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DIRECTIVE ANTENNA CONTROL SYSTEM

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1

This invention relates to directive antennas and particularly to means for controlling the directive operation of rotatable or oscillatory radar antennas.

As is known, antenna systems comprising a paraboloidal or a cylindrical parabolic reflector, a primary antenna at the focus thereof and means for continuously rotating or spinning the reflector about a vertical axis, for the purpose of searching in the horizontal or azimuthal plane, are widely used in radar systems installed on mobile craft. Also, in certain systems, mechanical means are provided for oscillating the reflector over an azimuthal angle or sector having a predetermined fixed angular width and a predetermined fixed position or orientation relative to the longitudinal axis or lubber line of the mobile craft. Ordinarily, the bisector of the scanning sector is aligned with the longitudinal axis of the craft. For reasons explained more fully hereinafter, it now appears desirable to provide simple electrical means for changing the angular width of the sector, and therefore for controlling the frequency of the target presentation on the cathode ray tube indicator, and means for changing the mean position of the scanned sector relative to the axis of the craft.

It is one object of this invention to adjust, in an oscillating antenna system, the width of the scanned angular sector.

It is another object of this invention to adjust, in an oscillating antenna system, the position of the mean direction of radio action corresponding to the bisector of the scanned angular sector.

It is another object of this invention to provide simple electrical means for easily regulating, in an oscillating antenna system, the degree of oscillation of the antenna.

It is another object of this invention to provide simple electrical means for easily regulating, in an oscillating radar antenna system arranged for scanning an angular sector, the angular width of the sector.

It is still another object of this invention to provide simple means for easily regulating, in an oscillating antenna system arranged for scanning an angular sector, the position of the bisector of the sector relative to a given reference line.

It is a further object of this invention to control, in a radar system comprising a rocking parabolic reflector, the frequency of the target spot presentation on a conventional tube indicator.

In accordance with one embodiment of the

2

invention, the motor driving a spinner parabolic reflector installed on an airplane also drives, in synchronism with the reflector, a pair of diametrically opposite radial wipers of a potentiometer having a circular resistance. The diametrically opposite points or terminals of the circular resistance are connected to the opposite terminals of a battery. The wipers are connected in series with an adjustable resistance or rheostat and the primary winding of a polarized relay which controls, through a power relay, the direction of rotation of the motor. Each wiper during rotation passes from a point on the potentiometer resistance of positive potential to a point of negative potential, or vice versa, and, as the wipers pass through the mid-points of the two semicircular sections or branches of the circular resistance, the polarity of the voltage across the wipers is reversed. Consequently the potentiometer functions as a rheostope and each radial wiper oscillates over an arc of the associated semicircular resistance section. When the voltage across the wipers has a positive polarity and a predetermined intensity dependent upon the adjustment of the rheostat, the relay operates in one direction and reverses the motor; and when the wiper voltage has a negative polarity and a predetermined intensity the relay operates in the opposite direction and again reverses the motor. Hence the reflector oscillates over a scanning sector having an angular width related to or determined by the adjustment of the resistance. Also, the sector width may be easily changed within certain limits, as explained hereinafter, merely by adjusting the rheostat.

The polarized relay has a secondary or bias winding one terminal of which is connected to the wiper of one linear potentiometer and the other terminal of which is connected to the wiper of another linear potentiometer. The two terminals of the two linear potentiometers are connected to a battery and the uncorrespondent terminals are directly connected together so that the two potentiometers constitute an adjustable double potentiometer. With the wipers at the mid-points of the respective potentiometers the bias current through the secondary winding is zero and, under this condition, the bisector of the scanning sector is coincident with the longitudinal axis of the airplane. With one or both wipers displaced from the potentiometer mid-point or mid-points, the bias current has a direction, negative or positive, of flow and an intensity which are related, respectively, to the sense and amount of the relative displacement

