Feb. 11, 1947. M. A. EDWARDS 2,415,678

ANTENNA

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Fig. 1.

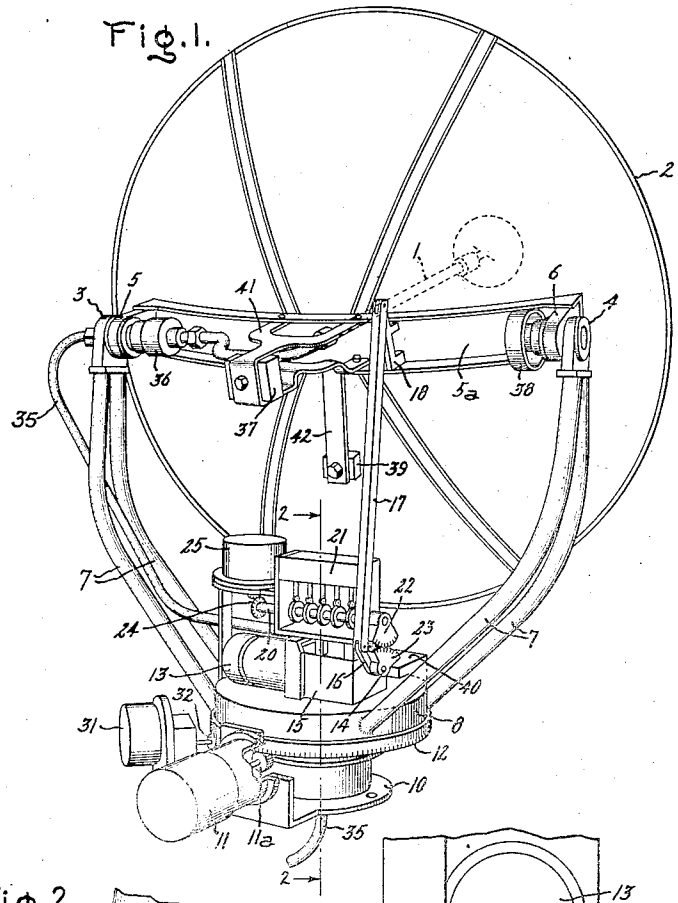
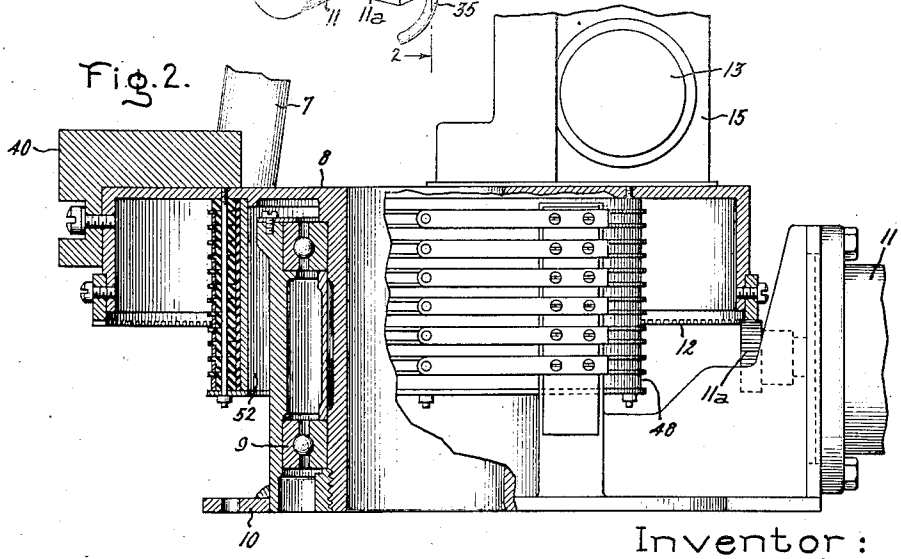


Fig. 2.



