

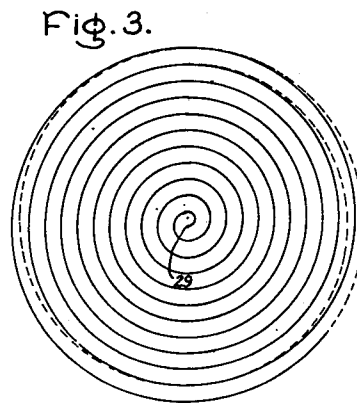
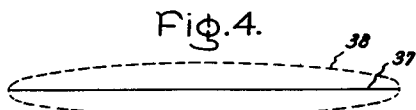
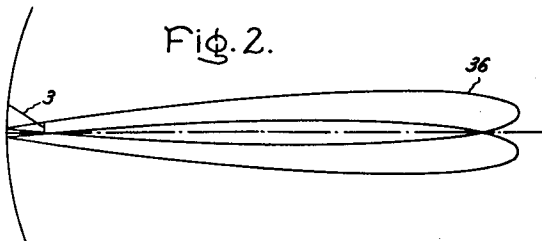
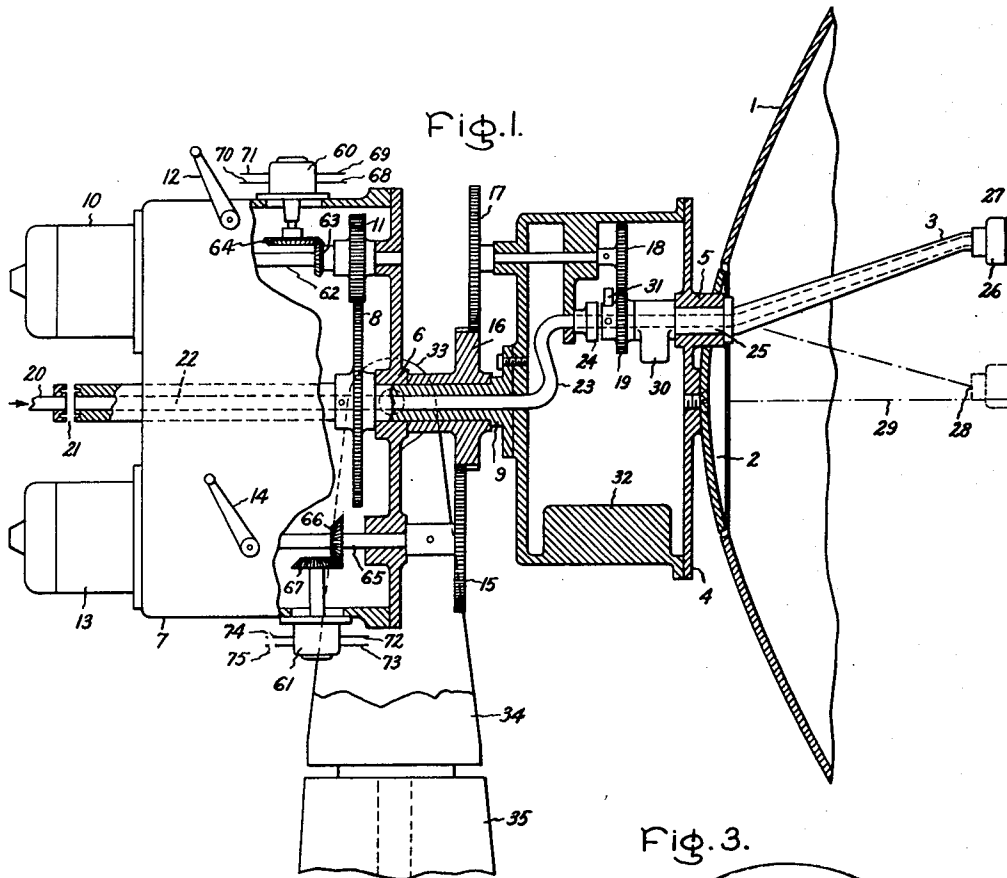
Oct. 17, 1950

