Jan. 13, 1948. A. C. BECK 2,434,253

DIRECTIVE CENTIMETRIC ANTENNA

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FIG. 3

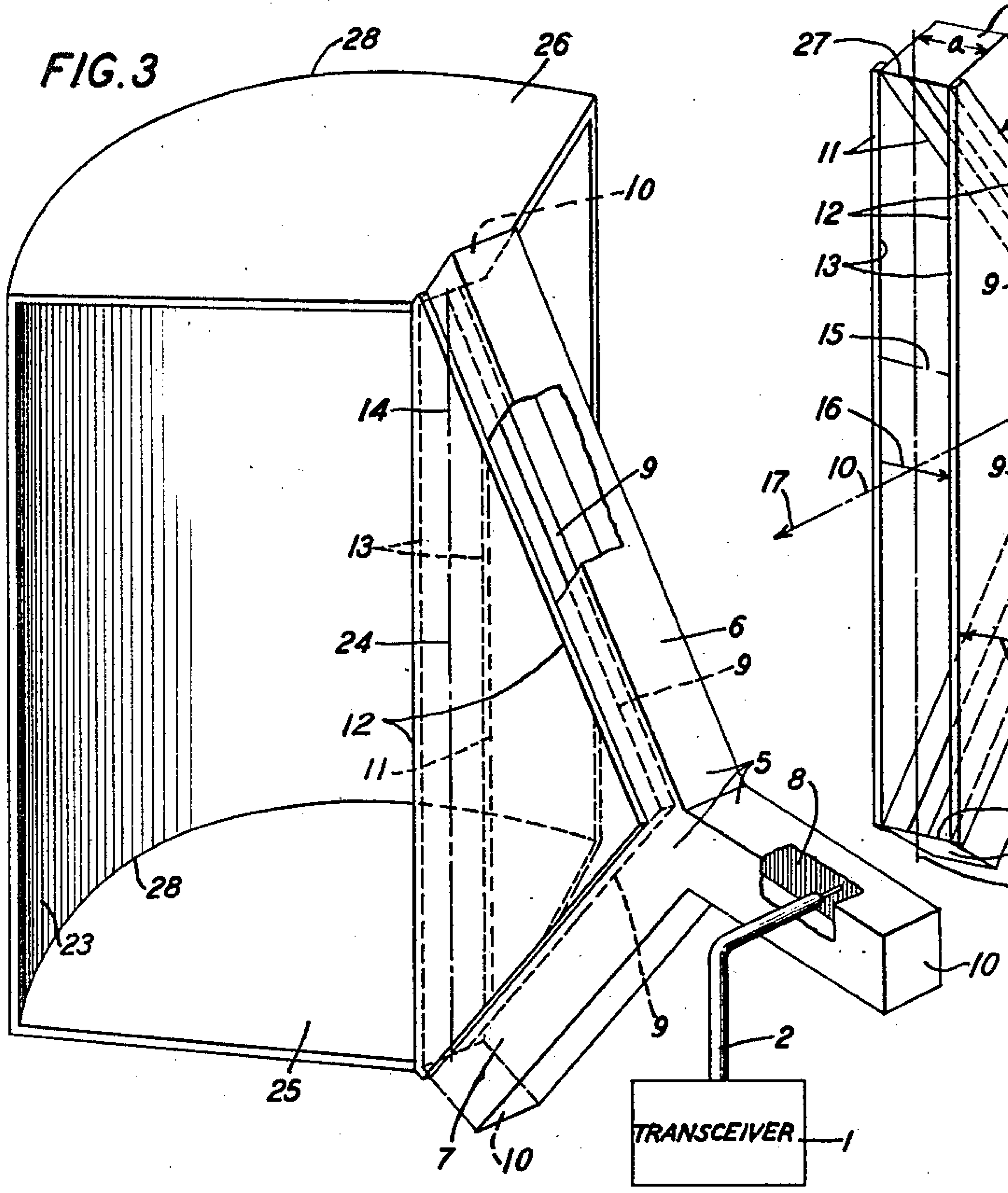


FIG. 1

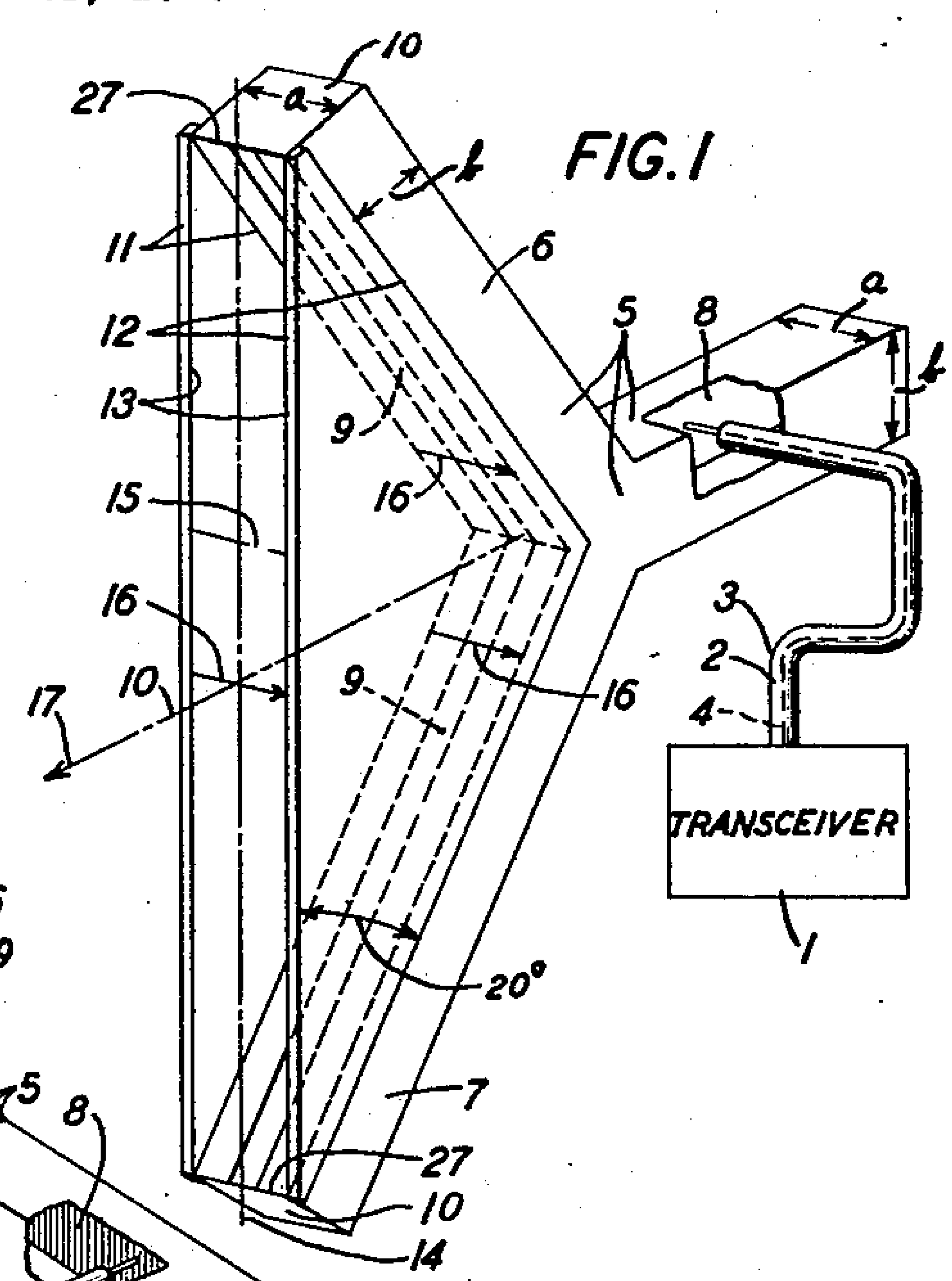
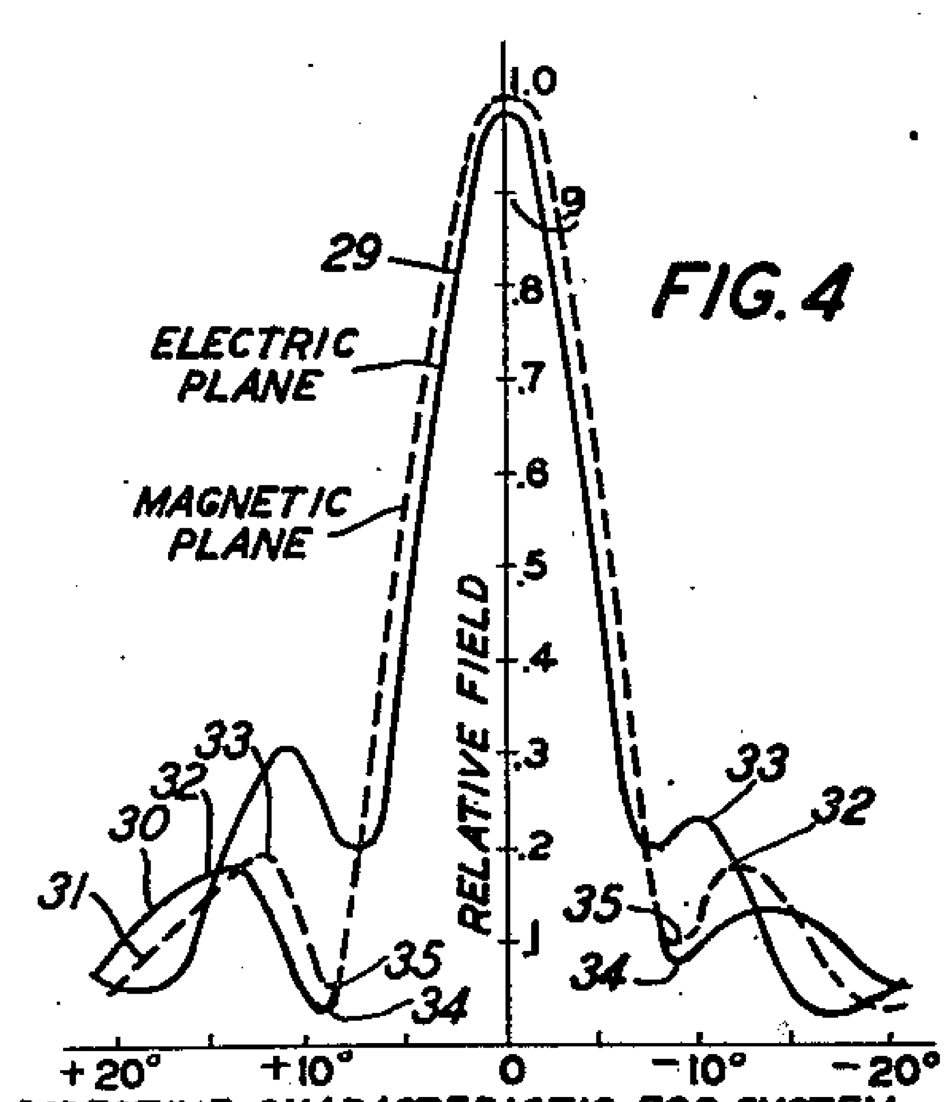
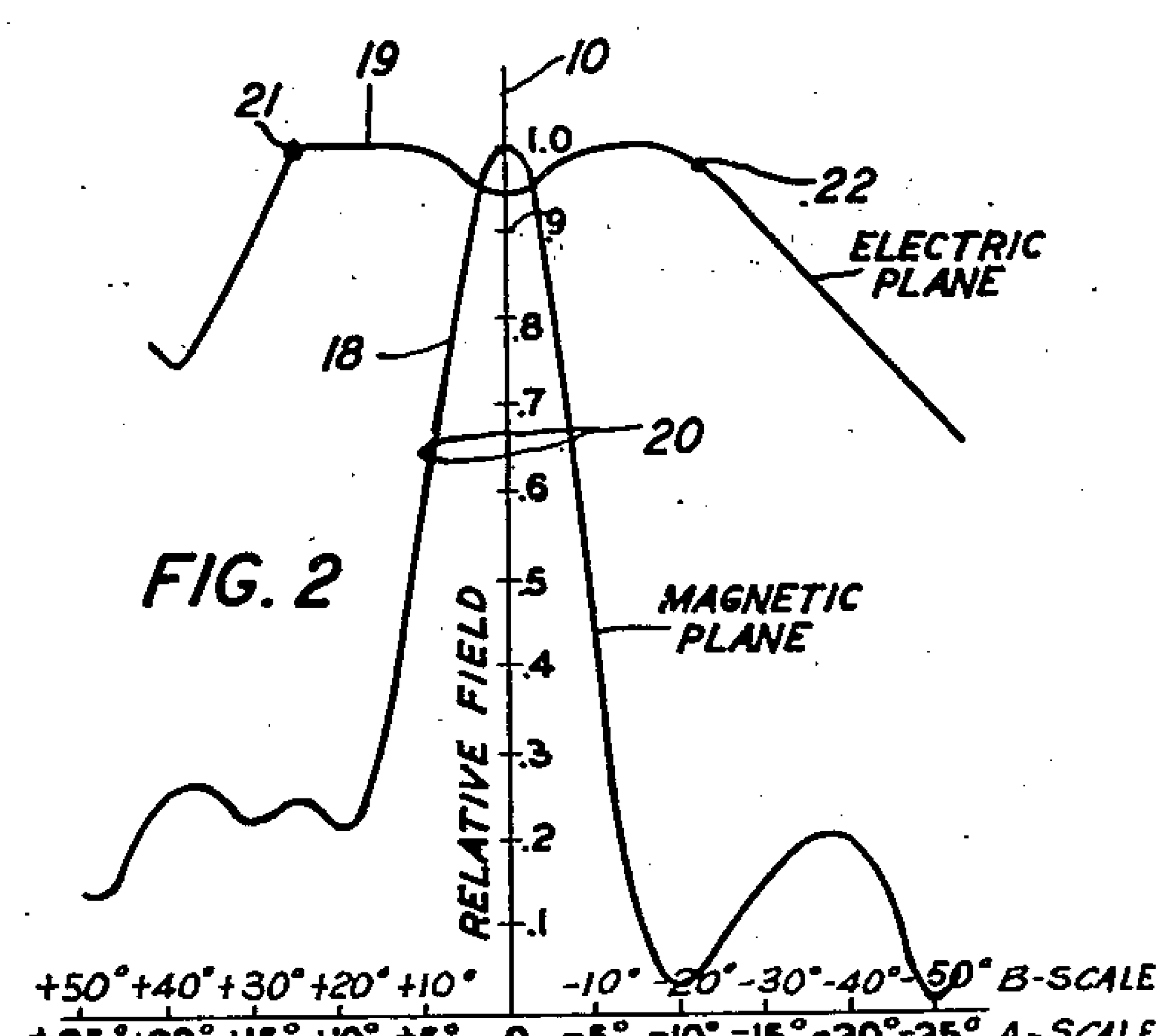


FIG. 4



DIRECTIVE CHARACTERISTIC FOR SYSTEM OF FIG. 3

FIG. 2



"A" SCALE FOR CURVE 18 - "B" SCALE FOR CURVE 19
DIRECTIVE CHARACTERISTIC FOR SYSTEM OF FIG. 1

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DIRECTIVE CENTIMETRIC ANTENNA