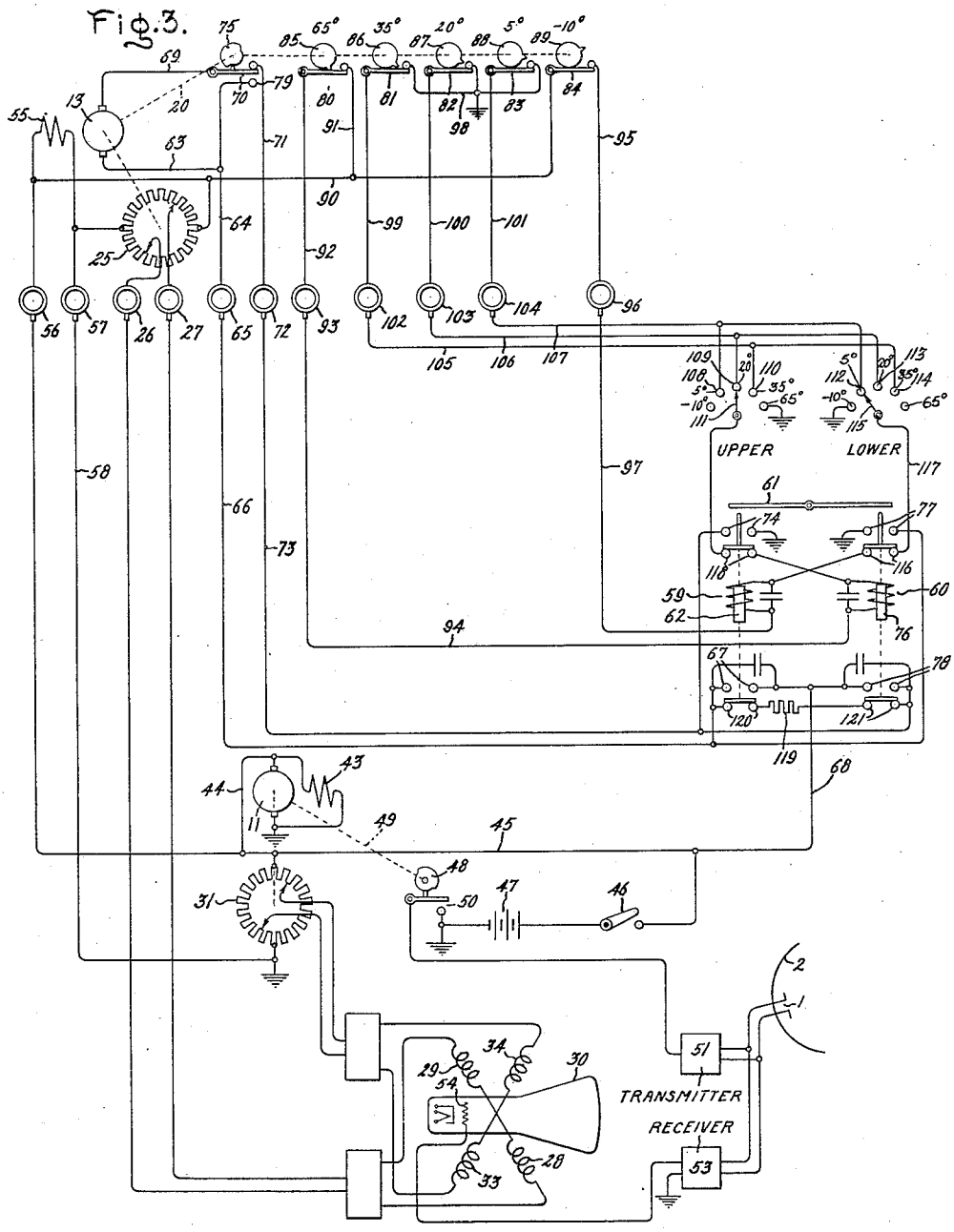
Inventor:
Martin A. Edwards,
by Harry E. Dunham
His Attorney.

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Fig. 3.



