

CHAPTER 15

OPERATING PRINCIPLES OF A REPRESENTATIVE HEMISPHERICAL SCAN RADAR, AN/SPS-42 (PART II)

INTRODUCTION

This chapter continues the discussion of the hemispherical scan Radar Set, AN/SPS-42. The functional operation of the receiving, indicating, sidelobe suppression, waveform generating, antenna positioning, and power distribution sections are treated in this chapter. The synchronizing and transmitting sections of the AN/SPS-42 radar system are discussed in chapter 14 of this training course.

RECEIVING FUNCTION

The purpose of the receiving function (fig. 14-3) is to detect target echoes and to convert the echoes into identifiable signals. The echo

signals are displayed as target information on the screen of a plan position indicator (PPI) and a range-height indicator (RHI).

RECEIVING SECTION INPUTS

There are twelve inputs to the receiving section (fig. 15-1). These are the target return echo from the antenna, the local oscillator signal from the transmitting section, the sensitivity-time trigger, T_{stc} , the delayed early trigger, T_e , the coho enable trigger, T_{coho} , the MTI gate, \bar{E}_2 , short range video gate, M3, long range video gate, M2, short range timing pulse, T_{c1} , long range timing pulse, T_{c2} , MTI video gate trigger, T_v , and a test pulse.

The target return energy is routed to the receiver through the antenna and waveguide.

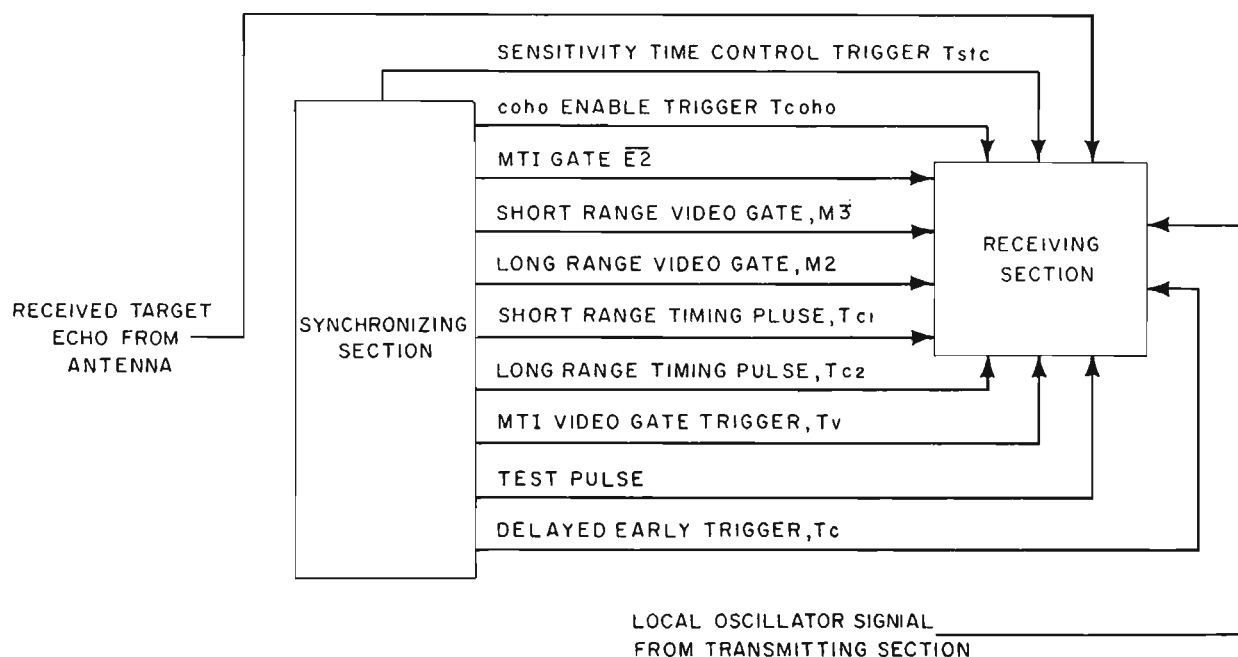


Figure 15-1.—Receiving section inputs. ^{032.266}

The frequency of the target return energy is between 2910.0 and 3090.0 megacycles.

The local oscillator signal is generated in the exciter and multiplier unit of the transmitting section. This signal is 12 mc above or below the transmitted frequency.

The sensitivity-time control trigger, T_{stc} , occurs 6.5 microseconds after the master trigger which initiates transmit time. The T_{stc} trigger initiates the generation of the sensitivity-time control signal.

The delayed early trigger, T_e , occurs 12 microseconds after the end of the sweep time, and initiates the generation of a dead-time gate in the sensitivity-time control circuit. The purpose of the dead-time is to blank the indicator during the sweep retrace time and to cut receiver IFs off during transmit time.

The coho trigger, T_{coho} , occurs 12 microseconds after master trigger time, and enables a coherent oscillator circuit in the MIT unit to lock in phase with the return echo gate. The action is described later.

MTI gate, \bar{E}_2 , is at a 0- or -15-volt level, and allows MTI video to pass to the clutter gate channel during the second transmission of a beam position. The two-transmission-per-beam action occurs during the normal MTI, CV, and CV-MTI modes of operation.

Short range video gate, M3, is at the 0- or -15-volt level, and allows short range video to pass through the coincidence video channel only when the beam elevation angle is above $12\frac{3}{4}$ degrees and during the second transmission on a beam position.

The long range video gate, M2, is also at either 0 or -15 volts, and allows the long range video to pass through the coincidence video channel only when the beam elevation angle is below $12\frac{3}{4}$ degrees and during the second transmission of a beam position.

Short range timing pulse, T_{c1} , generated in the synchronizing section is sent to the MTI unit during the first transmission on a particular beam position when the radar is in CV, MTI, or CV-MTI operation, and when the antenna beam elevation angle is above $12\frac{3}{4}$ degrees. The short range timing pulse is delayed for 819 microseconds and sent back to the synchronizing section as T_{mti} . This pulse, in turn, causes the termination of the first transmission on a particular beam position.

The long range timing pulse, T_{c2} , also generated in the synchronizing section is sent to the MTI unit during the first transmission on a particular beam position when the radar is in

CV, MTI, or CV-MTI operation, and when the antenna beam elevation angle is below $12\frac{3}{4}$ degrees.

The long range timing pulse is delayed for 2053 microseconds and sent back to the synchronizing section as T_{mti} which terminates the first transmission and starts the second transmission on a particular beam position.

MTI video gate trigger, T_v , is sent to the clutter gate to turn on the MTI video channel during the first 50 miles of travel of the transmitted beam when the radar is in MTI or CV-MTI operation.

When a test switch (not shown) is depressed, a test pulse from the synchronizing section is provided to check the operation of both the coincidence video and the MTI video channels.

ANTENNA AND MICROWAVE SECTION

The target echo enters the microwave section of the receiver through the antenna reflector (fig. 15-2) and primary feed of the antenna. The antenna reflector consists of two separate halves of a parabolic cylinder, each half of which is excited with its respective slot array (discussed in chapter 14). Isolation between the two sides of the feed is sufficiently great that the two halves of the reflector may be considered as two independent antennas placed side by side. The reflector focuses the reflected energy onto the active elements of the antenna feed, thereby concentrating the electromagnetic energy into the waveguide.

A rectangular waveguide is used with this radar system which is one-half wavelength wide and sufficiently large in its narrow dimension to prevent arc-over within the waveguide. The waveguide directs the target echo energy through a directional coupler and a duplexer to the waveguide-mixer.

The directional coupler is used to monitor the r-f energy supplied to the antenna. The duplexer acts as a switch which completes the path from the klystron final power amplifier in the transmitter to the antenna during the transmitting period, and completes the path from the antenna to the receiving section during receiving periods. The operation of the duplexer and directional coupler is treated in chapter 14 of this text.

