

March 11, 1947.

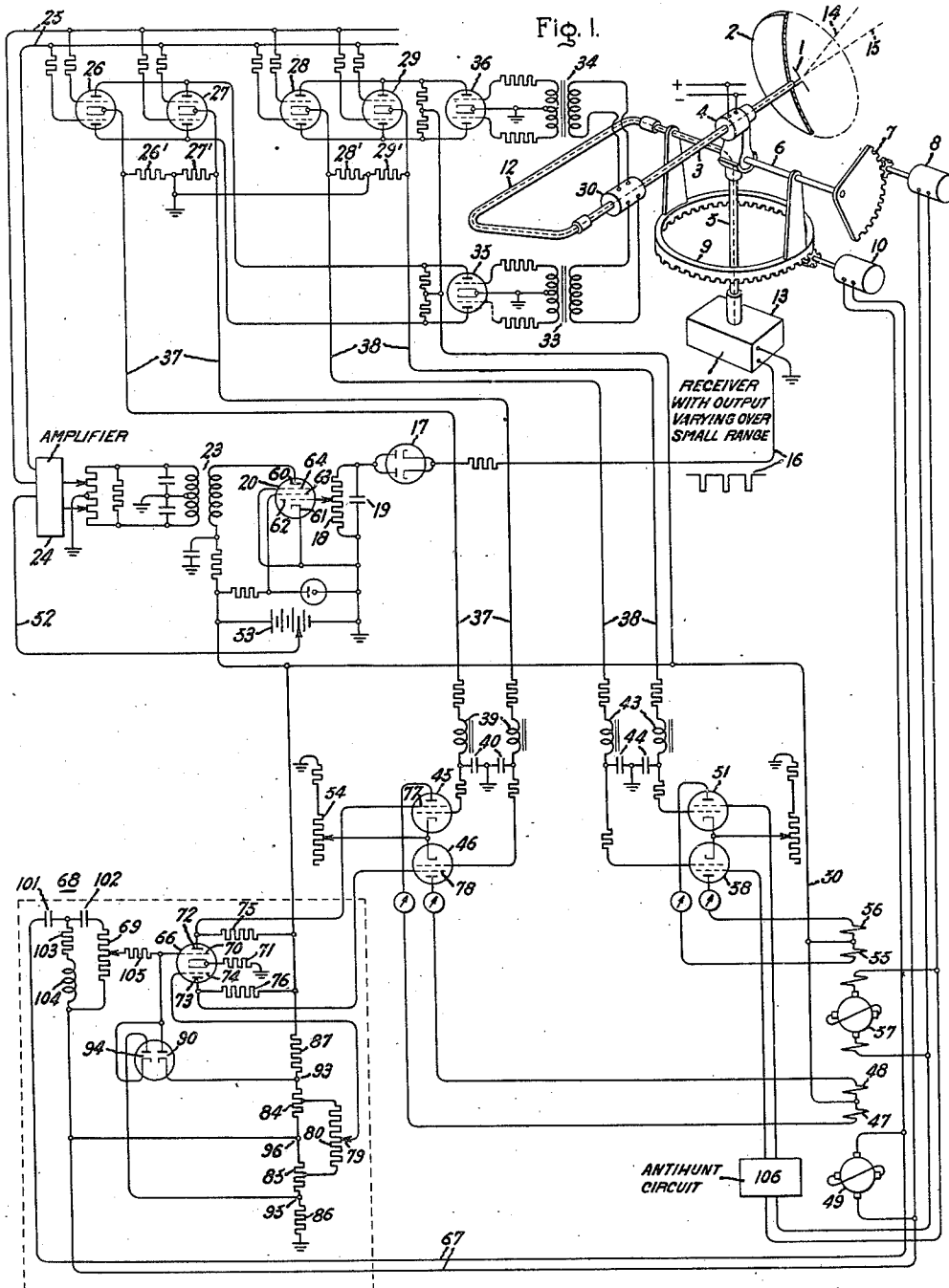
S. GODET

2,417,248

PULSE DIRECTION FINDER

Filed July 30, 1943

2 Sheets-Sheet 1



Inventor:
Sidney Godet,
by *Harry E. Dunkham*
His Attorney.