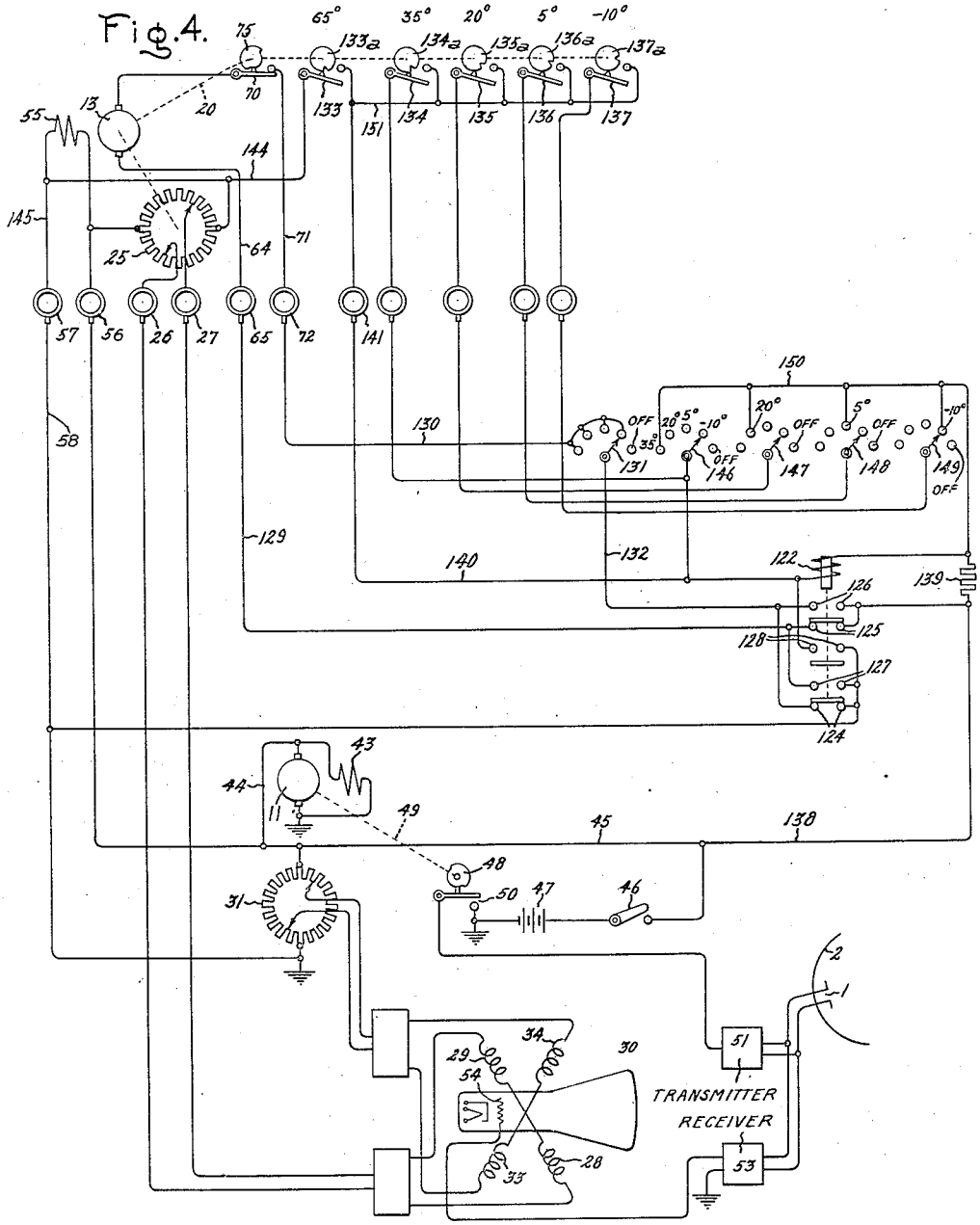
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ANTENNA

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Fig. 4.



Inventor:
Martin A. Edwards,

by Harry E. Dunham
His Attorney.

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ANTENNA

Martin A. Edwards, Scotia, N. Y., assignor to General Electric Company, a corporation of New York

Application October 3, 1942, Serial No. 460,590

6 Claims. (Cl. 250—11)

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The present invention relates to directional scanning antennas, known as scanners or spinners, for use in radio locating equipment.

In use the antenna is rotated in azimuth while the elevation may be continuously varied so the antenna transmits or receives radio waves from a sector of a spherical sector coordinated with the azimuth and elevation of the antenna.

It is desirable that the antenna be rotatable in azimuth at a high speed, that the elevation be controllable through a wide angle, and that the support for the antenna cause a minimum of interference with the radio waves. In prior constructions the desired speed has been prevented by excessive vibration, and the support has caused interference with the radio waves at some elevations.