MIXER-PREAMPLIFIER

The received signal is coupled from the duplexer to the crystal mixer assembly by the waveguide. At the end of each transmission, the

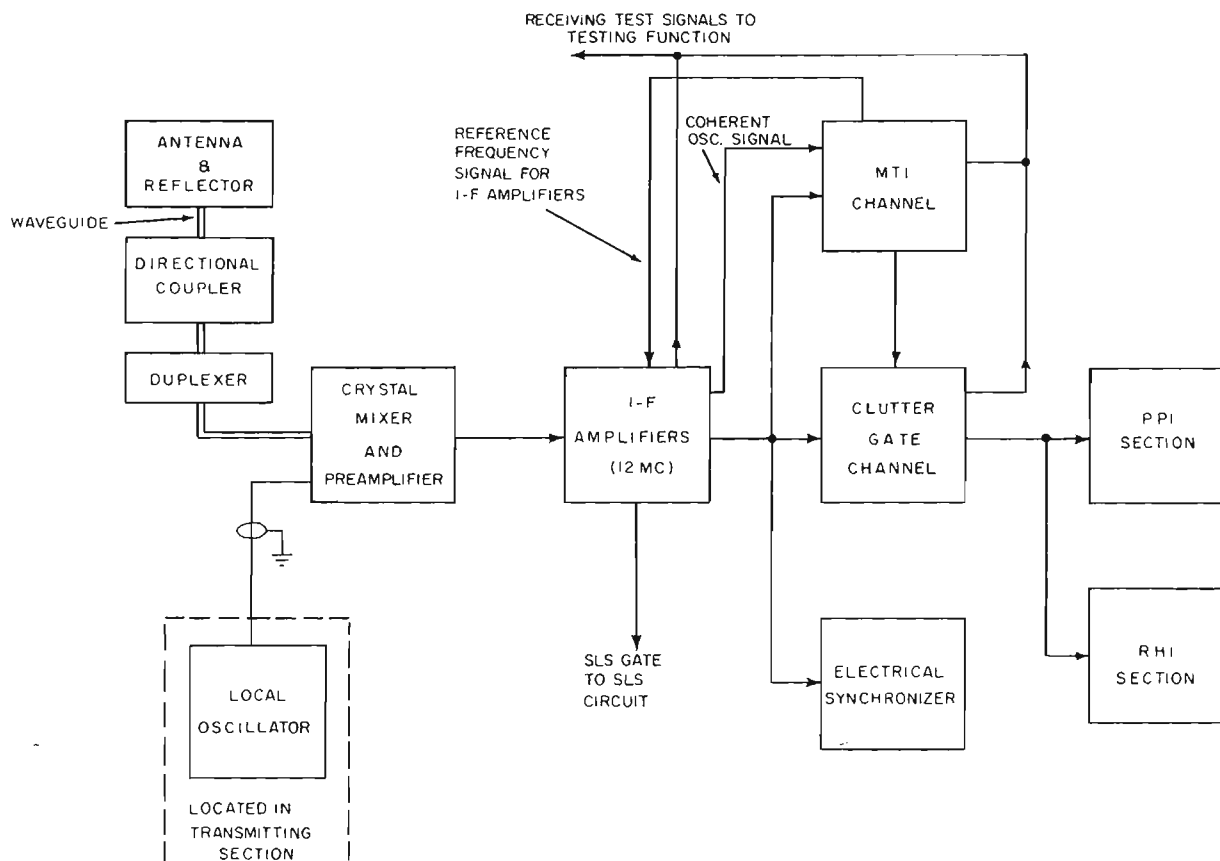


Figure 15-2.—Receiving section of Radar Set AN/SPS-42, simplified block diagram.

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crystal oscillators in the oscillator-amplifier section of the transmitting function are gated to provide a local oscillator signal separated 12 mc from the transmitted signal frequency. The local oscillator signal is routed through a coaxial cable to the crystal mixer. The local oscillator signal and the echo signal are mixed in the crystal mixer to produce a 12-mc intermediate frequency.

The i-f signal is amplified by a group of i-f preamplifier stages. The preamplifier consists of a duo-triode tube and pentode connected as a cascode amplifier in cascade with a shunt-peaked voltage amplifier. This circuit arrangement is used because of its high gain and low noise characteristics. The amplified output of the preamplifier is coupled through coaxial cable to a 12-mc i-f amplifier strip.

I-F AMPLIFIERS

The stages in the i-f amplifier strip amplify the low-level signals from the mixer-preamplifier. The i-f amplifier is divided into two

channels. These are the sensitivity-time control channel and the i-f amplifier channel. The i-f amplifier channel provides video outputs to the moving-target indicator channel (MTI), the clutter-gate channel, and to an electrical synchronizer. In addition to the video outputs, there is a 12-mc output signal to a coherent oscillator circuit in the MTI unit. The purpose of this oscillator is explained later.

The i-f amplifier section includes several control functions, such as manual gain control (MGC), fast automatic gain control (FAGC), and sensitivity-time control (STC).

The i-f signal from the waveguide-mixer (mixer assembly) is amplified in three i-f amplifiers, V1 through V3 (fig. 15-3), limited by V4, and further amplified in i-f amplifier V5.

The V5 output is applied to limiter-mixer V6, which is essentially a phase comparator that provides bipolar (positive- and negative-going) output. Stage V6 has two inputs. One of these inputs is the 12-mc i-f signal from V5, and the other is from a coherent oscillator located in the MTI unit.

CIRCUITRY OF SHIPBOARD ELECTRONICS EQUIPMENT

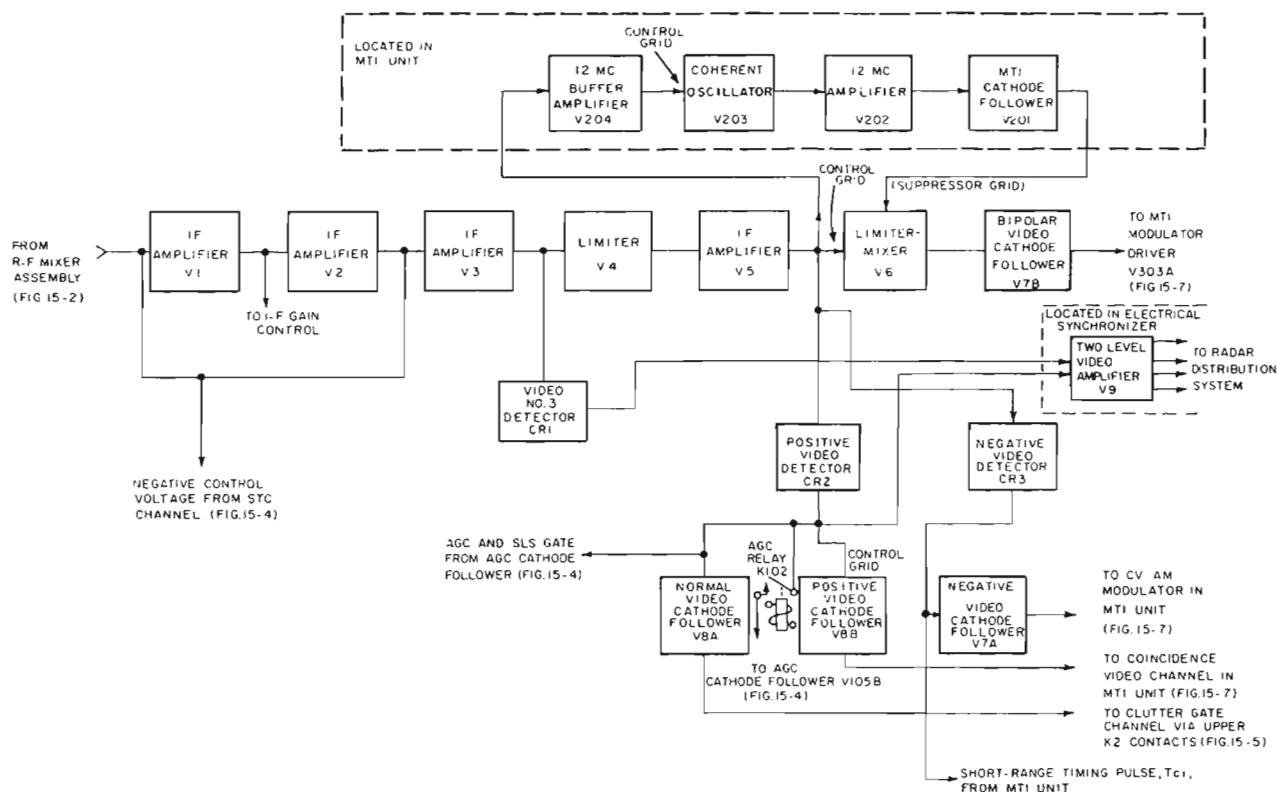


Figure 15-3.—I-f amplifier channel.

Coherent Oscillator

The coherent oscillator, V203, provides a 12-megacycle output which is made variable in phase by a 12-mc locking pulse received from the fourth i-f amplifier (V5) via 12-mc buffer amplifier V204. The coherent oscillator output is amplified in V202, and fed through cathode follower V201 to limiter-mixer V6. The 12-mc i-f signal to V6 is applied to the control grid while the coherent oscillator signal is applied to the V6 suppressor grid (tube not shown).

The limiter-mixer compares the phase of the 12-mc i-f signal from the first transmission on a given beam position with the phase of the second transmission on the same beam position. The phase of the first i-f signal is established as a reference phase by the coherent oscillator. The application of the locking pulse from the fourth i-f amplifier to the coherent oscillator control grid causes the oscillator frequency to pull into phase with the i-f signal. Thus, after four microseconds (the duration of the received pulse) the reference frequency output of V203 is at the same frequency and phase as the i-f signal. Because of amplification in 12-mc amplifier

V202, the phase of the 12-mc i-f reference frequency signal is shifted 180 degrees. This makes the reference frequency, as it appears at the suppressor grid of V6, 180° out of phase with the i-f signal at the control grid.

When clutter is present in the i-f signal, the arrival of the first clutter return causes the phase of the coherent oscillator (reference frequency) to shift to the phase of the clutter pulse. The phase of the reference frequency remains unchanged for the duration of the sweep time. Stationary targets which appear in the i-f signal after the first clutter pulse has been received will have a fixed phase relationship to the reference frequency for both sweeps on subsequent beam positions. If the phase of the i-f and reference frequencies are the same or have a fixed phase difference from sweep to sweep, the target information is made to cancel in the MTI unit. If all targets are stationary and MTI operation has been selected, the only presentation on the indicators will be the first four microseconds of the first clutter pulse.

