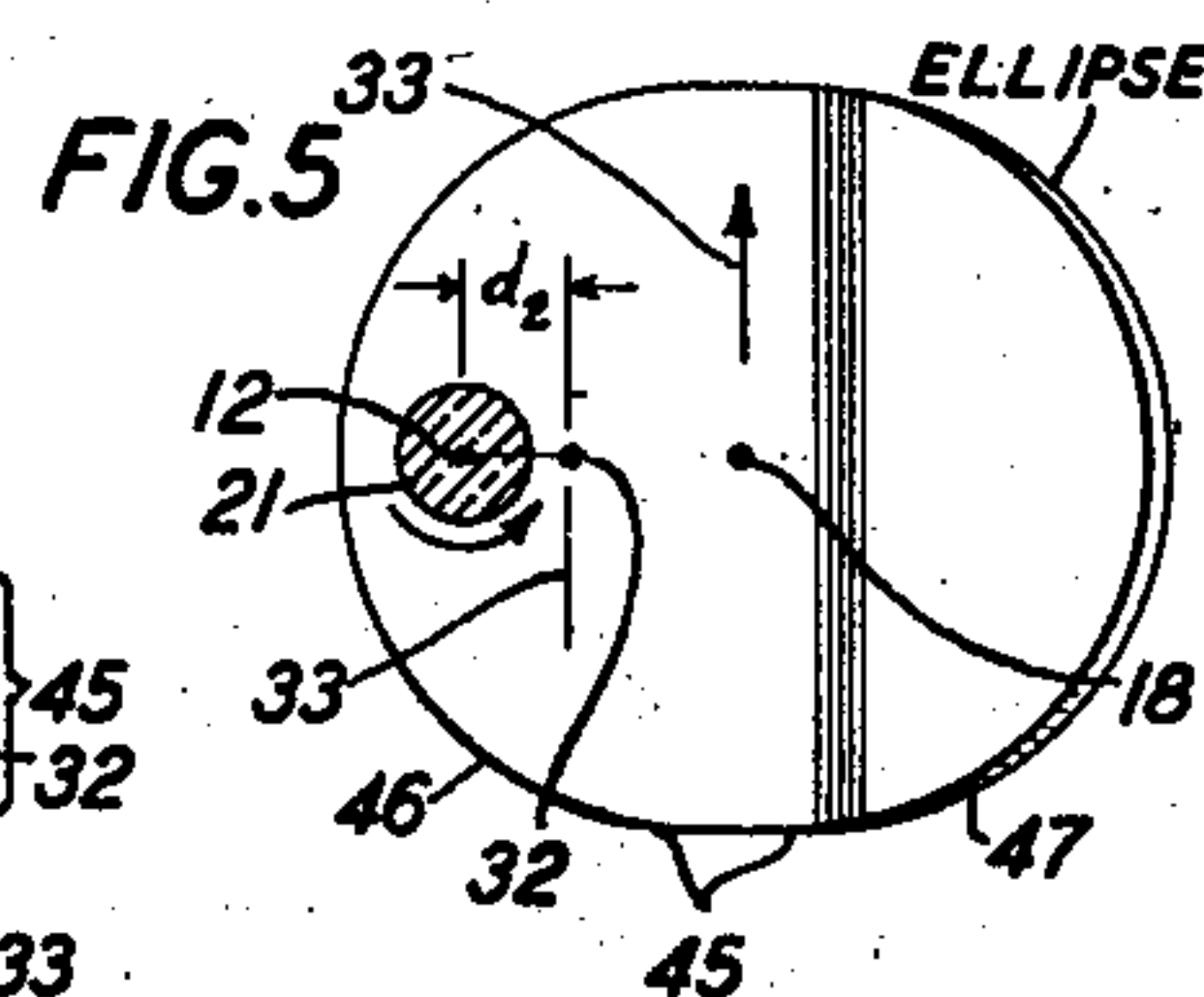
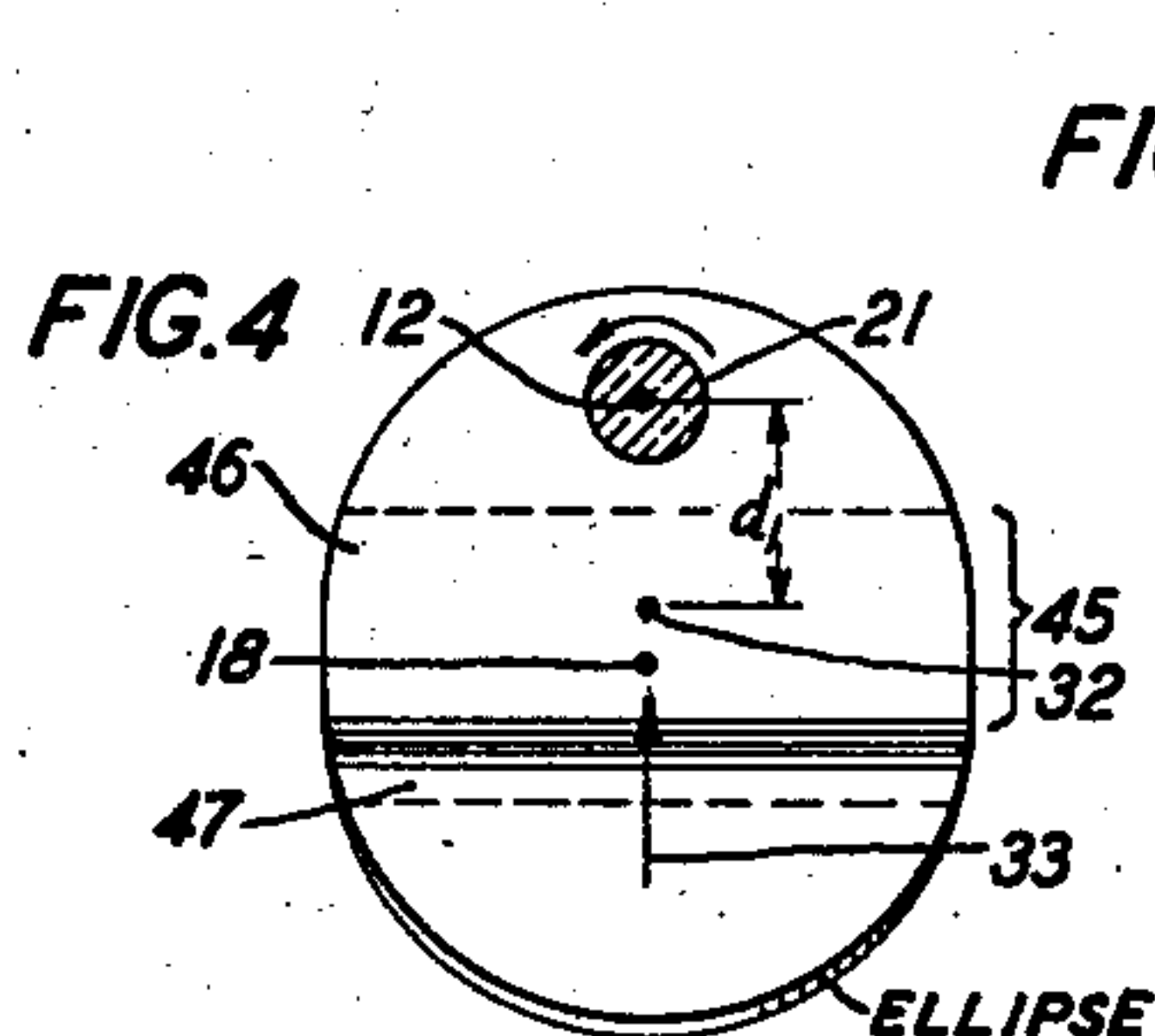
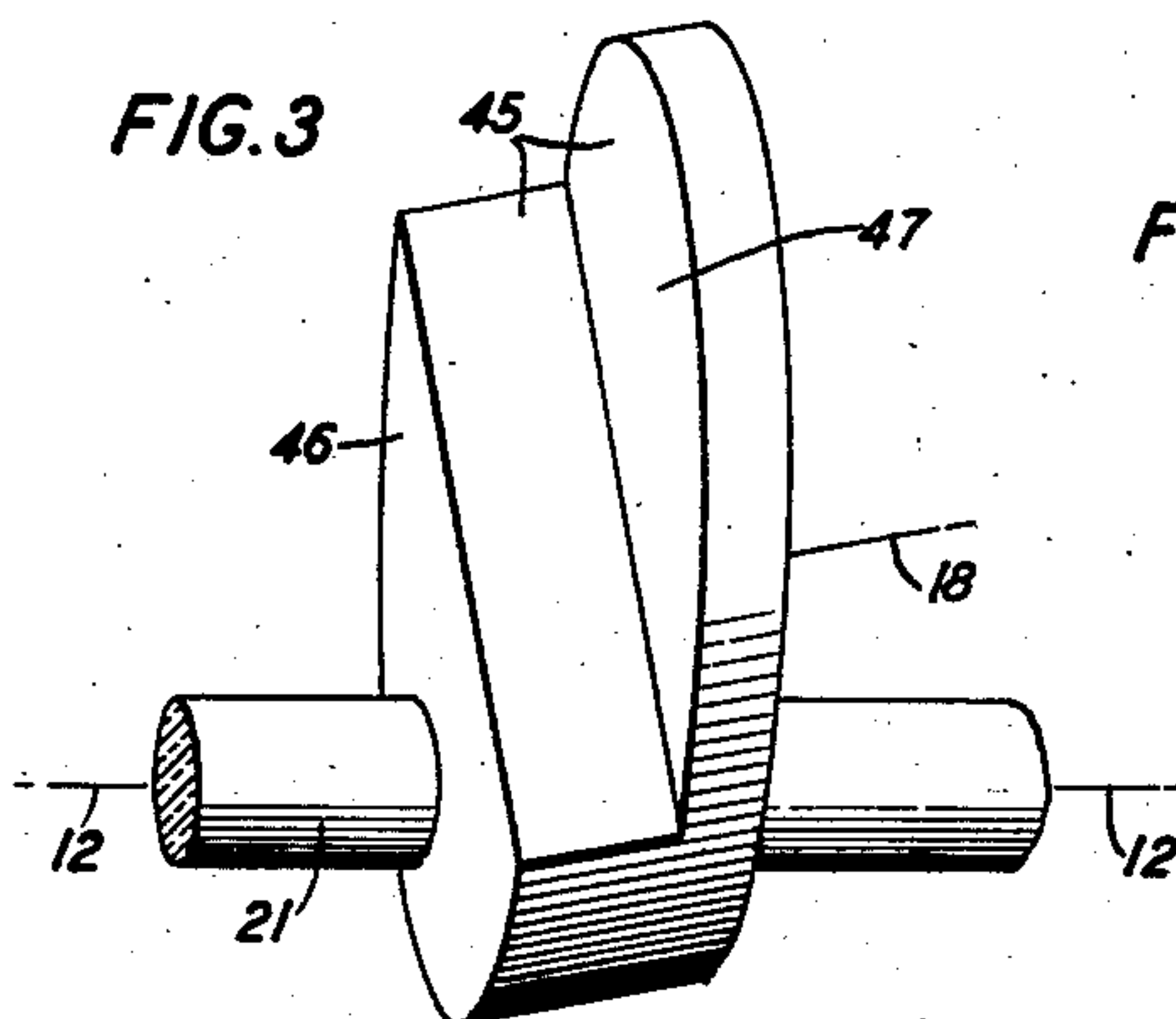
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## MICROWAVE RADAR DIRECTIVE ANTENNA