E. F. W. ALEXANDERSON ET AL
RADIO DETECTION AND RANGING SYSTEM
EMPLOYING MULTIPLE SCAN

2,526,314

Filed Aug. 17, 1945

2 Sheets-Sheet 1



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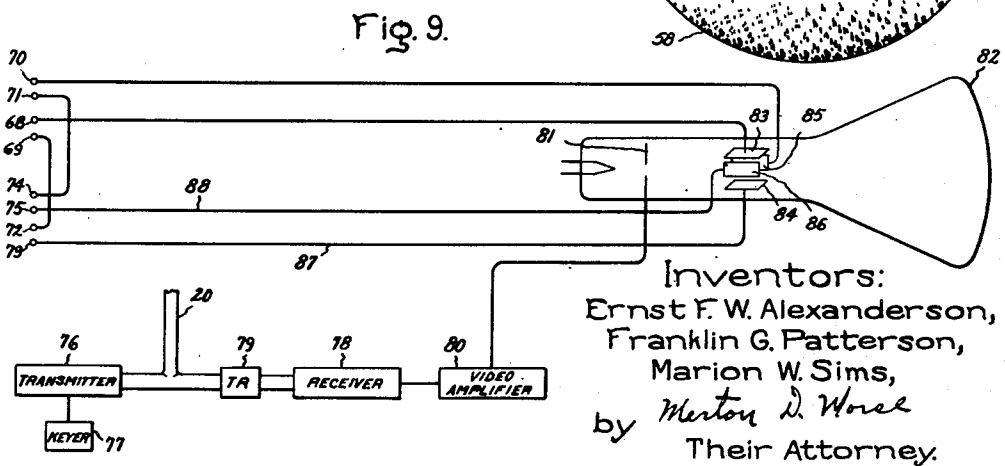
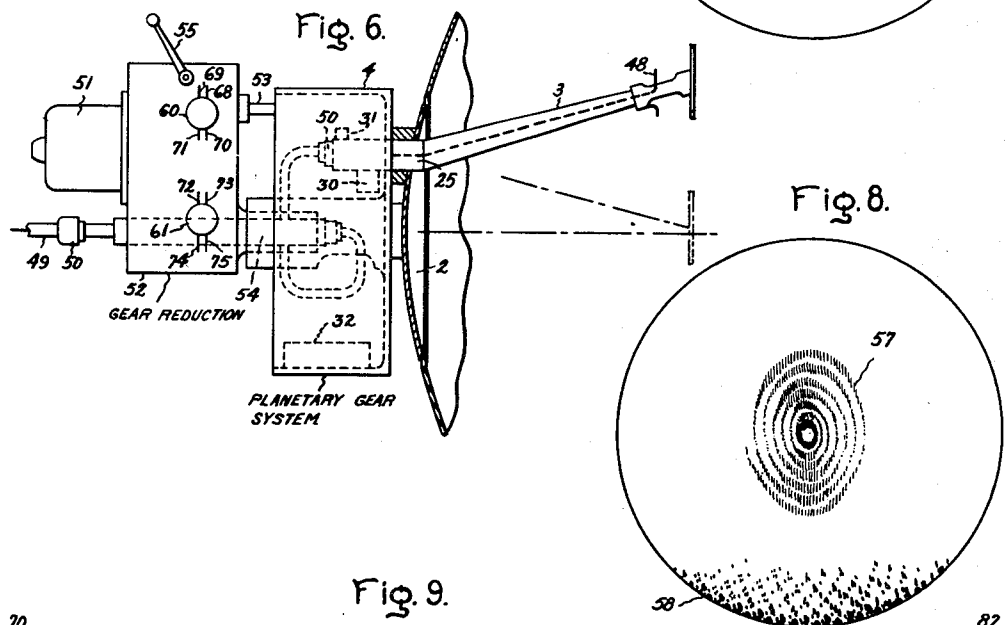
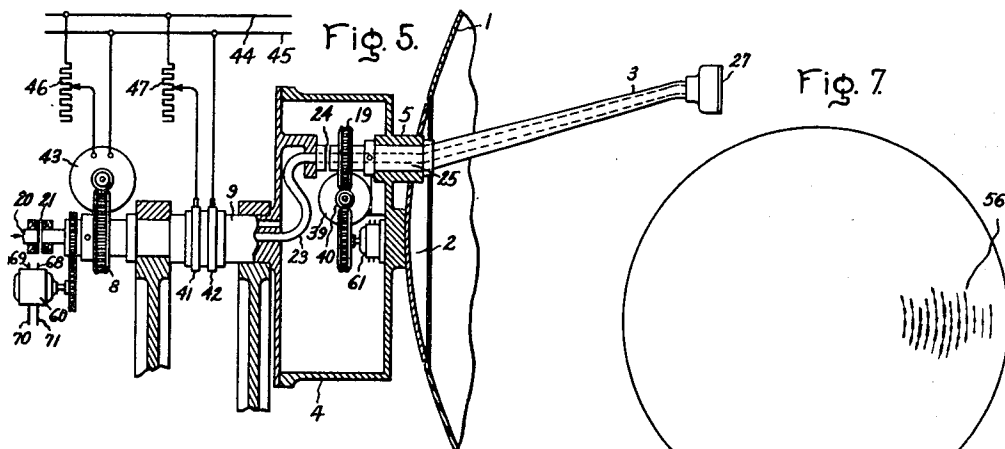
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UNITED STATES PATENT OFFICE