of the wipers. If the bias voltage is negative, the negative and positive operating voltages supplied by the circular potentiometer and required to operate the polarized relay in the two opposite directions are decreased and increased, respectively; and if the bias voltage is positive the aforementioned operating voltages are increased and decreased, respectively. Consequently, the mid-points of the arcs traversed by the two radial wipers are shifted from the mid-points of the two semicircular resistance sections in opposite directions dependent upon the polarity of the bias current and in equal amounts dependent upon the intensity of the bias current. Hence the bisector or mean wave path of the sector may be aligned with a wave path or direction making an angle in the azimuthal plane with the longitudinal axis of the aircraft and the orientation of the sector may be easily changed, within certain limits, as also explained hereinafter, merely by adjusting the double potentiometer.

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

Fig. 1 is a schematic illustration of an airplane search radar arranged for sector scan control in accordance with the invention; and

Figs. 2 and 3 are sector diagrams used in explaining the invention.

Referring to Fig. 1, reference numeral 1 denotes the floor of an airplane fuselage and numeral 2 designates a paraboloidal reflector positioned below the fuselage and having at its focal point a primary dipole antenna 3 which is connected by the rotatable coaxial line section 4, rotatable coaxial line coupler or junction 5 and stationary coaxial line section 6 to a translation device 7 such as a transmitter, a receiver or a radar transceiver. The paraboloid is attached by bracket members 8 and bolts 9 to a rotatable tubular casting 10 which extends downwardly from the housing 11. The casting 10 includes a driven gear 12 and is supported by the ball bearing 13. The coaxial line 4 extends through the housing 11, coaxially through the casting 10 and through the vertex of the reflector 2. The rotatable line section 4 is fastened to the reflector 2 and the stationary line section 6 is fastened to the top plate or cover 15 of housing 11 by the bushings 14. Reference numeral 16 denotes a motor included in the housing 11 and numeral 17 denotes a vertical drive shaft associated therewith. A drive gear 18 which engages driven gear 12, the gear ratio being 1 to 1, is attached to the bottom end of shaft 17, and an annular insulator 19 is attached to the top end of shaft 17.

Reference numeral 20 denotes a circular potentiometer comprising a resistance 21 and the radial wipers 22 and 23, the wipers being supported by the insulator 19. In certain radar installations the potentiometer 20 is a normal part of the spinner equipment and its primary function is to supply to the tube indicator a so-called azimuth sweep voltage. The impedance imposed on the potentiometer by the sector control apparatus of the invention, described in detail below, is high enough to have no effect on the primary function of the potentiometer. Numeral 24 designates a battery having a positive terminal 25 and a negative terminal 26, the negative terminal being connected to the ground 27. The terminals 25 and 26 are, in operation, connected through the

two-pole one-way switch 28 and conductors or leads 29 to the field winding of motor 16. Terminals 25 and 26 are also connected by the power lead 30 and the ground lead 31 to the diametrically opposite points 32 and 33 of the circular resistance 21. Reference numeral 34 denotes a four-pole two-way control switch having the two operating positions A and B. As will appear more fully, with the power switch 28 closed and the control switch 34 thrown into position A, the reflector 2 is oscillated over an angular sector; and with the switch 34 in position B, complete rotation or spinning of the reflector obtains.

