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ANTENNA SECTOR SCAN CONTROL

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This invention relates to sector scanning mechanism for a radar antenna and more particularly to means for automatically scanning any desired sector.

The invention is intended primarily for remotely controlling sector scanning of a radar antenna in a radar relay system wherein a searching radar is used to obtain radar data and relay such data to some remote location.

It is an object of this invention to provide automatic scanning of a selected sector by a radar antenna.

Another object of this invention is to provide means for selecting the sector to be scanned.

A further object of this invention is to provide means for scanning a sector of any desired angular width.

These and other objects will be apparent from the following specifications when taken with the accompanying drawing in which:

Fig. 1 is a schematic illustration of one form of the invention; and

Fig. 2 is a block diagram of a system including the circuit of Fig. 1.

Referring first to the system of Fig. 2 there is shown an antenna 5 coupled to antenna drive motor 6 by a mechanical link schematically illustrated by the dashed line 7. Power is supplied to antenna drive motor 6 from a source 9 through a reversing control 10. Reversing control 10 is shown coupled to antenna drive motor 6 by connections 8. Antenna drive motor 6 may be any form of electric motor that may be reversed by changing the polarity or phase of the power supplied thereto. However, the motor 6 may take other forms if desired, for example, a reversible steam driven engine or turbine. If an electric motor is employed, reversing control 10 may take the form of a relay controlled double-pole, double-throw reversing switch, the energy to the relay coil being supplied at terminals 11.

In certain applications of the present invention it may be desirable to locate the antenna 5, the antenna drive motor 6 and the reversing control 10 in a moving vehicle, for example an airplane in flight, while the control circuit 12 is located at a fixed point on the ground or in a second vehicle. If this is the case, the control signal appearing at terminals 11a of control circuit 12 may be coupled to terminals 11 by a suitable radio relay link illustrated as dashed lines 11b in Fig. 2. For reasons that will appear presently, it will also be necessary to couple position data from antenna 5 to control circuit 12 as illus-

trated by the dashed line 7a in Fig. 2. This may be accomplished by a second radio relay link or by a second channel in radio relay link 11b. The broken line A—A in Fig. 2 has been added to clearly point out the line of separation between units in the moving vehicle and units at the second location.

In still other applications of the present invention all of the units shown in Fig. 2 may be located in the same vehicle in which case the dashed line 7a may represent an appropriate mechanical connection and dashed lines 11b appropriate electrical connections. Since the present invention is primarily concerned with the novel features of the control circuit 12 rather than the specific arrangement of the system in Fig. 2, the details of control circuit 12 will now be explained by reference to Fig. 1.

Briefly, the circuit of Fig. 1 operates as follows: Azimuth information from the radar antenna 5 is supplied to synchro 13 by connection 7a. Synchro 13 supplies this azimuth data to a control transformer 15. The rotor of the control transformer 15 is positioned manually by hand control 15a to select the bearing of the sector to be scanned. The control transformer develops an error voltage whose phase and magnitude are proportional to the error between its manually positioned rotor and the antenna position data supplied by the synchro. This error voltage is variable in amplitude to set the size of the sector scan and is used to operate a differential relay. As the antenna rotates away from the selected sector bearing the error voltage developed by the control transformer after covering a certain angle becomes large enough to operate the differential relay to operate the antenna reversing means. The antenna then passes back past the selected sector bearing and develops an increasing error voltage in opposite phase. When the antenna has traveled far enough the error voltage developed again operates the differential relay to operate means for reversing the antenna again. Thus the antenna is made to scan a selected amount either side of said sector bearing.

Referring again to Fig. 1 the operation of the circuit will be described in detail. Azimuth information is received by antenna synchro 13 at connection 7a, which causes synchro 13 to rotate in synchronism with the antenna 5. The rotor of synchro 13 is energized from an alternating voltage source illustrated in Fig. 1 by terminals 14 and 16. Alternating current is also supplied at terminals 18 and 20 to contact 22 of

manually operated switch 28 and at point 24, one end of the primary winding of filament transformer 26. The filament transformer 26 is supplied current by closing switch contact 22 in either position to heat the filaments of duotriode tube 30. The alternating voltage supplied at terminals 14 and 16 is applied from terminal 14 to the center tap 32 of winding 34 on transformer 36 and from terminal 16 through contact 38 of switch 28 to the common junction 40 of coils 42 and 44 of differential relay 46.

