

Oct. 15, 1946.

A. C. BECK

2,409,183

MICROWAVE ANTENNA

Filed Aug. 19, 1942

3 Sheets-Sheet 1

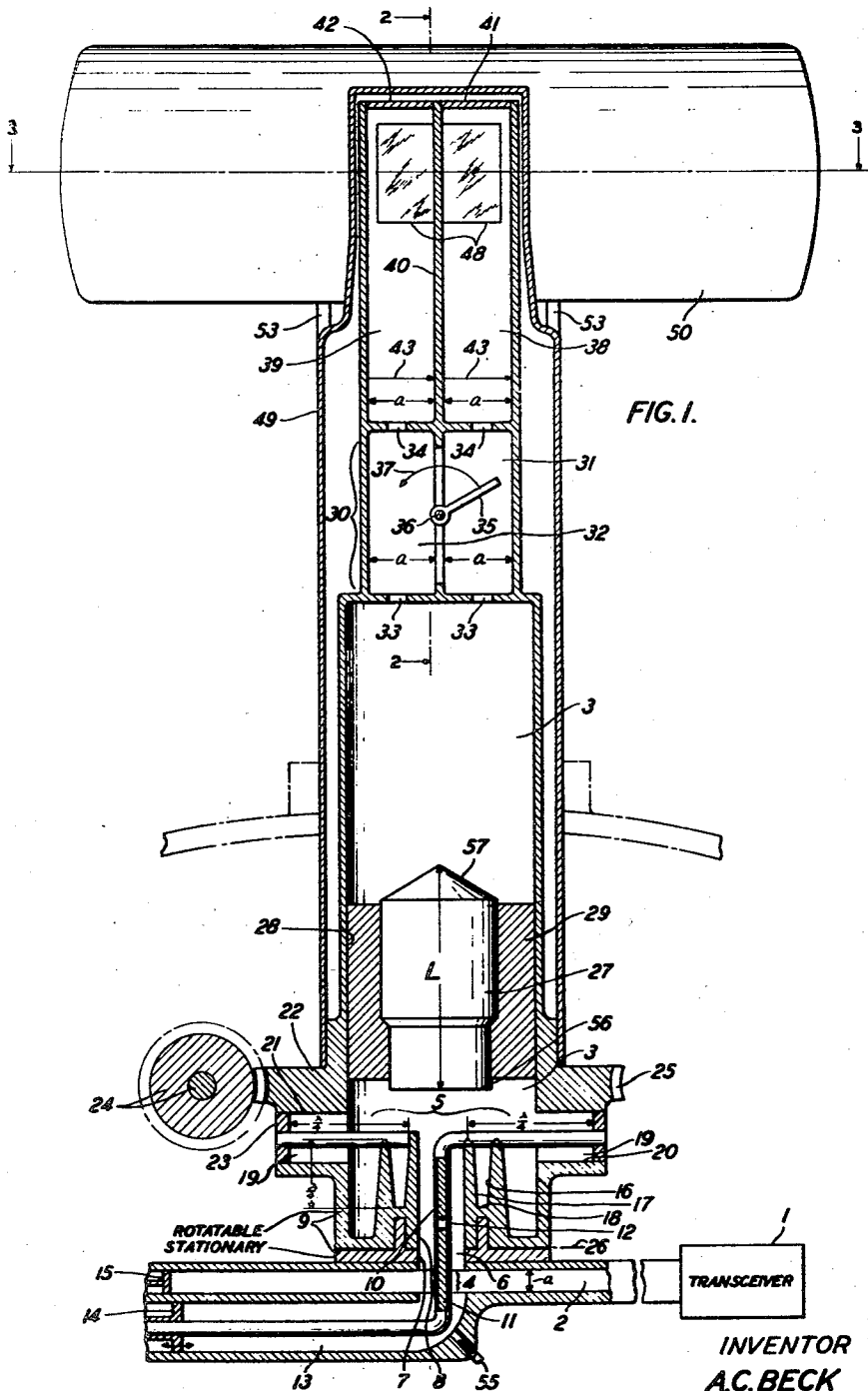


FIG. 1.