Reference numeral 35 denotes an adjustable resistance or rheostat having a movable contact 36. Numeral 37 designates a polarized relay having a primary or operating winding 38, a secondary or bias winding 39, an idle back contact 40, a front contact member 41 and an armature 42, the armature being connected to the ground or negative battery terminal 26 by lead 31. The armature of relay 37 operates in one direction when a current of, say, plus i amperes flows in winding 38; and it remains operated in that direction until a current of minus i amperes flows in the winding, at which time the armature operates in the other direction. Numerals 43 and 44 designate, respectively, a resistance and a condenser which are connected by leads 45 in series with contact 41 and the ground lead 31. Numeral 46 denotes an adjustable double potentiometer comprising two linear resistances 47 and 48, each having a positive terminal 49, a negative terminal 50, and a movable member 51. The movable wipers 51 are uncontrolled or ganged and are connected through leads 52 in series with the bias windings 39 of relay 37. The two resistances 47 and 48 are connected electrically in parallel by leads 54 and are positioned physically in parallel in a manner such that as wipers 51 are moved from the mid-points 55 of the resistances 47, 48 toward the left, for example, one wiper approaches the positive terminal of its associated resistance and the other approaches the negative terminal of its associated resistance. In short, the double potentiometer 46 is in certain respects the same as the circular potentiometer 20. Reference numeral 56 denotes a motor control relay having a winding 57, an inner armature 58, a single back contact 59, an outer armature 60, a single front contact 61 and a double contact member 62. The winding 57 is connected by leads 63 between the front contacts 41, 42 of polarized relay 37 and the positive terminal 49 of the double potentiometer 46. The back and front contacts 59 and 61 are connected together and, assuming switch 28 is closed, connected to the ground terminal 26 by lead 31. The double contact 62 is connected by lead 30 and through switch 28 to the positive terminal 25 of battery 24. Numeral 64 denotes a speed control resistance which, as explained below, functions to decrease or limit the speed of the paraboloid as it is oscillated.

Assuming switch 28 is closed and switch 34 is in position A, the primary winding 38 of relay 37 is connected over leads 65 in series with the adjustable resistance 35 and the radial wipers 22 and 23. The positive terminals 49 of potentiometer 46 and the associated terminal of winding 57 of relay 56 are connected by one of the leads 66 and the power lead 30 to the positive terminal 25 of battery 24; and the negative terminals 50 of potentiometer 46 are connected by another of the leads 66 and the ground lead 31 to the negative battery terminal 26. The speed control resistance

5

64 is connected in series with the battery 24 and the armature of motor 16 over leads 30, 31, 67 and 68 and, assuming relay 56 is not actuated, through the front relay contact 61 and outer armature 60 or, if relay 56 is energized, through the back relay contact 59 and the inner armature 58. With switch 34 in position B, the circuit including the primary winding 38 of relay 37 is open and the circuit including the potentiometer resistances 47 and 48 is open. Also, the circuit including the winding 57 of motor control relay 56 is open, so that the contact 58, 62 and the contacts 60, 61 are closed. Moreover, resistance 64 is short-circuited and the armature circuit of motor 16 is completed through switch 34. With switch 34 in an open or neutral position, the armature circuit of motor 16 is open and the circuits of relay 37, relay 56 and potentiometer 46 are open.

Referring to Figs. 1, 2 and 3, the operation of the system of Fig. 1 will now be explained. In this connection, it is assumed that switch 28 is closed, switch 34 is in position A, the movable wiper 36 is at the approximate center point of resistance 35 and the movable contacts 51 are on the mid-points 55 of the potentiometer resistances 47 and 48. Under the conditions assumed, motor 16 is energized since current is supplied directly to the motor field over leads 29 and also supplied to the motor armature through leads 30, 31, 67 and 68, resistance 64 and two contacts 58, 62 and 60, 61 of relay 56. The motor rotates the radial wipers 22, 23 and the reflector 2 at the same relatively slow speed inasmuch as the ratio of gears 12 and 18 is 1 to 1. When the reflector 2 is pointed forward and its axis 69, Fig. 2, is included in the vertical plane containing the longitudinal axis of the airplane, the radial wipers 22, 23 are in the position shown on the drawing and herein termed for convenience position D. In position D the wipers 22 and 23 engage the potentiometer points 70 and 71, respectively, which are midway between the point 32 of positive potential and the point 33 of negative potential. Since points 70 and 71 have similar potentials, the voltage across wipers 22 and 23 is zero and relay 37 is not energized.