If a moving target is present in the clutter, the phase of the i-f signal shifts because the phase of the moving target echo shifts with

respect to the clutter. This phase difference will be noted in the amplitude and polarity of the signal developed at the plate of limiter-mixer V6. The output from the plate of V6 is fed to the grid of bipolar video cathode follower V7B.

The bipolar video cathode follower is used to match the low input impedance of the line to the high output impedance of V6. Because the phase of the signals at the V6 grids may cause an increase or decrease in the amplitude of the V6 plate voltage, V7B must be able to pass either positive-going or negative-going signals. Thus, the V7B output may become more positive or less positive (with respect to ground) depending on the polarity of the V7B input.

Output Circuits

The cathode output of V7B is fed to an MTI modulator driver in the MTI unit (discussed later).

The output of 12-mc i-f amplifier V5 is applied to positive video detector CR2. The positive-going detected output of CR2 is applied to the grid of positive video cathode follower V8B. This signal is applied from the V8B cathode as a positive-going signal to the coincidence video channel in the MTI unit and subsequently to the indicators.

A negative-going automatic gain control (AGC) signal from the sensitivity-time control (STC) channel (discussed later) is applied to the positive video cathode follower control grid through the K102 contacts during fast automatic gain control (FAGC) operation to limit the maximum positive amplitude of the video signal at the V8B cathode. This, in turn, reduces the intensification of the indicator screen during strong spurious echo returns.

The rectified video signal from CR2 is also applied to normal video cathode follower V8A. The positive-going video signal causes an increase in the conduction of V8A, and thereby causes a positive-going signal to be developed across the V8A cathode resistance (not shown). The video signal from the cathode is fed to the clutter gate channel (discussed later).

During sidelobe suppression (SLS) operation, an SLS clamp pulse from the STC circuit is applied to the control grid of V8A. The SLS pulse reduces the V8A output during the presence of jamming signals. This prevents the leading edges of the jamming pulses from appearing on the indicators.

Negative video cathode follower V7A receives a negative-going video signal from negative video detector CR3. The input signal reduces

the conduction of V7A to develop a negative-going output signal at the V7A cathode. This signal is applied to the CV AM modulator, V406, in the MTI unit.

The short range timing pulse, T_{c1} , is applied to the V7A control grid from the MTI unit. This pulse, which occurs during the dead-time, places the V7A grid at ground potential for the duration of the T_{c1} pulse. This action ensures that receiver noise or random pulses will not pass to the CV AM modulator in the MTI unit.

The two-level video amplifier, V9, receives one input from i-f amplifier V3 via CR1, and a second input from i-f amplifier V5 via CR2. The purpose of the two-level video amplifier is to provide two levels of amplified video for the range-height indicator and distribution throughout the radar system.

Sensitivity-Time Control Channel

The sensitivity-time control channel develops the following: the STC signal which decreases the possibility of receiver saturation by nearby targets, the automatic gain control voltage which varies the gain of the receiver according to the strength of the input signal, the side-lobe suppression (SLS) gate that shuts off the receiver during the presence of strong undesired jamming pulses, and the SLS clamp which prevents the leading edge of the jamming pulses from appearing on the indicators.

The first and third i-f amplifiers (V1 and V5 of fig. 15-3) are STC controlled to reduce the receiver sensitivity during the first part of the radar receive period. This prevents jamming of the i-f amplifiers by high-level signals from close-in targets and clutter.

The average radar echo amplitude is inversely proportional to the fourth power of the range. The time between the transmitted pulse and the return echo is also proportional to the range. Because of these conditions, a definite relationship exists between the radar echo amplitude and the elapsed time.

The sensitivity of the receiver can be automatically adjusted to the average echo amplitude by generating a bias voltage which changes with respect to time. This bias voltage in the AN/SPS-42 receiver is a modified exponential voltage that is generated in the STC channel. It is used to bias the first and third i-f amplifiers in the i-f strip.

The controlling (STC) voltage is initiated by the sensitivity-time control trigger pulse, T_{stc} (fig. 15-4). This trigger is amplified in V101A. The amplifier is biased so that only signals of

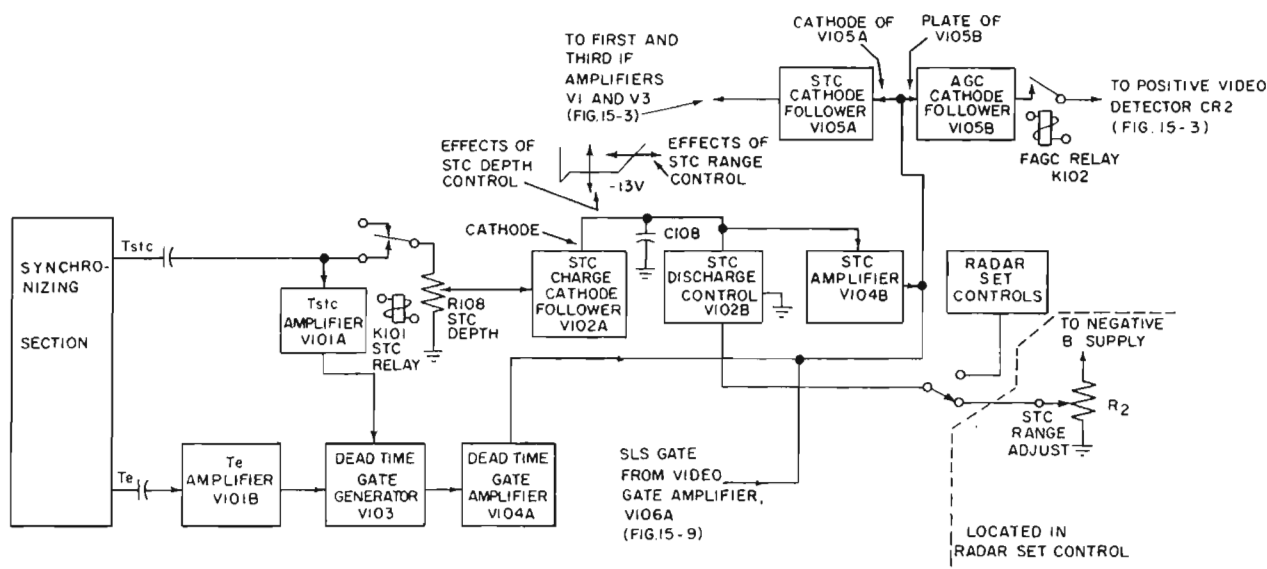


Figure 15-4.—Sensitivity time control channel.

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+10 volts or greater will be amplified. This eliminates the possibility of noise triggering the STC circuitry.

When STC relay K101 is energized (fig. 15-4), the T_{stc} trigger is applied to STC charge cathode follower V102A. The trigger causes V102A to conduct and thereby charge C108 (in the cathode circuit) to a value determined by the setting of STC depth control R108.

The slope of the C108 discharge is controlled by the STC discharge control tube, V102B through which C108 discharges. The STC range control, R2, which is located on the radar set control (fig. 14-1), feeds a negative bias voltage to the control grid of V102B and thereby controls the slope and duration of the output waveform.

The STC amplifier, V104B (fig. 15-4) inverts and amplifies the STC waveform. The V104B output drives STC cathode follower V105A which feeds its negative-going output to the control grids of the first and third i-f amplifier stages. This action controls the gain of the receiver over a radar echo return range from 0 to 50 miles.

Dead-Time Stages

You will recall from the discussion in chapter 14 that the early trigger (T_e) terminates the sweep time and starts the dead-time interval. The purpose of the dead-time stages is to blank the indicators during the sweep retrace time.

Dead-time gate generator (V103) is a bistable (flip-flop) multivibrator. The multivibrator is placed in the one state by early trigger pulse (T_e) which is received from the synchronizing function and amplified in V101B. The arrival of the amplified T_{stc} pulse from V101A places V103 in the zero state. This action produces a positive-going gate pulse at the V103 output which is applied to dead-time gate amplifier, V104A.

After amplification in V104A, the negative-going dead-time gate pulse is applied through STC cathode follower V105A to the first and third i-f amplifiers. This pulse cuts off these amplifiers to prevent the presence of the receiver video at the indicators during the period of the sweep retrace.

Fast Automatic Gain Control

Fast automatic gain control (FAGC) is used in Radar Set, AN/SPS-42, to overcome the effects of rapid variations of input signal amplitudes. The FAGC circuit is operative when K102 (fig. 15-4) is in the energized position (opposite to the position shown). The on-off condition of the FAGC relay, K102, is controlled from the radar set control.

When the FAGC circuit is energized (K102 contacts closed), a positive-going signal proportional to the amplitude of the received echo is applied to the V105B grid from the positive

video detector CR2 (fig. 15-3). The V105B plate potential therefore swings in the less positive- or negative-going direction an amount dependent upon the magnitude of the positive-going grid input. The negative-going plate output of V105B varies the bias on STC cathode follower V105A in accordance with the rapid variations of the input signal amplitude. The action produces a constant amplitude video output signal from i-f amplifiers V1 and V3 (fig. 15-3).