March 11, 1947.

S. GODET

2,417,248

PULSE DIRECTION FINDER

Filed July 30, 1943

2 Sheets-Sheet 2

Fig. 2.

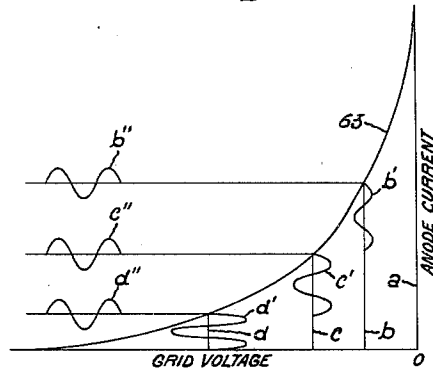


Fig. 3.

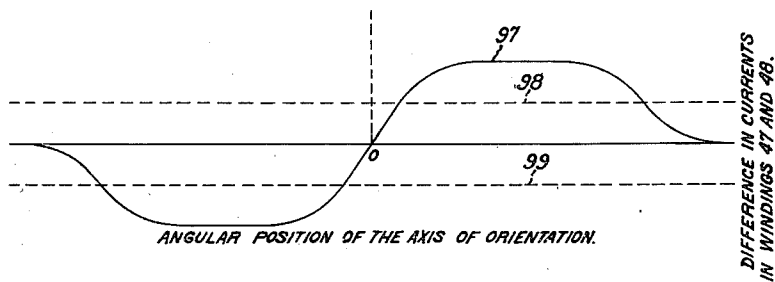
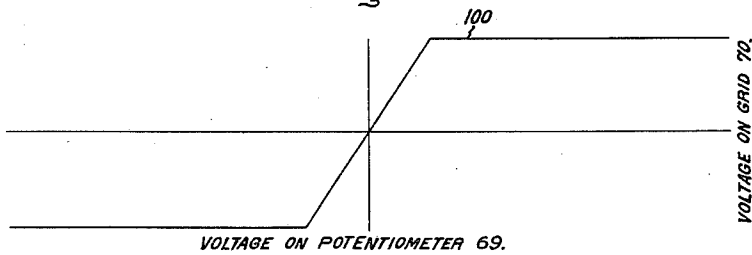


Fig. 4.



Inventor:
Sidney Godet,
by *Harry E. Dunham*
His Attorney

UNITED STATES PATENT OFFICE

2,417,248

PULSE DIRECTION FINDER

Sidney Godet, Albany, N. Y., assignor to General Electric Company, a corporation of New York

Application July 30, 1943, Serial No. 496,740

5 Claims. (Cl. 250—1.54)

1

My present application is a continuation-in-part of my application Serial No. 414,126, filed October 8, 1941, entitled "Directive radio system" and which is assigned to the assignee of my present application.

In my parent application a directive antenna is disclosed having an axis of orientation arranged to be varied in different planes and having an axis of directivity, or a direction from which the antenna has maximum effect, extending at a small angle to said axis of orientation. Means are provided to rotate the axis of directivity about the axis of orientation to produce a cyclically varying response of the antenna to waves received from any direction other than the direction of said axis of orientation. The time phase relation of this cyclical variation is then utilized to control the orientation of the antenna to maintain said axis of orientation in the direction from which waves are received.

My present invention has for its object to effect certain improvements in the device disclosed in that application whereby control of the orientation of the antenna disclosed therein in response to the direction from which radio waves are received is rendered somewhat more stable under certain varying conditions.

The intensity of waves received in the antenna, of course, varies in accord with the distance from which they are received, in accord with the orientation of the antenna with respect to the direction from which they are received and, where the received waves are echoes of radiated pulses, in dependence upon the size, character, position, or attitude, of the reflecting surface producing the echo.

An object of my present invention is to improve the action of the apparatus in controlling the orientation of the antenna during variations in intensity of the received waves such as those produced by changes in the attitude of the object producing the echo.