Assuming counter-clockwise rotation, when the radial wipers 22 and 23 reach the position designated by reference letter E, and therefore engage the positive point 72 and the negative point 73, respectively, a potential difference or voltage of, say, plus 2.0 volts is impressed across the primary winding 38 of relay 37 through the adjustable resistance 35, and the armature 42 of polarized relay 37 operates in a direction such that the contacts 41, 42 are closed. Thereupon the circuit including winding 57 of the motor control relay 56 is completed and relay 56 is actuated. The operation of relay 56 causes the two contacts 58, 62 and 60, 61 to open, and the two contacts 59, 60, 62 to close, with the result that the direction of rotation of motor 16, reflector 2 and radial wipers 22 and 23 is reversed. The wipers 22 and 23 then rotate clockwise and pass the zero or neutral points 70 and 71 and upon reaching the position denoted by reference letter F engage the negative point 74 and the positive point 75 having a potential difference of minus 2.0 volts. Hence, a negative potential is impressed across winding 38 whereby the armature 42 operates in a reversed direction, contacts 41, 42 become open and relay 5 is deenergized. With relay 57 deenergized, contacts 59, 58 and 60, 62 are open and contacts 58, 62 and 60, 61 are closed; and the direction of rotation of motor 16, reflector 2 and

6

radial wipers 22 and 23 is again reversed. Hence, the reflector is oscillated over an angular sector such as illustrated in Fig. 2 and designated by reference numeral 76. The sector 76 corresponds to the angle α between the lines representing positions E and F, Fig. 1.

The sector angle may be varied by adjusting the movable wiper 36 associated with the rheostat resistance 35. Thus, as the value of resistance 35 is decreased, the positive and negative voltages required to produce the relay operating currents of plus i and minus i are decreased. Consequently, the radial wipers and the reflector rotate through an angle α_1 which is smaller than α . As the value of resistance 35 is increased the voltages required to produce the operating currents are increased, and the wipers and the reflector rotate through an angle α_2 which is greater than α . In one embodiment successfully tested, the range of resistance 35 was such that a variation in the angular width of the scanning sector from 30 degrees to 180 degrees was obtainable, as shown by the shaded sectors 77 and 78, Fig. 2.

The position of the sector angle may be changed by moving the wipers 51 of the double potentiometer 46 along the resistances 47 and 48. With the wipers 51 positioned at the left of mid-points 55 the bias current supplied to the secondary winding 39 of polarized relay 37 is, say, positive, and with the wipers at the right of the mid-points the bias current is negative, the intensity of the current being proportional to the amount of displacement of the wipers. With the double potentiometer 46 adjusted to supply a bias current, the positive and negative currents required in the primary winding 38 to operate the relay 37 in the two directions, are unequal and the two extreme positions reached on the circular resistance 21 by each of radial wipers 22 and 23 are at unequal distances from the mid-points 70, 71 and the neutral position D of the radial wipers. Thus, for a bias of one polarity, the mean position for the radial wipers 22 and 23 is shifted counter-clockwise from position D to a position such as D₁, depending upon the bias intensity, and the extreme positions E and F are shifted accordingly. For a bias of the other polarity, the mean position of the radial wipers is shifted clockwise dependent upon the bias intensity, to a position such as D₂ and the extreme positions E and F are shifted corresponding amounts. As illustrated by the sectors denoted 79 and 80, Fig. 3, the sector-position potentiometer 46 permits the bisector of the narrowest sector angle to be aligned with any direction in the forward angular region 81 extending from the direction corresponding with 270 degrees less than one-half, for example, 15 degrees, of the angular width of the sector, through the 0 direction, to the direction corresponding to 90 degrees minus one-half the angular width of the sector.