INVENTOR
A.C. BECK
BY: *A. J. Zerbarani*
ATTORNEY

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FIG. 2.

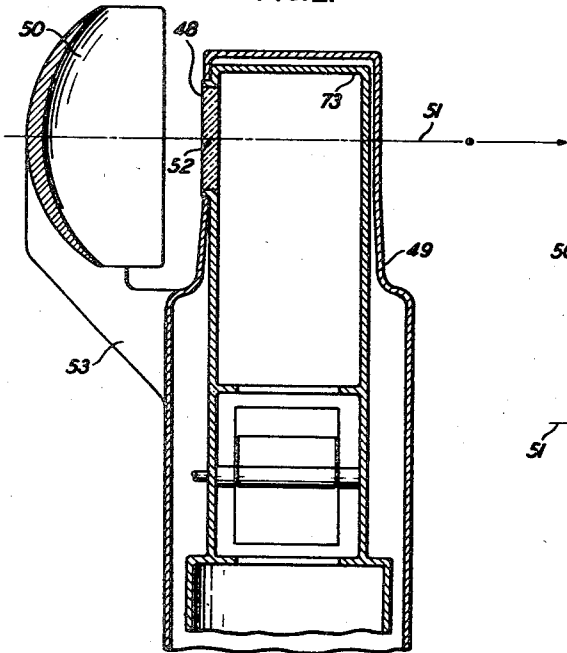


FIG. 3.

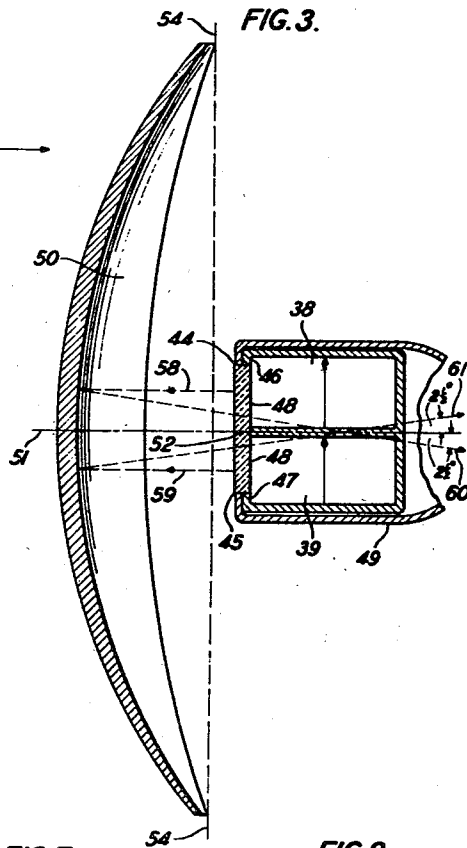


FIG. 6.

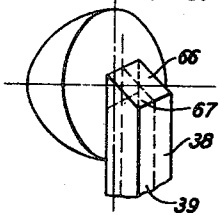


FIG. 7.

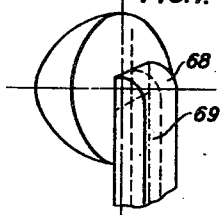


FIG. 8.

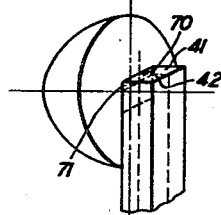


FIG. 9.

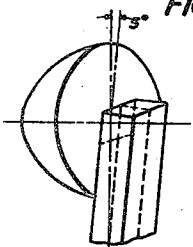
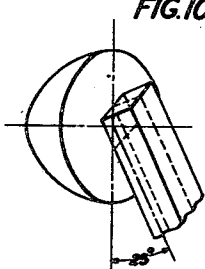


FIG. 10.



