

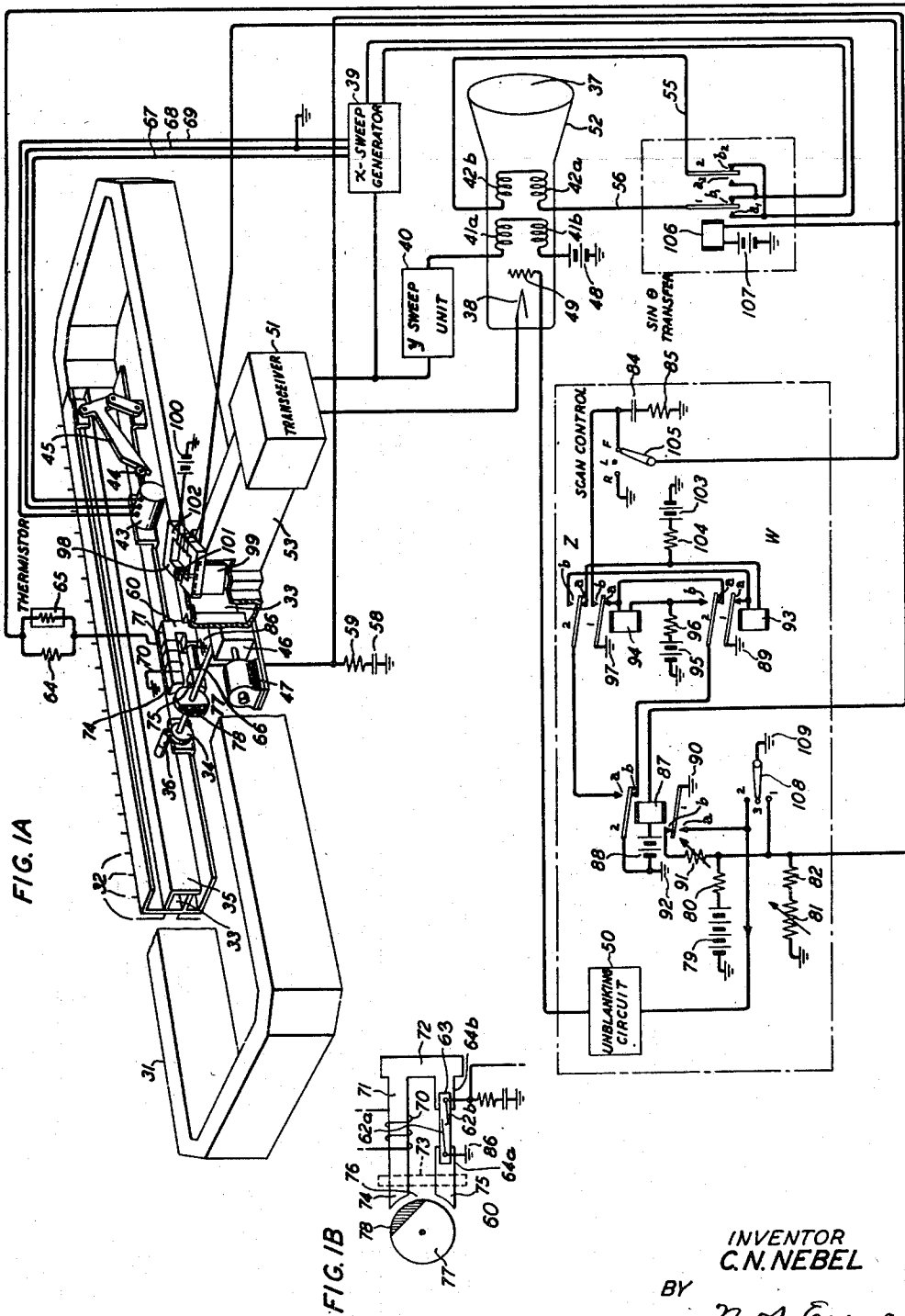
Aug. 15, 1950

C. N. NEBEL
ANTENNA AUXILIARY CONTROL CIRCUIT FOR
DIRECTIONAL BEAM SCANNING SYSTEMS

2,518,564

Filed July 25, 1945

3 Sheets-Sheet 1



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FIG. 2

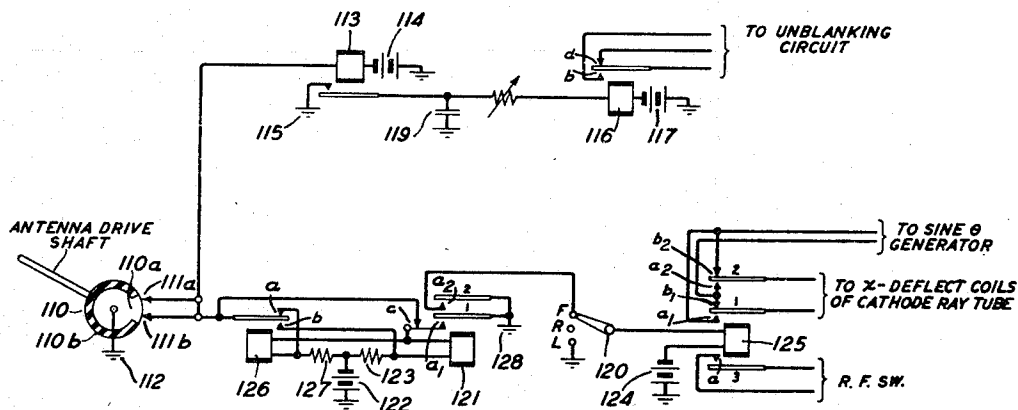
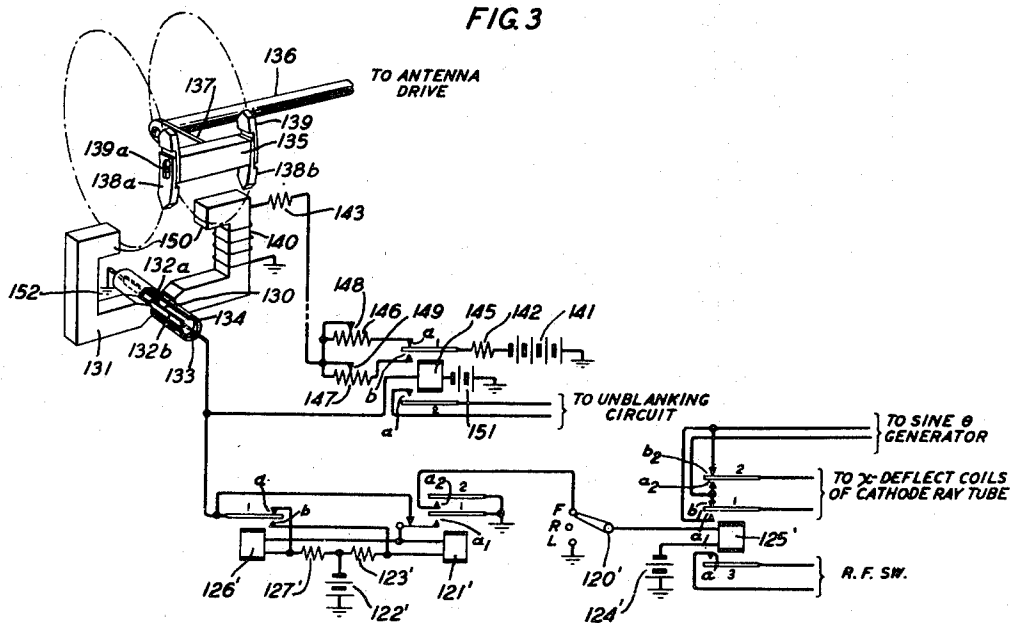