2,526,314

RADIO DETECTION AND RANGING SYSTEM
EMPLOYING MULTIPLE SCANErnst F. W. Alexanderson and Franklin G. Pat-
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Application August 17, 1945, Serial No. 610,920

20 Claims. (Cl. 343-16)

1 Our invention relates to radio detection and ranging systems in which electromagnetic waves are radiated and echoes thereof from remote objects are received at times dependent upon the distance of such remote objects.

It is a primary object of our invention to provide a new and improved antenna for such a system.

It is another object of our invention to provide a new and improved antenna for radio detecting and ranging systems which may be connected with either a wave guide or a coaxial line system and which is dynamically balanced.

It is a further object of our invention to provide a new and improved antenna for a radio detection and ranging system which provides selectively conical, spiral, or linear scanning.

It is a still further object of our invention to provide a new and improved multiple scanning antenna which is suitable for radio vision, searching, and pointing.

It is still another object of our invention to provide a new and improved multiple scanning antenna in which the mode of scanning may be changed rapidly and easily.

It is a still further object of our invention to provide a new and improved radio detection and ranging system which may employ multiple types of scanning and in which the true location of a reflecting object for each type of scanning is depicted on a cathode ray tube.

One of the features of our invention is the moving of a radiating antenna with respect to the focal point of a reflector to obtain a large angular motion of the projected beam without decrease in power or deterioration of the beam. The radiating element is rotated about two axes, one coinciding with the axis of the reflector and the other being displaced from but parallel to or generally parallel to that axis. The speed of rotation about the two axes is so controlled that different modes of scanning may be selected, the transition between modes being effected rapidly and without interrupting the operation of the system.

Other objects of our invention will appear from the following description of the invention and the novel features believed to be characteristic of the invention are set forth with particularity in the appended claims. Our invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in

2 which Fig. 1 is a vertical side view, partly in section, of an embodiment of our invention; Figs. 2-4 are graphs which illustrate certain operational characteristics of the multiple scan antenna of Fig. 1; Figs. 5 and 6 are modifications of the antenna of Fig. 1; Figs. 7 and 8 illustrate typical cathode ray tube displays obtained with the antennae of our invention; and Fig. 9 is a block diagram of a circuit of a radio detection and ranging system employing the antenna of our invention.

Referring to Fig. 1 of the drawing, we have there shown a rotationally symmetrical focusing reflector element 1 having the shape of a surface of revolution about its directive axis and having a focal point on said axis and which may be either a parabolic or spherical reflector. The reflector 1 has a central portion 2 which is supported to rotate about the axis of the reflector and which carries an antenna element 3 inclined at an angle to the axis of the reflector and arranged to rotate about an axis displaced from but substantially parallel to the axis of the reflector. The movable section 2 of the reflector is rigidly attached to a housing 4 which, in turn, contains a bearing support 5 for the antenna element 3. The housing 4 is rotatably supported in a bearing 6 in a transmission system 7. Rotating motion is imparted to the housing 4 and to the section 2 of the reflector by means of a gear 8 affixed to a shaft 9 which supports the housing 4. The gear 8 is driven by means of a motor 10 connected with a driving pinion 11 through a transmission system, not shown. A lever 12 in the transmission system is effective to change the speed of rotation of the driving pinion 11 and, consequently, the speed of rotation of the reflector element 2. Rotation of the antenna element 3 about an axis parallel with the axis of the reflector element 2 is effected by means of a second driving motor 13 which is connected through a transmission system (not shown) having a speed changing lever 14 to a driving pinion 15. The pinion 15 engages one-half of the face of each of the teeth on a floating gear 16 journalled on the shaft 9. The other half of the faces of the teeth of the floating gear 16, in turn, engage a gear 17 journalled in the housing 4. Gear 17 drives a pinion 18 which engages a gear 19 affixed to a hollow shaft journalled in the bearing 5. The gears 15-19 function as an epicyclic gear train effective to rotate the antenna element 3 about its own axis at a speed determined by the speed and direction of rotation of both the housing member 4 and the pinion 15.