With switch 28 closed and switch 34 in position B, the potentiometers 20 and 46, rheostat 35, 36 and the windings of relays 37 and 56 are disconnected from battery 24 and the motor control resistance 64 is short-circuited. The battery 24 is connected to the field of motor 16 directly and to the armature of motor 16 through switch 24, contacts 62, 58 of relay 56 and contacts 60, 61 of relay 56, whereby the motor 16 and the reflector 2 spin or rotate, continuously and counter-clockwise, at a relatively high speed. With switch 28 or switch 34 open, the motor 16 and

reflector 2 are completely disconnected from the battery 24.

It is thus apparent that, in accordance with the invention, the angular width and position of the scanning sector may be changed, easily and accurately, by means of a simple electrical arrangement. Moreover, the frequency of the target presentation on the cathode ray tube indicator included in a radar or in an aircraft radio bombsight may be readily controlled and, in fact, increased to a maximum, whereby a highly accurate bombsight is obtained. Thus, in a conventional prior art bombsight system employing a continuously rotating spinner reflector the desired target spot is presented n times per minute where n is the revolutions per minute of the reflector. If $n=20$ the target is seen on the indicator once every three seconds; and if the speed of the aircraft relative to that of the target is 300 miles per hour, the target spot is seen once every quarter mile as the aircraft moves along the bombing run. Consequently, if the bombing run is 6 miles the target will be observed momentarily only about twenty-four times during the run. By adjusting the angular width and position of the antenna scanning sector for optimum operation, in accordance with the invention, the number of times the target is seen, that is, the frequency of the target presentation during the bombing run, is relatively great, as compared to the frequency obtainable in conventional spinner antenna bombsight systems, and more accurate bombing is therefore secured.

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

What is claimed is:

1. In combination, a direct current motor, a source of direct current connected thereto, a relay controlled by said motor for reversing the direction of rotation of said motor, and an adjustable resistance included between said relay and said source for controlling said relay and changing the amount of rotation of said motor in each direction.

2. In combination, a directive antenna comprising a rotatable concave reflector, a first potentiometer comprising a circular resistance and a pair of rotatable wipers therefor, a direct current motor for oscillating said reflector and rotatable wipers over an angle not greater than 180 degrees, an adjustable resistance for changing the magnitude of said angle, a second potentiometer for changing the orientation of the bisector of said angle, said last mentioned potentiometer comprising a pair of parallel resistances and a pair of slidable wipers, a source of direct current connected to said circular resistance and

to said parallel resistances, and a polarized relay having a contact for reversing said motor, an operating winding connected through said adjustable resistance to said rotatable wipers, and a bias winding connected to said slidable wipers.

3. In combination, a directive antenna comprising a parabolic reflector, a potentiometer comprising a circular resistance and a pair of diametrically opposed rotatable wipers, a source of direct current voltage of given intensity connected to diametrically opposed terminals of said circular resistance, a direct current motor for rotating said reflector and wipers in like directions and at the same speeds and for reversing the polarity of the potentials on said wipers, an adjustable resistance for regulating the amount of rotation in each direction, and a polarized relay responsive in opposite senses or directions to positive the negative voltages having equal predetermined intensities smaller than said first-mentioned intensity, said relay having a primary or operating winding connected to said wipers and having a pair of contacts for changing the direction of rotation of said motor.

4. A combination in accordance with claim 3, a power relay having a winding connected in series with the contacts of the polarized relay, said power relay having two pairs of contacts for alternately connecting said source to said motor, the source being connected to the motor through one pair of contacts when the power relay is energized for securing clockwise rotation of the motor and connected to said motor through the other pair of contacts when the power relay is deenergized for securing counterclockwise rotation of the motor.

5. A combination in accordance with claim 3, a double adjustable potentiometer comprising two linear resistances connected in parallel and to said source and a pair of slidable wipers associated with said resistances, said relay having a secondary or bias winding connected to said slidable wipers, whereby the intensities of the negative and positive voltages supplied by said first-mentioned potentiometer to the primary winding of the polarized relay and required to operate said relay may be varied.

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