FIG. 3



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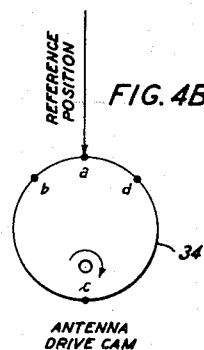
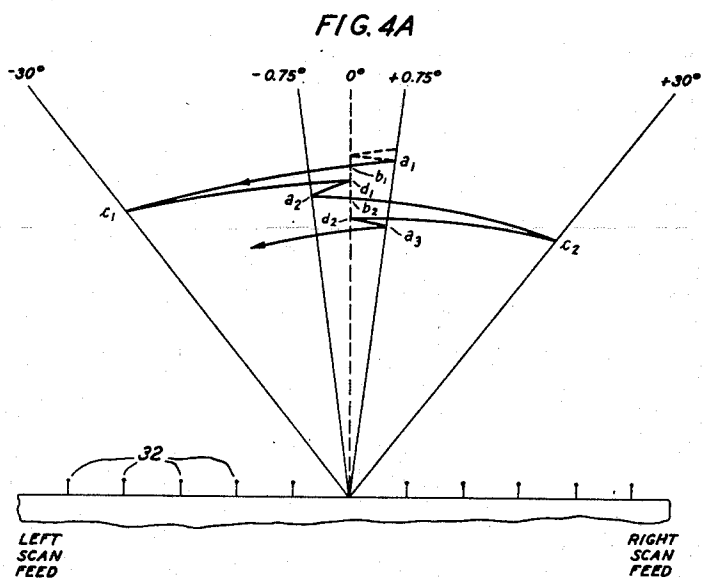


FIG. 5A

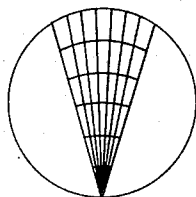


FIG. 5B

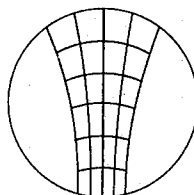
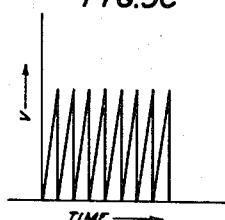
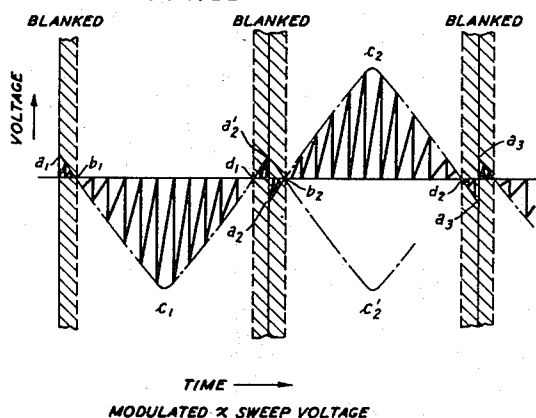


FIG. 5C



∝ SAWTOOTH OUTPUT

FIG. 5D



MODULATED ∝ SWEEP VOLTAGE

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2,518,564

ANTENNA AUXILIARY CONTROL CIRCUIT
FOR DIRECTIONAL BEAM SCANNING
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Application July 25, 1945, Serial No. 607,054

5 Claims. (Cl. 343-16)

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This relates in general to electromagnetic control systems and in particular to an electrical circuit for synchronizing certain auxiliary operations with the sweep of a scanning antenna.

In conventional radio ranging and detecting systems, the antenna scanning beam may be adjusted to move through a broad sector during the searching period and through one or another narrow sectors for detailed scanning after the target has been located and comes within short range. Whenever the antenna scanning sector is changed from narrow to broad or vice-versa, e. g., a corresponding change must take place in the indication on the screen of the cathode-ray indicator tube.

To produce a single broad searching sector it has been proposed that a plurality of narrow antenna scanning sectors be effectively combined, as for example, a sector lying generally to the left of the broadside or central scanning direction and another sector lying generally to the right thereof. Certain problems arise in this connection. If the antenna is of the phase velocity variation type, the direction of the antenna feed must be shifted from one end of the antenna wave guide to the other in moving the beam from either narrow sector to the other. Moreover, the indication on the cathode-ray screen must be shifted alternately between right and left sectors to correspond with the changing position of the antenna beam. And finally, since there is a slight overlap of a few milliseconds duration between the right and left antenna scanning sectors, it is necessary for the image on the cathode-ray indicating screen to be suppressed during the overlap period.

Heretofore, mechanical means have been employed to synchronize the above-described operations with the sweep of the antenna beam. However, such mechanical devices were not found entirely satisfactory because of the speed at which operations occur and because they were inaccessible for adjustment by the operator in aircraft installations.

According to the present invention, an electrical circuit operates to synchronize operation of auxiliary circuits with the antenna sweep of a scanning antenna. The circuit in one specific form comprises a circuit breaking device which is attached to the antenna drive shaft and which actuates relays to shift the antenna feed, suppress the indication on the screen of the cathode-ray tube, and reverse the sweep voltage on the indicator during designated intervals of the antenna cycle.

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The primary object of this invention is to provide a more efficient means for synchronizing the operation of auxiliary circuits with the sweep of the antenna beam in certain types of radio systems.