Another object of my invention is to improve the action of the apparatus when varying the orientation of the antenna through the direction from which waves are received to assure more positive stopping of the movement of the antenna in agreement with said direction.

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

2

taken in connection with the accompanying drawing in which Fig. 1 represents an embodiment of my invention and Figs. 2, 3 and 4 represent certain characteristics pertaining to its operation.

Referring to Fig. 1 of the drawing, I have represented at 1 therein an antenna arranged within a parabolic reflector 2, this antenna and reflector being arranged for rotation with a shaft 3 which is driven by a motor 4. The shaft 3 is arranged to be oriented in the horizontal plane about a vertical axis 5 and to be oriented in the vertical plane about a horizontal axis 6. The horizontal axis 6 carries a cam sector 7 which is driven by a motor 8 thereby to vary the position of the shaft 3 in the vertical plane. The shaft 6 is supported from a ring gear 9, which may be rotated by a motor 10 to vary the position of the shaft 3 in the horizontal plane.

The antenna 1 is connected by means of a concentric transmission line extending along the axis of shaft 3 through connection member 12 and thence along shaft 6 and downward through vertical shaft 5 to radio equipment 13. This equipment 13 may comprise receiving equipment and, if desired, a transmitting equipment cooperating with the antenna.

The antenna 1 and the parabolic reflector 2 are arranged to produce maximum response of the antenna to waves received from a direction 14, which extends at a small angle to the direction 15 of the shaft 3, the latter of which I shall refer to as the axis of orientation of the equipment.

The direction 14 of maximum response of the antenna is rotated about the axis of orientation 15 and transcribes the surface of a cone. Waves received from the direction of orientation 15 produce a constant response in the antenna notwithstanding this rotation, but waves received from any other direction produce a cyclically varying response in the antenna, the frequency of this cyclically varying response being equal to the frequency of rotation of the antenna which may be 30 cycles per second. The time phase relation of the cyclical response is dependent upon the direction from which the waves are received with respect to the direction of the axis of orientation 15. Thus, for example, if the waves are received from a direction below the axis 15 this cyclical response has one time phase relation. If the waves be received from a direction directly above the axis 15 this time phase relation is displaced by 180°, etc.

In the applications in which I particularly contemplate my invention to find its greatest utility,

the antenna 1 is employed both as a radiator and as a receiver, the equipment 13 supplying periodic pulses of, for example, one microsecond duration, occurring at a frequency of 2000 pulses per second, which pulses are radiated from the antenna in the form of a beam and which may impinge upon remote objects such as airplanes and produce echoes which are received upon the antenna 1 during the periods between the radiated pulses and which are transmitted to the equipment 13 where they are translated to unidirectional pulses.

These received pulses, as previously described, vary in intensity cyclically in a time phase relation dependent upon the direction of the received waves. The unidirectional pulses, which may be of negative polarity and which appear at the output of the receiving equipment 14, are indicated at 16 and may be supplied through a diode 17 to produce a unidirectional voltage upon a resistance 18 shunted by a condenser 19. This resistance may be of the value of one megohm and the condenser of .01 microfarad capacity. The cyclical variations which appear upon the resistance 18 are reproduced in the anode circuit of a discharge device 20 and are supplied through a transformer 23 and amplifier 24 in balanced relation with respect to a fixed voltage above ground between a pair of conductors 25. This fixed voltage above ground may, for example, be seventy-five volts supplied from source 53 over conductor 52 to the two conductors 25. These conductors 25 are connected to the different grids of four pairs of electron discharge devices 26, 27, 28 and 29. The voltages are supplied to the grids of devices in envelopes 26 and 28 in like phase and to the grids of devices in envelopes 27 and 29 in the opposite phase, as shown by the arrangement of connections on the drawing. The anodes of these discharge devices are energized with alternating current having the same frequency as the cyclical variations but having constant time phase relation. The anodes of the discharge devices in envelopes 26 and 27 are supplied with alternating current from one winding of a two-phase generator 30 mounted on and driven by the shaft 3 and which produces voltage having the frequency of the cyclical variation. The anodes of the devices 28 and 29 are supplied from a second winding on this same generator. The voltages produced on these windings are in quadrature relation and are supplied respectively through transformers 33 and 34 and balanced amplifiers 35 and 36 to the opposite anodes in the different pairs of discharge devices 26, 27; and 28, 29.