The object of my invention is to provide an improved antenna construction which is mechanically balanced so as to permit the desired high speed rotation, which has an improved control, and which has a support causing a minimum of interference.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My 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 drawings in which Fig. 1 is a perspective rear view of an antenna embodying my invention; Fig. 2 is an elevation, partly broken away, of the turntable; and Figs. 3 and 4 are control diagrams.

Referring to the drawings, there is shown an antenna 1 projecting along the axis of a parabolic reflector 2. The antenna and its associated reflector comprise a parabolic antenna unit which transmits or receives radio waves along a narrow beam concentric with the axis of the reflector. The antenna and reflector, which preferably is parabolic in form, are supported for tilting about a horizontal axis so as to vary the elevation of the antenna by trunnions 3 and 4 associated with brackets 5 and 6 fixed to a reinforcing channel 5a on the back of the reflector. The trunnions are at the upper ends of standards 7 rising from a turntable 8 journaled for rotation on a vertical axis (in azimuth) by ball bearings 9 (Fig. 2) carried in a base 10. The antenna is rotated in azimuth by a motor 11 on the base having a pinion 11a driving a crown gear 12 fixed to the turntable. The antenna is tilted about the axis of the trunnions 3 and 4 to vary its elevation by a

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reversible motor 13 driving a countershaft 14 through reduction gearing 15 and connected to the antenna through a crank arm 16 fixed to the countershaft which moves a link 17 connected to a crank arm 18 fixed to the channel 5a on the back of the reflector 2.

The elevation of the antenna is controlled by a cam shaft 20 carried in a frame 21 on the housing for the reduction gearing 15 and having a gear sector 22 which meshes with a gear sector 23 fixed to the countershaft 14. The cam shaft 20 accordingly moves through the same angle as the countershaft 14 and at any instant has a position corresponding to the elevation of the antenna. The cam shaft 20 is connected through bevel gears 24 to a rotating potentiometer 25 supported on the turntable and connected through slip rings 26 and 27 (Figs. 3, 4) to coils 28 and 29 which shift the beam of a cathode ray tube 30 vertically in accordance with the elevation of the antenna. A similar rotating potentiometer 31, supported on the base 10, driven at the same speed and in phase with the turntable by reduction gearing having a pinion 32 meshing with the gear 12 on the turntable, is connected to coils 33 and 34 which shift the beam of the cathode ray tube horizontally in accordance with the azimuth of the antenna. Through the rotating potentiometers 25 and 31 the position of the trace on the cathode ray tube screen is directly related to or coordinated with the azimuth and elevation of the antenna.

The electrical connection to the antenna is through a coaxial transmission line 35 which extends up through the center of the turntable and in through the center of the trunnion 3 and the back of the reflector 2 to the antenna. A rotating joint 36 at the trunnion 3 and a similar rotating joint (not shown) at the turntable permit the necessary relative movement between the parts of the transmission line.

The antenna presents a difficult balance problem. For effective scanning it must be rotated at a high speed and the elevation must be capable of continual change between rather wide limits. In the particular antenna illustrated the antenna is rotated in azimuth at a speed of 360–400 R. P. M. and is tilted in elevation between limits of −10° and +65° from the horizontal at a rate of 30° sec. (5 R. P. M.). The structural parts, as obvious from the drawings, are not symmetrical about the axis of rotation. The mechanism for varying and controlling the elevation of the antenna (the motor 13, gearing 15, cam shaft 20 and its associated gearing, link 17, potentiometer

25, etc.) is mounted back of the axis of the turntable as viewed from the front of the reflector so as to provide a clearance permitting tilting of the reflector to an angle below the horizontal (or above the horizontal if the antenna is inverted and suspended from a top support). For the same reason the standards 7 may be shifted or bent toward the back of the turntable. The center of gravity of the antenna 1 and its associated reflector 2 is forward of the axis of the turntable. The link 17 and the associated crank arms 16 and 18 occupy different positions for each elevation of the antenna and accordingly introduce a variable unbalance.