The nature of the present invention and its various objects and features may be seen from a study of the following specification and the appended drawings:

Fig. 1A shows a control circuit for reversing the antenna feed, reversing the indicator sweep voltage, and suppressing the image on the cathode-ray indicator in synchronism with the antenna scan. This circuit, which includes a magnetically operated relay of the type disclosed in the copending application of A. K. Schenck, Serial No. 607,055, filed of even date herewith, is well adapted for airplane installation;

Fig. 1B shows an enlarged and detailed view of the Schenck relay 60 of Fig. 1A;

Fig. 2 shows an alternative circuit according to the present invention which utilizes a conventional type of circuit breaker to perform the above-named auxiliary antenna functions.

Fig. 3 shows an improved form of the circuit of Fig. 2, in which the conventional circuit breaker has been replaced with one of the type disclosed in the copending application of A. K. Schenck;

Fig. 4A shows a graphical representation of a broad antenna scanning sector comprising overlapping right-hand and left-hand scanning sectors;

Fig. 4B shows an enlarged diagram of the eccentric antenna drive cam 34 of Fig. 1A;

Fig. 5A shows a graphical representation of the radial indication on the cathode-ray tube when the antenna is on the ground;

Fig. 5B shows the indication on the cathode-ray tube when the antenna is at altitude H;

Fig. 5C shows a plot of the voltage output of the X-sawtooth generator; and

Fig. 5D shows a plot of the x-sweep voltage after modulation by the antenna synchronizing operator.

The radio ranging and detecting system, of which the auxiliary antenna control circuit of the present invention is a cooperating part, comprises a large number of interdependent circuits connected to a coacting antenna, whereby the surrounding environment is scanned by a beam of pulsed microwave signals.

Referring to Fig. 1A, the transceiver 51 may be assumed to comprise microwave pulse trans-

mitting and receiving circuits of a type similar to those shown in Fig. 13, War Training Book 48, Preliminary Reference Manual for Radio Set AN/APQ-7, vol. 2, and broadly similar to the microwave pulse transmitting and receiving circuits disclosed in Fig. 1A of application, Serial No. 504,577 to O. E. De Lange, filed October 1, 1943, which is now Patent No. 2,426,182, issued August 26, 1947.

Circuits of the transceiver 51 are interconnected with the cathode-ray oscilloscope 52 through its cathode 38 and through the oscilloscope control circuits, which comprise the x-sweep circuit 39 connected to the x magnetic deflecting coils 42a and 42b, and the y sweep unit 40 connected to the y magnetic deflecting coils 41a and 41b, which are biased with a positive voltage by means of the 600 volt battery 48. The cathode-ray oscilloscope 52 is a conventional type comprising a fluorescent screen 37 upon which the movements of the magnetically controlled beam of electrons emanating from the cathode 38 trace a visible image. The blanking grid 49 in the cathode-ray tube 52 is connected to the unblanking circuit 50, which comprises any suitable means for placing a negative voltage bias on the grid 49 of a large enough value to suppress the electron beam from the cathode 38. Circuit details of the x-sweep circuits and the y-sweep and range circuits are similar to those of corresponding circuits shown in Fig. 13, War Training Book 48, Preliminary Reference Manual for Radio Set AN/APQ-7, vol. 2, mentioned above.

The secondary wave-guide 53 serves as the connecting element between the transceiver 51 and the exciting wave-guide 33 of the antenna 31, which is of the velocity variation type disclosed in application, Serial No. 496,325 of C. B. H. Feldman, filed July 27, 1943, and which comprises an array of dipoles 32 distributed along the leading edge of the antenna wave-guide 33, and positioned so that their probes extend into the interior of the guide 33 which serves as the source of excitation. The antenna guide 33 comprises a hollow pipe of rectangular cross-section formed into a substantially rectangular shape with the ends thereof joined so that energy from the transceiver 51 is fed into and withdrawn from the antenna 31 at the same point. The direction of flow of energy in the wave-guide 33 is regulated by means of the radio frequency switch 98 which comprises an aluminum vane 99 attached to a core 101 which is positioned in the field of an electromagnet 102. The portion of the wave-guide 33, to which are attached the dipoles 32, is of variable vertical dimension, the movable member 35 being positioned to ride by means of the knob 36 on the eccentric cam 34. The cam 34 is rigidly fixed to the drive shaft 66, which is attached to the antenna drive 47 through the gear reduction box 46.

Also attached to the antenna drive shaft 66, is the operating cam 77 of the relay 60 which is shown and described in detail in the copending application Serial No. 607,055 of A. K. Schenck, filed on even date herewith, and the disclosure of which is to be considered incorporated in the present specification.

The magnetically actuated contacts 62a, 62b of the relay 60 are protected from inductive surge by means of a circuit in shunt to ground which includes the 290 ohm resistance 59 in series with the 0.5 microfarad condenser 58.

A current control circuit which is connected in

shunt to ground across the electromagnet winding 70 of the relay 60 comprises the 600 ohm variable resistance 91 connected to ground 90 through the number 1 armature and its b contact of the relay 87, when that relay is energized, and the 2000 ohm variable resistance 81 in series with the 680 ohm resistance 82, when the relay 87 is de-energized. The electromagnet 70 of the relay 60 is energized by means of the 300 volt power supply 79 in series with the 15,000 ohm resistance 80.

The contact 62a of the relay 60 is connected to ground 86, while the contact 62b is connected to the energizing circuit of the relay 87, which includes the source 88 connected to ground 92.

Associated with the relay 87 are its number 1 and 2 armatures connected respectively to the ground 90 and the ground 92. The a contact associated with the number 1 armature is connected to the grid unblanking circuit 50, while the b contact associated with the number 1 armature of the relay 87 is connected to the circuit of the electromagnet 70.

The switch 109 is adjustable to any one of three positions, namely, contact 1 which connects the ground 109 to the circuit of the electromagnet 70; contact 2 which connects the ground 109 to the grid unblanking circuit 50, or contact 3 at which the switch is unoperated. For the purposes of the description hereinafter, the switch 109 will be positioned on contact 3.

The a and b contacts associated with the number 2 armature of the relay 87 are connected to a tandem operated relay circuit known as the W-Z type such as disclosed by O. Cesaro in United States Patent No. 1,751,263. The W-Z circuit includes the relays 93 and 94, their respective energizing batteries 103 and 95, respectively associated resistances 104 and 96, and the respectively cooperating relay armatures and associated contacts.

The switch 105 is adjustable to any one of three positions, namely, R which makes contact with the ground 54, for the right-hand antenna scanning sector; L at which the switch is open-circuited for the left-hand antenna scanning sector; and F at which the switch is connected to the W-Z circuit through the b contact associated with the number 1 armature of the relay 94, for the broad antenna scanning sector. The contact mentioned is protected from inductive surges by means of a shunt circuit comprising the 0.5 microfarad condenser 85 and the 240 ohm resistance 84 in series to ground.