High frequency pulses of energy to be radiated

by the element 3 are transmitted over a stationary wave guide 20 of the hollow pipe type through a rotating half wave choke 21 to the rotating section of the wave guide 22 formed within the hollow shaft 9. Within the housing 4 the wave guide system has a curved section 23 which is connected through a rotating half wave choke 24 to a section of wave guide within a second hollow shaft 25. The hollow shaft 25 connects with a wave guide within the angularly disposed antenna 3. At its outer end, the antenna 3 is provided with a dielectric housing 26 of a suitable material, such as polystyrene, which in turn supports a metallic splash plate 27 for reflecting electromagnetic waves from the wave guide to reflector 1 for formation into a beam of radiation.

As previously stated, the antenna 3 is inclined at an angle with both its axis of rotation about the shaft 25 and the axis of the reflector element 2. The dimensions of the antenna 3 are such that, as the shaft 25 rotates in the bearing 5, the antenna at its innermost position is displaced at a slight angle, preferably about one degree, with the axis of the parabolic reflector. This is illustrated in Fig. 1 by the dotted position of the antenna 3 in which the point 28, which corresponds to the innermost position of the antenna, is displaced slightly from the directive axis 29 of the reflector. Means are provided for dynamically balancing the antenna 3 for rotation about both the axis of the shaft 25 and the axis 29 and comprise a plurality of counterweights 30, 31, 32, the counterweights 30, 31 being disposed on opposite sides of the shaft 25 and the counterweight 32 being located within the housing 4 at a point diametrically opposite the shaft 25. The counterweights 30, 31 compensate for both the mass and torque of the antenna 3 as it rotates in the bearing 5 and the counterweight 32 provides dynamic balancing of the entire system of the antenna 3 including the counterweights 30, 31 and the driving connections for the antenna.

We also provide means for producing voltages which indicate the absolute position of the antenna 3 in space. This means employs two two-phase alternators 60, 61 so connected, respectively, that the rotors thereof rotate at all times at the same speed as the drum 4 and the antenna 3. Thus, the two-phase alternator 60 is connected to the shaft 62 which carries the gear 11 by means of a pair of bevel gears 63, 64. The gear train is such that the rotor of the alternator 60 at all times has the same direction of rotation, speed, and phase as drum 4. The two-phase alternator 61 is connected to the shaft 65 which drives the gear 15 through a pair of bevel gears 66, 67. This gear train likewise is so arranged that the rotor of alternator 61 at all times has the same direction of rotation, speed and phase as the radiating element 3. The alternator 60 is provided with output leads 68, 69 connected to the winding which gives an indication of the horizontal position of a reference point on the drum 4 and leads 70, 71 connected to the winding which gives an indication of the vertical position of that reference point. Similarly, leads 72, 73 of alternator 61 provide a voltage which varies as the horizontal displacement of the antenna 3 and means 74, 75 provide a voltage which varies as the vertical displacement from the antenna 3.

Means are provided for rotating the antenna and reflector both in azimuth and elevation and comprise a rotatable mounting 33 by means of which the elevation angle of the entire system may be varied. To this end, the reflector element

1 is rigidly supported from the transmission system 7 by suitable supports, not shown. The bearing 33 is provided in a pedestal 34 which, in turn, is journaled in a fixed support 35 to vary the azimuth angle of the antenna system. Variation of the azimuth and elevation angles of the antenna system may be effected either manually or by any suitable automatic means, not shown, the types of which are well known in the art.

The antenna system thus described is adapted particularly for the propagation of energy and, by proper correlation of the size of the reflector 1, the frequency of the waves and the dimensions of the antenna 3, a sharp beam of radiation may be easily generated in the microwave portion of the spectrum. Such sharp beams are particularly effective to obtain accurate pointing of an antenna for object location. Considering the antenna of Fig. 1, when the antenna 3 is tilted to its innermost position so that its center line terminates in a point corresponding to the point 28, if the antenna is spun rapidly about the axis 29, the radiated beam describes a cone about the axis 29 and provides a conical scanning beam. This is illustrated in Fig. 2 in which the antenna element 3 is indicated as inclined at its innermost position and so that it generates a relatively sharp beam 36 which rotates about the center line of the reflector. If now, the axis of rotation of the antenna 3 is displaced from the axis of the parabola to a position such that the antenna at the innermost part of its revolution just reaches the axis of the parabola, the beam of radiation described is a cone which is tilted from the axis of the parabola by an amount depending upon the displacement of the axis of element 3 and the innermost position of the cone will just reach the axis of the parabola. According to our invention, the original axis of rotation of the antenna 3, i. e., the axis of shaft 25, may be carried about the parabola axis at a constant radius as an additional rotation to provide different scanning patterns.