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3 Sheets-Sheet 2



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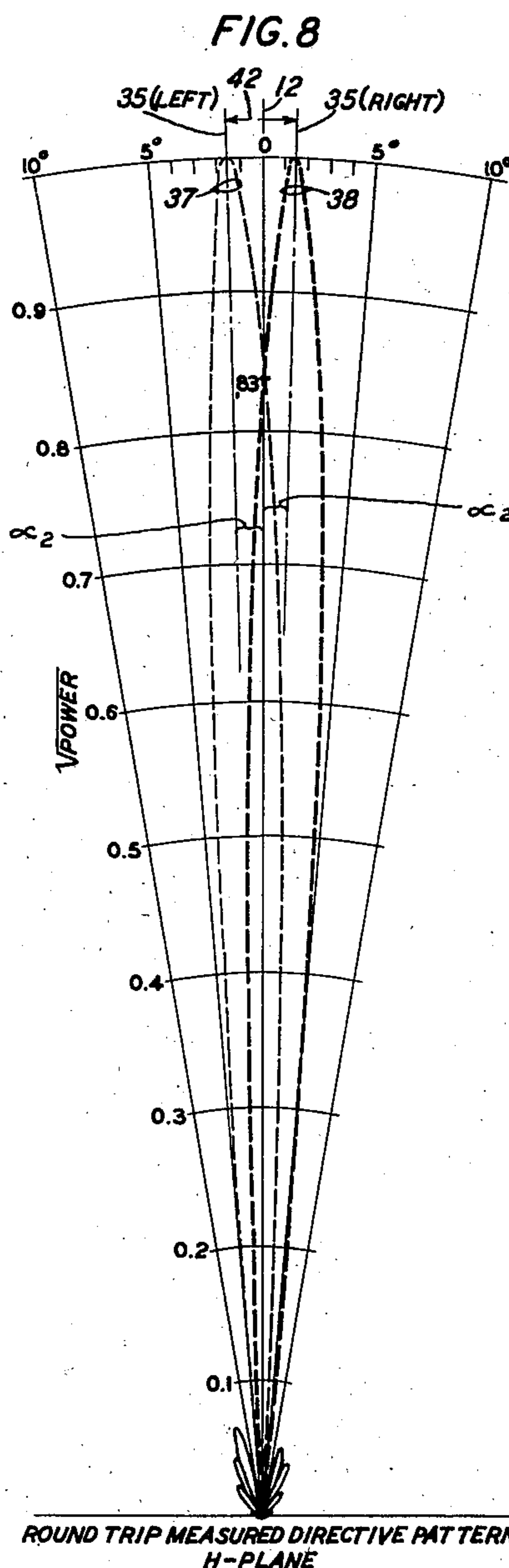
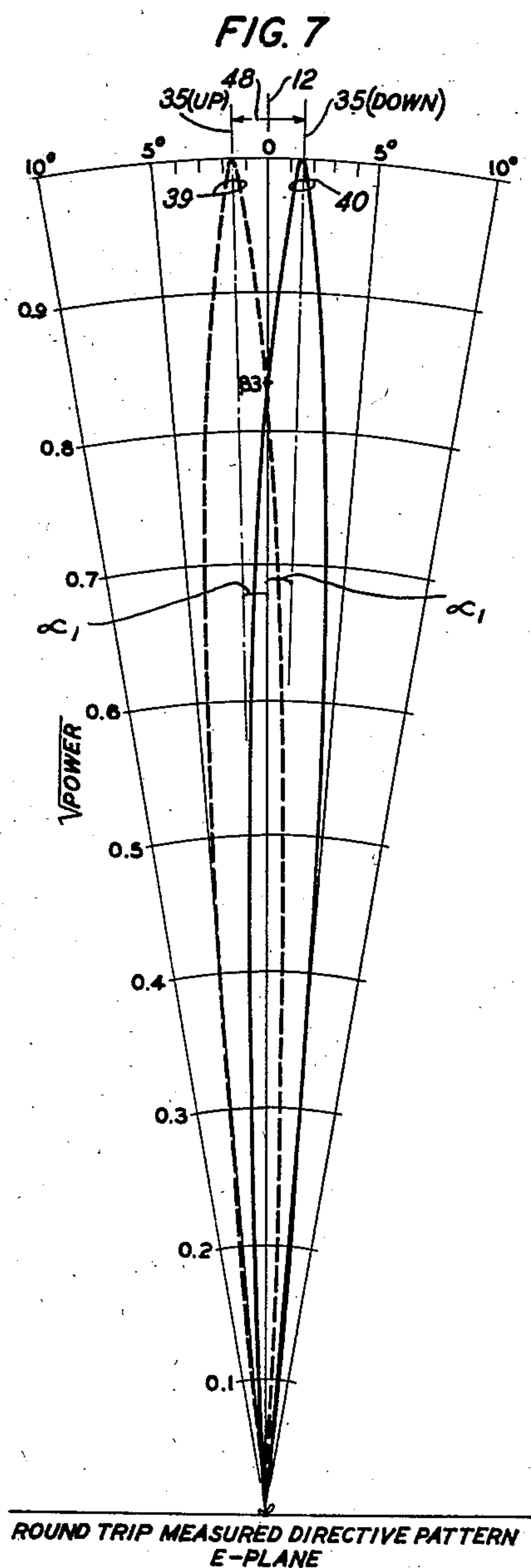
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MICROWAVE RADAR DIRECTIVE ANTENNA

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3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

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## MICROWAVE RADAR DIRECTIVE ANTENNA

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Application November 22, 1943, Serial No. 511,310

14 Claims. (Cl. 250—11)

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This invention relates to directive antenna systems and particularly to conical scanning microwave radar antennas.