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FIG. 5

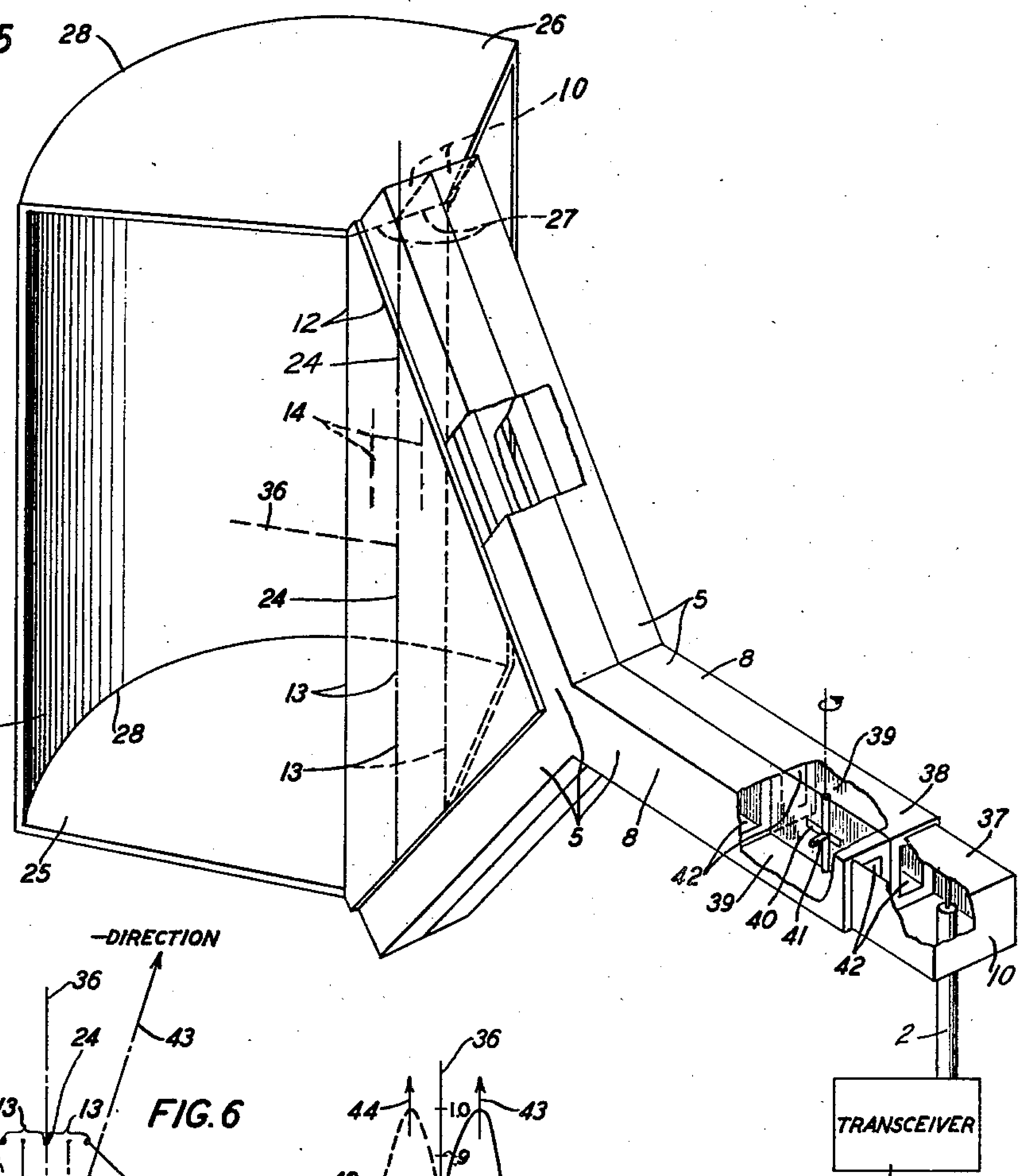


FIG. 6

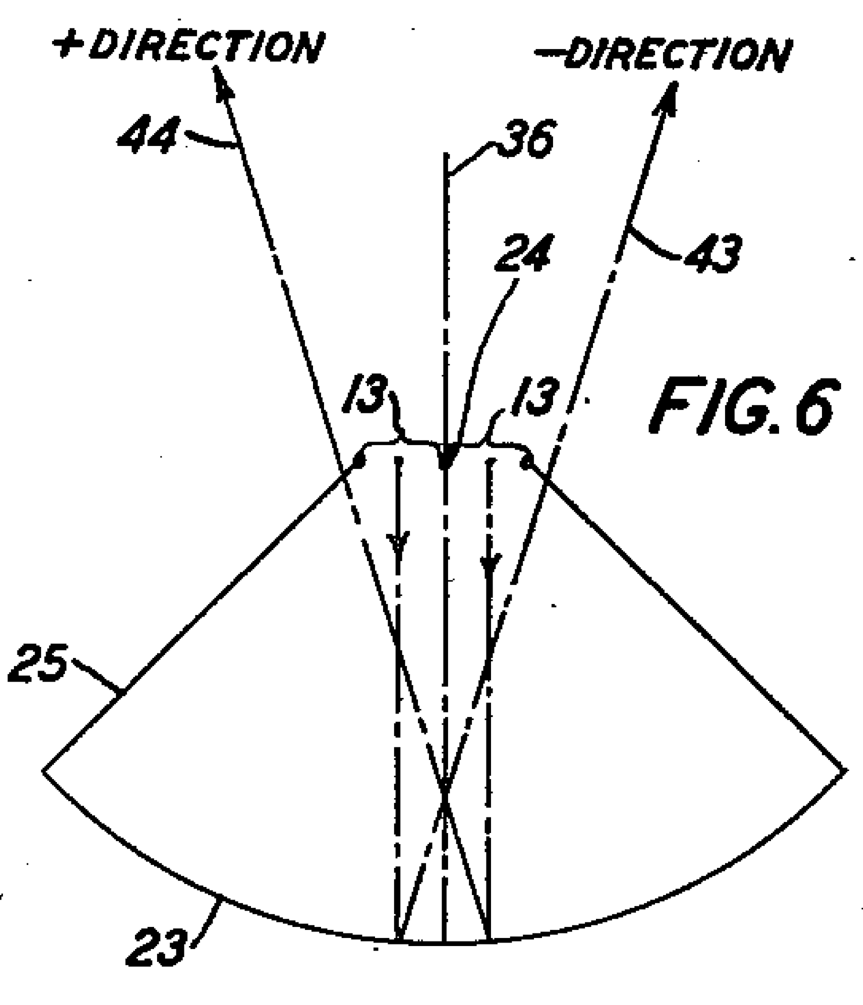
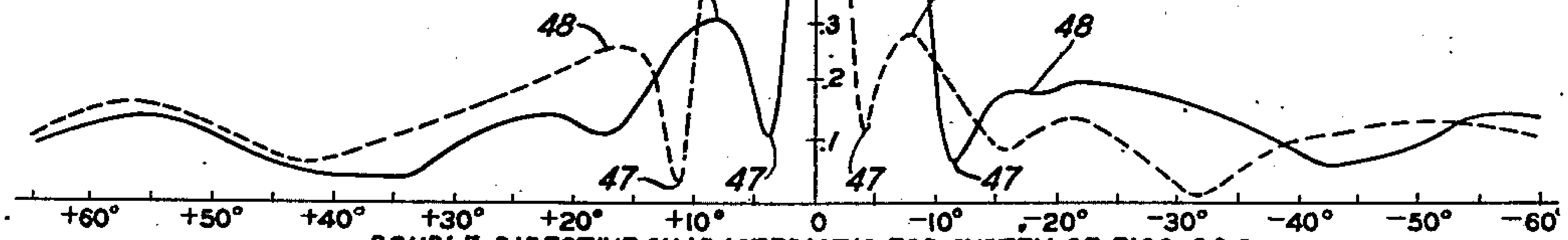


FIG. 7



DOUBLE DIRECTIVE CHARACTERISTIC FOR SYSTEM OF FIGS. 5 & 6

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DIRECTIVE CENTIMETRIC ANTENNA