When the antenna and its displaced axis, namely, the axis of the shaft 25, are carried rapidly about the axis 29 of the parabolic reflector and at the same time the antenna 3 is rotated slowly about the displaced axis of the shaft 25, the motion of the antenna is a spiral, the pitch and number of revolutions in the spiral depending upon the number and rate of revolutions chosen. Both the pitch and number of revolutions may be quite large or small, as desired. This is illustrated by the curve shown at Fig. 3 in which the spiral path of the conical beam is described as starting at the axis 29 of the parabola and advancing outwardly to the limiting position of the antenna 3. If, for example, the speed of rotation of the drum 4 and the movable section 2 of the reflector about the axis 29 is 2400 R. P. M. and the speed of rotation of the antenna 3 about the axis of the shaft 25 is of the order of 100 R. P. M., the number of revolutions in the spiral is approximately 12, depending upon the relative directions of motion of the antenna 3 about its axis and the drum 4 about its axis. In the apparatus of Fig. 1, such relative speeds of the associated elements are obtained by means of the transmission systems and the operating levers 12, 14. For certain positions of the lever 12, 14, the antenna 3 may be held to its innermost position so that the radiating element corresponds to the point 28 whereby conical scanning is effected. For other positions of the lever 12, 14, the drum 4 and the section 2 may be rotated rapidly about

5

the axis 29 and the element 3 rotated less rapidly about the axis of the shaft 25 so that spiral scanning is effected. Preferably, the width of the radiated beam and the pitch of the revolutions in the spiral are correlated by the choosing of proper gear ratios so that the path of the beam, in returning from its outermost position to its central position, is out of phase with the outgoing path. In this way, an interlace is provided so that successive spirals interleave in their coverage, this increasing the chances of detecting weak targets. Such interlacing may be effected by shifting the spiral by a phase of 120 degrees in successive revolutions. This is indicated in Fig. 3 by the dotted portion of the spiral path which corresponds to a portion of the returning path of the beam.

Many other modes of scanning may also be obtained by the antenna of our invention. Thus, if the relative rotations of the antenna about its axis and the reflector element carrying the antenna about the axis 29 have the ratio of 2:1 in speed, with the antenna having the faster speed and rotating in a direction opposite to that of the reflector, the resultant scanning motion is either a linear one or a long, thin elliptical one, depending upon whether or not the radiating element has an initial off-set with respect to the axis 29. Thus, referring to Figs. 1 and 4 jointly, if the point 28 is displaced vertically downward so that the antenna element in its innermost position lies along the axis 29 and the antenna 3 is rotated in the bearing 5 at a speed twice the speed of the rotation of the drum 4 and in a direction opposite to the rotation of the drum 4, the linear scan 37 shown in Fig. 4 is obtained. If the antenna 3, however, is designed so that at its innermost position 28 it is inclined at a small angle with the axis 29, the long, thin elliptical scan indicated by the dotted line 38 is obtained. Furthermore, the direction of the linear scan or the elliptical scan may be oriented by any desirable angle, depending upon the initial position of the antenna 3 with respect to the axis 29. In this manner, the linear scan may be vertical, horizontal, or any intermediate position.

The various scanning patterns obtained by our multiple scan antenna are useful for different purposes. The spiral scan illustrated in Fig. 3 has been found extremely satisfactory for search purposes in the locating of targets or reflecting objects in space. The conical scan illustrated by the pattern 36 of Fig. 2 is particularly useful for radio pointing purposes in order to obtain bearings or to direct communication between a transmitter and a reflecting object. The linear or thin elliptical scan is particularly useful for obtaining the location of surface targets lying in a horizontal plane, such as positions of ships at sea. In addition, the spiral scan also offers a suitable pattern for radio vision presentation of objects in the field of view and is particularly useful in navigating an airplane in fog or darkness. In operating the system of Fig. 1, preferably spiral scanning is obtained until a reflecting object is sighted. Thereafter, the antenna and reflector may be rotated both in azimuth and elevation to direct the reflector at the reflecting object. The speeds of rotation of the gears 8 and 15 may then be changed by means of control levers 12 and 14 so that the antenna is maintained at its innermost position, namely, at the point 28, and conical scanning is effected.