INVENTOR
A. C. BECK

BY: *A. J. Zerbarini*

ATTORNEY

Oct. 15, 1946.

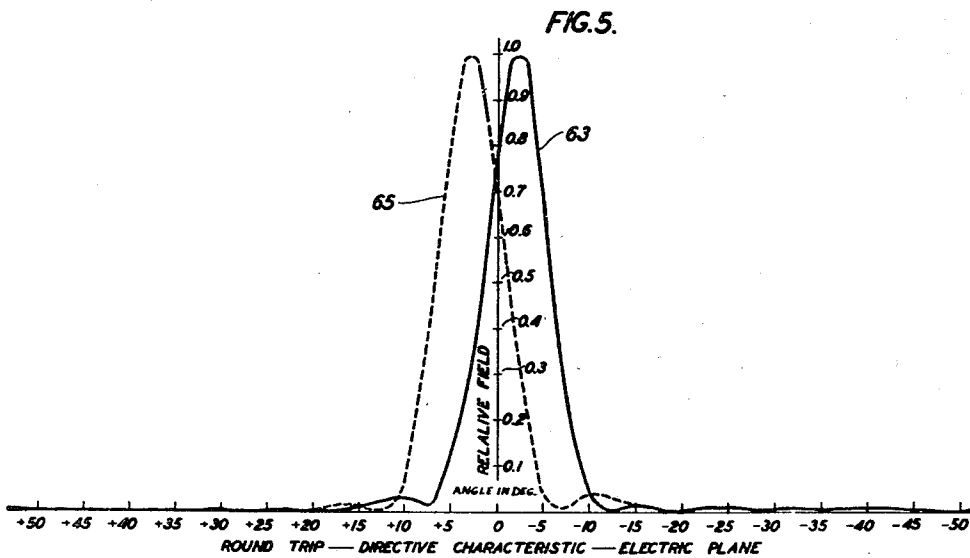
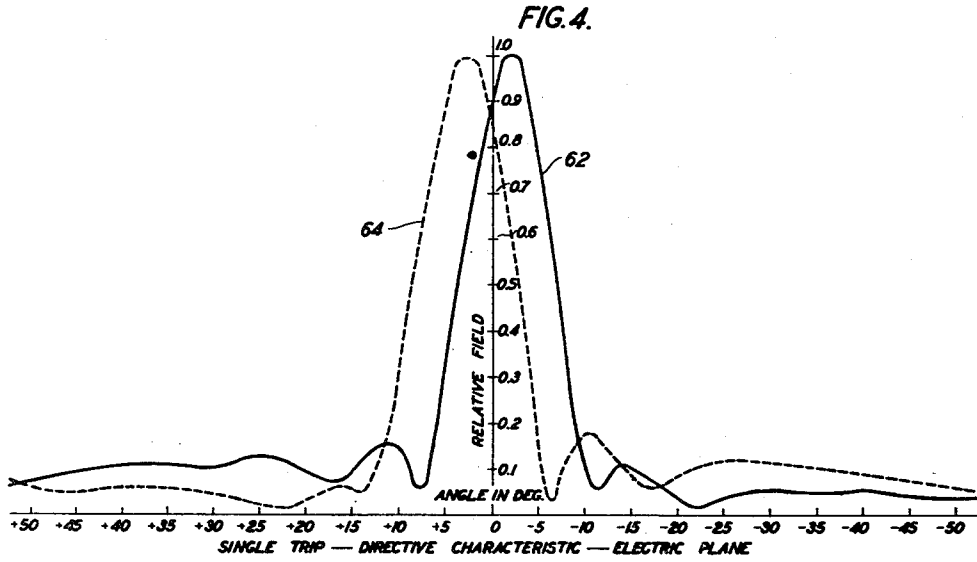
A. C. BECK

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3 Sheets-Sheet 3



INVENTOR
A.C. BECK

BY: *a. j. Zerberini*

ATTORNEY

UNITED STATES PATENT OFFICE

2,409,183

MICROWAVE ANTENNA

Alfred C. Beck, Red Bank, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 19, 1942, Serial No. 455,322

12 Claims. (Cl. 250-11)

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This invention relates to directive antenna systems and particularly to antenna systems of the type utilized in radio range and direction finding systems.