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FIG. 8

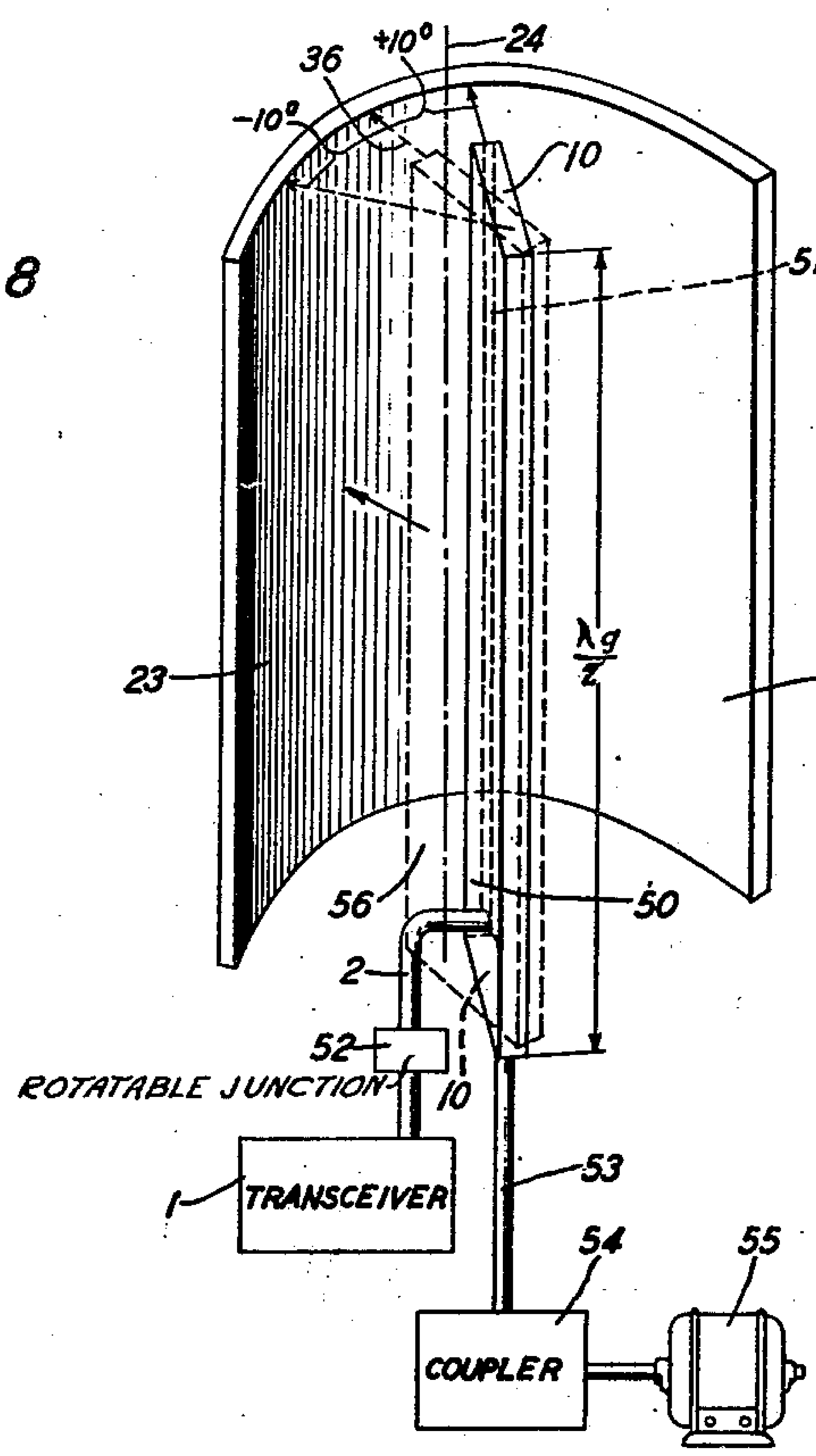
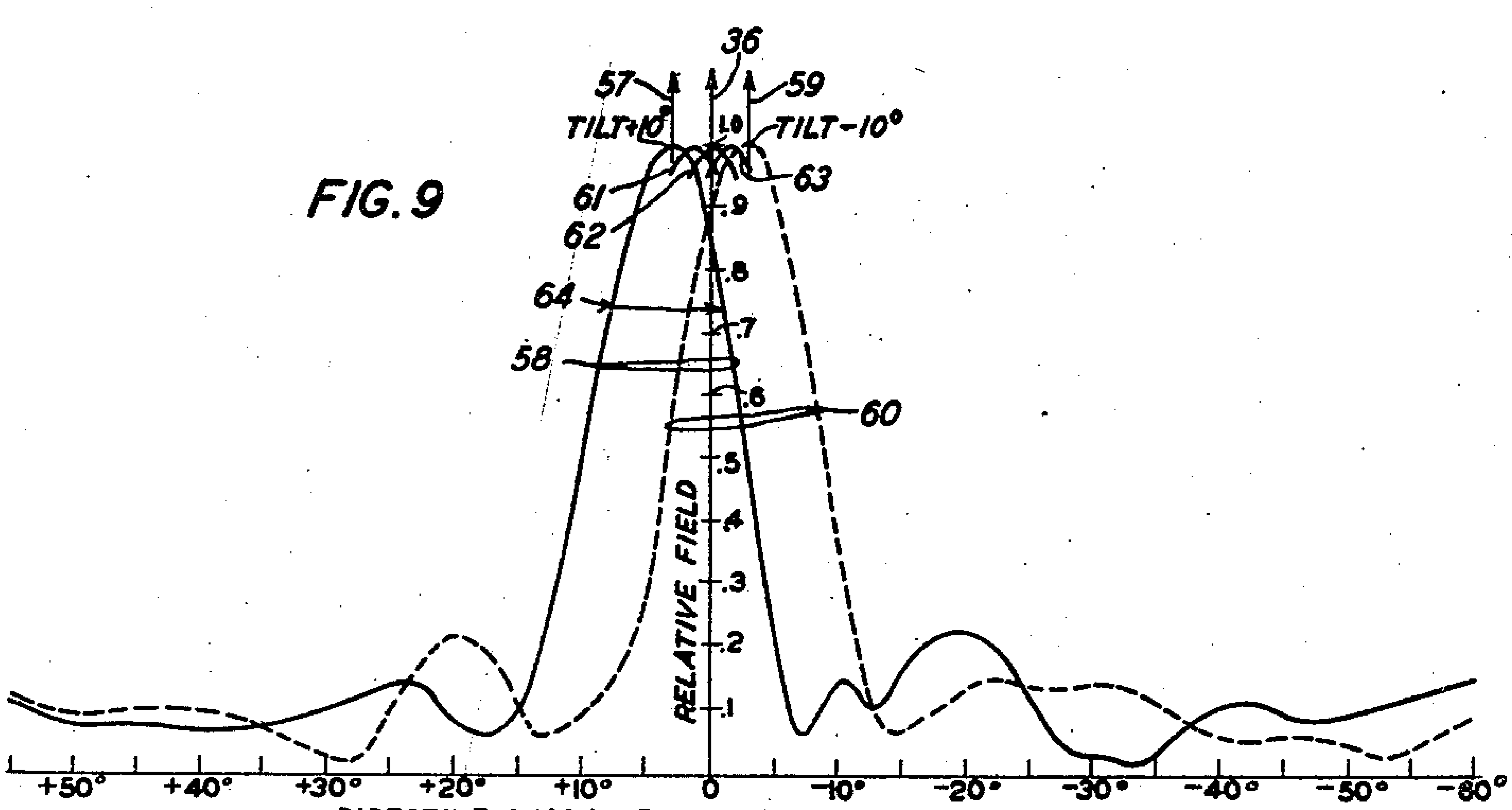


FIG. 9



DIRECTIVE CHARACTERISTIC FOR SYSTEM OF FIG. 8

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DIRECTIVE CENTIMETRIC ANTENNA