These discharge devices 26, 27, 28 and 29 are connected to operate in the manner of a rectifying commutator, as described in my above referred to patent application, to produce a unidirectional voltage between a pair of conductors 37 connected to the cathodes of devices 26 and 27, and between a pair of conductors 38 connected to the cathodes of devices 28 and 29, these voltages having polarity and magnitude dependent upon the direction from which the waves are received with respect to the axis of orientation 15 in a respective plane. These voltages are produced by variations in current in cathode resistors 26', 27', 28' and 29' each of which is connected between ground and the cathodes of the discharge devices in the respective envelopes 26, 27, 28, 29. This voltage between conductors 37, connected to opposite terminals of resistances 26' and 27', is supplied through choke coils 39 across a pair of condensers 40. Similarly the voltage

between conductors 38, connected to opposite terminals of resistances 28' and 29', is supplied through choke coils 43 across condensers 44.

The voltage on condensers 40 may have a certain polarity when the received waves arrive from a direction to the right of the axis of orientation 15 in the horizontal plane and the opposite polarity when the waves are received from a direction to the left of the axis 15 in the horizontal plane. Similarly the voltage on condensers 44 may have a certain polarity when the waves are received from a direction below the axis of orientation 15 and the opposite polarity when they are received from a direction above the axis 15. Of course, the magnitude of these voltages is dependent upon the amount of the deviation of the axis of orientation from the direction from which the received waves arrive and is zero when it agrees with that direction.

The voltage on condensers 40 is supplied between the control grids of a pair of push-pull connected electron discharge devices 45 and 46 the anodes of which are connected through respective field windings 47 and 48 of an amplidyne generator 49, and through conductor 50 to the positive terminal of a source of operating potential 53 the negative terminal of which is connected to ground and thence through variable resistance 54 to the cathodes of the two discharge devices 45 and 46. This generator 49 generates a voltage having a polarity and magnitude dependent upon the relative energization of its two field windings 47 and 48 and which voltage is zero when these windings are equally energized. This voltage is supplied to the motor 10 to rotate the antenna 1 in the horizontal plane about the vertical axis 5 to direct the axis of orientation 15 toward the direction from which the waves are received.

The voltage on condensers 44 is likewise supplied between the two control electrodes of discharge devices 51 and 52 the anodes of which are connected through respective field windings 55 and 56 of amplidyne generator 57 to the conductor 50 extending to the source of anode operating potential. The amplidyne generator 57 produces a unidirectional voltage having magnitude and polarity dependent upon relative energization of the two field windings 55 and 56 and this voltage is supplied to the motor 8, which rotates the shaft 6 to maintain the axis 15 directed in the direction from which waves are received in the vertical plane. Of course, when the axis 15 is directed in the direction from which the received waves arrive the voltage on condensers 40 and 44 disappears and the motors 8 and 10 become deenergized and stop.

In an echo system such as that here described the waves received from the antenna have an intensity dependent upon the range to the object producing the echo. They also have intensity dependent upon the particular surface of the remote object which produces the echo, and the attitude of that surface with respect to the direction of propagation of the impinging pulses. The surface may be small or large and the remote object may have several surfaces which may change as the object moves thereby varying the intensity of the echo over a considerable range and at a rapid rate. Of course, as previously described, the intensity varies cyclically with the rotation of the antenna.

It may occur that during the operation of the equipment in response to waves received from a remote airplane, for example, the received echo

becomes very weak because of a change in position or attitude of the reflecting surface of the airplane. When this occurs the control of the orientation of the antenna in response to the echo may become weak or loose; that is, the equipment tends to lose its relationship to the direction from which the waves are received. On the other hand, if the remote aircraft varies to a position such that large reflecting surfaces are exposed to the impinging impulses and a large echo is produced, then the control may become too rigid such that the action is jerky, or unsmooth, and to some extent unsatisfactory. These effects are to a large extent obviated by the equipment described due to the action of the automatic gain control system of the equipment 13 and that of the diode 17 and the discharge device 20.