As is known, the peak or nose of the maximum lobe of highly unidirectional antennas commonly employed for telegraph and telephone communication is relatively blunt or flat over an appreciable angular range of wave directions and is ordinarily not sufficiently pointed or sharp to select one of the several distinct directions included in the aforementioned range. Also, as is known, at least three distinct antenna arrangements have been suggested for obtaining, in the short wave (10 to 200 meters) and ultra-short wave (1 to 10 meters) fields, a greater degree of directive selectivity than that provided by the so-called "signal" antennas and, in particular, for securing the high degree of directive sensitivity required in radio direction finding systems of the airport landing, radio range (radar) and radio scanning types. Thus, Figs. 2 and 3 of Patent 2,083,242 to W. Runge illustrate respectively a "lobe-rotation" or conical scanning system and a "lobe-sweeping" system; and Patents 2,217,321 to W. Runge and 2,002,181 to W. Ilberg illustrate "lobe-switching" arrangements. While these arrangements have performed fairly satisfactorily in the short and ultra-short wave fields they are not readily adapted for use in the microwave field (below 1 meter). It now appears desirable to secure a microwave antenna system having a high directive sensitivity and, in particular, to secure an efficient centimeter antenna of the lobe-switching type which may be employed in the direction finding systems mentioned above.

It is one object of this invention to determine accurately the propagation direction of a radio wave.

It is another object of this invention to energize or "illuminate" efficiently, and for maximum gain, a microwave concave type reflector.

It is still another object of this invention to utilize, in a lobe switching radio scanning system, waves polarized in the scanning plane.

It is a further object of this invention to obtain a two-position lobe switching microwave scanning antenna arrangement having a high directional sensitivity.

It is still another object of this invention to eliminate reflection losses in a transmission system comprising two air-filled wave guides connected together through a solid dielectric channel.

In accordance with the preferred embodiment

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of the invention a pair of branch vertical rectangular wave guides, each having side walls of different dimensions, an open end and a closed end, are positioned adjacent to each other. The corresponding open ends are connected through a wave guide switch of the type disclosed in the copending application of A. G. Fox, Serial No. 422,408, filed December 10, 1941, to a main cylindrical wave guide and a translation device such as a radio range transceiver of the pulse type. The parallel guides each have an aperture in one of the narrow walls adjacent the closed end, the two apertures being in the same plane so that their directions of maximum action are parallel to each other and perpendicular to the plane of the apertures. A paraboloidal reflector having its focus between the two apertures is utilized for changing the parallel directions of action to angularly related directions extending in the desired horizontal scanning plane at equal angles to the reflector axis. In operation, a substantial amount of the energy propagated through each aperture impinges on the reflector and the energy distribution over the reflector is, by reason of the relative sizes of the aperture and the reflector and the spacing therebetween, fairly uniform. The wave guide switch functions to render the parallel branch guides alternately inactive, whereby the maximum lobe for the entire system is switched between two predetermined positions in the horizontal scanning plane. Also, the connection between the parallel guides and the transceiver is such that the wavelets conveyed by each of the parallel branch guides are polarized perpendicular to the longitudinal guide axis and in the plane of the guide apertures. Hence, the wave components projected or collected by the system are polarized in the lobe switching or scanning plane and highly satisfactory reflected pulses are received, particularly in short range scanning operations.