It has been found that the antenna can be balanced for satisfactory operation at the desired high speeds by counterbalance weights 37, 38, 39, and 40. The counterbalance weight 37 is carried by arms 41 projecting from the back of the reflector and holding the weight in line with the antenna 1. The counterbalance weight 37 shifts the center of gravity of the antenna and reflector to a point slightly forward of the turntable axis as viewed from the front of the reflector. The balance weight 37, the antenna 1, and the reflector 2 are equivalent to a weight directly over the axis of the turntable and an additional weight on the antenna 1 in front of the reflector. If the counterbalance weight 37 is large enough to bring the center of gravity of the weight of the antenna and the reflector directly above the axis of the turntable, the operation will be improved if an additional balance weight is fastened to the antenna in front of the reflector. In the present construction the balance weight 37 is accordingly equivalent to this larger balance weight and the additional weight on the antenna. The balance weight 38 on the trunnion 4 acts as a counterbalance for the transmission line 35 and the rotating joint 36. The balance weight 39 carried by an arm 42 depending from the channel 5a at right angles to the arms 41 acts as a counterbalance for the link 17 since it has a movement opposite that of the link. The counterbalance weight 40 is fixed to the front edge of the turntable, and it, together with the unbalanced weight of the antenna reflector and weight 37 (in front of the turntable axis as described above), counterbalances the weight of the motor 13 and the associated parts on the back of the turntable. The unbalance due to the motor 13 and its associated parts should theoretically be counterbalanced by an equal and opposite weight at the front of the turntable. If this were done the weight 40 would be above the turntable and would interfere with the tilting of the reflector unless the trunnions 3 and 4 were raised further above the turntable. Since space is at a premium a more compact antenna assembly is obtained by counterbalancing the motor 13 and its associated parts with the balance weight 40 (below the center of gravity of the motor 13, etc.) and the unbalanced weight of the antenna 1, reflector 2, and weight 37 (above the center of gravity of the motor 13, etc.).

Because the center of gravity of the antenna, reflector, and balance weight 37 is in front of the turntable axis, the counterbalancing effect varies with the elevation of the antenna. This is compensated by the weight 39 which has an effect cancelling the variation due to the elevation of the antenna.

With the balance weights as shown it is possible to distribute the weight so the moment of inertia of the entire rotating system about the mechanical axis of rotation is greater than the moment of inertia about a cross axis through the center of gravity of the system so the system rotates stably about its mechanical axis. As indicated in the description, the functions of the balance weights are not limited to counterbalancing certain parts, and for best results the weights should be varied experimentally for each antenna system. The location of the balance weights and the arrangement of the parts is, however, such that only a small amount of experimentation should be required.

The control diagrams of Figs. 3 and 4 are quite similar except in the arrangement for selecting the range of elevation of the antenna. Corresponding parts in the control diagrams are accordingly indicated by the same reference numerals.

In each of the control diagrams the azimuth motor 11 is a direct current motor having a field winding 43 shunted across the armature terminals, one of which is grounded and the other of which is connected through conductors 44 and 45 to a switch 46 in the high side of a direct current power supply 47. The azimuth motor accordingly operates continuously when the switch 46 is closed. In addition to rotating the antenna in azimuth, as described above, the azimuth motor 11 through a suitable connection indicated by the dotted line 49 rotates a cam 48 which controls a switch 50 in circuit with the transmitter, indicated by the block 51, and arranged so that the transmitter is cut off during part of the azimuth range of the antenna. For example, the antenna might be mounted on a ship in a position such that the structure of the ship blocked the antenna beam during part of its azimuth range. In Fig. 2 the cam 48 and the switch 50 comprise a slip ring with a suitable brush (not shown) at the bottom of a stack of slip rings fixed to the underside of the turntable 8 around a supporting sleeve 52. The other slip rings in the stack are connected to the parts on the turntable. The receiver, indicated by the block 53, is not controlled by the switch 50 but is on at all times since there is no need for cutting the receiver off.

During the rotation of the antenna in azimuth the transmitter 51 is effective to transmit directional pulses of radio waves throughout the desired azimuth range. Reflections of the transmitted waves picked up by the receiver 53 are translated in frequency and rectified and supplied to the grid 54 of the cathode ray tube 30 to modulate the beam of the cathode ray tube so as to provide the desired indication on the cathode ray tube screen. As explained above, the position of the cathode ray tube beam is controlled by the coils 28, 29, 33, and 34 so that it is coordinated with the azimuth and elevation of the antenna.