In Fig. 5, we have shown a modification of our

6

invention in which multiple scanning action of an antenna may be obtained without the use of gear transmission systems but through the employment of a pair of variable speed motors, such as direct current motors. In this modification, the shaft 25 journaled in the bearing 5 and supporting the antenna 3 is rotated in the bearing 5 by means of a motor 39 which is connected through a suitable driving gear 40 with the gear 19. The leads for the motor 40 (not shown) are brought out, in a manner well known, to a pair of slip rings 41, 42 on the shaft 9. The shaft 9, in turn, may be driven by a motor 43 geared to the gear 8. The leads connected to the motor 43 and the slip rings 41 may be supplied with voltage from any suitable source (not shown) connected across conductors 44, 45. Resistances 46, 47 having variable contact points may be employed to control the speeds of the motors 39, 43 to vary the mode of scanning of the antenna system. In all other respects the systems of Figs. 1-5 are the same and may employ the same type of mounting for varying the azimuth and elevation positions of the antenna, a similar system of counterweights to effect dynamic balancing of the rotating elements, and reference voltage alternators 60, 61.

In the modification shown in Fig. 6, we have illustrated a form of our invention in which the antenna 3 employs a dipole radiating element 48 and is supplied with pulses of high frequency signal over a coaxial transmission line 49 having the usual tubular outer conductor and centrally disposed inner conductor. The coaxial line likewise employs a plurality of rotating choke couplings 50 between those portions of the transmission system which rotate at different speeds. The driving system for the antenna and rotatable section 2 of the reflector comprise a motor 51 which is connected to a transmission or gear reduction system 52 out of which project two rotating shafts 53, 54, the relative speeds of which may be varied by means of a control lever 55. The rotating housing 4 preferably includes a planetary gearing system (not shown) connected between the rotating shafts 53, 54, the housing 4, and the shaft 25, which rotates the antenna 3, to produce desired speed ratios between the shaft 25 and the housing 4. In this manner, spiral, conical, or linear scan may be obtained simply by changing the position of the control lever 55. In all other respects the system of Fig. 6 is the same as that of the systems of Figs. 1 and 5 and requires the same type of mounting for obtaining variation in azimuth and elevation angles, as well as dynamic balancing of all rotating elements. Likewise, reference voltage alternators 60 and 61 are provided for purposes to be explained later.

In Fig. 7 we have illustrated the screen of a cathode ray tube when using the spiral scanning system of our invention for search purposes. By proper control of the illumination of the tube, the scanning lines may be removed from the screen and a target or reflecting object produces a series of dots indicated by the field 56 in Fig. 7. After the object is located in space, the reflector and antenna may be directed by moving the system in azimuth and elevation so that the target is centered in the middle of the picture, as is indicated by the field 57 in Fig. 8. The pattern 58 in Fig. 8 is that caused by ground targets when spiral scanning is employed with the antenna system trained on a reflecting object near the horizon.

7

Referring now to Fig. 9, we have there illustrated a portion of the circuit of the complete radio detection and ranging system employing an antenna of the type described. The transmitter 76 is recurrently pulsed by means of a keyer 77 to supply high frequency pulses over the wave guide 20 to an antenna so that high frequency pulses may be radiated into space. Echoes of the radiated pulses received by the antenna are supplied over the same wave guide 20 to a receiver 78, where they are converted in frequency, amplified, and detected to produce unidirectional pulses corresponding to the outgoing pulse and to each of the received echoes. The receiving equipment includes the usual TR box 79 which operates to protect the equipment of the receiver from the high intensity of the pulses produced by the transmitter 76. The received pulses, after detection, are amplified in a video amplifier 80 and supplied to the control electrode 81 of a cathode ray oscilloscope 82. The cathode ray oscilloscope has a set of vertical deflection plates 83, 84 and a set of horizontal deflection plates 85, 86.

The two phases of the alternators 60, 61 carried at the antenna may be considered to represent the rectangular components of the two motions respectively of the drum 4 and the antenna 3 of the antenna structure. In accordance with our invention, the voltages representing the vertical components of the drum and antenna, respectively, are connected in series and to the vertical plates of the cathode ray oscilloscope 82. This is represented in Fig. 9 by the lead 87 which connects the lead 73 and the antenna reference alternator to the vertical deflection plate 84. The lead 72 of the antenna reference alternator is connected in series with the leads 69, 68 of the drum reference alternator, the lead 68 being connected to the vertical deflection plate 83. Similarly, the voltages representing the horizontal components are connected in series and to the horizontal plates of the oscilloscope. Thus, lead 75 is connected directly to plate 86 by conductor 88. Lead 74 is connected in series with the leads 71, 70 and to the deflection plate 85. In this manner, the spot in the cathode ray tube traces a pattern which represents the angular position of the antenna beam at all times. The amplifier 80, by connection to the grid 81, is arranged to illuminate the spot whenever a signal is received. As a result, it is evident that, whenever the moving beam transmitted by the antenna scans a reflecting object, the signal from that object is presented on the face of the tube in a position representing the position of the object in the field of view. Since the rotors of the reference alternators are turned at the same absolute speed, respectively, as the drum 4 and the antenna 3, the scanning action of the cathode ray tube 82 is the same whether spiral, conical, or linear scanning of the antenna is being used.