The receiver of the equipment 13 is preferably provided with an automatic gain control system of any conventional type capable of maintaining the output from the receiver within a narrow range of variation in intensity notwithstanding variations in the range of the object producing the echo. Variations in the received intensity produced by variations in range occur relatively slowly and thus such an automatic gain control system may have a long time constant. This automatic gain control system, however, due to its long time constant, and the slowness of its action, cannot correct or compensate for variations in the output intensity produced by variations in the attitude of the remote reflecting object, surface, or aircraft since such variations may occur very rapidly. Neither does it remove the 30 cycle modulation produced by rotation of the antenna. The diode 17 is poled to be rendered conductive during each of the negative unidirectional pulses appearing at the output of the receiver 14 thereby to produce a bias voltage upon the resistance 18, which varies with the variations in the envelope of the received pulses. The device 20 is a remote cut-off pentode of any suitable type but preferably has an anode 60, a cathode 61 connected to ground and to the lower terminal of resistance 18, a control electrode 62 connected to a variable tap on resistance 18, a screen grid electrode 63 connected to the positive terminal of source 53, and a suppressor electrode 64 connected to the cathode.

This device has an anode current-grid voltage characteristic, the lower curved portion of which is represented by the curve 65 of Fig. 2 in which anode current is plotted as ordinates against grid voltage as abscissae. The different vertical lines *a*, *b*, *c* and *d* represent different values of voltage which appear upon the resistance 18, the line *a* corresponding to zero voltage, for example, and the lines *b*, *c* and *d* corresponding to different increasing values of voltage negative with respect to zero. The vertical lines *a*, *b*, *c*, and *d* intersect the curve 65 at different points in the lower curved portion thereof, and thus at points of decreasing slope.

Of course, this unidirectional voltage on resistance 18 varies in accord with the cyclical variations produced by rotation of the antenna, these cyclical variations being represented in Fig. 2 at *b'*, *c'* and *d'* when the axis 15 is at a fixed small angle with the target. When the received pulses are relatively weak due to a certain attitude of the remote reflecting surface, these cyclical variations *b'* are relatively small as is the bias voltage *b*, and the cyclical variation is reproduced in the anode circuit of the discharge device

with the intensity indicated by the curve *b''* in Fig. 2. When the received pulses are of greater intensity, as when the bias voltage is of the value *c* or *d*, then the cyclical variations are of the intensity indicated at *c'* and *d'*. They are reproduced in the anode circuit of the discharge device 60 with the intensity indicated at *c''* and *d''*.

It will be observed that the intensity of the cyclical variations *b'*, *c'*, *d'*, as indicated in Fig. 2, may vary over a considerable range, as, for example, 4 or 5 to 1, without varying materially the intensity of these variations as reproduced in the anode circuit of the device 60 as represented by the curves *b''*, *c''*, *d''*, these latter curves being of about equal amplitude notwithstanding the variation in amplitude of about 1 to 4 in the curves *b'* to *d'*. This is, of course, due to the changing slope in the characteristic curve 65 expressing the relation between anode current and grid voltage in the discharge device 60.

This means that the cyclical voltage variation which is applied to the control electrodes of the discharge devices in envelopes 26, 27, 28 and 29 is of constant intensity for a fixed error angle, that is, for a fixed angle between the axis of orientation and the direction of arrival of received waves, notwithstanding the variations in amplitude of this cyclical variation which is due to the changes in the reflecting surfaces or the attitude of the remote body from which the echo is received over a considerable range of such variations. This range may be within the narrow range of variation in output voltage of the receiver of equipment 13.

Thus the automatic volume control system of receiver 13, which may be relatively slow in its action, may compensate for any slow variations in the range to the remote echo-producing surface and may maintain its output within a narrow range of variations. The cyclical variations in the output of the receiver, varying in amplitude within this narrow range, are then supplied through the diode 17 to the device 20 and are reproduced in the output of device 20 with substantially constant amplitude for a fixed error angle notwithstanding the rapid variations in amplitude produced by changes in the reflecting surface and the attitude thereof. Thus variations in the degree of control exercised by the discharge devices 26, 27, 28, 29 over the orientation equipment 5, 6, 7, 8, 9, 10 of the antenna is much reduced and the action of the orientation equipment is more satisfactory during intensity variations in the received signal produced for the reasons mentioned. The looseness of the control during weak signals and the jerkiness of it during strong signals is substantially reduced.