The connection from the armature of the switch 105 leads respectively to the electromagnetic winding 102 of the radio frequency switch 98 and the energizing circuit of the relay 106 which includes the power source 107. The number 1 and 2 armatures of the relay 106, which is called the sine θ relay, are connected respectively to the x magnetizing coils 42a and 42b of the cathode-ray tube 52. The contacts a₁, b₂ and a₂, b₁ of the relay 106 are connected in pairs so as to reverse the polarity of the leads 55 and 56 to the x deflecting coils 42a and 42b.

Connections between the synchronizing generator 43 and the x-sweep circuits is made by means of the leads 67, 68, and 69. A conventional sawtooth generator in the x-sweep circuit is connected across the rotor of the synchronizing generator 43 by means of the input leads 67 and 68, while the output of the stationary windings of the generator 43 is connected across the leads 68 and 69, which are connected into the input of a conventional amplifier included in the x-sweep circuits.

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A roller attached to the rotor of the synchronizing generator 43 is held by means of a spring against the curved edge on the wider end of a tapered toggle arm 45, which attached at a pivotal point on its small end to a fixed bar on the wave-guide 33, and at the other point on its small end to the movable member 35 of the antenna wave-guide 33.

Before a detailed discussion is presented of the operation of the system, three auxiliary circuit operations will be discussed which the present invention makes possible to synchronize with the operation of the antenna.

The present embodiment of the control circuit particularly designed for airplane use, enables operation of auxiliary circuits to be synchronized with the sweep of the antenna beam in a velocity variation type of antenna such as antenna 31 of Fig. 1A. The beam of the antenna 31 is caused to sweep through a designated angle, as shown in Fig. 4A, by the rotation of the eccentric antenna drive cam 34 which is shown in an enlarged view in Fig. 4B. The rotation of the cam 34 causes a periodic variation in the vertical dimension of the antenna wave guide 33 by the up and down motion of the guide member 35, to which is attached a knob 36 riding on the cam 34. This operation shifts the phases of the exciting energy in the successive dipoles 32, thereby causing the antenna beam to move periodically, back and forth, through one or another of two angles or sectors depending on the end from which the antenna is excited.

The antenna 31 is so designed that a beam approximately 0.4 degrees wide passes through a broad forward scanning sector of approximately 60 degrees, comprising right-hand and left-hand narrow sectors which overlap for about 1.5 degrees in the center as shown in Fig. 4A. Radiation is confined mainly to the quadrant between the horizontal line in the direction of the airplane's motion and the vertical line from the antenna to the ground.

When the broad scan is performed, necessitating the movement of the antenna beam back and forth across both the right-hand and left-hand sectors, one function of the antenna auxiliary control circuit is to periodically shift the source of excitation from one end of the antenna wave guide to the other. This operation is carried out by means of the radio frequency switch 98 hereinafter known as the "R. F. switch" which comprises a magnetically operated stainless steel vane operating periodically during the 60-degree scan to effect the reversal of the power flow in the antenna wave guide.

A second function of the auxiliary control circuit during the broad scan is to change the sector indicated on the screen 37 of the cathode-ray tube 51 in accordance with the change in the position of the antenna beam from the right-hand sector to the left-hand sector or vice-versa.

In order to obtain an approximate facsimile of the ground area on the indicating screen of the cathode-ray oscilloscope it is necessary for the x and y sweep circuits to trace out a curve closely identical to the interception line of the radiated antenna pattern with the ground plane. When the antenna is on the ground the interception pattern takes the form of a group of V's intersecting at a point as shown in Fig. 5A. When the antenna rises above the ground, the intersections of the conical contours of the antenna beam with the ground form a family of hy-

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perbolas, the curvature depending on the angle of the beam as shown in Fig. 5B.

Currents proportional to the motion of the antenna beam over the ground are developed in electronic circuits and super-imposed according to an x and y system of coordinates so that the motion of the beam from the cathode 38 on the oscilloscope screen 37 may duplicate the progressive travel of the transmitted antenna beam. This is achieved by x and y sweep circuits 39 and 40, currents from which are circulated through the deflecting coils 41a, 41b, and 42a, 42b of the cathode ray oscilloscope 52, their component voltages adding up vectorially to produce the desired motion of the beam.

Both x and y sweep circuits are timed by means of a pedestal pulse which is fed in from a conventional timing pulse generating circuit included in the transceiver 51.

The pedestal timing pulse is fed directly into the x -sweep generator 39 from the circuit of the transceiver 51. However, the pulse is delayed in the y sweep unit 40 so that the starting time of the y sweep will correspond to the time of travel of the transmitted pulse to the ground directly beneath the airplane and back. A positive bias is placed on the y deflecting coils 41a, 41b, by means of the battery 48 in order to bring the indication down to the lower portion of the oscilloscope screen 37 as shown in Figs. 5A and 5B.

The time duration of the x -saw-tooth voltage shown graphically in Fig. 5C is governed by the length of the incoming pedestal pulse which, in turn, is governed by the maximum value required for the y sweep in order to have it cover the oscilloscope screen. The repetition rate of the x -saw-tooth fluctuations is adjusted in accordance with the antenna searching range.

The x -saw-tooth voltage is fed into the rotor winding of the antenna synchronizing generator 43. The roller 44, which is on an arm attached to the generator rotor shaft, is held against the edge of the toggle arm 45, the roller being drawn along the curved surface as the wave guide moves up and down. This causes the saw-tooth output of the generator 43 to be modulated in accordance with the antenna scanning angle, since the vector sum of the voltage induced in the windings of the generator 43 by the motion of its rotor varies as the sine of the angle swept by the antenna beam.

Fig. 5D shows a plot of the antenna generator output voltage against time, the reference letters showing the generator voltages at various points in the cycle of the cam 34 correspond to the reference letters used in Fig. 4A and 4B which show the positions of the antenna beam as the cam rotates. The subscripts 1 and 2 designate first and second cam rotations. When the antenna beam, as shown in Fig. 4A, is at position a_1 , slightly to the right of center, the generator output is slightly positive, as shown in Fig. 5D. When the antenna beam moves to the straight-ahead position, at b_1 , the output of the generator 43 decreases to zero. As the scanning antenna beam moves out to an angle 30 degrees to the left of center, the generator output increases to a maximum in a negative direction at c_1 , returning to zero at d_1 when the beam returns to its central position. If the antenna beam were scanning only the left-hand sector, this same cycle would again be repeated with the second rotation of the cam 34, the generator 43 output varying from a slightly positive out-

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put at a_2' to a maximum negative output at c_2' . However, when the antenna beam scans the broad sector, the output of the generator 43 is reversed by means of the sine θ switch, so that the slightly positive voltage a_2' becomes the slightly negative voltage a_2 when the antenna beam begins its scan of the right-hand sector. When the antenna beam moves out to a maximum angular scanning position at 30 degrees to the right of center, the generator voltage increases to a maximum positive output at point c_2 . Thus, the angle indicated on the oscilloscope screen 37 follows the angle swept by the scanning antenna beam, the sine θ switch functioning each time the antenna beam moves from the left-hand sector to the right-hand sector or vice-versa.