The SLS gate amplifier, V106 (fig. 15-9) provides an output that shuts off the receiver during the presence of jamming signals. This action is treated in detail later.

CLUTTER GATE

The clutter gate (fig. 15-5) acts as an electronic switch which controls the presentation of MTI video, normal video, or coincidence video to the radar indicators. The clutter gate continuously samples the returned video pulses and if any pulse is 10 microseconds or longer in duration, it is recognized as clutter.

The clutter gate is composed of three major channels: the clutter recognition channel, the MTI video channel, and the normal video channel. A brief description of the clutter gate operation follows.

In the normal mode of operation, the input to the clutter gate is either normal video or coincidence video. In the absence of clutter, normal video is passed to the indicators through the normal video channel. In the presence of clutter, the normal video channel is gated off and the MTI video channel is gated on. Thus, MTI video will be displayed on the indicators.

In the MTI mode of operation, the inputs to the clutter gate will be both MTI video and normal video. MTI video will be displayed during the first 50 miles of the transmission sweep, and beyond 50 miles in the presence of clutter. Beyond 50 miles, in MTI operation, the absence of clutter will cause the normal video channel to be gated on, thus causing the normal video to be displayed on the indicators. When clutter appears beyond 50 miles, the MTI video channel is gated on, thereby causing MTI video to be displayed. At the presence of clutter in either mode of operation, a clutter recognition trigger is generated and sent to the MTI unit.

Clutter Recognition Channel

The clutter recognition channel identifies any pulse of 10 microseconds or longer in duration as clutter. If the pulse is 10 microseconds or

longer, the clutter recognition channel gates on the MTI video channel. If the pulse is shorter than 10 microseconds, the clutter recognition channel gates on the normal video channel. At the appearance of clutter, the clutter recognition channel also generates a clutter recognition trigger pulse which is sent to the MTI unit.

The selection of either normal video or coincidence video for application to the clutter gate is performed by CV ON/OFF relay K2. When the operator selects CV (coincidence video) at the front panel of the radar set control, a ground is applied to K2 and the relay energizes.

In the energized condition, K2 supplies coincidence video to the clutter gate input. In the deenergized condition (as shown) K2 supplies normal video to the clutter gate.

The operation of the clutter gate is the same for coincidence video and normal video. Because the K2 contacts are in the normal video position, a normal video input is assumed throughout this discussion.

The normal video input is coupled to the base clipping network (CR2 through CR4) where noise at the base of the signal is eliminated. The input video is amplified in video amplifier V3A and fed to cathode follower V3B. Stage V3B is cut off by the negative video signal from V3A, and thus produces a negative-going video signal which is used to drive delay line DL1.

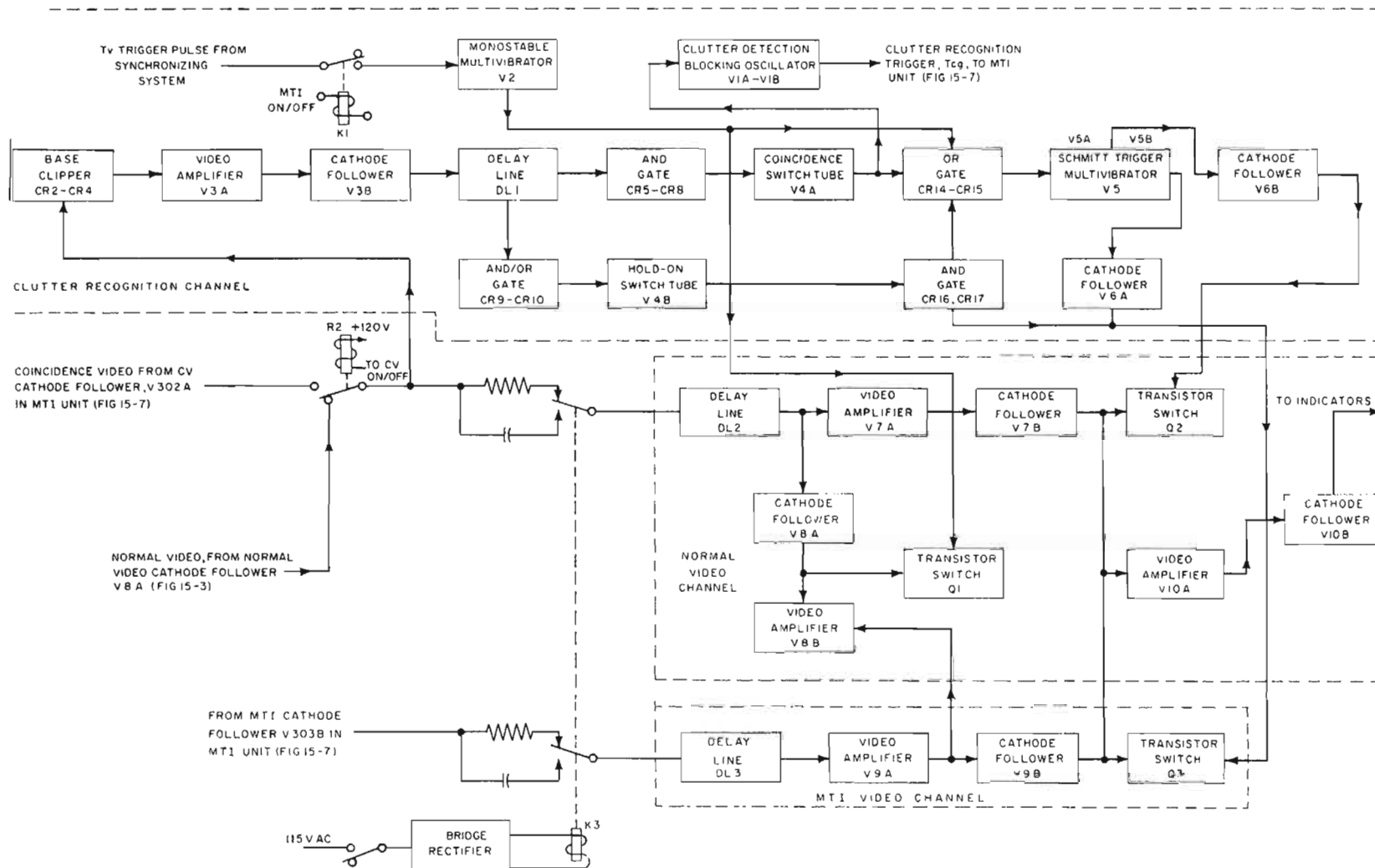
The delay line, DL1, does not produce an output if the input pulse is shorter in duration than 10 microseconds. When the input pulse is 10 microseconds or longer in duration, DL1 recognizes the pulse as clutter and produces two outputs. One of these outputs is applied through AND gate CR5 through CR8 to coincidence switch tube V4A, and the other is fed through AND/OR gate CR9 and CR10 to the hold-on switch tube, V4B.

The delay line (fig. 15-6) presents a 10-microsecond delay between taps 2 and 5, and an additional 2-microsecond delay between taps 5 and 6. To understand the operation of the line, assume that a 10-microsecond pulse is applied to the junction of CR5 and terminal 2 of the line.

First note that the potential at the CR9-CR10 junction is +1.48 volts as a result of the voltage divider action of R20 and R22. This potential causes CR5 through CR9 to conduct from the -150-volt supply through R21 and R22 to the +150-volt supply.

Diode CR12 conducts through R25 and a positive potential of about .2 volt is developed at the R23-CR12 junction. This potential is applied to the anode of CR11. Because the anode of

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Figure 15-5.—Clutter gate channel.

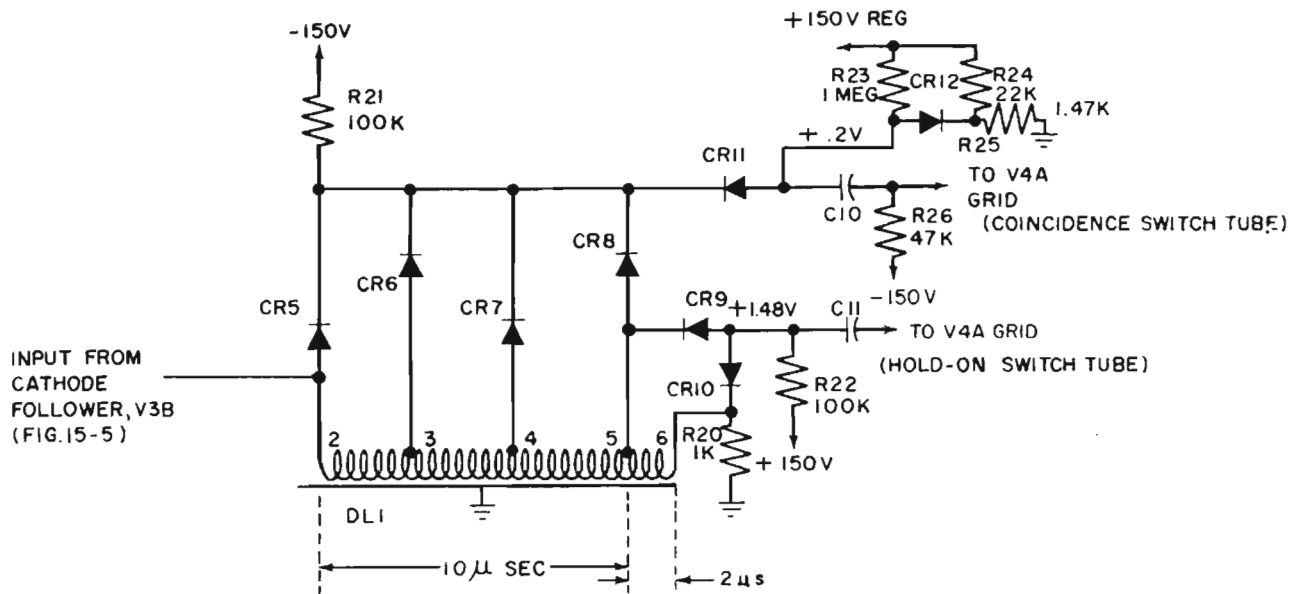


Figure 15-6.—Delay line, DL1. 032.271

CR11 is +.2 volt and the cathode is +1.48 volts, CR11 does not conduct.