In the lower left-hand portion of Fig. 1, I have shown a further discharge device 66, which is employed to eliminate hunting in the action of the orientation equipment. Voltage from the output of amplidyne generator 49 and which is supplied to motor 10 is also supplied over conductors 67 through a high pass filter 68 to a potentiometer 69, from which a variable portion of this voltage is supplied to the control electrode 70 of this discharge device 66. The high pass filter 68 is disclosed and claimed in my copending application Serial No. 445,945, filed June 5, 1942, and which is assigned to the assignee of my present application.

This discharge device 66 comprises a cathode which is connected to ground through a coupling resistance 71 and two anodes 72 and 73 operating in push-pull relation, each having associated

therewith a control grid 70 and 74, respectively. The two anodes are connected to the source of anode potential 53 through respective resistances 75 and 76. The voltage on the anode 72 is supplied to the screen electrode 77 in the discharge device 45. Similarly the voltage on the anode 73 is supplied to a control electrode 78 in the discharge device 46. These voltages vary in balanced relation due to action of the coupling resistance 71 the voltage variations on which are impressed between the control electrode 74 and cathode.

Thus voltages produced by the generator 49 of either polarity are supplied with corresponding polarity through the high pass filter 68 to the control electrode 70 where it increases or decreases the current through resistances 75 and 71 thereby producing opposite or balanced voltage variations on the anodes 72 and 73. The balanced voltage variations are applied to the screen electrodes 77 and 78 of the discharge devices 45 and 46 where these variations oppose the initial effect in the anode circuit of the devices 45 and 46 which brought about the voltage produced by the generator 49. In this way the tendency of the equipment to hunt is reduced.

The control electrode 74 is connected to a variable tap 79 on a potentiometer 80 the opposite points of which are connected to taps on resistors 84 and 85, which are connected between resistors 86 and 87 in a series bleeder circuit across the source of potential 53. By varying the contact 79 on potentiometer 80 the conductivity of the lower portion of discharge device 66 may be increased or decreased thereby varying the voltage on the control electrode 78 of the device 46. In this way any inequalities in the conductivities of the devices 45 and 46 and in the two sections of device 66, as due to aging, manufacturing variations therein, etc., may be compensated for.

The control electrode 70 of device 66 is also connected through a diode 90 to a point 93 at the lower terminal of resistance 87. This control electrode is also connected through a diode 94 to a point 95 at the upper terminal of resistance 86, the two diodes 90 and 94 being poled oppositely. The point 96, which may be midway in voltage between points 93 and 95, is connected to the lower terminal of input potentiometer 69. These diodes are provided for the purpose of preventing wide variations in potential on the control electrode 70 in either direction from the potential of point 96 due to the antihunt voltage derived from generator 49. This avoids certain undesired effects which may occur during operation of the equipment.

For example, let us suppose that a voltage of one polarity or the other is produced on condensers 40, as when axis 15 is directed at some angle other than zero to the direction of the received waves. This voltage acting through devices 45 and 46 and field windings 47 and 48 produces a voltage at the output of generator 49 of a certain polarity. The voltage of the generator 49 is supplied to the motor 10 to orient the antenna in the horizontal plane in a direction to reduce the voltage on the condensers 40, as the axis 15 approaches the direction of the received waves. The voltage of the generator, however, is also supplied through the high pass filter 68 to the control electrode 70 of device 66 where it is amplified and supplied to the screen electrodes 77 and 78 of device 45 in balanced relation and in such sense as to oppose the initial effect of this device in producing voltage by generator