An important advantage, from a mechanical standpoint, of the embodiments of our invention described and illustrated is the fact that, since both axes of rotation of the element 2 and the shaft 25 are parallel, the entire system may be statically and dynamically balanced and thus may be operated at relatively high speeds. Furthermore, all motions are uniform rotations so that a minimum of vibration of elements is obtained. The systems moreover require only two rotating coupling joints and may employ either wave guides or coaxial transmission lines.

Another important advantage of our system is

8

the ease and facility with which modes of scanning may be changed. Thus, the system may be shifted rapidly from spiral to conical or linear scan as desired. Thus, the spiral scan may be used for radio vision purposes until a reflecting object is sighted and a conical scan employed for higher precision in locating the position of that object in space. In particular with the spiral scan, it has been found that complete coverage of a 36° field of view, for example, may be obtained in one-third of a second. Furthermore, by interlacing the outgoing and returning scanning, extreme accuracy in searching is obtained.

It should be pointed out that in the structure of Fig. 5, alternator 61 gives an indication of the speed of antenna 3 in bearing 5. In order that the output voltage of this alternator may be employed for scanning a cathode ray tube, means (not shown) must be provided to combine the output voltages of alternators 60, 61 to provide a resultant voltage for conductors 72-75 of Fig. 9, the frequency of which is the difference in frequency of the voltages of alternators 60 and 61.

While in the drawings and the foregoing description we have described the means for rotating our radiating element as being supported in the rear of a focusing reflector, it is apparent that such means may be located in front of the reflector with the dipole or wave guide facing the parabolic or spherical reflector. In such instance, of course, the reflector and rotating means preferably are mounted so that they move in elevation and azimuth as a unit. In such a structure, of course, it is evident that the reflector may be unitary in construction so that the rotating section 2 is not required.

While our invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without departing from the invention. We therefore aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An antenna comprising a reflector having a directive axis, a radiating element positioned in front of said reflector, means for rotating said element about said directive axis, said element being supported for rotation about a second axis displaced from and parallel to said directive axis, said reflector being in fixed position relative to said second axis, and selective means for rotating said element about said second axis.

2. An antenna comprising a reflector having a directive axis, a radiating element positioned in front of said reflector, means for rotating said element about said directive axis, said element being supported for rotation about a second axis fixed with respect to said reflector and displaced from and parallel to said directive axis, means for rotating said element about said second axis, and means for selectively controlling the rotation of said element about said axes thereby to vary the radiation pattern of said antenna.

3. A directive antenna system comprising a focussing reflector having the shape of a surface of revolution about its directive axis and having a focal point on said axis, a radiating element supported in front of said reflector at a point displaced from said axis, means for rotating said element about said axis, and means for varying the distance between said point and said axis while said element is rotating about said

axis to control the radiation pattern of said antenna, said last means maintaining said point in a plane perpendicular to said axis.

4. An antenna comprising a rotationally symmetrical focussing reflector having a directive axis, a radiating element supported in front of said reflector and rotatable about a second axis displaced from and rotatable about said directive axis, and means for rotating said element about both of said axes, and means for varying the distance between said axes while said element is rotating about said axes to control the radiation pattern of said antenna.

5. An antenna comprising a focussing reflector having a directive axis, a radiating element supported in front of said reflector and rotatable about a second axis displaced from and rotatable about said directive axis, means for rotating said element about both of said axes, and means for changing the speed of said rotation about one of said axes.

6. An antenna comprising a focussing reflector, a radiating element supported in front of said reflector, and means for rotating said element about the directive axis of said reflector and an axis displaced from and rotatable about the directive axis of said reflector to describe a spiral path in front of said reflector.

7. An antenna comprising a focussing reflector, a radiating element supported in front of said reflector, and means for rotating said element about both the directive axis of said reflector and an axis displaced from and rotatable about the directive axis of said reflector to describe a substantially linear path in front of said reflector.

8. An antenna comprising a radiating element, means for rotating said element about a first axis, means for rotating said element about a second axis parallel to and displaced from said first axis at a speed correlated with the speed of rotation about said first axis to move said element through a spiral path, and means for focussing the beam radiated by said element.

9. An antenna comprising a radiating element, means for rotating said element about a first axis, means for rotating said element about a second axis parallel to and displaced from said first axis, and means for selectively controlling the speeds of rotation of said element about said respective axes to oscillate said element through a substantially linear path in space.