A third function of the auxiliary control circuit is to suppress the image on the cathode-ray indicator screen during the interval of overlap between the right-hand and left-hand antenna scanning sectors, as shown in Fig. 4A. Fig. 5D shows the interval of blanking with reference to the magnitude and polarity of the output of the generator 43. The indicator is thus blanked while the antenna beam moves from a_1 to b_1 , from d_1 to a_2 and from c_2 to b_2 , etc., so that for the purposes of indication, the antenna beam appears to sweep from -30° to $+30^\circ$ without interruption.

Fig. 1A shows the relationship between the operation of the scanning antenna and the auxiliary antenna control circuit which functions to reverse the R. F. switch, operate the sine θ transfer and blank the cathode ray tube indicator screen. These operations will now be described in detail.

In Fig. 1B the relay 60, which is of the type disclosed in Patent 2,289,830 to W. B. Ellwood, July 14, 1942, comprises a pair of iron strips 62a and 62b with amalgamated tips which are hermetically sealed in a longitudinal position in the glass envelope 63. The Ellwood relay 60 is fitted into the recessed ends of the zinc plated magnetic iron poles 64a and 64b. An electromagnet 70 which is wound on the magnetic iron core 71 is held by means of the spacers 72 and 73 in a position parallel to the relay 60 so that the latter lies in the path of the magnetic flux. The spacer 72 comprises zinc plated magnetic iron while the spacer 73 comprises non-magnetic aluminum. The zinc plated magnetic iron legs 74 and 75 protrude through the holes in the aluminum spacer 73 to enclose the air-gap 76.

The disk 76 which comprises a non-magnetic yoke 77 and soft iron shoe 78 is rigidly fixed on the antenna cam drive shaft 66 which is rotated by means of the antenna motor 47 acting through the gear reduction box 46. When the soft iron shoe 78 rotates into position closing the gap between the legs 74 and 75, the reluctance of the magnetic circuit is sufficiently reduced to cause the closure of the magnetically responsive contacts 62a and 62b.

The period of closure of the contacts 62a, 62b is controlled by regulation of the flux through the electromagnet 70, which is continuously energized from the power supply 79. A current regulating circuit includes the 2,000 ohm variable resistance 81 in series with the 680 ohm resistance 82 which acts as a variable shunt to ground across the circuit of the electromagnet 70. The thermistor 65 functions to maintain constant current with changes in temperature in the circuit of the electromagnet 70.

A separate control for adjusting the precise

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release position of the Ellwood relay is provided by the 600-ohm variable resistance 91. When the relay 87 is energized, the number 1 armature engages its b contact, thereby placing the resistance 91 in shunt to ground 90 across the resistances 81 and 82. Operation of the Ellwood relay is not affected by this reduction in voltage, since once the relay is in operation, only a relatively small current is necessary to keep it so.

Referring to Figs. 1A, 1B, 4A and 4B, operation of a preferred embodiment of the control circuit adapted to reverse the R. F. switch, reverse the cathode-ray indicator and sweep voltage, and blank the indicator screen may be analyzed as follows. A circuit of the W-Z type, such as shown in United States Patent 1,751,263 to O. Cesareo, functions to enable a series of operations to recur every two revolutions of the scan drive cam. This is necessitated by the fact that one revolution of the antenna drive cam 34 corresponds to the sweep of the beam over the right-hand or left-hand scanning sector, as shown in Fig. 4A, while two revolutions are required for a complete traverse of the broader scanning sector.

For operation of the circuit in the broad scan, the switch 105 is positioned on the F contact. The switch 108 is unoperated on contact 3. The function of the switch 108 is to prevent operation of the control relay for system adjustment purposes by applying the ground 109 through contact 1, or for manual control of blanking by applying the ground 109 through contact 2.

The antenna drive cam 34 is eccentrically shaped, as shown in Fig. 4B, so that as it rotates the vertical dimension of the antenna wave guide is varied from a minimum value when point c is in the reference position to a maximum value when point a is in the reference position. Fig. 4A shows the positions of the antenna beam during rotation of the drive cam 34; the letters in Fig. 4A corresponding to the letters on the cam 34, their subscripts 1 and 2 indicating first or second rotation.

Assume the antenna drive cam 34 to be rotating in a clockwise direction. When point a reaches the reference position, the antenna beam is in a position approximately 0.75 degree to the right of the straight-ahead position, designated as $+0.75$ degree on Fig. 4A. At this time, the soft iron shoe 78 of the disk 77 is so positioned with respect to the legs 74 and 75 that the contacts 62a and 62b remain closed.

During the interval in which the cam 34 rotates from point a to point b, an arc of approximately 20 degrees, the contacts 62a, 62b continue to be closed, thus holding the relay 87 in operation by applying the ground 86 to its circuit.

While the relay 87 remains operated, its number 1 armature has functioned to break its a contact, thereby disconnecting the ground 90 from the unblanking circuit 50, so that a bias is placed on the grid 49 of the cathode-ray indicator, suppressing the beam from the cathode 38. The indicator screen 37 is thus blanked during the interval in which the antenna beam moves from $+0.75$ degree to 0 degree.

The number 2 armature of the relay 87 has functioned to break its a contact and engage its b contact, releasing the R. F. switch and reversing the sine θ transfer on the indicator tube through the following circuit operations.

The ground 92 is connected to complete the

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energizing circuit of the relay 94, which includes the source 95 and the resistance 96.

Thus energized, the relay 94 has attracted its number 1 armature to break its *b* contact and engage its *a* contact, thereby removing the ground 97 from the circuit of the R. F. switch 98. The switch 98 comprises a stainless steel vane 99 attached to a rectangular shaped magnetic core 101, which is held in position with reference to the electromagnet 102 by means of a spiral spring. When the electromagnet 102 is energized by means of a circuit which includes the 27-volt source 100, the core 101 overcomes the torque of the spring, and aligns itself with the magnetic field, thereby actuating the vane 99 to reflect the radio frequency energy from the transceiver 51 into the right end of the antenna wave guide. When the ground 97 is removed from the circuit of the electromagnet 102, the core 101 is released to return to its normal position, reflecting energy into the left end of the antenna wave guide.