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FIG. 10

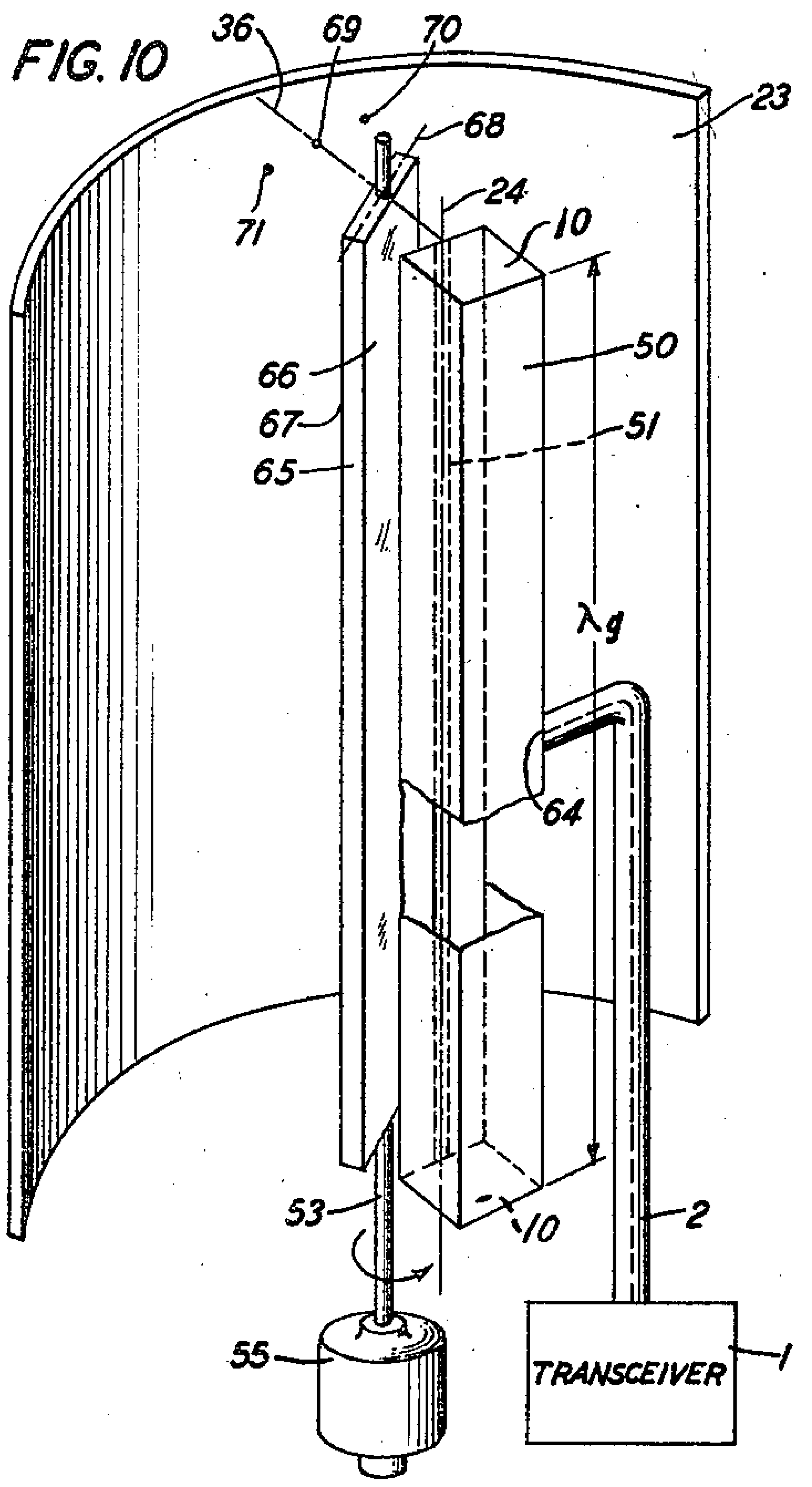


FIG. 13