The ~~copending~~ application of A. P. King, Serial No. 499,450, filed August 21, 1943, discloses a microwave conical scanning antenna system comprising a paraboloidal reflector associated with a wave guide aperture which is ordinarily equipped with a dielectric window of uniform thickness. The apertured guide rotates about the reflector axis in the focal plane of the reflector and produces the conical scan. As disclosed in the King application the scan is slightly elliptical, the two principal axes of the ellipse being parallel to the directions of the electric and magnetic polarizations of the transceived wave. While the waves may have any polarization, in the preferred embodiment described in the King application the electric and magnetic vectors are included in the vertical and horizontal planes, respectively.

In practice it has been found that the minor axis of the elliptical scan or ellipse obtained in the above system is parallel to the electric vector of the linearly polarized waves transmitted or received by the aperture. Also, it has been found that the major lobe of the antenna system is not circular in cross-section but elliptical, the lobe being wider in the electric plane than in the magnetic plane. Consequently, if the axis of the antenna system is aligned with the target and if the axis of the major lobe describes a cone about the antenna axis, the amplitudes of the waves received when the lobe axis is in the electric plane and when it is in the magnetic plane, are unequal. Stated differently, since the lobe is wider in the electric plane and since the beam deflection or cone angle is smaller in the electric plane, the intensity of the waves received along the antenna axis is greater with the principal lobe axis in the electric plane than it is with the lobe axis in the magnetic plane. As will be discussed in detail later, this intensity difference is highly detrimental since it produces in automatic tracking radar systems an unwanted second harmonic modulation of the detected or received waves.

It is one object of this invention to control, in a conical scanning radar antenna system, the beam deflection or cone angle in the electric plane.

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It is another object of this invention, in a conical scanning radar antenna system, to obtain a beam deflection in the electric plane which is greater or smaller than, or equal to, the beam deflection in the magnetic plane.

It is another object of this invention to control, in a conical scanning antenna system, the shape of the cone described in space by the lobe axis, and hence the shape or contour of the scan.

It is another object of this invention to compensate, in a scanning antenna system in which the main lobe describes an elliptical cone, for the difference, between the widths of the major lobe and the difference between the beam deflections or conical scanning angles, when the lobe axis is in the electric plane and when it is in the magnetic plane.

It is a further object of this invention, in a conical scanning radar antenna system comprising a paraboloid and in which the rotating major lobe has different widths or different angles of deflection with the lobe axis in the electric plane and with it in the magnetic plane, to receive from a target aligned with the reflector axis echo pulses of equal intensity as the lobe rotates and, in particular, as it successively assumes its electric plane and magnetic plane positions.

In accordance with one embodiment of the invention, in a conical scanning antenna system comprising a paraboloidal reflector or secondary antenna and a wave guide aperture or primary antenna which rotates in the focal plane of the reflector, the aperture is equipped with a stepped dielectric plate or window comprising two areas of different thickness, for the purpose of controlling the contour of the scan. The two plate sections have different electrical lengths or depths and different impedances. The areas of the thick and thin sections are critically proportioned dependent upon their relative thickness and the shape of scan, or the change in shape of scan, required to secure equi-intensity signals. Thus, by properly proportioning the two areas the cone angle in the electric plane may be made greater or smaller than the cone angle in the magnetic plane, whereby an elliptical scan is secured, or the eccentricity of an elliptical scan obtained without using the stepped plate is altered. Also, the conical scanning angles in the two planes may be made equal whereby a true circular scan is



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secured. Assuming the major lobe does not have the same width in the electric and magnetic planes and equi-intensity echoes are required when the target is on the reflector axis, the areas are proportioned so that the cone angle changes in a proper manner as the aperture rotates. More specifically, the areas are dimensioned so that the angle in any plane is proportional to the lobe width in the aforementioned plane, that is, so that the greatest beam deflection occurs in the plane, electric or magnetic, in which the major lobe is the broadest, whereby an elliptical scan is realized. With the reflector axis on a target, the waves received have the same amplitude, regardless of the particular orientation of the rotating wave guide aperture.

As incorporated in the particular conical scanning system disclosed in the aforementioned A. P. King application, in which system the lobe is wider and the beam deflection smaller when the lobe axis is in the electric plane, the stepped plate is proportioned so as to increase the beam deflection in the electric plane a definite amount, whereby the difference in width of the lobe in the magnetic plane position and in the electric plane position and the undesirable ellipticity or undesirable difference of the beam deflections in the two planes, are compensated and equi-intensity waves are received with the target aligned with the reflector axis.

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 sectional view of a conical scanning antenna system such as disclosed in the King application except that the transceiving aperture or primary antenna element is equipped with a stepped dielectric plate constructed in accordance with the invention;

Fig. 2 is a schematic illustration of the electric or E plane directive diagram and the magnetic or H plane directive diagram of the prior art system disclosed in the King application, that is, the system of Fig. 1 without the stepped dielectric plate;

Fig. 3 is a perspective view, and Figs. 4 and 5 are front views, of a dielectric plate dimensioned in accordance with the invention and used in the system of Fig. 1;

Fig. 6 is a schematic illustration of the E plane and H plane directive diagrams, and Figs. 7 and 8 illustrate respectively the measured E plane and H plane directive patterns, of the conical scanning system illustrated by Fig. 1 and including a stepped dielectric plate; and

Fig. 9 is a conical scanning diagram, viewed in the perspective, for the system of Fig. 1 comprising the stepped plate.