The input pulses are negative-going and of variable duration (depending on the duration of the radar echo return). At the instant the leading edge of the input pulse is applied to the anode of CR5, this diode cuts off. Diode CR5 will remain cut off for 10 microseconds if the duration of the input pulse is 10 microseconds.

After the time delay between terminals 2 and 3 of DL1, the negative-going input pulse is applied to the anode of CR6. Thus, this diode is also cut off.

If the input pulse is assumed to be slightly longer than 10 microseconds in duration, each of the diodes (CR5 through CR8) will be driven to cutoff in succession as the pulse travels down the delay line. With CR5 through CR8 cut off, the cathode potential of CR11 rises toward the -150-volt supply, and CR11 is gated on. This action causes a negative pulse to be fed through C10 to the control grid of coincidence switch tube V4A.

A pulse that is shorter than 10 microseconds in duration could not cut off CR5 through CR8 at the same time. Thus, the CR11 cathode would not go negative enough to cause CR11 to conduct, and no negative pulse would be applied to the V4A grid.

The coincidence switch tube, V4A, receives the negative-going input pulse from DL1 when the clutter input pulse to the line has a duration greater than 10 microseconds. The coincidence

switch tube amplifies and inverts the signal and feeds it to the clutter detection blocking oscillator, V1, and through OR gate (CR14-CR15) to Schmitt trigger multivibrator V5.

Diode CR9 (fig. 15-6) operates similar to CR11, when a pulse greater than 10 microseconds is applied, to couple a negative-going output through CR11 to the control grid of hold-on switch tube V4B. Diode CR10 ensures that the pulse duration at the V4B grid is limited to 2 microseconds.

Note that 2 microseconds after CR9 conducts, CR10 receives a negative pulse at its cathode. The voltage drop across CR10 is negligible, and the negative pulse at terminal 6 of DL1 is applied to the anode of CR9. Thus, CR9 ceases conduction and the duration of the negative output pulse to the V4B grid is terminated after the 2-microsecond delay between terminals 5 and 6 of DL1.

Switch Tubes

When coincidence switch tube V4A (fig. 15-5), feeds its positive trigger through OR gate CR14 and CR15 to the Schmitt trigger multivibrator, V5, this stage changes its conducting state. Before triggering, V5B is conducting and V5A is cut off. The change in the condition of the multivibrator causes a positive-going V5B output to be fed through cathode follower V6A and CR16 to hold-on switch tube V4B. Because of the action of the delay line DL1, hold-on switch tube

V4B keeps the Schmitt trigger multivibrator on for two microseconds longer than the video input pulse duration.

The V6A positive-going output is also applied to transistor switch Q3 at the input to the MTI video channel. The positive-going Q3 input pulse gates on the MTI video channel.

If coincidence switch tube V4A is not triggered, V5 is held in a condition which allows a pulse to be fed through cathode follower V6B and transistor switch Q2, of the proper polarity to gate on the normal video channel.

The clutter detection blocking oscillator stage, V1, consists of an amplifier and blocking oscillator. When clutter is detected by the delay line (DL1), the coincidence switch tube sends a positive pulse to V1B, causing this stage to conduct. This causes conventional blocking oscillator action in V1A. The blocking oscillator develops a positive pulse which is fed to the MTI unit as the clutter recognition trigger, T_{cg} .

During the first 50 miles of the transmission sweep in MTI and CV-MTI operation, the monostable multivibrator, V2, generates a gate of 600 microseconds duration. The generation of this pulse in V2 is initiated by trigger pulse T_v , which is received from the synchronizing function at the start of each transmission period and applied to V2 via the closed contacts of MTI ON/OFF relay K1. This relay is energized when the operator selects either the MTI or CV-MTI mode of operation.

The 600-microsecond pulse from V2 passes through OR gate CR14 and CR15 to the Schmitt trigger multivibrator, V5. The arrival of this pulse at V5 causes the V5 output through V6B to gate on the MTI video channel for 600 microseconds, which is equivalent to a radar reception distance of about 50 miles.

The V2 output pulse is also fed to transistor switch Q1. The presence of this pulse at Q1 causes it to conduct and essentially ground the grid of normal video amplifier V8B. This action prevents the normal video from entering the MTI channel during the first 50 miles of radar reception.

MOVING TARGET INDICATOR

The moving target indicator unit (fig. 15-7) receives video inputs from the i-f amplifier (fig. 15-3) and develops video signals to be sent through the clutter gate to the indicators. The MTI unit operates during three modes: MTI, CV, and CV-MTI. During normal operation, the video outputs from the MTI unit are gated off.

MTI operation is used to detect the presence of moving targets in clutter, and is available on the bottom four transmitted beam positions.

Coincidence video operation is an effective means of eliminating random pulse jamming. In coincidence video operation, the target return must be present at the same range on two successive transmissions of a beam position before video is passed to the indicators.

CV-MTI operation provides a means of eliminating random pulse jamming and detecting moving targets in the presence of clutter. CV-MTI operation is available on the bottom 16 beam positions.

The MTI unit consists of three major channels. These are the MTI video channel, the coincidence video channel, and the coherent video channel.

Bipolar video from V7B (fig. 15-3) is fed through MTI modulator driver V303A (fig. 15-7) to MTI oscillator V401. The oscillator produces a 26.5-mc signal which is frequency modulated by the video input from V303A. The oscillator (V401) provides an input to MTI delay line driver V403 and to MTI undelayed amplifier V402.

In addition to the input from V401, MTI delay line driver V403 receives the long range timing pulse, T_{c2} , from the synchronizing section. During the presence of T_{c2} , the MTI carrier is amplitude modulated and fed to long range delay line DL2.

The delay line (DL2) introduces a delay of 2053 microseconds (the time of one transmission period) in the first transmission on each of the bottom four beam positions. After delay, DL2 feeds its output to TDL preamplifier V504.

Stage V504 amplifies the delayed echo. This signal is passed through three MTI post amplifiers (V101 through V103) to the MTI phase comparator, V104. The TDL preamplifier (V504) output is also fed to the first TDL CV post amplifier, V505. The purpose of this output is explained later.

The MTI phase comparator, V104, provides a means of comparing the phase of the delayed MTI i-f signal with the phase of the undelayed MTI signal. The phase difference between the two echoes is reproduced as a detected video which is sent through a low-pass filter (not shown in the diagram) to a differentiator circuit.

The differentiator circuit produces an output voltage proportional to the rate of change of phase between the delayed and undelayed signals. This information is passed through MTI residue amplifiers V107B and V107A, and phase splitter V106B to a full-wave bridge rectifier.

This circuit produces a positive output to MTI gate transistor Q101.

Transistor Q101 prevents any MTI video output to the clutter gate during the normal mode of operation or during the first transmission period of MTI operation. The MTI gate $\overline{E}2$, which is applied to Q101 from the synchronizing function, places the base of Q101 (an NPN transistor) at a positive potential during the normal mode and during the first transmission period of MTI operation. This action causes Q101 to conduct and essentially short the grid of MTI residue cathode follower V106A to ground. During the second transmission on each beam position in MTI operation, the MTI gate $\overline{E}2$ is not present at Q101 and the transistor does not conduct. In this condition, a positive video signal (the MTI residue video) is developed at the grid and cathode of V106A and sent via the CV-MTI OFF/ON relay contacts and V302B and A to the clutter gate.

In coincidence video operation, the radar transmits twice on each beam position. The echo return from the first transmission is compared in time with the undelayed second echo return. In order to obtain an output from a pulse coincident video system, the radar echo return must be present at the same range on each of the two successive transmissions of a beam position.

The operation of the system during coincidence video is similar to that described for MTI operation. When CV has been selected, pulse coincident video will be substituted for normal video in the clutter gate.