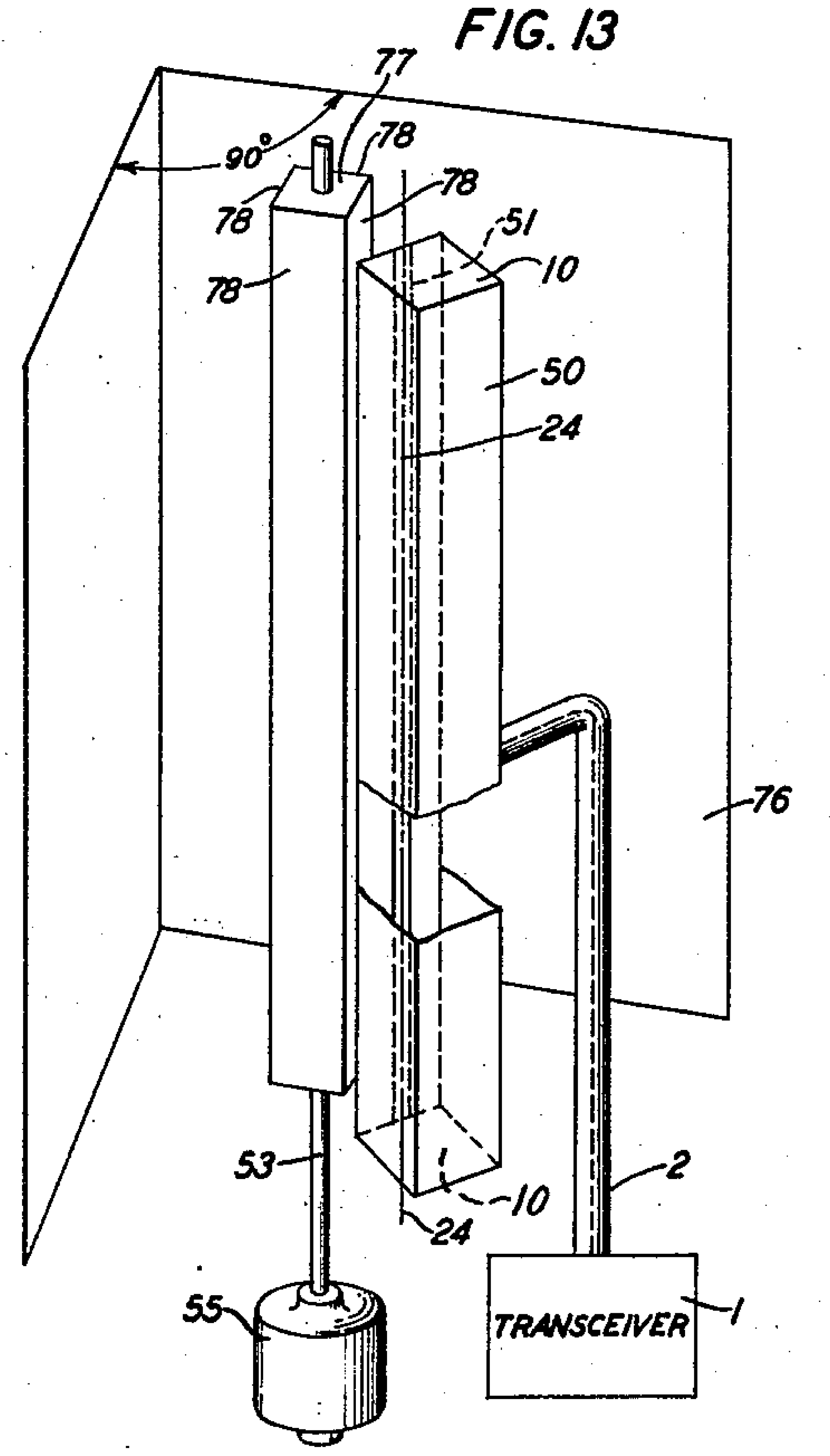
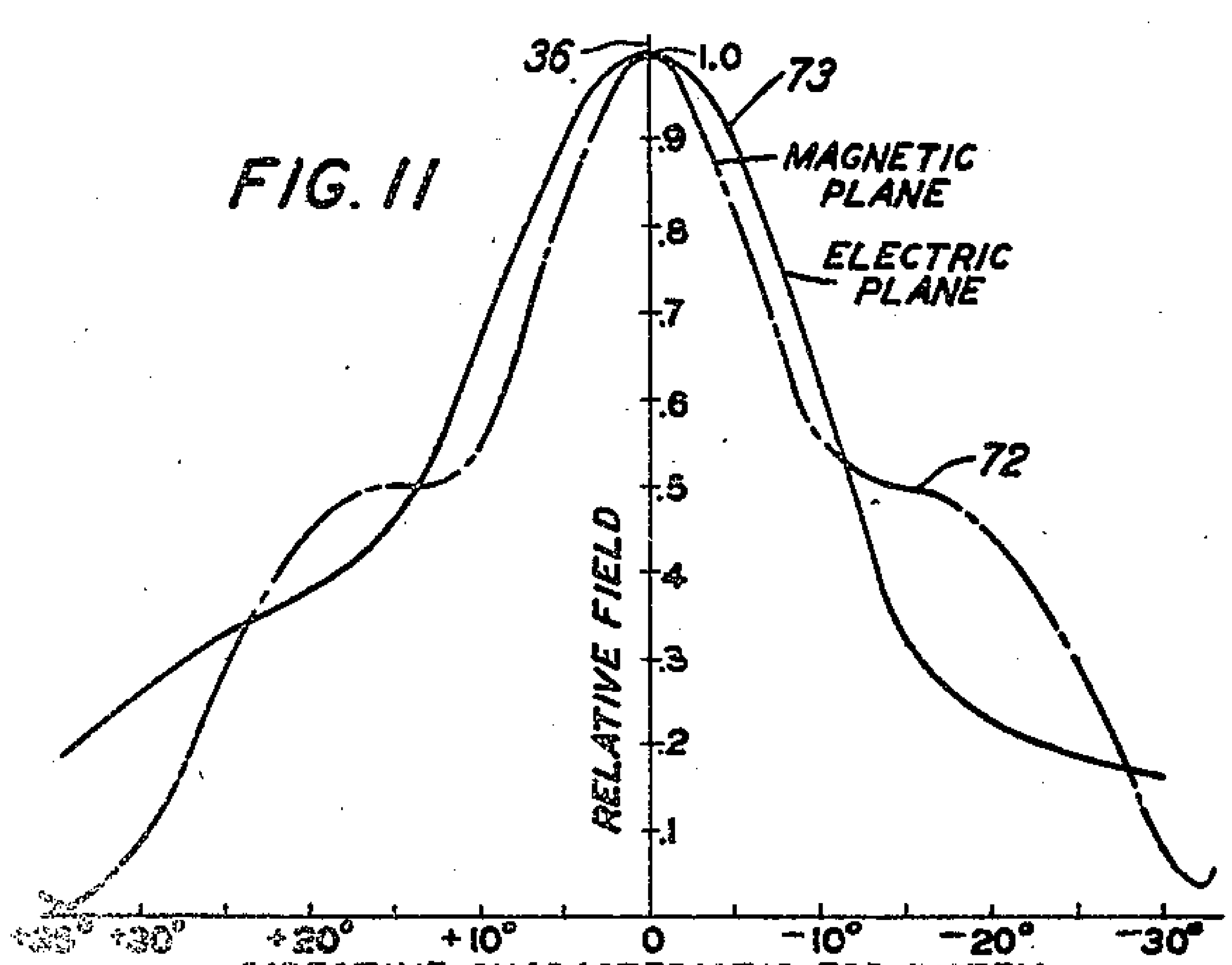
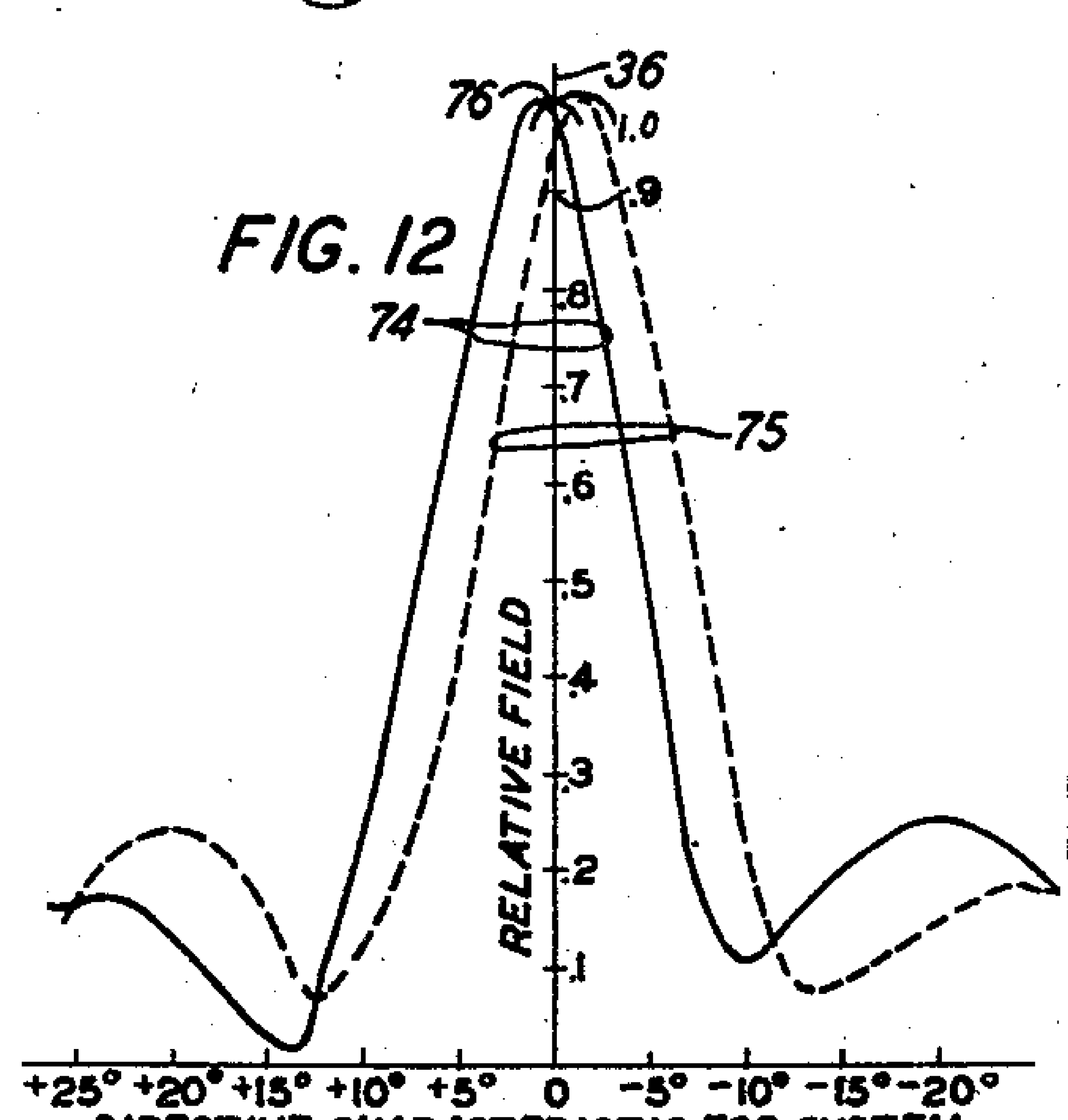