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:

Figs. 1, 2 and 3 illustrate, respectively, a cross-sectional front view, a cross-sectional partial side view and a cross-sectional partial top view of the preferred embodiment of the invention;

Figs. 4 and 5 are curves illustrating the measured directive characteristics of a system constructed in accordance with the invention;

Figs. 6, 7, 8, 9 and 10 illustrate vertical branch wave guide arrangements any of which may be

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substituted for that included in the preferred embodiment.

Referring to the drawings, the preferred embodiment illustrated by Figs. 1, 2 and 3 is especially designed for installation in a submarine, but it should be understood the invention may be incorporated in apparatus installed on other types of mobile bodies or at a fixed station. In Fig. 1, reference numeral 1 denotes a translation device comprising a transceiver of the pulse type commonly employed in the radio ranging systems. Numeral 2 designates a horizontal rectangular wave guide connected to the transceiver and having a narrow electric plane side, hereinafter called the *a* wall, and a wide magnetic plane side, hereinafter called the *b* wall. Guide 2 is connected to a vertical cylindrical guide 3 through an antenna coupling arrangement comprising the pick-up or receiving antenna 4 positioned within guide 2 parallel to the narrow walls *a*, an exciter or transmitting doublet antenna 5 positioned within and aligned with a diameter of guide 3, and a coaxial line 6 comprising an outer and an inner conductor. The outer conductor is formed by tubular surfaces 7 and 8 of cylindrical block member 9, and the inner conductor is formed by the two colinear plugs 10 and 11 mounted inside the sleeve 12. Plug 10 and sleeve 12 are each rotatable. The two end sleeve portions or sections overlapping plugs 10 and 11 are each approximately a quarter wave-length long, so that each plug is connected to the sleeve through an open quarter wave line having a zero impedance, substantially.

The pick-up antenna 4 is tuned by means of a variable coaxial tuner 13 comprising a short-circuiting adjustable disc 14; and the load end of guide 2 is terminated in a movable reflecting piston 15, whereby the resonant length of the pick-up antenna 4, and the spacing between antenna 4 and the reflector 15, may be adjusted, in accordance with the manner now well understood in the art, for optimum transfer of energy between guide 2 and antenna 4. The unbalanced coaxial line 6 is connected to the balanced dipole 5 through a balance-to-unbalance coupling circuit comprising the quarter wave vertical cylindrical surface 16 of member 9, the quarter wave vertical cylindrical surface 17 and the horizontal annular short-circuiting surface or connection 18. Each half of dipole 5 extends beyond the wall of circular guide 3 and into a socket or recessed section 19 comprising the surface 20 of member 9, the surface 21 of tubular member 22 and the disc member 23. The depth or length of each of sections 19 is such that dipole 5 has the proper length for optimum resonance. Reference numeral 24 designates a remotely controlled, manually driven worm which is associated through worm gear 25 with member 22, for smoothly rotating the vertical portion of the structure including the entire cylindrical guide 3, the bearing or plane of rotation being denoted by numeral 26. As is apparent, during the rotation, plug 10 of the inner conductor of coaxial line 6 rotates relative to plug 11, and the contiguous tubular surface 8 of the outer conductor of line 6 rotates relative to each other.

Reference numeral 27 denotes a heavy tapered cylindrical polystyrene plug which, as explained below, has a critical length and is attached or fitted to the inner surface 28 of the guide wall member 22 at a point a short distance above doublet 5 by means of the cylindrical member 29, the junction or connection being water-tight.