10. An antenna comprising a reflector having a directive axis, a radiating element supported from said reflector at a point displaced from said axis, means for rotating said element about a second axis passing through said point and displaced from said directive axis and parallel therewith, and means for rotating both said reflector and said element about said directive axis.

11. An antenna comprising a reflector having a directive axis, a radiating element supported from said reflector at a point displaced from said axis, means for rotating said element about a second axis passing through said point, means for rotating both said reflector and said element about said directive axis, and means for controlling individually the speeds of rotation of said element about said axes to control the radiation pattern of said antenna.

12. An antenna comprising a rotationally symmetrical reflector having a stationary part and a rotatable part, said rotatable part being disposed along the directive axis of said reflector, said rotatable part comprising a central portion

of said reflector and being supported for rotation about the directive axis of said reflector, a radiating element supported in front of said reflector at a point displaced from said axis, said element being rotatable about a second axis parallel to said directive axis and displaced therefrom, means for rotating said rotatable part and said element about said directive axis, and means for rotating said element about said second axis at a speed correlated with the speed of rotation about said directive axis to move said element through a spiral path in front of said reflector.

13. An antenna comprising a rotationally symmetrical reflector having a stationary part and a rotatable part, said rotatable part being disposed along the directive axis of said reflector, said rotatable part comprising a central portion of said reflector and being supported for rotation about the directive axis of said reflector, a radiating element supported in front of said reflector at a point displaced from said axis, said element being rotatable about a second axis parallel to said directive axis and displaced therefrom, means for rotating said rotatable part and said element about said directive axis, and adjustable means for rotating said element about said second axis at a speed correlated with the speed of rotation about said directive axis to move said element through an elliptical path in front of said reflector.

14. An antenna comprising a rotationally symmetrical reflector having a stationary part and a rotatable part, said rotatable part being disposed along the directive axis of said reflector, said rotatable part comprising a central portion of said reflector and being supported for rotation about the directive axis of said reflector, a radiating element supported in front of said reflector at a point displaced from said axis, said element being rotatable about a second axis parallel to said directive axis and displaced therefrom, means for rotating said rotatable part and said element about said directive axis, means for rotating said element about said second axis, and means for controlling individually the speeds of rotation about said axes to vary the radiation pattern of said antenna.

15. An antenna system comprising a reflector having an axis, means for rotating said reflector about said axis, a radiating element supported by said reflector and displaced from said axis, means for rotating said element about a second axis parallel to said first axis and displaced therefrom, said element being angularly disposed with respect to said second axis, whereby said element describes a spiral path in front of said reflector.

16. An antenna system comprising a rotationally symmetrical reflector having a directive axis, means for rotating said reflector about said directive axis, a radiating element supported by said reflector and displaced from said axis, means for rotating said element about a second axis parallel to said directive axis and displaced therefrom, said element being angularly disposed with respect to said second axis, and means for controlling individually the speeds of rotation of said element about both of said axes to control the radiation pattern of said antenna.

17. An antenna system comprising a reflector having an axis, means for rotating said reflector about said axis, a radiating element supported by said reflector and displaced from said axis, means for rotating said element about a second

11

axis parallel to said first axis and displaced therefrom, said element being angularly disposed with respect to said second axis, and means whereby the azimuth position of said reflector may be varied.

18. In a radio echo system in which impulses are transmitted and in which echo impulses are received after reflection from an object in space, an antenna comprising a reflector and a radiating element positioned in front of said reflector, means providing uniform rotation of said element about each of a pair of parallel axes, one of said axes being fixed with respect to said reflector, and means providing an indication of the instantaneous position of said element in space.

19. In a radio echo system in which impulses are transmitted and in which echo impulses are received after reflection from an object in space, a rotationally symmetrical focussing reflector having a directive axis, an antenna comprising a radiating element positioned in front of said reflector, means providing uniform rotation of said element about both said directive axis and a second axis fixed with respect to said reflector and displaced from and parallel to said directive axis, a viewing screen, means projecting a cathode ray beam on said screen, and means deflecting said beam so that the position thereof corresponds with the position of said element in front of said reflector.

20. In a radio echo system in which impulses are transmitted and in which echo impulses are

12

received after reflection from an object in space, a focussing reflector having a first axis, a radiating element, means providing uniform rotation of said element about both said first axis and a second axis displaced from and parallel to said first axis, means producing first and second voltages varying respectively with the position of said element with respect to said first and second axes, a viewing screen, means projecting a cathode ray beam on said screen, means whereby said beam may be deflected, and means supplying said voltages in series to said deflecting means, whereby the position of said beam on said screen corresponds with the position of said element with respect to said reflector.

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