Referring to Fig. 1, reference numeral 1 denotes a translation device such as a transmitter, a receiver or a radar transceiver, the device being connected to a main circular guide 2 by means of a coaxial line 3 having an outer conductor 4 and an inner conductor 5. Conductor 5 extends transversely into guide 2 so that waves polarized as shown by arrows 6 are transferred between guide 2 and line 3. Numeral 7 denotes a piston tuner positioned in guide 2 approximately a quarter wavelength, or an odd multiple "N" of a quarter wavelength, from the inner conductor 5 for the purpose of securing unilateral propagation in guide 2 and matching the impedances of guide 2 and line 3. Numeral 8 denotes a parab-

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oloidal reflector, which constitutes a "secondary antenna" member and is hereinafter termed a "paraboloid." The paraboloid 8 has an apex 9, a focal plane 10, a focus 11 and a principal axis 12. Numeral 13 denotes a dummy guide of circular cross-section. As illustrated, the linear portions of guides 2 and 13 positioned in front of the paraboloid 8 extend perpendicularly to the paraboloid axis 12 and, as explained in the above-mentioned application, the dummy guide is provided for the purpose of securing symmetrical directive action in the plane containing guide 2 and reflector axis 12.

The guide 2 has a circular opening 14 concentric with the antenna axis 12 and facing toward the concave surface of reflector 8. Numeral 15 denotes a rotatable short circular guide section having a transverse opening 16 facing opening 14 and an aperture or primary antenna element 17 facing reflector 8. The longitudinal axis 18 of guide 15 and the antenna axis 12 form an acute angle. The short guide section 15 is mounted for rotation on a dielectric shaft 19 connected to motor 20 and comprising a mycalex section 21 and Plexiglas section 22. Numerals 23 and 24 denote polystyrene plates which support shaft 19 and are in turn supported by the dielectric struts 25 and the base-plate 26 which is mounted on shaft 27. The central circular portion 28 of dielectric plate 23 constitutes a circular window included between the openings 14 and 16 and functions as a bearing for shaft 19. Numerals 29 and 30 denote, respectively, a zero impedance wave guide junction or coupler of the stationary type and a zero impedance wave guide coupler of the rotatable type. The first coupler 29 is included between, and constitutes a means for coupling, the opening 14 and the plate portion 28; and the rotatable coupler 30 is included between, and constitutes a means for coupling, the opening 16 and the plate portion 28. The opening 16 in guide member 15 is equipped with a polystyrene plate or window 31. For the purpose of description, reflector 8 and guides 2 and 13 are shown rigidly connected together by struts 25, and device 1 is shown mounted on plate 26, whereby a unitary structure adapted for vertical and horizontal rotation is secured. Ordinarily, in actual practice, the device 1 is stationary, a rotatable junction being included in the coaxial line 3 for permitting steering of the reflector 8 and associated rotating guide 15.

Assuming that the aperture 17 is open or is equipped with a thin dielectric window having a uniform thickness substantially different from a quarter wavelength, the transmitting operation and the receiving operation of the complete antenna system will now be described. First of all, at or near the center of aperture 17 there is a point 32 at which the energy may be considered to be radiated or collected to obtain the same directive characteristic as is actually observed, this effective point of radio action being hereinafter termed the "effective center of radiation" or "the effective center of reception." In transmission, assuming motor 20 is not operating, microwaves supplied by transmitter 1 over line 3 to guides 2 and 15 are emitted by aperture 17. The emitted waves have their electric vector or polarization in a vertical plane as shown by arrow 33, and are propagated toward the paraboloid 8. The waves impinge upon all parts of the paraboloid and, upon being reflected, are transmitted in a direction making an angle  $\alpha$  with the reflector axis 12 and lying on the side away from the axis



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18 of the guide section 15. Numeral 34 denotes, by way of example, a wave component travelling from the effective radiation center 32 toward the reflector apex 9 and numeral 35 designates the common direction of the reflected wave components. With motor 20 operating, the guide 15 rotates and the center of the aperture including the effective center 32 revolves about the reflector focus 11. Direction 35 corresponds to the principal axis of the major lobe of the antenna and, as it rotates, it describes in space a cone of elliptical cross-section. In other words, the angle  $\alpha$  varies as the aperture 17 and the resulting lobe revolve. The receiving operation is, by virtue of the reciprocity theorem, the converse of the transmitting operation, the reflector axis 12 and the axis of the major receiving lobe forming an angle  $\alpha$ . If the direction of the incoming wave, as received from a distant station or reflective surface, is not aligned with the reflector axis 12, the antenna system is rotated in the horizontal and vertical planes, as indicated by arrows 36, to a position at which the axis 12 is aligned with the incoming direction. With the antenna properly oriented the principal axis of the major receiving lobe makes a variable angle  $\alpha$  with the actual direction.