The elevation motor 13 has a field winding 55 connected through slip rings 56 and 57 and conductors 45 and 58 to the high and grounded sides of the power supply 47.

The difference between the control diagrams of Figs. 3 and 4 lies in the manner of controlling the connections to the armature of the elevation motor 13 so as to control the elevation of the antenna.

In Fig. 3 the armature of the elevation motor 13 is controlled by reversing relays 59 and 60 having an interlock 61 which prevents simultaneous energization. When the relay 59 is energized, its armature 62 is raised from the normal position illustrated, completing a circuit to the elevation

motor armature which extends from one side of the armature through conductors 63, 64, slip ring 65, conductor 66, contacts 67, and conductor 68 to the high side of the power supply, and from the other side of the armature through conductor 69, limit switch 70, conductor 71, slip ring 72, conductor 73, and contacts 74 to ground. Energizing the relay 59 causes the elevation motor 13 to run in the direction to depress or lower the antenna. When the relay 60 is energized, its armature 76 is raised, completing a circuit to the elevation motor armature which extends from one side of the armature through conductors 63 and 64, slip rings 65, conductor 66, and contacts 77 to ground, and from the other side of the armature through conductor 69, limit switch 70, conductor 71, slip ring 72, conductor 73, contacts 78, and conductor 68 to the high side of the power supply. When the relay 60 is energized, the elevation motor runs in the direction to raise the elevation of the antenna.

The limit switch 70 is controlled by a cam 75 on the cam shaft 20. If the antenna should pass its upper or lower limit of elevation, the cam 75 moves the switch 70 to contact 79, short circuiting the elevation motor armature and bringing it quickly to rest by dynamic braking so as to prevent travel beyond the desired limits. The limit switch is a safety device which is not normally in use.

The elevation of the antenna is controlled by normally closed switches 80, 81, 82, 83, and 84 which are controlled by cams 85, 86, 87, 88, and 89 on the cam shaft 20 arranged to open the switches at the arbitrarily selected degrees of elevation indicated above the respective cams. The switch 80 which controls the upper limit of elevation of the antenna is in series with the coil of the relay 60 which causes elevation of the antenna and at the upper limit opens the circuit through the relay and causes it to open the circuit to the elevation motor. The circuit through the switch 80 extends from conductor 90, connected to the high side of the power supply through the slip ring 56, through conductor 91, switch 80, conductor 92, slip ring 93, and conductor 94 to the relay 60. The switch 84 which controls the lower limit of elevation of the antenna is similarly in series with the coil of the relay 59 which causes lowering of the antenna through a circuit which extends from conductor 90 through switch 84, conductor 95, slip ring 96, and conductor 97 to the relay 59. The switches 81, 82, and 83 which control the elevation of the antenna intermediate its upper and lower limits are connected to common ground conductors 98 respectively in series with conductors 99, 100, and 101, slip rings 102, 103, and 104, and conductors 105, 106, and 107 to contacts 108, 109, 110 of an upper limit selector switch 111 and contacts 112, 113, and 114 of a lower limit selector switch 115. The contacts of the selector switches 111 and 115 are labeled in degrees corresponding to the switches so as to aid in understanding the operation. It is obvious that the degrees are arbitrarily chosen.

In use the elevation motor runs in one direction until the desired limit of travel is reached, at which it is reversed and runs to the other limit. The extreme upper and lower limits are controlled as described above by the switches 80 and 84 which open at the respective limits. At the upper limit the switch 80 opens the circuit to the relay 60, and when the armature 76 drops to the position illustrated the relay 59 is energized through a circuit which extends from conductor 90, connected to the high side of the power supply, through switch 84, conductor 95, slip ring 96, conductor 97, relay 59, contacts 116, conductor 117, and lower limit selector switch 115 to ground. When operating between the extreme upper and lower limits the selector switches 111 and 115 will be connected to the grounded contacts corresponding to the upper and lower limits. When the relay 59 picks up, the elevation motor is energized in the direction to lower the antenna. Upon reaching the lower limit the switch 84 opens, opening the circuit to the relay 59 and causing its armature 62 to return to the illustrated position. In this position the relay 60 is energized through a circuit extending from the high side of the power supply through conductors 90, 91, switch 80, conductor 92, slip ring 93, conductor 94, relay 60, contacts 118 and selector switch 111 to ground.