The rotor of control transformer 15 is positioned by a hand control 15a and determines the bearing about which the sector scanning is done. When the position of the rotor in control transformer 15 corresponds to the position of the rotor in the antenna synchro, there will be no output voltage from the rotor of control transformer 15. The rotor of control transformer 15 connects through potentiometer 48 to the primary 52 of transformer 36.

An error voltage is produced in winding 52 whenever the angular position of the rotor in control transformer 15 differs from that of the rotor in the antenna synchro. The phase of the error voltage depends upon whether the rotor of control transformer leads or lags that of the antenna synchro, and the amplitude of the error voltage depends upon the extent of lead or lag. The secondary of transformer 36 is center tapped so that error voltages of the same amplitude but of opposite phase are applied to grids 54 and 56 of the two halves of rectifier tube 30. If there is no error voltage, the plate current will be the same in the two halves of tube 30 and in the coils 42 and 44 of relay 46. This holds contact 58 in its neutral position. When an error voltage is present it will be essentially in phase with the plate voltage on one half of tube 30 and essentially 180° out of phase on the other half. The output of one half of tube 30 is increased and that of the other half is decreased. When this error voltage reaches a predetermined value, it will actuate relay 46 which in turn actuates latch-in relay 60 which is latched in the "up" or "down" position depending upon the relative angular position of the antenna at the time.

The angular position of the rotor of control transformer 15 is set manually to select the center bearing about which the sector scanning is performed. The amplitude or size of the sector is controlled by variable tap 62 on potentiometer 48. This pick-off tap determines the fraction of the error voltage that is applied to the primary 52 of transformer 36. The lower the setting of resistance 48, the greater must be the error voltage from control transformer 15 to actuate differential relay 46. As a result the scan amplitude is increased.

Now that the basic components have been described, the details of relay operation etc. will be described by following through a complete cycle of the system. Switch 28 is normally in the up or continuous scan position, relay 60 is in the up position and the antenna is continuously rotating in a clockwise direction. Assume that switch 28 is thrown "down" for sector scanning as the antenna is approaching the selected sector bearing. As soon as the antenna passes the selected bearing, an error voltage of increasing amplitude is developed and is applied in phase to grid 56 of the lower half of discriminator rectifier 30 and out of phase to grid 54 of the upper half of tube 30. As the outer boundary of the scan sector is reached the output of rectifier 30

is large enough to operate relay 46 and pull contact 58 down which energizes coil 62 to close contact 66 at point 68. This closes the circuit to the terminals 11a with the result that rotation of the antenna is changed to the counterclockwise direction. This direction of rotation is continued until the antenna again passes the center of the sector and reaches its other limit. After passing the selected bearing an error voltage of increasing magnitude but opposite in phase is developed. When the amplitude is large enough, coil 42 of relay 46 is energized to pull contact 58 to the up position which in turn energizes coil 64 of relay 60. Coil 64 opens contact 66 which breaks the circuit to the radio control transmitter which results in reversing the antenna rotation once more.

When switch 28 is returned to the up position for continuous antenna rotation, the heater of rectifier tube 30 is kept energized to keep the circuit ready for immediate sector scanning operation. Also if relay 60 was last in the down position to provide counterclockwise antenna rotation coil 64 is energized through contacts 70 to operate relay 60 and open contact 66 to give clockwise antenna rotation as before on continuous scanning.

Thus it may be seen that our invention provides a means for automatic scanning of any predetermined angular width about any selected bearing angle. It should be noted that although our invention has been described as providing azimuth sector scanning, it may readily be used for angular scanning in any plane.

It is believed that the construction and operation as well as the advantages of our improved sector scan control will be apparent from the foregoing detailed description thereof. It will also be apparent that while we have shown and described our invention in a preferred form, changes may be made in the circuit disclosed without departing from the spirit of the invention as sought to be defined in the following claims.

What is claimed is:

1. In a motor driven scanning antenna system including means for reversing the drive of said motor in response to a change in signal applied thereto, an electrical system for causing said antenna to oscillate through a predetermined arc comprising, a synchro transmitter unit and a control transformer electrically coupled at their respective stator windings, said synchro unit having its rotor mechanically coupled to said antenna so as to rotate in synchronism therewith, means coupled to said control transformer for positioning the rotor thereof at a predetermined angle with respect to the stator of said control transformer to select a reference point on said scanning arc, a differential relay having first and second coils, first and second phase-sensitive detectors electrically coupling the rotor of said control transformer to said first and second coils respectively, the relative amplitudes of the signals applied to said first and second coils of said relay being a function of the phase and amplitude of the signal at the rotor of said control transformer, said relay being adapted to complete a first circuit when the unbalance of signals applied to said two coils reaches a predetermined magnitude in a first direction and to complete a second circuit when said unbalance in signals reaches a predetermined magnitude in the opposite direction and means coupled to said relay and said drive reversing means for reversing the

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direction of said drive upon the completion of either circuit by said relay.