As previously indicated, the rotating major lobe of the system of Fig. 1, not modified in accordance with the invention, is wider in the electric plane and the direction 35 or principal lobe axis describes an elliptical cone, the minor axis of the ellipse being in the electric plane. These conditions or directive effects are illustrated, in a somewhat exaggerated manner for the purpose of explanation, by Fig. 2. Thus, reference numerals 37 and 38 denote the two positions, hereinafter termed for convenience the "left" and "right" positions assumed in the magnetic or "H"-plane by the lobe during its rotation, and numerals 39 and 40 denote the two positions, hereinafter termed "up" and "down," assumed by the lobe in the electric or "E"-plane. Numerals 41 and 42 denote, respectively, the minor axis and the major axis of the elliptical scan. As shown, the lobe in position 37 or 38, is wider than it is in position 39 or 40. The minor axis 41 and the major axis 42 are parallel to the E-plane and H-plane, respectively, the beam deflection or cone angle  $\alpha_1$  in the E plane being smaller than the cone angle  $\alpha_2$  in the H-plane. It is important to note, considering the E plane and the H-plane, that in this prior art arrangement the cone angle is smaller in the plane in which the lobe is the wider. As discussed in detail below, the cone angle in either plane is, in accordance with the invention, controlled so as to be proportional to the lobe width in that plane. The King application states that the ellipticity in the scan is caused by the ellipticity in the cross-sectional area of the transceiving aperture and the angularity of the associated rotating guide section. More specifically, the cross-sectional ellipticity and the feed guide angularity apparently cause the center 32 of radiation to shift, at least to some extent, radially relative to reflector axis 12 as the aperture 17 rotates; and the maximum shift or increase in radial spacing between the radiation center 32 and axis 12 or focus 11 is unfortunately in the magnetic, instead of the electric, plane.

As a consequence of the two conditions described above, assuming the reflector axis 12 is aligned with the target, the echo pulses received with the lobe axis in the magnetic plane and with

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it in the electric plane differ in intensity, and an amplitude modulation of the received echo waves obtains. As shown in Fig. 2, the intensity denoted by numeral 43 of the echo pulse received along axis 12 with the lobe in the H-plane is less than the intensity denoted by numeral 44 of the echo pulses received along axis 12 with the lobe in the E-plane. The points, 43 and 44, where the lobe crosses the reflector axis 12 in the magnetic and electric plane are usually termed the "crossover" points. Since, during each scan or lobe rotation, the lobe is positioned twice in the electric plane and twice in the magnetic plane, the frequency of the modulation is twice the scanning frequency. Assuming the antenna is utilized in a radar system arranged for automatic direction tracking, the second harmonic modulation contains no useful intelligence and may interfere with the proper operation of the detector circuits which function to determine the sense and degree of the antenna pointing error.

As described so far, the structure and operation are substantially the same as that illustrated by Fig. 5 of the above-mentioned application of A. P. King. In accordance with the present invention a stepped dielectric plate or window 45 composed, for example, of polystyrene, is positioned in the transceiving aperture 17 of the rotating guide section 15. As illustrated in Figs. 1, 3, 4 and 5, the plate 45 comprises a thick section 46 and a thin section 47 having equal or unequal transverse areas. The stepped plate functions to control or determine the cone angle or beam deflection in the electric (vertical) plane containing the wave polarization 33, Fig. 1, or the magnetic (horizontal) plane, or in both planes, as will now be explained.

While the theory explaining the change in cone angle during the rotation of the stepped dielectric plate is not completely understood, applicants have discovered that a stepped plate, in contrast to certain plates of uniform thickness, apparently causes the effective center 32 of radio action to shift its position radially from the focus 11 or reflector axis 12. The amount or degree of shift in the E-plane differs from that in the H-plane. More broadly, the radial distance or spacing between the effective center 32 and the focus 11 depends upon, and is a function of, the orientation of the stepped plate. More particularly, it depends on whether the line connecting the effective center and the reflector axis is in the E-plane or H-plane. Also the radial spacing depends upon the relative areas and relative thicknesses of the thick and thin plate sections 46 and 47. The thickness of the thick section 46 or the thin section 47 may be in the order of a quarter wavelength, as measured in the dielectric, or may be substantially different from a quarter wavelength. As the radial spacing changes, the cone angle  $\alpha$  or beam deflection changes proportionally. For example, as the radial distance increases the lobe axis or direction 35 inclines at a larger angle relative to reflector axis 12, the direction 35 and the effective center 32 being of course at all times on opposite sides of reflector axis 12.

Referring to Figs. 4 and 5, Fig. 4 illustrates the orientation of plate 45 when the imaginary radial line connecting the reflector axis 12 and the effective center 32 is in the E-plane and the spacing in the E-plane between the reflector axis 12 and effective center 32 is  $d_1$ ; and Fig. 5 illustrates the plate orientation when the aforesaid imaginary line is in the H plane and the spacing in the H-plane between the reflector axis 12 and the trans-



ceiving center is  $d_2$ . Assuming that the thickness of the thick section 46 is a quarter wavelength, more or less, as measured in the dielectric, it is known from experiments that if the area of this thick section 46 is increased and the complementary area of the thin section 47 decreased, the spacing  $d_1$  is decreased and the spacing  $d_2$  is not substantially changed, since  $d_1$  increases more rapidly than  $d_2$ . Hence the cone angle in the E plane, that is, the beam deflection  $\alpha_1$ , Fig. 2, is decreased while the beam deflection  $\alpha_2$  in the H-plane is not altered substantially. On the other hand, experiments show if the area of the thick section 46 is decreased and the area of the thin section 47 increased, the spacing  $d_1$  is increased and the spacing  $d_2$  is not changed materially. Hence  $\alpha_1$  is increased while  $\alpha_2$  is altered only slightly. Again, assuming that the thickness of the thin section 47 is in the order of a quarter wavelength, theory indicates that if the area of the thick section 46 is increased and the area of the thin section decreased, the spacing  $d_1$  is increased while  $d_2$  is not changed substantially so that  $\alpha_1$  is increased and  $\alpha_2$  remains unchanged substantially. On the other hand, with the relative thicknesses as last assumed, if the area of the thick section 46 is decreased and the area of the thin section 47 increased, the spacing  $d_1$  and the angle  $\alpha_1$  are, it is supposed, decreased while the spacing  $d_2$  and the angle  $\alpha_2$  remain substantially constant. As a special case, when the whole plate is of the order of one quarter wavelength thick, the angle  $\alpha_1$  is approximately zero, whereby only linear scanning in the H-plane is secured. More specifically, if the thickness of the thick section 46 is a quarter wavelength and its area is increased a maximum amount so that the plate 45 has a uniform thickness of a quarter wavelength, the spacing  $d_1$  and the cone angle  $\alpha_1$  are, it is known, decreased to zero, approximately, whereby only magnetic plane scanning obtains. Also, if the thickness of the thin section 47 is a quarter wavelength and the area of the thick section 46 is decreased to zero, so that the plate 45 has a uniform thickness of a quarter wavelength, the spacing  $d_1$  and the cone angle  $\alpha_1$  are, according to theory, decreased to zero, approximately, whereby only linear scanning in the magnetic plane obtains.