FIG. 11



DIRECTIVE CHARACTERISTIC FOR SYSTEM OF FIG. 10 WITHOUT VANE

FIG. 12



DIRECTIVE CHARACTERISTIC FOR SYSTEM OF FIG. 10 WITH VANE

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Patented Jan. 13, 1948

2,434,253

UNITED STATES PATENT OFFICE

2,434,253

DIRECTIVE CENTIMETRIC ANTENNA

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Application August 21, 1943, Serial No. 499,453

16 Claims. (Cl. 250—11)

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This invention relates to directive radio systems and particularly to directive antennas especially adapted for use in centimetric radar systems.

As is known, centimetric and decimetric waves having a wavelength, respectively, of one to ten centimeters and ten to one hundred centimeters are now being used in radio directional and ranging (radar) systems. For waves of these microwave wavelengths the conventional prior art dipole-parabolic reflector antennas used with longer wavelengths are not satisfactory, and it appears advantageous to obtain for use with microwaves more efficient antennas. More particularly, it now appears desirable to secure lobe switching radar antennas having a high gain and negligible minor lobes and lobe sweeping antennas having a sharp major lobe in the electric and magnetic planes.

It is one object of this invention to secure a highly directive microwave radar antenna.

It is another object of this invention to obtain highly efficient lobe switching centimetric antennas and lobe sweeping centimetric antennas.

It is still another object of this invention to energize efficiently the entire line focus of a cylindrical parabolic reflector.

It is a further object of this invention to obtain a highly efficient radar antenna having narrow electric and magnetic plane lobes.

In accordance with one embodiment of the invention, the linear broadside slot antenna of a leaky wave guide of the first kind is aligned with the focal line of a parabolic reflector, the slot antenna and the focal line having equal lengths. In accordance with another embodiment, a linear broadside slot antenna is positioned parallel to the focal line of a parabolic reflector and oscillated through a given angle for the purpose of obtaining a sweeping lobe. In accordance with still another embodiment, the focal line of a cylindrical parabolic reflector is positioned parallel to, and included between, two linear aperture wave guide antennas, and a transceiver is connected alternately to the antennas whereby lobe switching is secured.

The above and other embodiments of 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 perspective view of a directive antenna constructed in accordance with the invention and Fig. 2 illustrates the measured directive characteristic for the antenna of Fig. 1;

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Fig. 3 is a perspective view of another directive antenna of the invention and Fig. 4 illustrates the measured directive characteristic for the embodiment of Fig. 3;

Fig. 5 is a perspective view and Fig. 6 a diagrammatic sectional view of a lobe switching antenna constructed in accordance with the invention, and Fig. 7 illustrates the measured double directive characteristic for the embodiment of Figs. 5 and 6;

Fig. 8 is a perspective view of a lobe sweeping antenna of the invention and Fig. 9 illustrates the oscillatory directive characteristic for the antenna of Fig. 8;

Fig. 10 is a perspective view of another lobe sweeping antenna of the invention and Figs. 11 and 12 are measured directive characteristics used in explaining the embodiment of Fig. 10;

Fig. 13 is a perspective view of a different embodiment of the invention for securing lobe sweeping action.