2. An electrical system as in claim 1, said system further comprising an adjustable signal divider coupled between the rotor of said control transformer and said first and second phase-sensitive detectors for controlling the magnitude of said scanning arc.

3. An electrical system as in claim 1, said system further comprising manually operated switch means for disabling said phase-sensitive detectors to cause said antenna to scan continuously in one direction.

4. In a motor driven scanning antenna system including means for reversing the drive of said motor in response to a change in signal applied thereto, an electrical system for causing said antenna to oscillate through a predetermined arc comprising a synchro transmitter unit and a control transformer electrically coupled at their respective stator windings, said synchro unit having its rotor mechanically coupled to said antenna so as to rotate in synchronism therewith, means coupled to said control transformer for positioning the rotor thereof at a predetermined angle with respect to the stator thereof to select a reference point on said scanning arc, a differential relay having first and second coils, said relay being adapted to close a first circuit in response to an unbalance of signals applied to said coils of a predetermined magnitude and a first direction of unbalance and to close a second circuit in response to an unbalance of signals of a predetermined magnitude and the opposite direction of unbalance, first and second phase-sensitive detectors electrically coupling the rotor of said control transformer to said first and second coils, respectively, of said relay, the relative amplitudes of the signals applied to said first and second coils of said relay being a function of the phase and amplitude of the signal at the rotor of said control transformer, a two position, latch type relay coupled to said drive reversing means to control the operation thereof, said differential relay being coupled to said latch type relay to cause it to assume a first position upon completion of said first circuit and to cause it to assume a second position upon completion of said second circuit, said drive reversing means reversing the direction of the scan of said antenna each time said latch type relay changes position.

5. An electrical system as in claim 4, said system further comprising an adjustable signal divider coupled between the rotor of said control transformer and said first and second phase-sensitive detectors for controlling the magnitude of the scanning arc.

6. An electrical system as in claim 4, said system further comprising manually operated switch means for disabling said phase-sensitive detectors to cause said antenna to scan continuously in one direction, said latch type relay being connected to assume said first position upon the operation of said manually operated switch to disable said detectors.

7. In a motor driven scanning antenna system

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including means for reversing the drive of said motor in response to a change in signal applied thereto, an electrical system for causing said antenna to oscillate through a predetermined arc comprising a synchro transmitter and a control transformer, each having a rotor winding and stator windings, means electrically connecting together the respective stator windings of said synchro transmitter and said control transformer, means mechanically coupling the rotor of said synchro transmitter to said antenna so as to rotate in synchronism therewith, means including an alternating current source for energizing the rotor winding of said synchro transmitter, said control transformer being operative to produce at its rotor a single error signal having a phase and amplitude proportional to the angular difference between the rotors of said synchro transmitter and said control transformer, means coupled to said control transformer for mechanically positioning the motor thereof at a selected angle with respect to the stator to select a reference point on said scanning arc, a phase-sensitive detector including a pair of electron tubes, each having at least an anode, a cathode and a control grid, means coupling the anodes of said tubes to said alternating current source and arranged to apply in-phase energizing potentials to said tubes, means coupling the rotor of said control transformer to the control grids of said tube for applying said error signal to said grids in phase-opposition, a differential relay having first and second coils connected in the anode circuits of said first and second tubes, respectively, said relay being arranged to close a first circuit in response to an unbalance of currents in said coils of a predetermined magnitude and a first direction of unbalance and to close a second circuit in response to an unbalance of currents of said predetermined magnitude and the opposite direction of unbalance, the relative amplitudes of the currents in said first and second coils being proportional to the amplitude and phase of the signals respectively applied to the grids of said first and second tubes relative to the energizing potential of said anodes, and means operable by said relay for operating said reversing means.

8. Apparatus in accordance with claim 7 further comprising an adjustable signal divider coupled between the rotor of said control transformer and the control grids of said first and second tubes for controlling the magnitude of said scanning arc.

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