Regardless of the correctness of the above theory, it has been found that by proper selection of both the relative areas and the relative thicknesses of plate sections 46 and 47, the deflection  $\alpha_1$  in the E-plane may be increased or decreased to a value greater or smaller than the beam deflection  $\alpha_2$  in the magnetic plane, without appreciable change in the beam deflection  $\alpha_2$ . In practice the relative thicknesses and relative areas required for securing a particular or desired beam deflection  $\alpha_1$  are for convenience determined experimentally, that is, by the so-called "cut-and-try" method.

Referring again to the embodiment of Fig. 1, the transceiving aperture is equipped with a stepped dielectric plate 45 dimensioned so as to secure an E plane beam deflection  $\alpha_1$  greater than the H-plane beam deflection  $\alpha_2$  by an amount related to the width of the E plane lobe 39 (or 40) or, more accurately, an amount related to the difference in width between the E-plane lobe 39 (or 40) and the H plane lobe 37 (or 38). Thus, referring again to Figs. 3, 4 and 5, the thicknesses and areas of plate sections 46 and 47 are adjusted or changed to values such that, with the reflector axis aligned with the target, echo pulses of con-

stant intensity are received as the lobe rotates, and regardless of the orientation of the stepped plate. Stated differently, the thicknesses and areas are adjusted to values such that observation of the directional patterns of the major lobe indicates the cone angle  $\alpha_1$  has been properly related to the lobe width when the lobe axis is in the E-plane.

As shown in Figs. 4 and 5, with the cone angle  $\alpha_1$  and the lobe width properly related, the spacing  $d_1$  is greater than  $d_2$ . Also, referring to Figs. 4, 5 and 6, with plate sections 46 and 47 properly dimensioned, the intersection of the lobe and the reflector axis 12 remains fixed at point 43. In addition, the major axis 48 of the elliptical scan is in the E-plane containing the polarization 33, instead of the H-plane as in the prior art arrangement, Fig. 2. The E plane cone angle  $\alpha_1$ , Fig. 6, is larger than the H-plane cone angle  $\alpha_2$ , instead of smaller as shown in Fig. 2. When incorporated in the automatic tracking radar system previously described, the antenna system of Fig. 1 including the stepped plate 45 functions to eliminate the undesired second harmonic modulation. In an actual embodiment constructed in accordance with Figs. 1, 3, 4 and 5 and successfully tested for an operating wavelength of approximately 10.7 centimeters the thicknesses of the thick and thin plate sections were respectively 0.155 wavelength and 0.028 wavelength, as measured in the polystyrene dielectric; and the area of the thin section 47 was larger than the area of the thick section 46, the ratio of the thick area to the thin area being approximately 0.89.

Referring to Figs. 7 and 8 which illustrate the measured patterns E-plane and H-plane directive patterns, respectively, for a conical scanning system constructed in accordance with the invention and illustrated by Fig. 1, it will be observed that the electric plane lobes 39 and 40 are wider than the magnetic plane lobes 37 and 38. Compare, for example, the width of either lobe 39 or 40, Fig. 7, at the 0.4 point on the radial scale representing the square root of power scale with the width of either lobe 37 or 38, Fig. 8, at the corresponding point in the power scale. The crossover point 43 is the same for the E and H planes, the point being at 0.83 on the radial scales in both Figs. 7 and 8. Hence, by actual test, equi-intensity echo pulses are received with the reflector axis 12 aligned with the target. The cone angle  $\alpha_1$  in the E plane is relatively small, that is, slightly greater than 1.5 degrees; and the cone angle  $\alpha_2$  in the H-plane is slightly less than 1.5 degrees and, therefore, smaller than  $\alpha_1$ . Note that the major axis of the elliptical scan is in the E plane since the dimension 48, Fig. 7, is larger than the dimension 42, Fig. 8. Assuming the lobe is in the "down" position denoted by numeral 40, and assuming the tip or nose of the lobe moves clockwise, the lobe occupies in succession the "left" position 37, the "up" position 39 and the "right" position 38. The lobe itself does not spin or rotate about the reflector axis 12, but revolves bodily about the reflector axis in a manner such that any particular portion of its surface points in the same direction during the entire revolution of the lobe. For example, the upper surface always faces vertically up during the scan cycle.

Thus far it has been assumed that continuous transmission or continuous reception of the energy occurs during the lobe revolution as in a true conical scanning system. As is explained in the aforementioned King application, intermittent or pulse transmission and reception by a radar



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transceiver is ordinarily utilized, and instead of true conical scanning, lobe switching is sometimes employed. In lobe switching the beam switches from one position to another of four quadrature fundamental positions on the elliptical scan, the beam remaining most of the time of each cycle in the up, down, left and right positions. In one lobe switching system arranged for automatic direction tracking and testing, double pulses were utilized in each of the four fundamental positions, as will now be explained.