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The uppermost end of guide 3 is connected to the lower end of a wave guide switch 30 of the type disclosed in the aforementioned copending application of A. G. Fox. Switch 30 comprises two parallel wave guide tuned sections 31 and 32, each having orifices 33 and 34, detuning member 35 which is rotated about shaft 36 by means of a motor (not illustrated), as indicated by arrow 37. If desired, an additional set of tuned sections may be included in switch 30, between sections 31, 32 and guide 3, for the purpose of increasing the band width characteristic of the switch. The upper end of switch 30 is connected to a pair of parallel branch rectangular wave guides 38 and 39 having the common *b* or wide wall 40 and the flat end pieces 41 and 42, respectively. The narrow transverse dimensions, or *a* walls, of the tuning guide sections 31 and 32 and of branch guides 38 and 39, are positioned parallel to the doublet 5 for utilization of the transverse electric wave component represented by arrows 43. Reference numerals 44 and 45 designate rectangular antenna apertures positioned adjacent the cover or end pieces 41 and 42 and in the back narrow walls 46 and 47 (Fig. 3) of guides 38 and 39. Apertures 44 and 45 are equipped with a common water-tight polystyrene member 48. The vertical portion of the rotatable structure is preferably enclosed in a tubular shield 49 having a large aperture opposite apertures 44 and 45.

Referring particularly to Figs. 2 and 3, reference numeral 50 denotes a section of a paraboloidal reflector facing apertures 44 and 45 and having a horizontal axis 51 and a finite focus 52 positioned between apertures 44 and 45. The reflector 50 is attached by two brackets 53 to the tubular shield member 49 so that the antenna apertures 44 and 45 and reflector 50 may be rotated as a unit for radio range searching purposes. While a sectional paraboloidal reflector having the plane 54 of its opening spaced from the reflector focus 52 is preferably employed in order to secure a wide angle directive lobe in the vertical plane and a narrow angle lobe in the horizontal plane, if desired, a conventional paraboloidal reflector having a circular cross section may be utilized. In accordance with the invention the focal length of the reflector, the reflecting area of the reflector and the aperture areas are selected to obtain optimum energization of the sectional reflector. Considered from a mechanical standpoint the structure is exceedingly rugged and is designed to withstand heavy water pressure. Thus, the polystyrene member 48 is relatively thick and strong, and functions to prevent water from entering guide 3 when the submarine is submerged. In addition the polystyrene plug 27 is solidly embedded or fitted to the member 28 so that in the event of breakage of member 48 water is prevented from entering horizontal guide 2. Since water may leak into vertical guide 3 or may condense therein, a drain 55 is preferably provided at the bottom of the system.

In operation, considering first the transmitting action of the system, pulses of a microwave frequency are supplied by device 1 to guide 2 and to the vertical pick-up antenna 4, and are then conducted by coaxial line 6 to the horizontal tuned dipole 5 which functions to energize the cylindrical guide 3 with horizontally polarized waves. While most of the energy passes through the polystyrene plug 27, reflection does occur at the junction 56 of the lower portion of guide 3 and poly-

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styrene plug 27, and at the junction 57 of plug 27 and the upper portion of guide 3. Preferably, the electrical length L of plug 27 is made equivalent to approximately a multiple of a half wavelength so that the two reflected waves propagated back into guide 3 mutually cancel. After passing through the polystyrene channel 27 the waves are conveyed through the upper portion of cylindrical guide 3 to sections 31 and 32 of wave guide switch 30. As explained in the A. G. Fox application mentioned above, the radial rotating member 35 functions to detune, alternately, sections 31 and 32 and thereby to block successively the flow of energy in these sections. Hence, dependent upon the position of member 35, energy in the form of a train of pulses flows through one or the other of the branch guides 31 and 32 to one or the other of the apertures 44 and 45. The horizontally polarized waves issuing alternately from apertures 44 and 45 impinge upon reflector 50, the directions 58 and 59 of maximum action, respectively, for the elemental antenna apertures 44 and 45, being parallel and substantially perpendicular to the plane of the apertures or member 48. Reflector 50 functions, in effect, to bend or change the two parallel propagation directions 58 and 59 to the diverging directions 60 and 61, respectively, which make equal angles with the parabolic reflector axis 51, as shown in Fig. 3. The maximum direction 60 of radiation for the combined system comprising the left-hand aperture 44, as viewed from reflector 50, and of reflector 50, is positioned at the right of the reflector axis 51, and the maximum direction 61 for the system comprising the right-hand aperture 45 and reflector 50 is positioned at the left of axis 51. Assuming axis 51 of the antenna system is aligned with a reflective target the pulse train is returned to the reflector 50 and conveyed to the transceiver successively through dielectric channels 31 and 32, the receiving action of the system being reciprocal to the transmitting action.