Simultaneously with the release of the R. F. switch, the ground 97 is removed from the circuit of the sine θ relay 106 which was energized by the 27-volt source 107. Deenergized, the relay 106 has released its armatures 1 and 2 to break their *a* contacts and engage their *b* contacts, reversing the current through the coils 42a and 42b of the cathode-ray indicator tube, thereby reversing the *x*-sweep, as described hereinbefore.

Through its number 1 armature and *a* contact, the relay 94 is locked in operation, so that it remains energized, even after the relay 87 becomes deenergized. As long as the relay 94 remains energized, its number 2 armature remains in engagement with its *a* contact. The *b* contact of the relay 94 is protected against inductive surges by the condenser 85 connected to ground through resistance 84.

When the antenna drive cam 34 has moved in a clockwise direction to position *b*, which is approximately 20 degrees from position *a*, as shown in Figs. 4A and 4B, the antenna beam assumes a straight-ahead position, which is designated as 0 degrees. At this point, the soft iron shoe 78 has moved out of position with respect to the legs 74 and 75, and the contacts 62 and 62' reopen. As described hereinbefore, the exact point of opening can be regulated by means of the rheostat 91.

When the contacts 62a, 62b of relay 60, Fig. 1B open, the relay 87 becomes deenergized.

The number 1 armature of the relay 87 is released to break its *b* contact and reengage its *a* contact, thus unblanking the cathode-ray tube indicator, as described hereinbefore.

The number 2 armature of the relay 87 is released to disengage its *b* contact and reengage its *a* contact. This operation deenergizes the relay 93 by short-circuiting it to ground 92 through a circuit which includes the number 2 armature and its *a* contact of the relay 94, and the number 2 armature and its *a* contact of the relay 87. The 1 and 2 armatures of the relay 93 are thus released to break their *a* contacts, while the number 2 armature engages its *b* contact.

Again referring to Figs. 4A and 4B, while the antenna driving cam 34 rotates from point *b* to point *c* in a clockwise direction (from approximately 20 degrees to 180 degrees), the antenna beam moves from 0 degree to -30 degrees. While the antenna cam 34 rotates from point *c*

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to point *d* (from approximately 180 degrees to 340 degrees), the beam rotates from -30 degrees back to 0 degree. During this period, the cathode-ray indicator remains unblanked, the R. F. switch is positioned so that power in the antenna wave guide flows to the left, and the sine θ sweep is also to the left.

When the antenna drive cam 34 has rotated approximately 340 degrees, reaching the point *d* as shown in Figs. 4A and 4B, the disk 85 has rotated so that the Ellwood contacts 62a, 62b again close, operating the relay 87, which operates the R. F. switch, sine θ transfer and blanking relay as follows.

The number 1 armature of the relay 87 operates, again breaking its *a* contact and engaging its *b* contact, so that the cathode-ray indicator screen 37 is blanked during this period.

The number 2 armature of the relay 87 operates, again breaking its *a* contact and engaging its *b* contact. It should be recalled that at this instant in the time cycle, the armatures 1 and 2 of the relay 94 are operated, engaging their *a* contacts, and the armatures 1 and 2 of the relay 93 are released, so that the number 2 armature engages its *b* contact. The following operations now take place.

The ground 92 is applied to short-circuit the relay 94 through a circuit which includes the number 2 armature of the relay 87 and its *b* contact, and the number 2 armature of the relay 93 and its *b* contact.

The armatures 1 and 2 of the relay 94 thereupon release to engage their *b* contacts, as shown in Fig. 2. This applies the ground 97 to the circuit of the electromagnet 102, actuating the R. F. switch 98 to feed radio frequency energy to the right. Likewise, the ground 97 completes the circuit of the sine θ relay 106 which thereupon actuates its armatures 1 and 2 to engage their *a* contacts, again reversing the *x*-sweep voltage on the cathode-ray indicator tube.

During the interval in which the antenna drive cam 34 is rotating from point *d* to point *a* (approximately 340 degrees to 0 degree), the antenna beam moves from 0 degree to approximately 0.75 degree. During the rotation from point *a* to point *b* beginning the second cam cycle, the antenna beam moves from approximately 0.75 degree back to 0 degree.

As soon as the antenna drive cam 34 reaches point *b* in its second cycle the contacts 62a, 62b again open up, deenergizing the relay 87.

The number 1 armature of the relay 87 releases to engage its *a* contact, unblanking the cathode-ray indicator screen 37 as described hereinbefore.

The number 2 armature of the relay 87 releases to engage its *a* contact. This causes the relay 93 to become energized by connecting its circuit to the ground 92. The relay 93 is energized by means of the source 103 acting through the resistance 104.

While the antenna driving cam 34 completes its second rotational cycle point *b* through point *c* to point *d* (from 20 degrees to 340 degrees) in a clockwise direction, the antenna beam moves from 0 degree to +30 degrees and from +30 degrees back to 0 degrees. During this period, the cathode-ray indicator screen 37 remains unblanked, the R. F. switch is positioned so that power in the antenna wave guide flows to the right, and the sine θ sweep is also to the right.

When the antenna driving cam 34 again reaches point *d*, (approximately 340 degrees), the

indicator screen is blanked, the two revolution cycle of the cam is ready to be repeated.

A better understanding of the sequence of operations may be had from a study of the accompanying table in conjunction with Fig. 4A of the drawings.

Sequence of relay operations

Position of Drive Cam	Ellwood Relay	Relay 87	Relay 93	Relay 94
0-20	Operated	Operated	Operated	Operated
20-180	Released	Released	Released	Do.
180-340	do.	do.	do.	Do.
340-0	Operated	Operated	do.	Released.
0-20	do.	do.	do.	Do.
20-180	Released	Released	Operated	Do.
180-340	do.	do.	do.	Do.
340-0	Operated	Operated	do.	Operated.

Position of Drive Cam	R.F. Switch	Sweep and H. F. Power	Antenna Scan	Indicator Screen
0-20	Released	Left	+0.75° to 0°	Blanked.
20-180	do.	do.	0° to -30°	Unblanked.
180-340	do.	do.	-30° to 0°	Do.
340-0	Operated	Right	0° to -0.75°	Blanked.
0-20	do.	do.	-0.75° to 0°	Do.
20-180	do.	do.	0° to +30°	Unblanked.
180-340	do.	do.	+30° to 0°	Do.
340-0	Released	Left	0° to +0.75°	Blanked.