Referring to Fig. 1, reference numerals 1 and 2 denote, respectively, a transceiver and a coaxial line connected thereto, the line having an outer conductor 3 and an inner conductor 4. Numeral 5 designates a V leaky wave guide antenna comprising the branch wave guides or legs 6 and 7 and the stem or main wave guide section 8. Each branch guide contains a longitudinal slot antenna 9. The two slot antennas face each other and form an angle having a value, for example, 20 degrees, dependent upon the phase velocity in guides 6 and 7 and such that maximum action occurs along the bisector of the aforesaid angle. The branch guides 6 and 7 and the main guide 8 are each equipped with a reflective transverse end wall 10. The inner conductor 4 of line 2 projects into the stem section 8 in a direction parallel to the *a* wall of section 8 so that the main guide 8 and the branch guides 6 and 7 transmit and receive H_{11} waves polarized horizontally, that is, in a direction aligned with the transverse or shorter dimension of each of slots 9. As described so far, the structure constitutes the well-known prior art V leaky pipe antenna. In accordance with the invention, triangular metallic shield members 11 and 12 are provided, each member being attached to corresponding *b* walls of the two branch guides 6 and 7. The two members 11 and 12 form a linear aperture antenna 13 having a longitudinal axis 14 perpendicular to bisector 10 and a transverse dimension or width 15 greater than the width of either of slots 9. In other words, the members 11 and 12 function to transform the two narrow "slot" antennas 9, each angularly related to bisector 10, into a wide "aperture" antenna 13 perpendicularly related to bisector 10.

In operation, Fig. 1, centimetric waves generated in the transceiver 1 are supplied over line 2 to the guide section 8 and thence to the two legs 6 and 7, the wavelets conveyed in wave guide branches 6 and 7 and delivered to the slot antennas 9 being horizontally polarized as shown by arrows 16. The wavelets emitted through the two slot antennas 9 combine in phase, by reason of the critical angle between the slots 9, for the direction 17 which is aligned with the bisector of the angle formed by the slot antennas 9. Stated differently, considering the vertical plane containing the branch guides 6 and 7 and hereinafter denoted the "magnetic" plane, maximum action occurs in the direction 17. Considering the horizontal or the "electric" plane containing bisector 10 and perpendicular to the magnetic plane, the triangular members 11 and 12 function to prevent side radiation and in general to produce maximum action in direction 17. In the case of reception, the reciprocal operation obtains, as is well known, and echo waves reflected by a distant target are collected by the aperture antenna 13.

Referring to Fig. 2, curves 18 and 19 illustrate, respectively, the magnetic plane and electric plane directive characteristics for the system of Fig. 1. It will be observed that the maximum lobe 20 of the magnetic plane characteristic is relatively narrow, that is, about 7 degrees wide at the half power point corresponding to 0.7 on the power square root scale. Also, beginning at points 21 and 22 on curve 19 corresponding, respectively, to the +25-degree and the −20-degree directions, the curve slopes downwardly at each end, so that sidewise radiant action, as for example, radiation and reception in the +50-degree or −50-degree direction, is minimized.

Fig. 3 illustrates a structure comprising a cylindrical parabolic reflector having its line focus energized by the antenna of Fig. 1. In more detail, reference numeral 23 denotes a cylindrical parabolic reflector and numeral 24 designates the line focus of reflector 23. A V leaky guide antenna 5 equipped with triangular shields 11 and 12, as illustrated by Fig. 1, is positioned so that the longitudinal axis 14 of linear aperture antenna 13 is aligned with the focal line 24. The reflector 23 and the focal line 24 have a length equal approximately to the length of the aperture antenna 13. Numerals 25 and 26 denote sectoral end shields each extending between an extremity 27 (Fig. 1) of the aperture antenna 13 and the associated extremity 28 of the reflector 23.

In operation, Fig. 3, microwaves emitted by the aperture antenna 13 energize the entire line focus 24 of reflector 23 and, in the electric plane, an exceedingly sharp directive lobe 29, Fig. 4, is secured. In the case of reception the parabolic reflector functions to receive the echo waves and to energize the aperture antenna 13 throughout its length. Considering the magnetic plane, the directive characteristic is similar to the magnetic plane directive characteristic for the system of Fig. 1. In Fig. 4, reference numerals 30 and 31 denote the measured magnetic plane directive characteristics of the structure of Fig. 3 with and without the end-pieces 25 and 26, respectively. It will be noted from these two curves that in practice the end-pieces 25 and 26 function to secure an improved magnetic plane characteristic inasmuch as the minor lobes 32 of curve 30 are smaller than the minor lobes 33 of curve 31, and the nulls

34 of curve 30 are deeper than the nulls 35 of curve 33.

The lobe switching antenna of Figs. 5 and 6 comprises a cylindrical parabolic reflector 23, such as used in the system of Fig. 3, and two V-shaped directive antennas 5 each equipped with triangular shield members 11 and 12, as illustrated by Fig. 1. The rectangular aperture antennas 13 and the focal line 24 of the parabolic reflector are parallel to each other and the focal line 24 is included between the two aperture antennas 13. Numeral 36 denotes the principal axis of the parabolic reflector. The sectoral end-pieces 25 and 26 each extend between the transverse edges 27 of both aperture antennas and the corresponding edge 28 of reflector 23. The transceiver 1 is connected by coaxial line 2 to a main wave guide section 37 and to a wave guide switch 38 of the type disclosed in my Patent 2,409,183 granted on October 15, 1946. The switch 38 comprises two detuning chambers 39, a partition 40, a rotatable vane 41, two near-end orifices 42 facing guide section 37 and two far-end orifices 42 facing guide sections 8. One of the far-end orifices 42 connects the left chamber 39 to section 8 of the left-hand antenna 5 and the other orifice 42 connects the right chamber 39 to section 8 of the right-hand antenna 5. The vane is continuously driven by means of a motor (not shown).

In operation, Fig. 5, the pulse energy generated in transceiver 1 is supplied over line 2, guide section 37 and switch 38 alternately to the two antennas 5. Since one aperture antenna 13 is positioned on the left side, and the other on the right side, of the focal line 24, the direction of maximum radiant action is switched between two paths making equal angles with the axis 36 of the reflector 23. Thus, referring to Fig. 6, with the left aperture 13 connected by switch 38 to the transceiver 1, maximum transmitting and receiving radiant action occurs in the right or minus direction 43 and with the right aperture connected by switch 38 to transceiver 1 maximum transmitting and receiving action occurs in the plus direction 44, these directions making equal angles with the axis 36 of the reflector. As shown in Fig. 7, the directive characteristic 45 for the system comprising the reflector 23 and the left aperture 13 is substantially the same as the directive characteristic 46 for the system comprising the reflector 23 and the right aperture 13. Moreover, each directive characteristic is highly satisfactory since the nulls 47 are deep and since the minor lobes 48 are relatively small. In connection with Fig. 7, it is important to note that the curves 45 and 46 illustrate separate and distinct characteristics and not different positions of the same characteristic. Stated briefly, the directive characteristic does not move gradually from the position shown by curve 45 to that shown by curve 46 but is switched or jumped from one position to the other. In radar operation, with the axis 36, Figs. 6 and 7, aligned with the target, echo pulses having the same intensity are received by both antennas, the intensity being 0.8 as indicated by reference numeral 49 on the vertical "field" scale, Fig. 7.

Referring to Fig. 8, which illustrates a lobe sweeping antenna, reference numeral 50 denotes a leaky wave guide of the first kind having a pair of transverse end reflective walls 10, a longitudinal slot antenna 51 and a length of approximately one-half wavelength as measured in the guide. The guide 50 is positioned so that the slot antenna 51 extends parallel to the focal line 24 of a cylindrical parabolic reflector 23, the focal line being included between the reflector 23 and the slot antenna 51. The guide 50 is connected to the transceiver 1 by a coaxial line 2 having a rotatable junction or coupling 52 such as disclosed in my copending application mentioned above. A shaft 53 is attached to the bottom of guide 51 and is connected through the coupler 54 to motor 55. With motor 55 operating, the coupler 54 functions to oscillate shaft 53 and slot antenna 51 through a predetermined angle, for example, 20 degrees, so that the slot antenna 51 moves back and forth through the focal line 24, the angle being centered on the axis 36 of reflector 23. The mean position for guide 50 is denoted by reference numeral 56.