Referring to Figs. 4 and 5 the curves illustrate respectively, the two "single trip" and the two "round trip" directive characteristics taken in the horizontal scanning plane, that is, in the electric plane of the wave component, for a system constructed in accordance with the invention. Curves 62 and 63 illustrate the single and round trip characteristics for aperture 44 with reflector 50, and curves 64 and 65 illustrate the corresponding characteristics for aperture 45 and reflector 50. The single trip characteristics are conventional directive characteristics which may be determined by measuring the field established by the antenna or by measuring the response of the antenna to incoming waves. The round trip characteristic, which is of importance in object location systems, may be obtained by utilizing a target spaced from the antenna, transmitting pulses from the antenna while rotating the antenna through 360 degrees and noting the relative intensity of the received pulses. It should be noted that the minor lobes of both the single trip and the round trip characteristics are negligible, as is advantageous in object location systems. More specifically, in scanning systems successful operation can not be secured with antennas having large minor lobes since ambiguous indications are obtained. On the other hand, while pronounced minor lobes are undesirable in signal systems, satisfactory intelligence communication may be secured with antennas having large secondary lobes. As shown by Figs. 4 and 5 the ratio, in applicant's system, of the intensity of the

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maximum lobe to the intensity of the largest minor lobe is high, that is, in the order of 5. The minor lobe suppression is secured, in accordance with the invention, in part by using a unidirectional wave guide aperture adjacent the focus of the reflector for efficiently illuminating the reflector. In addition, in accordance with the invention, the waves utilized in the horizontal plane lobe switching system of the invention are polarized in the scanning or lobe switching plane. By using horizontally polarized waves, in a horizontal plane lobe switching system installed on a ship or submarine, undesired pulse reflections from ocean waves are rendered negligible and of small intensity as compared to those obtained when vertically polarized waves are employed. Stated differently, in accordance with the invention, the false indications produced by undesired reflection from ocean waves, and ordinarily very pronounced during target searching operations at close range (300 yards), are minimized.

Referring to Fig. 6, reference numerals 66 and 67 denote end reflector members which may be employed in the structure of Fig. 1 in place of the top end members 41 and 42, respectively, and which are inclined at an angle of 45 degrees relative to the vertical walls of the branch guides 38 and 39. In Fig. 7 reference numerals 68 and 69 denote curved reflector members which may be used in place of the end reflectors 41 and 42. In Fig. 8 numerals 70 and 71 denote shield members which may be added to the horizontal reflector members 41 and 42 of Fig. 1. The structures illustrated by Figs. 9 and 10 are each the same as that illustrated by Fig. 1, except that in the structure of Fig. 9 the branch guides 38 and 39 are tilted away from reflector 50 and make an angle of 5 degrees with the vertical and, in the structure of Fig. 10, the guides are tilted toward the reflector 50 and make an angle of 25 degrees with the vertical. While the attenuation and reflection losses occasioned by the bend or corner 73, Fig. 2, are avoided by employing the curved reflector of Fig. 7, and are almost eliminated by using the arrangement of Fig. 6, and while the structures illustrated by Figs. 6 to 10, inclusive, may produce a more nearly flat wave front and may effect a reduction in secondary lobes, it has been found by experiment that the advantage gained by utilizing the arrangements of Figs. 6 to 10 is not large and that for all practical purposes the system of Fig. 1 is highly satisfactory.

Although the invention has been explained in connection with certain embodiments thereof, it should be understood that it is not to be limited to the embodiments described since other apparatus may successively be employed in practicing the invention.