The alternative embodiments of auxiliary antenna control circuits according to the present invention which are shown in Figs. 2 and 3 of the drawings are designed to be used in conjunction with an antenna of the phase velocity variation type, such as the antenna 31 of Fig. 1. The antenna, the antenna synchronizing generator, the transceiving circuit, the x and y sweep circuits, and the cathode-ray oscilloscope, although not shown in Figs. 2 and 3, are assumed to be present in the respective systems with which these two circuits cooperate, and are assumed to be similar in character and operation to those elements shown and described with reference to Fig. 1A.

The embodiment of Fig. 2 is one in which a make-and-break device attached to the antenna drive-shaft and rotating therewith is utilized instead of the magnetically actuated Schenck relay described with reference to Fig. 1A above.

Referring to Fig. 2, the rotary contactor or cam 110 is rigidly attached to the antenna drive-shaft 110, the contacts 111a and 111b making contact with the cam 110 continuously during its rotation. During a short interval of the cam's rotation, the contacts 111a and 111b ride on the conducting portion 110a of the cam 110, and are thereby connected to ground 112. During the remainder of the cam's cycle of rotation, the contacts 111a and 111b ride on the insulating portion, 110b, and are therefore disconnected from ground. Operation of the blanking circuit, the sine θ transfer, and the R. F. switch is keyed by the rotation of the cam 110, as follows.

When the contacts 111a and 111b are closed, applying the ground 112, the primary blanking relay 113 is energized by the source 114, and thereby actuated to pull up its number 1 armature to make contact to ground 115. This operation completes the circuit of the relay 116 which is energized by the battery 117. When the relay 116 is energized, it actuates its armature to break its a contact and engage its b contact, thereby blanking the indicating screen on the cathode-ray tube.

The period of operation of the relay 116, and

hence, of the blanking, may be adjusted by means of the variable series resistance 118 and the condenser 119, which shunts the circuit to ground.

The sequence of the blanking operations, the sine θ transfer, and the R. F. switching are governed through a two-cycle operation of the cam 110 by means of a W-Z circuit, which operates in a manner similar to that described with reference to Fig. 1. Assume that the switch 120 has been positioned on the F contact for the full sweep of the antenna beam.

When the ground 112 is applied to the W-Z circuit, the Z relay is energized by current passing from the source 122 through the resistance 123, the relay windings and the c contact to ground through the contacts 111a and 111b. The Z relay 121 therefore pulls down its number 1 and 2 armatures, breaking the c contact, and engaging the contacts a_1 and a_2 , respectively. The Z relay 121 is locked in operation by the ground 128 which is applied through the number 1 armature and its contact a_1 . The ground 128 is applied through the number 2 armature and its a_2 contact to complete the circuit of the relay 125, which is energized by the source 124. The relay 125 then pulls down its number 1 armature to break its b contact and engage its a contact, thereby reversing the polarity of the sweep voltage on the indicator tube. The number 2 armature of the relay 125 is actuated to engage its a contact, thereby operating the RF switch to transfer the antenna wave guide feed, as described above.

During this operation, the W relay 126 is short-circuited, and thereby deenergized, since ground is applied to one side of its windings through its number 1 armature and a contact, and to the other side of its windings through the number 1 armature and a_1 contact of the relay 121.

When the cam 110 swings around, releasing the contacts 111a and 111b, the ground 112 is removed from the number 1 armature and a contact of the W relay 126. This operation permits the W relay 126 to become energized by current flowing from the source 122 through the resistance 127, the W windings, and to the ground 128, which is connected to the circuit through the number 1 armature and a_1 contact of the Z relay 121.

When the W relay 126 becomes energized, it pulls up its number 1 armature, breaking its a contact and engaging its b contact.

As the cam 110 makes one complete revolution, again closing the contacts 111a-111b to ground 112, the W relay 126 remains energized, current passing from the source 122 through the resistance 127 and the W windings to ground at c . Simultaneously, the Z relay 121 becomes deenergized, being short-circuited by ground applied through the number 1 armature and b contact of the W relay 126, and at the contact c . When the Z relay 121 becomes deenergized, it releases its number 1 and 2 armatures, so that the ground 128 is removed from the circuit of the relay 125.

The number 1 armature of the relay 125 drops back, releasing its a contact and engaging its b contact, again reversing the sine θ voltage. The number 2 armature of the relay 125 breaks its a contact, thereby again reversing the R. F. switch to change the direction of the antenna feed.

As soon as the ground 112 is removed from the contacts 111a-111b, the W relay 126 releases, its number 1 armature dropping back to engage its a contact. This conditions the circuit for a repetition of the cycle of operations just described.

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In the circuit of Fig. 2, the timing of the operations can be adjusted with reference to the speed of the antenna drive shaft by mechanical manipulation of the cam. In airplane installations, however, the cam in order to be in proximity to the antenna, is often placed in a position which is highly inaccessible to the operator of the radio set. This difficulty is overcome by the circuit shown in Fig. 3 which utilizes a relay having magnetically responsive hermetically sealed contacts, such as disclosed by Ellwood in Patent 2,289,830. The relay contacts are actuated in response to rotation of the antenna drive-shaft and the duration of their closure electrically controlled as disclosed in the copending application to A. K. Schenck.

The circuit of Fig. 3, which incorporates the Schenck circuit-breaking device, operates as follows:

The Ellwood relay 130, which is positioned in a gap of the horse-shoe shaped soft iron yoke 131, comprises resilient magnetically responsive contacts 132a and 132b, which are hermetically sealed in the glass tube 133 encased in the non-magnetic coating 134. The permanent magnet 135 is attached to the antenna drive-shaft 136 by means of the arm 137 which is mounted rigidly on the shaft and rotates therewith. To the permanent magnet 135, the adjustable pole-pieces 138a and 138b are attached by means of the fillister-head iron machine screws 139a and 139b.

Rotation of the permanent magnet 135 in and out of the gap 150 causes a periodic change in the magnetic flux surrounding the yoke 131, thereby causing a periodic closure of the magnetically responsive contacts 132a and 132b, thus energizing the relay 145 by applying the ground 152 to its circuit, which includes the energizing source 151.

The interval of closure of the contacts 132a and 132b is controlled by the current in the control winding 140, which is wound about the yoke 131 in such a manner as to produce the polarity indicated.