SIDE LOBE SUPPRESSION SECTION

The side lobe suppression (SLS) circuit provides a means of preventing large ground returns, jamming signals, and interference caused by other radars from disrupting the indicator displays.

The radar antenna (fig. 14-1), which consists of a vertical array of 44 pairs of slot radiators, is monodirectional, that is, it provides an appreciable gain in signal strength in one direction only. The radiation pattern in the direction of maximum gain is called the major lobe, or main beam (fig. 15-8) of the antenna. The radiation pattern also contains secondary maxima called side lobes, which are offset from the main beam.

The gain of the side lobes of the monodirectional antenna used with Radar Set AN/SPS-42 is approximately 20 db less than that of the major lobe. If a signal source is located in a

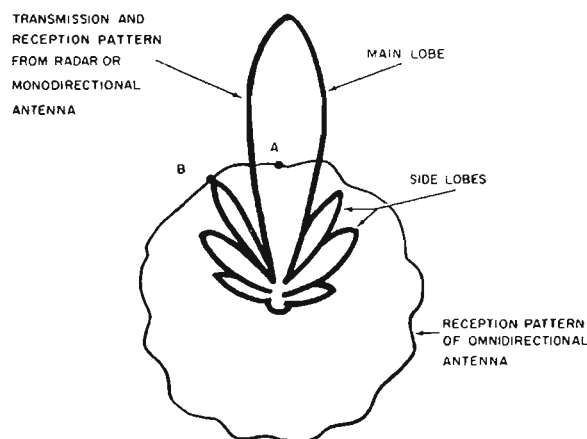


Figure 15-8.—Representative radar beam pattern.

032.273

side lobe, however, and if the return energy from the source is of sufficient magnitude, the radar receiver will detect the false target despite the reduced gain of the antenna in this direction. In such case, the objectionable target video appears on the indicators when the antenna side lobe is pointing at the target.

When the extraneous signal consists of jamming radiation or radiation from another radar operating in the same frequency range as Radar Set AN/SPS-42, the amplifier circuits of the radar receiver may saturate. Saturation can occur even though the jamming source is not located within the main beam of the antenna. Such strong signal saturation causes "blooming" on the indicator displays. Blooming is defined as a loss of definition resulting from defocusing of the electron beam caused by overmodulation by strong signals. This overmodulation is likely to mask legitimate targets which appear within the bloomed area.

The sidelobe suppression circuit (fig. 15-9) consists essentially of a monodirectional receiver, an omnidirectional receiver, a signal comparator with its associated amplifiers and trigger circuits, and an i-f amplifier channel. The omnidirectional receiver receives target echoes from the omnidirectional (or omni) antenna, while the monodirectional receiver receives its signal from the radar or monodirectional (or mono) antenna.

The omni antenna provides the same signal gain in all directions (fig. 15-8). Hence, the strength of the target signal received via the omni antenna is not dependent upon the direction in which the antenna is pointing. The signal from the omni antenna can therefore be used to

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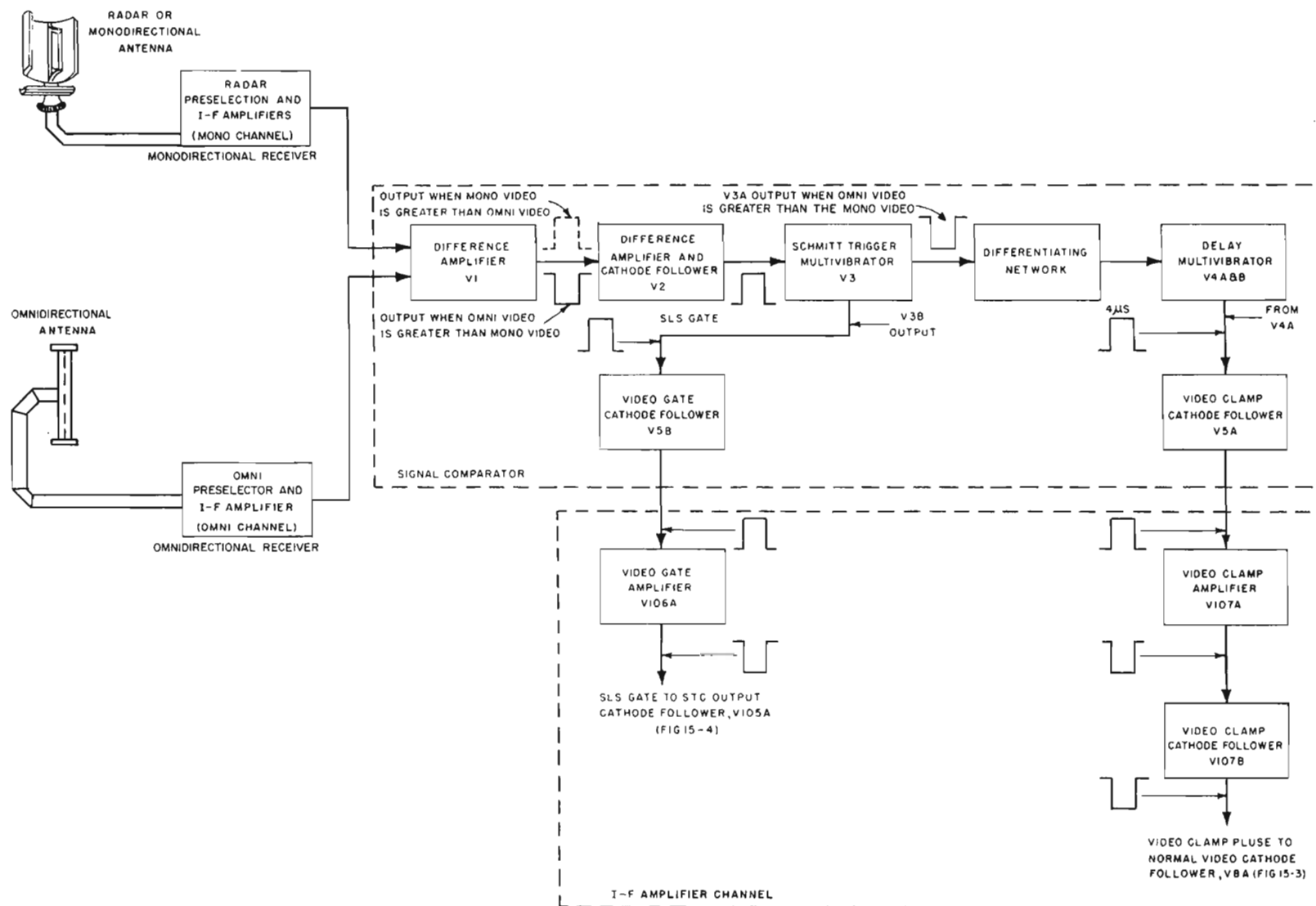


Figure 15-9.—Side lobe suppression circuit.

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establish a signal reference level which is compared with the same target signal from the mono antenna, whose input signal amplitude is highly dependent upon whether or not the antenna is pointing at the target in question. This provides a method of determining by means of signal comparison, whether a target echo is originating inside or outside the main beam of the radar antenna.

The mono antenna has greater gain than the omni antenna only when the antenna is pointing in the direction of the target. For a given target at A (located in the main lobe beam), the mono antenna will produce a greater gain in the echo return than will the omni antenna for the same target. However, echoes received from the mono antenna or omni antenna for a target at B will produce virtually the same gain. Thus, by comparing the signal strength from both antennas, it can be determined whether or not a target is outside the main beam.

If the target lies outside the main beam, appropriate action can be taken to suppress the off-beam or erroneous echoes. The signals from both antennas are converted to the intermediate frequency, amplified, and detected in separate receiver channels (fig. 15-9).

The two receiver channels are identical except that the output of the mono-SLS i-f amplifier is attenuated in a voltage divider. As a result, equal signals applied to the inputs of the two receivers produce unequal outputs, with the omni video output being the larger of the two. In case of a target located in a side lobe, therefore, the two antennas will provide the same gain, and the signal inputs to the two receivers will be equal in amplitude. At the receiver outputs, however, the omni video will be larger due to the attenuation of the mono video.

The video output signals from the two receivers are routed to a difference amplifier (V1) in a signal comparator. The difference amplifier, V1, produces an output equal to the difference in the two input signals. When the omni video signal is larger than the mono video, the V1 output is negative going. This output is amplified and inverted in V2 (A section) and fed through the cathode follower section of V2 (B section). The V2 output pulse will be positive going only when the omni video input to V1 is greater than the mono video.

The positive-going pulse from V2 is applied to the A section of Schmitt trigger multivibrator, V3. The A section conducts and the B section cuts off. The positive-going B section output is the SLS gate pulse which is fed through V5B and amplified in V106A and fed to STC

cathode follower, V105A (fig. 15-4). Thus, even as the target is being received, the negative-going SLS gate is superimposed on the STC voltage thereby causing the first and third i-f amplifiers of the radar receiver to cut off for the duration of the side lobe echo.

When the mono video is greater than the omni video, the V1 output will be positive. The V2 output will be negative going, and V3 does not produce an SLS gate output. In this condition, the normal STC voltage is not affected by the SLS circuit output.