49. Due, however, to the differentiating action of high pass filter 68 the voltage on grid 70 reduces at a more rapid rate than does the voltage on condensers 40, and, in fact, attains zero and reverses in polarity before the antenna reaches the point where the voltage on condensers 40 disappears. This reversal in voltage on the control electrode 70 produces a variation in voltage on the screen electrodes 77 and 78 to drive the antenna toward agreement with the direction from which the received waves arrive, when the voltage across condensers 40 disappears. The antihunt voltage on the screen grids 77 and 78 of devices 45 and 46 remains due to the action of the filter 68 and tends to drive the antenna beyond the point of such agreement. When the point of agreement is passed, however, the voltage on condensers 40 reverses and opposes the effect of the antihunt voltage and causes the antenna to be oriented smoothly into agreement with the direction of received waves when its motion stops.

If, however, the antihunt voltage be too great, as sufficiently great to exceed the effect of the voltage on the condensers 40 produced by the received signal, the signal is then insufficient to overcome the effect of the antihunt voltage with the result that the antihunt voltage may drive the antenna through the position of agreement and thence on through the position of maximum received signal and on away from the target altogether. This is prevented by biasing the diodes 90 and 94 to become conductive when the voltage on the electrode 67 exceeds a predetermined value in either direction. Preferably the diodes 90 and 94 should be biased to become conducting when the voltage on control electrode 70 exceeds a value sufficient to produce a difference in currents in windings 47 and 48 equal to half the difference that is produced by the maximum voltage on condensers 40 produced by a received signal.

The high pass filter 68 comprises series condensers 101 and 102 and a shunt branch comprising resistance 103 and an inductance 104, said elements being proportioned to pass to potentiometer 69 voltages of the frequency at which hunting may occur, for example, three cycles per second, and to exclude lower frequencies as those below a quarter of a cycle per second, such as may occur by variation of the signal due to the motion in flight of a remote aircraft. As an example, the elements of this filter may have the following values:

Condenser 101=4 microfarads
Condenser 102=1 microfarad
Resistance 103=80,000 ohms
Inductance 104=20,000 henries
Resistance 69=500,000 ohms
Resistance 105=500,000 ohms

The action above described may be somewhat better understood by reference to the curves of Figs. 3 and 4. In Fig. 3 the curve 97 represents the difference in currents produced in field windings 47 and 48 by the voltage on the condensers 40, plotted as ordinates, against the angular position of the axis of orientation, plotted as abscissae, the angle between the axis of orientation and the direction of the arriving signals being zero at the center of the figure. The difference in currents represented by the curve 97 is positive when the angle is at the right of the direction from which waves are received and negative when it is at the left. This difference in current increases substantially linearly as it passes through the zero

11

of magnitude and polarity dependent upon the position of said device relative to said direction, a motor to drive said device in said plane, a pair of electron discharge devices, means responsive to said unidirectional voltage to control the currents in said devices oppositely, means responsive to the difference in said currents to supply voltage of corresponding magnitude and polarity to said motor, a further electron discharge device having an anode, a cathode and a control electrode, means to supply said voltage between said control electrode and cathode, said further de-

12

vice being connected to control said first two devices in sense opposite to the effect of said unidirectional voltage thereby to prevent hunting, a pair of unilateral conducting devices connected between said control electrode and cathode and poled oppositely and biased to become conductive when the voltage between said control electrode and cathode exceeds a predetermined value sufficiently small that said voltage does not overcome said first mentioned unidirectional voltage in controlling said device.

SIDNEY GODET.

position and then increases at a decreasing rate to a substantially constant portion due to the action of the automatic volume control system. This current later decreases as the orientation of the antenna is varied to angles sufficiently large that the reflecting object leaves the field of the antenna. The dotted lines 98 and 99 correspond to the difference in currents produced in field windings 47 and 48 by the voltage on the control electrode 70 at which the respective diodes 90 and 94 become conducting. Thus notwithstanding that the voltage produced at the output of potentiometer 69 may be high, the voltage supplied to the control electrode 70 of the antihunt device 66 cannot vary over limits greater than that which produces the difference in the currents in windings 47 and 48 indicated by the two curves 98 and 99.