In operation, Figs. 8 and 9, pulsed centimetric waves supplied over line 2 from transceiver 1 are emitted through the slot antenna 51 in a broadside direction perpendicular to the plane of the slot 51 and are then focussed by the reflector 23. Upon reflection by the distant target the wavelets collected by reflector 23 are supplied to the linear slot antenna 51 and thence conveyed to transceiver 1. With the slot antenna 51 at the extreme right or plus position, Fig. 9, maximum radiation is in the left or minus direction 57 and the major lobe of the directive characteristic has the position denoted by numeral 58. As the slot antenna 51 rotates to the left, the direction of maximum action moves toward the right. With the slot antenna 51 in the mean position the direction of action is aligned with the reflector axis 36. When the slot antenna 51 is in the extreme left or minus position, maximum action occurs in the right or plus direction 59, the position of the major lobe of the directive characteristic being denoted by reference numeral 60. As indicated by the major lobe peaks 61, 62 and 63, as slot antenna 51 oscillates the major lobe moves back and forth between the extreme positions 57 and 59, and radio scanning obtains.

The lobe sweeping system illustrated by Fig. 10 differs from that of Fig. 8 primarily in that the line 2 is connected to the mid-point 64 of the leaky guide and the leaky wave guide 50 is maintained stationary. The lobe sweeping action is accomplished by means of an auxiliary metallic reflector or vane 65 having the two parallel reflector surfaces 66 and 67. As in Fig. 8, numerals 10 denote end reflective wall members. Assuming the transverse magnetic plane dimension of the leaky guide 50, Fig. 10, is the same as that of the leaky guide 50 of Fig. 8, the length of guide 50 of Fig. 10, as measured in wavelengths in the guide, is twice that of the guide 50 of Fig. 8. The shaft 53 associated with motor 55 extends longitudinally through vane 65 and, in operation, the vane is continuously rotated. The rotatable vane 65 is included between the slot antenna 51 and the reflector 23; and the focal line 24 is aligned with the slot antenna 51.

In operation, Fig. 10, centimetric energy is supplied to and received from the slot antenna 51 by transceiver 1 over line 2. During one-half revolution of vane 65 the reflective or mirror side 66 faces the slot antenna 51 and an image slot antenna exists. With the transverse axis 68 of vane 65 perpendicular to the axis 36 of the parabolic reflector 23, the image slot antenna is on the axis 36 as shown by reference numeral 69, and with the transverse axis parallel to the axis 36 the image antenna is absent, that is, the vane functions as if removed. As vane 65 moves through one-half revolution the image antenna moves from the position shown by numeral 70 through the focal line 24 to the position shown by numeral 71; and the couplet formed by the slot antenna 51 and its image makes one complete right-to-left sweep through an angle centered on the axis 36. Consequently, the beam or lobe produced by the combination or couplet comprising the stationary primary slot antenna and the moving image antenna formed by the vane makes one complete sweep for one-half revolution of the vane 65. Similarly, during the remaining half-revolution, the reflector side 67 faces the slot antenna and the couplet makes a complete sweep. Thus, there are as many sweeps per revolution of shaft 53 as the number of reflective sides of vane 65. If vane 65 were four-sided, as in the structure illustrated by Fig. 13, four sweeps would be made during each revolution of shaft 53.

Referring to Fig. 11, curves 72 and 73 denote, respectively, the measured electric (horizontal) and magnetic (vertical) plane directive characteristics for a structure constructed in accordance with Fig. 10, substantially, except that the vane 65 is omitted. As shown by these curves, maximum action for the system without vane 65 occurs in a direction aligned with the parabolic axis 36. The magnetic plane characteristic comprises substantially only a single lobe in view of the directive action of the slot antenna 51; and the electric plane characteristic comprises substantially only a single lobe by reason of the directive action of reflector 23.

Fig. 12 illustrates the measured lobe-sweeping characteristic of a system constructed in accordance with Fig. 10 and including a rotating vane. Thus, the maximum lobe 74 is at the left of axis 36 when the reflective side 66, or 67, of vanes 65 is oriented so that the image antenna is at the right of axis 36 and in the position denoted by numeral 70. When the reflective side 66, or 67, is positioned so that the image antenna is at the left of axis 36 and in the position denoted by numeral 71, the maximum lobe 75 is at the right of axis 36.

Referring to Fig. 13, the lobe sweeping antenna is fundamentally the same as that of Fig. 10, except that a "corner" reflector 76 of the type disclosed in Patent 2,270,314 to J. D. Kraus, issued January 20, 1942, is used instead of a parabolic reflector and a four-sided auxiliary plane reflector 77 is employed instead of a two-sided vane. The rotating quadrilateral reflector 77 extends parallel to the corner reflector and is included between the slot 51 and the corner reflector 76. In operation, the maximum transmitting lobe for the entire system makes one complete right-to-left sweep during a quarter-revolution of reflector 77, that is, one sweep for each of the reflective sides 78.

Although the invention has been explained in connection with certain embodiments, it should be understood that it is not to be limited to the apparatus disclosed, inasmuch as other equipment may be employed in practicing the invention.

What is claimed is:

1. A lobe sweeping antenna comprising a rectangular wave guide having a longitudinal slot antenna, a transceiver connected to said guide, and means for moving said guide about a longitudinal guide axis.

2. A lobe sweeping antenna comprising a rectangular wave guide having a longitudinal slot antenna, a transceiver connected to said guide,

means for oscillating said guide about a longitudinal guide axis, and a concave reflector facing said slot antenna.

3. In combination, a cylindrical parabolic antenna reflector having a focal line, a wave guide having a longitudinal slot antenna extending parallel to said focal line and facing said reflector, a transceiver connected to said guide, and means for oscillating said slot antenna.

4. In combination, a triangular wave guide antenna comprising two angularly related wave guides having longitudinal slots facing each other and connected to a transceiver, a pair of triangular side shield members each extending between a pair of correspondent sides of said guides, said shield members forming a linear aperture antenna extending perpendicular to the bisector of the angle between said slots.

5. In combination, a wave guide antenna in accordance with claim 4, and a cylindrical parabolic reflector having its focal line aligned with said linear aperture antenna.

6. In combination, a wave guide antenna in accordance with claim 4, a cylindrical parabolic reflector having a length substantially equal to the length of said aperture antenna and a focal line aligned with said linear aperture antenna, and a pair of end shield members each extending between correspondent extremities of said aperture antenna and said reflector.

7. In combination, a concave reflector having a line focus, means for energizing the focus or for collecting energy therefrom, said means comprising a linear wave guide having in a side wall a linear slot antenna, one dimension of said slot antenna being parallel to said line focus, and a translation device connected to said wave guide.

8. In combination, a cylindrical parabolic reflector having a line focus, a linear wave guide having a longitudinal axis positioned parallel to said line focus and a side wall facing said reflector, a slot in said wall, and a translation device connected to said guide.

9. A broadside wave guide antenna connected at a given point to a translation device and having at least one end reflecting wall, said point and reflecting wall being spaced a half of a guide wavelength, whereby the directly propagated and reflected energies are cophasal.

10. In combination, a cylindrical parabolic reflector having a line focus, a wave guide having a longitudinal slot antenna coincident with said focus, and a translation device connected to said guide.

11. In combination, a concave reflector having a line focus, a metallic wave guide having at least one transverse reflecting wall, said guide having a longitudinal slot antenna facing said reflector, a translation device connected thereto at a given point, the distance between said point and said transverse wall being electrically equal to a half of a guide wavelength, whereby the waves as emitted or collected at said point and the waves as reflected at said transverse wall are cophasal.

12. A lobe sweeping antenna system comprising a hollow reflector, a wave guide having a longitudinal slot antenna extending parallel to and facing said reflector, a transceiver connected to said guide, a linear reflective vane positioned parallel to and included between said slot antenna and said reflector, and means for rotating said vane.

13. A lobe sweeping antenna system in accordance with claim 12, said reflector being a cylindrical parabolic reflector.

14. A lobe sweeping antenna system in accordance with claim 12, said vane having two reflecting surfaces.

15. In combination, a linear wave guide comprising a pair of transverse end reflective walls and a side wall extending therebetween, said side wall containing a slot antenna, the longitudinal dimension of said guide being equal to a half wavelength or a multiple thereof, as measured in the guide, said wavelength being dependent upon a transverse dimension of the guide, and a translation device connected to said guide, whereby said longitudinal dimension is dependent upon said transverse dimension and the phase velocity of said guide, and maximum transmitting or receiving action occurs in a direction perpendicular to said side wall.

16. In combination, a cylindrical parabolic reflector having a focal line, a linear rectangular wave guide comprising a side wall containing a slot antenna, a pair of transverse end reflective walls connected to the extremities of said side wall and spaced a distance equal to a wavelength as measured in the guide, and a translation device connected to the mid-point of said guide.

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