It is sometimes desirable that the scanning be limited to a range of elevation intermediate the upper and lower limits. This intermediate range is controlled by the selector switches 111 and 115 through the normally closed switches 81, 82, and 83 which are opened at the designated limits. The operation of the switches will be explained for the position illustrated in which the upper limit selector switch 111 is set at 20° and the lower limit selector switch 115 is set at 5°. When the antenna is moving toward the 20° position, the relay 59 is deenergized and the relay 60 is energized through a circuit extending from the high side of the power supply through conductors 90, 91, switch 80, conductor 92, slip ring 93, conductor 94, relay 60, contacts 118, selector switch 111, contact 109, conductor 106, slip ring 103, switch 82, and ground conductor 98. At the 20° limit the switch 82 opens, deenergizing the relay 60 and causing the energizing of the relay 59 through a circuit which extends from the high side of the power line through conductor 90, switch 84, conductor 95, slip ring 96, relay 59, contacts 116, conductor 117, lower limit selector switch 115, contact 112, conductor 107, slip ring 104, conductor 101, switch 83, and ground conductor 98. At the 5° limit the switch 83 opens, deenergizing the relay 59 and energizing the relay 60 through the circuit described above.

When it is desired that the antenna be kept at any one of the designated limits, both selector switches 111, 115 are moved to the same position, thereby opening the circuits to the relays 59 and 60 at the selected position. Both relays then move to the position illustrated in which the conductors 66 and 73 in series with the elevation motor armature are short circuited through a dynamic braking resistor 119 and contacts 120 and 121. The dynamic braking quickly brings the elevation motor to rest at the desired angle.

The control of Fig. 4 is not so flexible as Fig. 3 since the upper limit of elevation of the antenna is fixed and only the lower limit is variable.

As in Fig. 3 the elevation motor armature 13 is connected through the safety switch 70 which is controlled by the cam 75 on the cam shaft 29 so that the safety switch opens when the antenna moves beyond the upper and lower limits.

The circuit to the elevation motor slip rings 65 and 72 is controlled by a reversing relay 122 having contacts 124 and 125 energizing the motor in the direction to raise the antenna, contacts 126 and 127 energizing the motor in the direction to lower the antenna, and holding contacts 128 for holding the relay in its raised position in which the contacts 126 and 127 are closed. The circuit to the motor extends from the slip

ring 65, connected to one side of the motor, through a conductor 129 to either the contacts 125 or 127 and from the slip ring 72, connected through the safety switch 70 to the other side of the motor, through a conductor 130, a selector switch 131, and a conductor 132 to either the contacts 124 or 126. The contacts 125 and 126 are alternatively connected to the high side of the power supply, and the contacts 124 and 127 are alternatively connected to the low side of the power supply.

The elevation motor is controlled at its upper limit by a normally open switch 133, and at the selected lower limits by normally open switches 134, 135, 136, 137, each of the switches being controlled by cams 133*a*, 134*a*, 135*a*, 136*a* and 137*a* on the cam shaft 29 each of which causes its respective switch to be closed only at the designated angular position of the antenna. For convenience the switches are labeled in the arbitrarily selected degrees of elevation of the antenna corresponding to the positions at which the switches are closed.

When the relay 122 is in the deenergized position illustrated, the elevation motor 13 is rotating in the direction to raise the antenna. When the antenna reaches its upper limit, the switch 133 closes and energizes the relay 122 through a circuit which extends from the high side of the power supply through switch 46, conductor 138, resistance 139, the coil of relay 122, conductor 140, slip ring 141, switch 133, and conductors 144 and 145 connected to the slip ring 57 which is connected to the grounded side of the power supply. This causes the relay to pick up, opening the contacts 124 and 125 and closing the contacts 126, 127, and 128. The contacts 128 are holding contacts which hold the relay in its raised position. The elevation motor now runs in a direction to lower the antenna, and the switches 134, 135, 136, and 137 will be momentarily closed at the designated positions. The switches 134 to 137 are respectively connected to selector switches 146, 147, 148, and 149 which are moved in unison with the selector switch 131, and each of which has a contact connected through a conductor 150 to one side of the relay coil 122. The other side of the relay coil 122 is connected through the conductor 140 and slip ring 141 to a conductor 151 connected to the other side of each of the switches. When the antenna reaches a position corresponding to the setting of the lower limit selector switches 146—149, the closure of the corresponding switch short circuits the coil of the relay 122 and causes it to drop to the position illustrated in which the elevation motor is energized in the direction to raise the antenna.