In addition to the action of the SLS circuit to suppress side lobe targets, this circuit is also used to suppress jamming signals and signals from radar systems operating on or near the same radio frequency as that of the AN/SPS-42.

The presence of a positive-going output pulse from V3B (as discussed) indicates that the side lobe suppression circuit has been activated. Likewise, a negative pulse from V3A indicates the SLS circuit is active. The pulse from the A section of V3 is differentiated and applied to the input of delay multivibrator, V4. This circuit is a monostable multivibrator.

The differentiated pulse consists of a negative spike, corresponding to the leading edge of the Schmitt trigger pulse output when the SLS gate is generated, and a positive spike corresponding to the trailing edge. The positive spikes are shorted to ground through a diode, leaving the leading edge negative spikes to trigger the delay multivibrator.

When a negative pulse is received at V4, the A section of the tube goes to cutoff for 4 microseconds, after which V4 reverts to its stable state with the A section conducting and the B section cut off. The resultant 4-microsecond positive pulse is passed through video clamp cathode follower V5A to video clamp amplifier V107A.

Stage V107A inverts and amplifies the input signal. The V107A output is clamped at the input to V107B to a predetermined level. The output of V107B is applied to the grid of normal video output cathode follower V8A (fig. 15-3). When the 4-microsecond negative pulse is present at the V8B grid, the tube will be biased to cutoff for the duration of the pulse, and transients introduced by the SLS gate or transients caused by short (less than 4 microsecond) jamming pulses are eliminated from the radar receiver output.

ANTENNA POSITIONING SECTION

The primary purpose of the antenna positioning section (fig. 15-10) is to provide for control

of the azimuth rotation of the radar antenna. Control of the antenna rotation and position is accomplished manually or automatically.

During the automatic mode of operation, the radar antenna rotates clockwise at any one of four selected speeds. The normal speed is 15 rpm, with an accuracy of 10% under wind conditions up to 80 knots. The other antenna operating speeds are 4.8, 11.5, and 30 rpm, respectively. The antenna can be positioned manually through 360° in accordance with a rate signal developed by cranking a hand tachometer.

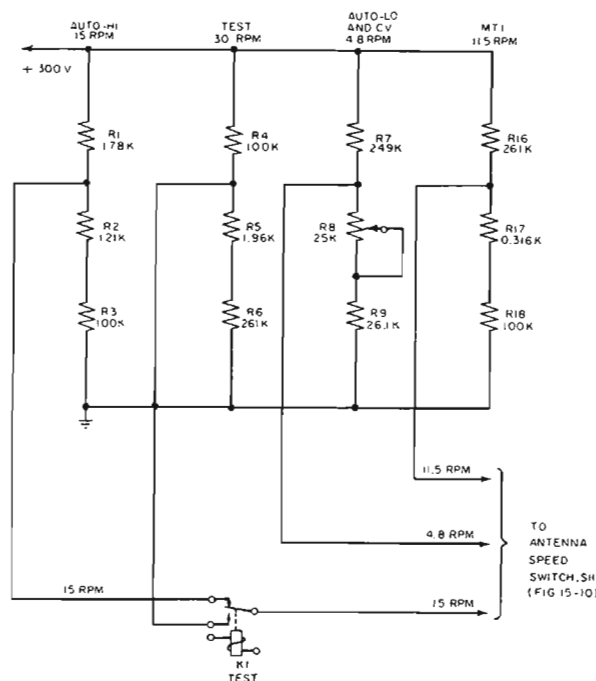
The antenna positioning section is a closed loop and requires no input signal from the other major sections of the radar system. The only inputs necessary are the a-c and d-c operating voltages from the power supplies used by the antenna positioning section. It is possible, however, to inject a voltage error into the loop for test purposes.

The antenna positioning section provides synchro-positioning data voltages for the indicating section (discussed later). The synchro-signal-voltage positions the sweep on the cathode-ray tube of the plan position indicator (PPI) to correspond in azimuth (bearing) with the radiating surface of the radar antenna throughout the 360° rotation.

The antenna pedestal (fig. 15-10) houses the antenna drive motor, antenna gear boxes, tachometer, and two synchro transmitters. Rotation of the antenna causes a d-c voltage proportional to the speed of rotation to be generated by the tachometer, G1. The tachometer d-c voltage is routed to the servoamplifier where it is compared with a selected (fixed) antenna speed command signal voltage to determine if the antenna is rotating at the selected speed.

The d-c signal command voltages required to produce the four antenna speeds are obtained from four voltage dividers (fig. 15-11). The auto-hi (15 rpm) voltage divider, comprising R1, R2, and R3, produces a voltage at the R1-R2 junction which is fed through the K1 contacts (in the position shown) to the antenna speed switch, S11, in the electronic control servoamplifier (fig. 15-10). With S11 in the AUTO position, the d-c command signal is fed through section 2 and through the contacts of K4 (all in the position shown), through the K2 contacts (in the position shown), to the arm of the tachometer slope adjust, R35.

The d-c voltage generated by tachometer G1 is developed across voltage divider R35 and R36. It is across these resistors that the tachometer and the d-c command signals are compared.



032.276

Figure 15-11.—Method of producing antenna speed d-c command signals.

If the antenna is rotating at the proper speed, the d-c command signal (from the R1-R2 junction, fig. 15-11) and the tachometer (G1) input voltage are equal in magnitude, and no error voltage is introduced to the servoamplifier. If the tachometer voltage is incorrect for the selected speed, the comparison will produce an error voltage at the input to amplifier V2 (fig. 15-10). The error voltage is fed through the lower contacts of K2 to the amplifier gain control, R43.

The error voltage developed at the arm of R43 is amplified in V2 and V3, and fed to a phase inverter, V4. The V4 output is push-pull amplified in V5 and V6 and applied to the motor-generator. The output voltage of the motor-generator is determined by the magnitude of the push-pull amplifier output. The motor-generator voltage output drives the antenna drive motor, B1.

The antenna circuit operates similarly to control the antenna rotation at any selected speed. The d-c command voltage to be compared with the tachometer input is determined by the position of S11 (fig. 15-10). This switch selects a different voltage divider (fig. 15-11) for each selected antenna speed. The push-pull amplifier output, in turn, provides a magnitude

of voltage to the motor-generator to control antenna speed.

INDICATING FUNCTION

The indicating function of Radar Set AN/SPS-42 presents visual displays of airborne targets and their positions in terms of azimuth, elevation, and range. The ground range is presented up to 160 nautical miles through an azimuth of 360 degrees. The slant range is presented up to 75,000 feet through the same angular scan.

The indicating function contains three major sections. These are the data-stabilization section, the azimuth and ground-range indicating section, and the slant-range and height indicating section.

DATA-STABILIZATION SECTION

Detection and display of target information must be performed with a high degree of accuracy. In order to achieve this, the radar antenna must be space stabilized to compensate for pitch and roll of the ship on which the antenna is installed.

The data-stabilization section receives pitch and roll information from the ship's stable elements (motion and directional instruments), and azimuth information from the antenna. With this information, the data-stabilization section performs mathematical operations to produce output signals which enable the radar data to be displayed in space-stabilized coordinates on the cathode-ray tube screen. The target data presentation on the screen is obtained by cancelling out any information which results from motions of the ship. The indicator display is then true target information as though the ship were not pitching and rolling.

As the ship pitches and rolls, the attitude of the antenna (mounted on the ship's deck) varies accordingly. Unless compensated for, these motions will appear on the radar indicator and could possibly be interpreted falsely as target motions.

In order to make proper corrections for such errors, the ship's motion or motions are electronically subtracted from the return signal data in the data-stabilization section prior to the display of the echo return on the indicators. Electronic stabilization is quicker, simpler, and more accurate than the more conventional electromechanical servosystem for stabilizing the radar antenna platform.

Space stabilization geometry is discussed in chapter 14 of this text, with the aid of figure 14-13. Space stabilization geometry refers to the accurate relationships of the various angles giving rise to the signal data displayed on the indicators. These relationships include the position of the radar beam with respect to the ship's deck, the attitude of the ship's deck with respect to the horizontal plane, and the angle of the ship's course with respect to the meridian.

The various error signals are sensed by potentiometer rotors and resolvers contained in separate azimuth, pitch and roll, and own ship's course correction channels. The error signal is electronically corrected for motions of the antenna platform. The corrected signals (corrected for azimuth, pitch and roll, and own ship's course information) are used by the indicators in displaying the return echo in its correct position on the cathode-ray tube screen.

AZIMUTH-RANGE INDICATING SECTION (PPI)

The azimuth-range indicating section, also known as the plan position indicator (PPI), is primarily used to indicate the position or positions of targets at ground range and the bearing of the ship with respect to true north. The PPI-scope (fig. 15-12) can display clouds, mountains, islands, and other large objects which may be present in the space scanned by the antenna. However, the presentation of large masses can be eliminated from the display by a special circuit network incorporated in the equipment. The screen display becomes visible each time a radial sweep scans the face of the scope. The frequency of the sweep is dependent on and is equal to the rate of antenna revolution.