Current is fed into the control winding 140 from the battery 141, and is regulated by means of a control circuit which functions as follows. When the relay 145 is unoperated, current from the battery 141 flows through the resistance 122, the number 1 armature and its a contact, the rheostat 146, the brush 148 and the resistance 143 and through the winding 140 to ground. When the relay 145 is operated, current from the battery 141 flows through the resistance 142, the armature 144 and its b contact, the rheostat 147 and its brush 149, the resistance 143 and the winding 140 to ground. Thus, a different current passes in the bias winding 140 when the contacts 132a and 132b are open than when they are closed.

In order to adjust the exact positions of opening and closing of the contacts 32a and 32b with respect to the position of the antenna beam, the following initial adjustments are made in the control rheostats 146 and 147. With the relay 145 deenergized as the magnet 135 swings into place in the gap 150, the position of closure of the contacts 132a and 132b is adjusted by means of the brush 148 on the rheostat 146. Similarly, with the relay 145 operated, as the rotating magnet 135 moves out of the gap 150, the opening position of the contacts 132a and 132b is adjusted by means of the brush 149 on the rheostat 147. Rough adjustments may be made

by changing the positions of the pole-pieces 138a and 138b with their respective screws 139a and 139b.

As in the circuit of Fig. 2, when the contacts 132a and 132b close, the relay 145 is operated to pull up its number 2 armature to engage its a contact, thereby blanking the screen of the cathode-ray indicator tube.

Simultaneously, closing of the contacts 132a and 132b keys operation of the W-Z combination to shift the sine θ voltage, and the radio frequency switch, (as described with reference to Fig. 2), thus moving the antenna beam and the cathode-ray screen indication from left to right, or vice-versa, during the full sweep. Primed numerals in Fig. 3 indicate elements, the operation of which is similar to that described with reference to Fig. 2.

An auxiliary antenna control circuit designed according to the principles of the present invention is not limited to the particular embodiments herein set forth.

What is claimed is:

1. In a velocity variation type of antenna which comprises an array of dipoles distributed along the length of a wave-guide, a cam connected to said wave-guide and rotatable to change a dimension of said guide, a driving means connected to said cam, a source of high frequency energy, a switch having a plurality of contacts, one contact of said switch adapted to move said energy source to excite the left end of said antenna wave-guide, whereby the antenna beam is caused to scan a left-hand sector, a second contact of said switch adapted to move said energy source to excite the right end of said antenna wave-guide, whereby the antenna beam is caused to scan a right-hand sector, a third contact of said switch connected to electromagnetic means operating synchronously with said antenna driving means to alternate said energy source between the right and left ends of said antenna wave-guide, thereby causing said antenna beam to scan a broad sector, comprising a combination of right and left narrow scanning sectors.

2. A radio system which comprises in combination a velocity variation type of antenna comprising an array of dipoles distributed along the length of a wave-guide, a cam connected to said wave-guide and rotatable to change a dimension of said guide, a driving means connected to said cam, a transceiver connected to said antenna and a cathode-ray indicating device connected to said transceiver, a source of high frequency energy, a switch having a plurality of contacts, one contact of said switch adapted to move said energy source to the left end of said antenna wave-guide, and transpose the voltage on said indicator tube, whereby said antenna beam and the corresponding indication on the cathode-ray indicator are caused to scan a left-hand sector, a second contact of said switch adapted to move said energy source to the right end of said antenna wave-guide, and transpose the voltage on said indicator tube, whereby said antenna beam and the corresponding indications on the cathode-ray indicator are caused to scan a right-hand sector, and a third contact of said switch connected to electromagnetic means operating synchronously with said antenna driving means to alternate the positions of said energy source and said indicator voltage whereby the antenna beam and the indication on the cathode-ray indicator are caused

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to move periodically through a broad scanning sector comprising a combination of the right-hand and left-hand scanning sector.

3. A radio system which comprises in combination a velocity variation type of antenna comprising an array of dipoles distributed along the wave-guide, a cam connected to said wave-guide and rotatable to change a dimension of said guide, a driving means connected to said cam, a transceiver connected to said antenna and a cathode-ray indicating device connected to said transceiver, a source of high frequency energy, a switch having a plurality of contacts, one contact of said switch adapted to move said energy source to the left end of said antenna wave-guide, and transpose the voltage on said indicator tube, whereby said antenna beam and the corresponding indication on the cathode-ray indicator are caused to scan a left-hand sector, a second contact of said switch adapted to move said energy source to the right end of said antenna wave-guide, and transpose the voltage on said indicator tube whereby said antenna beam and the corresponding indications on the cathode-ray indicator are caused to scan a right-hand sector, and a third contact of said switch connected to electromagnetic means operating synchronously with said antenna driving means to alternate the positions of said energy source and said indicator voltage whereby the antenna beam and the indication on the cathode-ray indicator are caused to move periodically through a broad scanning sector comprising a slightly overlapping combination of the right-hand and left-hand antenna scanning sectors, and electromagnetic means operating synchronously with said antenna driving means to suppress the indication on said cathode-ray indicator during the period of said overlap.

4. A system of the kind described comprising a radio antenna of the velocity-variation type in which the direction of action is dependent in part on a transverse dimension of the antenna, a radio wave transceiver for applying wave energy to said antenna and receiving therefrom such applied wave energy as may be reflected from distant objects and intercepted by said antenna, driving means for periodically varying the said transverse dimension between limits such that the direction of action sweeps through one or the other of two overlapping sectors in space accordingly as said transceiver is

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effectively connected to one end or the other of said antenna, switching means adapted to effectively connect said transceiver to either end of said antenna, electric contactor means operated by and in synchronism with said driving means and operative on said switching means to change the end of the antenna to which said transceiver is connected at such times that during each period of said driving means the said direction of action sweeps completely across both of said sectors in succession with a reversal within the overlapping portion of the said sectors, a cathode-ray oscilloscope comprising a luminescent screen, cathode-ray deflecting means, a sweep voltage wave generator synchronized with the said driving means and adapted to deflect the cathode-ray across one or the other of two overlapping sectors on said screen according to the polarity of said sweep voltage wave, a reversing switch for reversing the polarity of said sweep voltage wave at a point in each cycle lying within the overlap portion thereof, whereby the cathode-ray sweeps across the said sectors on said screen as the said direction of action sweeps across said first-mentioned sectors, said reversing switch being actuated in response to operation of said electric contactor means, and means controlled by said contactor means for blanking said ray periodically to prevent the production of overlapping traces thereby.

5. A system in accordance with claim 4 in which said contactor means comprises an electromagnetic relay actuated once and released once at different points during each period of said driving means dependent on an electrical bias applied thereto, means for changing the said bias from one operating value to a second operating value during each said period, and means for separately adjusting the two said bias values.

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