Fig. 4 represents the antihunt voltage which appears at the output of potentiometer 69 plotted as abscissae against voltage on the control electrode 70 plotted as ordinates. The antihunt voltage may increase to any desired value produced by generator 49 but the voltage on the control electrode 70, which is effective in controlling the action of devices 45 and 46, cannot exceed the values represented by curve 100 of Fig. 4. The difference in these voltages, of course, exists on resistance 105 which may be of 500,000 ohms.

Of course, similar antihunt equipment represented by the rectangle 106 is employed in connection with elevation control devices 51, 53, 57.

While I have shown a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto since various modifications both in the circuit arrangements and in the instrumentalities employed may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

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

1. In combination, a radio antenna system having an axis of orientation, means to render said antenna system more responsive to waves from a direction at a small angle to said axis than from any other, means to rotate said direction about said axis of orientation, means to radiate pulses and to receive echoes thereof on said antenna from a remote object, whereby said echoes vary cyclically in intensity in accord with said rotation and also vary in intensity in accord with the range of said remote object and in accord with the variations in the reflecting surfaces of said object with movement thereof from which said echoes are received, means to maintain the output from said receiving means within a narrow range of variation in intensity notwithstanding wide variation in range to said object, said output being subject to rapid variation over said range in response to said variation in the reflecting surfaces producing said echo, means to produce cyclical variations of constant amplitude from said output notwithstanding said variation in said output over said range, and means responsive to said cyclical variation.

2. In combination, a radio antenna system having an axis of orientation, means to render said antenna system more responsive to waves from a direction at a small angle to said axis than from any other, means to rotate said direction about said axis of orientation, means to radiate pulses and to receive echoes thereof on said antenna from a remote object, whereby said echoes vary cyclically in intensity in accord with

said rotation and also vary in intensity in accord with the range of said remote object and in accord with the variations in the reflecting surfaces of said object with movement thereof from which said echoes are received, means to maintain the output from said receiving means within a narrow range of variation in intensity notwithstanding wide variation in range to said object, said output being subject to rapid variation over said range in response to said variation in the reflecting surfaces producing said echo, means to produce cyclical variations of constant amplitude from said output notwithstanding said variation in said output over said range, and means responsive to said cyclical variations of constant amplitude to maintain said axis of orientation directed in the direction of said object during movement of said object.

3. In combination, a directive antenna having an axis of orientation, means to render said antenna more responsive to waves from a direction at a small angle to said axis than from any other direction, means to rotate said direction about said axis, a receiver connected to said antenna, means to radiate periodic pulses toward remote objects whereby echo pulses are received in said receiver varying in intensity in accord with the range of the reflecting object, in accord with variations in the reflection produced by said object in the direction of said axis and cyclically in accord with said rotation of said antenna, means in said receiver to convert said echo pulses to unidirectional pulses, variable over a small range in intensity produced principally by said variations in reflection, a discharge device having an anode, a cathode and a control electrode, means to develop from said unidirectional pulses a negative bias voltage varying over the lower curved portion of the anode current grid voltage characteristic of said device, said bias having impressed thereon said cyclical variations, the curvature of said portion of said characteristic being such that said cyclical variations appear between said anode and cathode with substantially constant intensity notwithstanding said variations in said bias over said small range, and means to control the orientation of said axis in response to said cyclical variation.

4. In combination, a device to be oriented with respect to a certain direction in a predetermined plane, means to produce a unidirectional voltage of magnitude and polarity dependent upon the position of said device relative to said direction, a motor to drive said device in said plane, a pair of electron discharge devices, means to control said devices in opposite sense in response to variations in said unidirectional voltage, means responsive to the difference in current in said electron discharge devices to energize said motor to drive said device toward said certain direction, means responsive to said energization to control said electron discharge devices in sense opposite to the sense of said control means to prevent hunting of said devices, said last means having a differentiating action with respect to said motor energization tending to drive said device beyond said certain direction, and means to limit the effect of said energization responsive means to less than the effect produced by said unidirectional voltage whereby said device is oriented in said certain direction notwithstanding said differentiating action.

5. In combination, a device to be oriented with respect to a certain direction in a predetermined plane, means to produce a unidirectional voltage