In the Fig. 4 construction the antenna accordingly is continuously raised and lowered between the upper limit and the selected lower limit. Each of the selector switches has an off position in which the elevation motor is deenergized. When the selector switches are moved to the off position the antenna accordingly will remain in the position to which it has been moved.

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

1. In combination, an antenna, a reflector therefor, bearings supporting said antenna and reflector for tilting about a horizontal axis, a turntable carrying the bearings for rotating the reflector about a vertical axis, mechanism carried by the turntable for varying the tilting of the reflector within predetermined angular limits, said mechanism having a moment of inertia about said vertical axis variable with the tilt of said reflector, a balance weight on the reflector for counterbalancing forces due to the tilting of the reflector, and a second balance weight movable laterally of said vertical axis in accordance with the tilt of said antenna to compensate for variations in said moment of inertia.

2. In combination, an antenna reflector unit for rotation in azimuth and tilting in elevation so as to scan an arc determined by its elevation, a turntable rotatable on a vertical axis supporting the antenna unit for rotation in azimuth, mechanism carried on and rotatable with the turntable for tilting the antenna unit in elevation within predetermined angular limits, said mechanism being behind said vertical axis with respect to the front of said reflector and having a horizontal component of movement, a balance weight mounted on the back of the reflector and so proportioned that the combined center of mass of said weight and said units lies in front of said vertical axis, a second balance weight on the front of said turntable to balance said unit and said first weight about said vertical axis, and a third balance weight mounted upon said reflector and having a horizontal component of movement therewith opposite to that of said mechanism.

3. In combination, a turntable rotatable on a vertical axis, a directional antenna supported on the turntable for tilting on a horizontal axis, means for rotating the turntable, a reversible motor on the turntable for rotating the antenna on its horizontal axis, and a control for reversing the motor at upper and lower limits whereby the antenna scans a sector of a sphere comprising means on the turntable responsive to the tilt of the antenna, means remote from the turntable for selecting the limits, and reversing means controlled by said tilt responsive and limit selecting means.

4. In combination, an antenna and reflector unit, a turntable rotatable about a vertical axis and having trunnions supporting said unit for tilting about a horizontal axis, mechanism carried by said turntable for varying the tilt of said unit within predetermined angular limits, said mechanism having a moment of inertia about said vertical axis variable with said tilt, and a balance weight mounted upon said turntable for horizontal movement in accordance with the tilt of said unit and in a direction to compensate for variation of said moment of inertia.

5. In combination, an antenna and reflector unit, a turntable rotatable about a vertical axis and having trunnions supporting said unit for tilting about a horizontal axis, mechanism mounted upon said turntable on one side of said vertical axis and having a horizontal component of movement to vary the tilt of said unit within predetermined angular limits, and a balance weight mounted upon said reflector on the opposite side of said vertical axis and having a horizontal component of movement opposite to that of said mechanism, whereby variation of the moment of inertia of said mechanism about said vertical axis is compensated by a similar variation of the moment of inertia of said balance weight.

6. In combination, an antenna and reflector unit having the antenna in front of the reflector, trunnions supporting the unit for tilting about a horizontal axis, a turntable rotatable about a vertical axis and supporting said trunnions, a motor mounted upon said turntable behind said

vertical axis with respect to the front of said reflector, a link connected between said motor and said reflector for varying the tilt of said unit within predetermined angular limits, said link having a horizontal component of movement whereby its moment of inertia about said vertical axis varies in accordance with said tilt, a balance weight arranged in conjunction with said unit to counterbalance the weight of said motor about said vertical axis, and a weight mounted upon said reflector and movable horizontally in accordance with the tilt of said reflector to compensate said variation of said moment of inertia.

MARTIN A. EDWARDS.

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