Referring to Fig. 9 and assuming eight pulses are emitted per scan, the major lobe axis 35, Fig. 6, is aligned successively with the directions 49, 50, 51, 52, 53, 54, 55 and 56 which lie on the surface of a cone 57 having an elliptical cross-section 58 in a plane perpendicular to the reflector axis 12. The ellipse 8 has its major axis 48 in the E-plane and its minor axis 42 in the H-plane. The eight pulses received during each cycle of scan will all have approximately the same amplitude when the reflector axis 12 is aligned with the target. If the axis 12 is not pointed at the target, the received or echo pulses will be amplitude modulated at a frequency equal to the scanning rate. During that part of the scan when the reflector axis 12 points most directly at the target the echo pulses have the greatest amplitude. Consequently, the phase of the resultant modulation, with respect to a reference phase corresponding to a point on the scanning cycle, is an indication of the direction of the antenna pointing error. Also, the amplitude of the resulting modulation is an indication of the magnitude of the pointing error. Control currents representing the phase and amplitude of the modulation are obtained and supplied to the automatic tracking circuits, whereby the paraboloid is automatically moved or turned in the azimuthal and elevational planes in such a way as to accurately align the paraboloid axis 12 with the target. This amplitude modulation, it will be noted, has a frequency equal to the scanning rate, and there will not be any modulation at twice the scanning rate as is present in the prior art system corresponding to Fig. 2, in which system the cross-over points 43 and 44 are not superimposed.

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

What is claimed is:

1. A rigid dielectric plate having a thick section and a thin section, the ratio of the transverse area of said thick section to that of said thin section being in the order of 0.89 and the ratio of the thickness of the thick section to that of said thin section being in the order of 5.53.

2. In combination with an antenna element having a direction of maximum radio action angularly related to and revolving about a given axis, the spacing between the effective center of radio action of said element and said axis being different in planes containing said axis and successively containing said direction, means included in said element for compensating for the difference in said spacing.

3. In combination with a revolving antenna having a revolving directive lobe the axis of which forms an acute angle with the axis of revolution and the width of which varies during the lobe rotation, means included in said antenna for vary-

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ing said angle during the lobe rotation in accordance with the variation in said width.

4. In combination with an antenna system comprising a rotating wave guide having an end transceiving aperture and a longitudinal axis angularly related to the axis of revolution, said aperture having an effective center of transmission and reception spaced from the axis of revolution, means positioned in said aperture for controlling said spacing.

5. In combination with a conical scanning antenna system having a major lobe revolving conically about a given axis, said axis and the lobe axis forming a cone angle, means included in said system and positioned in the path of the waves emitted or received for controlling the cone angle in at least one plane containing said axes.

6. In combination with a conical scanning antenna having a major lobe revolving at an angle to and about a given axis, the widths of said lobe in quadrature planes each containing the lobe axis and the given axis being different, means included in said system and positioned in the path of the emitted or received waves for obtaining each of said planes a beam deflection directly related to the lobe width in said plane.

7. In combination with a conical scanning antenna system having a major lobe revolving about the antenna axis, said axis and the lobe axis forming a cone or conical scanning angle, the width of said lobe when the lobe is in one plane containing the lobe axis and the antenna axis being different from the lobe width when the lobe is in another plane containing said axes, means included in said antenna system and positioned in the path of the radio waves for securing cone angles in said planes proportional to the respective lobe widths.

8. In combination, a wave guide having an aperture for emitting or receiving radio waves, a stepped dielectric plate positioned in said aperture and having two sections or portions of different uniform thicknesses.

9. In an antenna system, a wave guide having a longitudinal axis and a transverse aperture at one end for emitting or collecting radio energy, a stepped dielectric plate positioned in said aperture and comprising two sections or portions having different uniform thicknesses, and means for rotating said guide about a line perpendicular to the plane of said aperture and forming an acute angle with said axis.

10. In an antenna system, a wave guide having a longitudinal axis and a transceiving aperture at one end, a stepped dielectric plate positioned in said aperture and comprising two sections having different uniform thicknesses, means for rotating said guide about a line perpendicular to the plane of said aperture and forming an acute angle with said axis, and wave guide means for supplying or receiving from said aperture waves having a constant linear polarization.

11. In an antenna system, a secondary antenna comprising a hollow reflector having a focus, a primary antenna comprising a circular wave guide aperture facing said reflector, a dielectric plate positioned in said aperture, the thickness of one portion of said plate being different from that of the remaining portion, and means for rotating the mid-point of said dielectric plate about said focus.

12. In combination, a paraboloidal reflector, a wave guide having an open end facing said reflector and a longitudinal axis angularly related to the principal axis of the reflector, a dielec-



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tric plate positioned in said open end and having a non-uniform thickness, a transceiver connected to said guide, and means for rotating said longitudinal guide axis about the reflector axis.

13. In combination, a paraboloidal reflector 5 having a focus, a circular guide having a longitudinal axis and an elliptical aperture for transmitting radio energy facing said reflector, an elliptical polystyrene plate positioned in said aperture, said plate comprising two sections having 10 different thicknesses, means for rotating said guide, and means for supplying to, or receiving from, said aperture waves having a stationary linear polarization.

14. In combination with a dual-plane lobe 15 switching antenna system having a principal axis, said system comprising a wave guide aperture and means for switching in each of the two planes the major lobe between two positions at which

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the lobe crosses over or intersects said axis at the same point, means for superimposing the cross-over points for the two planes, said means comprising a dielectric window of non-uniform thickness positioned in said aperture.

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