What is claimed is:

1. An antenna system comprising a pair of wave guides each having a separate aperture for emitting and collecting radiant energy, a concave reflector facing the separate apertures and having a focus positioned between said apertures.
2. An antenna lobe switching system comprising a concave reflector having a finite focus, a pair of antenna elements equally spaced from said focus, each of said elements comprising a wave guide having an aperture facing said reflector, and means for alternately connecting a transceiver to said guides.
3. In combination, a parabolic reflector having a focus, a pair of unidirectional antenna elements facing said reflector and equally spaced from said focus, said elements each comprising an aperture

in the side wall of a dielectric guide, and means for alternately energizing said elements.

4. A combination in accordance with claim 3, and reflecting members for closing the end of said guides adjacent said apertures, said members being inclined at 45 degrees to said wall and facing the parabolic reflector.

5. A combination in accordance with claim 3, and reflecting members for closing the ends of said guides adjacent said apertures, said members having a curved surface facing said parabolic reflector.

6. An antenna lobe switching system for scanning in a given plane comprising a parabolic reflector having a finite focus, a pair of antenna elements equally spaced from said focus, said elements being included in the focal plane of said reflector and in the desired scanning plane, said elements comprising rectangular wave guides each having an aperture facing said reflector and located in corresponding narrow side walls of said guides, and means for alternately energizing said guides with waves polarized in the plane of said wall.

7. A lobe switching antenna system comprising a pair of parallel rectangular wave guides each having a side aperture at one end, a concave reflector facing said apertures and having its axis perpendicular thereto, said apertures being equally spaced from said axis, and means for connecting a transceiver alternately to the other end of said guides.

8. An antenna lobe switching system comprising a pair of wave guides, a translation device, and means for alternately connecting said device to corresponding ends of said guides, said guides each having a side aperture adjacent the other end, said apertures facing the same compass point direction and having parallel directions of maximum action, and a concave reflector facing said apertures, said reflector having a principal axis parallel to said direction and a focus symmetrically disposed relative to said apertures, whereby said parallel directions of action are changed to directions making equal angles with said axis and the wavelets emitted and collected by said apertures and impinging on said reflector travel alternately in propagation directions making equal angles with said axis.

9. A lobe switching microwave antenna comprising a paraboloidal reflector, a pair of wave

guides having apertures facing said reflector and equally spaced from the reflector focus, a transceiver connected to said guides, and switching means for alternately rendering said guides non-conductive.

10. A microwave antenna system for scanning in a given plane comprising a concave reflector having a finite focus, means for emitting and collecting alternately at two points equally spaced from said focus in the reflector focal plane waves polarized in said plane, said means comprising a pair of rectangular wave guides connected at one end to a transceiver through a wave guide switch, said guides having square apertures at said points, and said apertures being included in the electric plane of said guides.

11. An antenna system comprising a pair of quadrilateral wave guides having sides of different dimensions, said guides being open at one end and closed at the other, means connected to the open ends for supplying or receiving microwaves polarized in the plane of the short side, an aperture in one narrow side of each guide adjacent the closed end, and a concave reflector facing said aperture and having its axis and direction of maximum radio action positioned perpendicular to the plane of said apertures, whereby waves emitted or collected by said system are polarized in the plane of maximum wave propagation.

12. A microwave lobe switching antenna system comprising a pair of parallel quadrilateral dielectric channels having one pair of corresponding ends closed and the other pair open, a transceiver, means for alternately transferring between the transceiver and the open ends of said channel wavelets polarized linearly in a polarization plane containing one side of each guide, said wavelets being polarized perpendicularly to the longitudinal axes of said channels, each guide having an aperture in said side at its closed end, a paraboloidal reflector having its axis perpendicular to the polarization plane and its focus positioned in said plane between said apertures, whereby the maximum directive lobe of said system is successively aligned with two angularly related directions included in a propagation plane perpendicularly related to said polarization plane containing said axis and the waves emitted and received by said system are polarized in said propagation plane.

ALFRED C. BECK.