The PPI-section contains all of the azimuth and range display circuits and their associated controls. The display elements consist of rangemarkers which designate target position at ground range, a range strobe to locate and intensify the target position on the screen, a heading marker to indicate ship's bearing with respect to true north, and two cursors to localize target returns on the scope. These displays are geometrically presented on the cathode-ray tube screen by means of synchronized time-sharing and sweep-generating circuits in combination with a sweep deflection channel. This section receives its signals from the data-stabilization section, range-height indicating section, and local reference sources.

CIRCUITRY OF SHIPBOARD ELECTRONICS EQUIPMENT

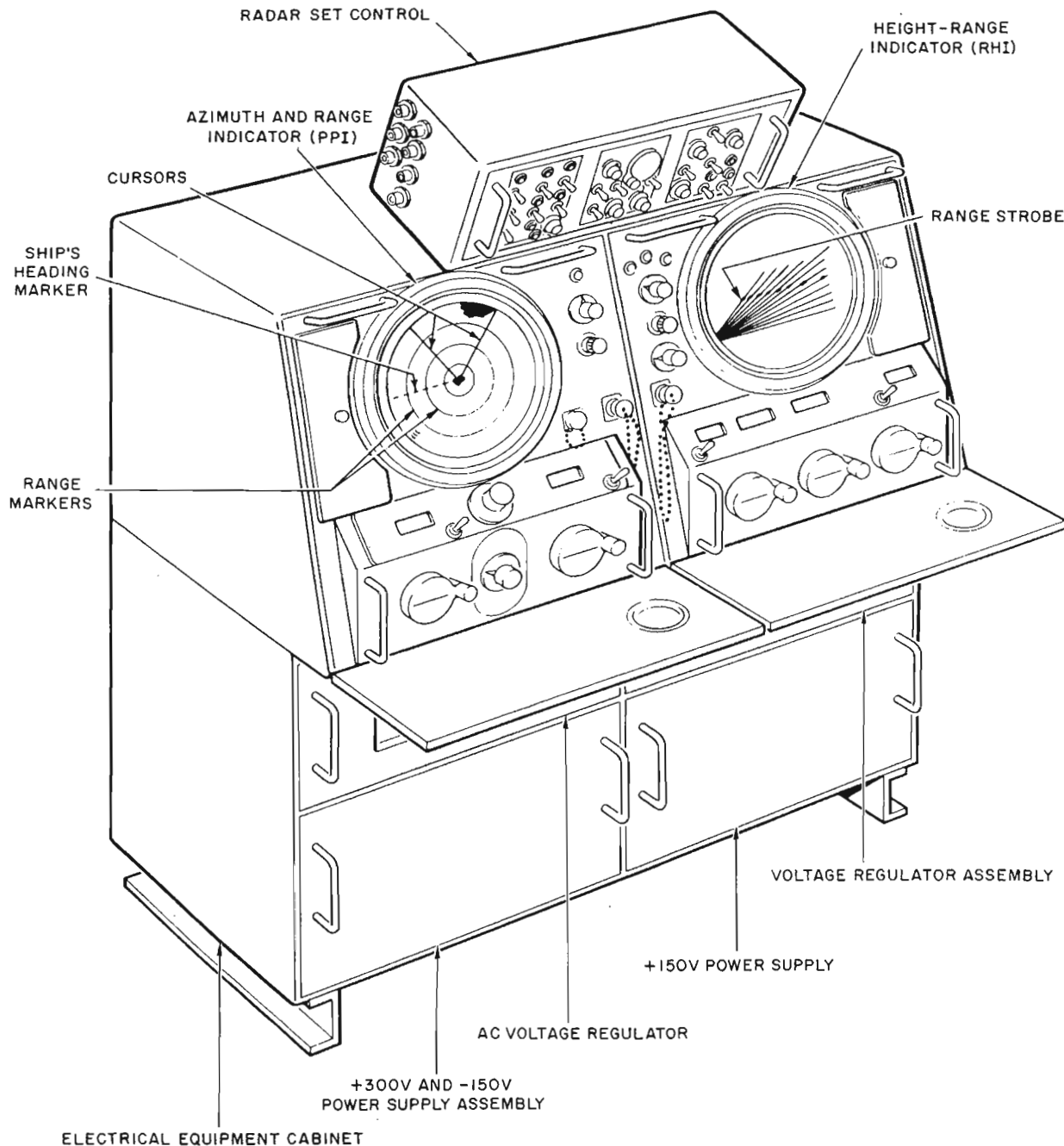


Figure 15-12.—Radar indicator. 032.277

SLANT-RANGE AND HEIGHT-INDICATING SECTION

The slant-range and height indicator (fig. 15-12), also known as the range-height indicator (RHI), provides target height information at slant range in the same increments as for the azimuth-range indicator. Target height data

is provided up to 75,000 feet except for a cone of 80° immediately over the antenna. The electronic display elements provided in this section are: a height line, an elevation-angle cursor, a range strobe, and target signal.

The RHI unit displays targets on a rectangular display of slant range against target altitude. The RHI sweeps originate in the lower left-hand

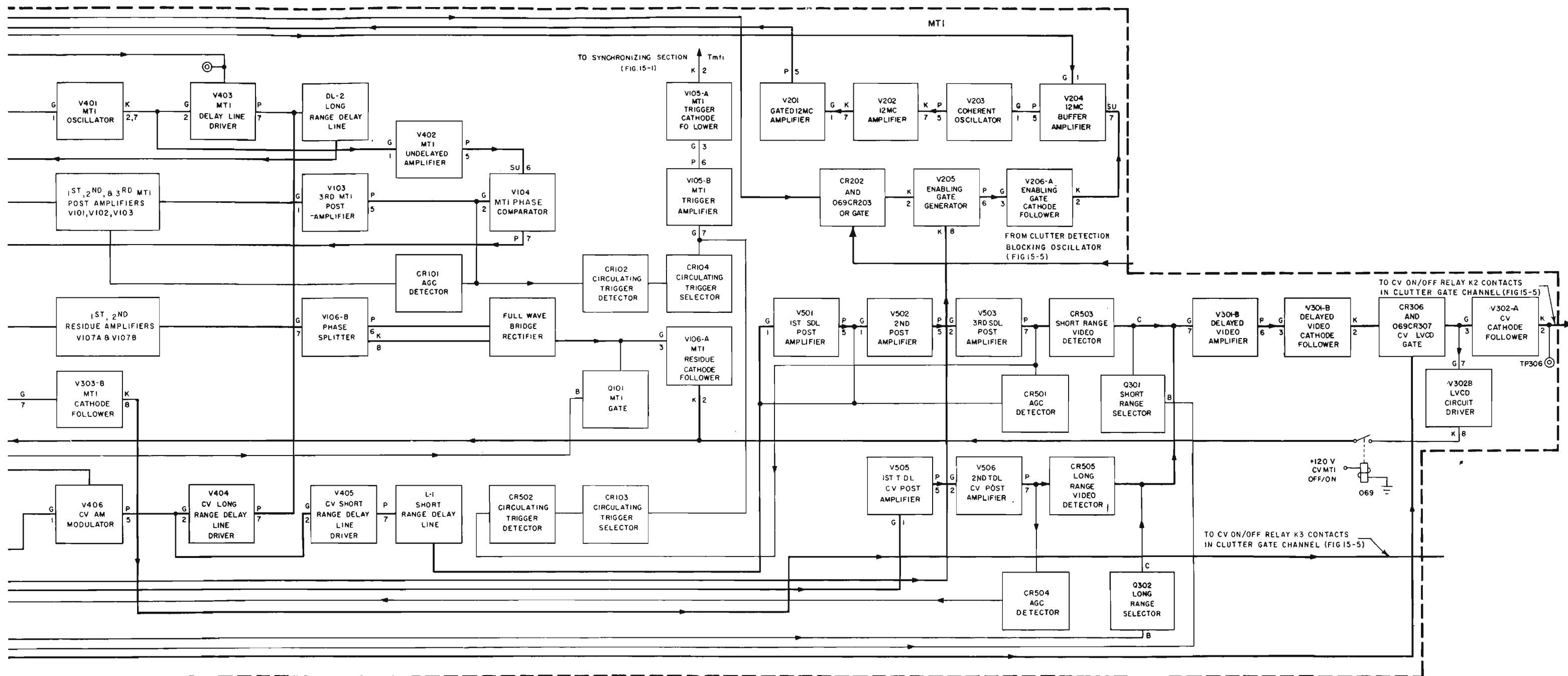
corner of the rectangular display and move to the right along an angle corresponding to the elevation angle of the antenna beam. Thus, the RHI presents a fan of 26 separate lines radiating from the left-hand corner of the display, each line corresponding to one of the 26 elevation steps of the radar beam.

The target distance from the sweep origin (lower left-hand corner of the display) represents the target slant range. The target distance vertically above the CRT baseline represents the target height above the horizon line. The angle subtending the sweep line and the CRT baseline represents the elevation angle of the target.

ER-MIXER V6 CONTROL GRID (FIG.15-3)

IMITER-MIXER V6 SUPPRESSOR GRID (FIG 15-3)

TO TRIGGER PULSE FROM SYNCHRONIZING SECTION (FIG. 15-1)

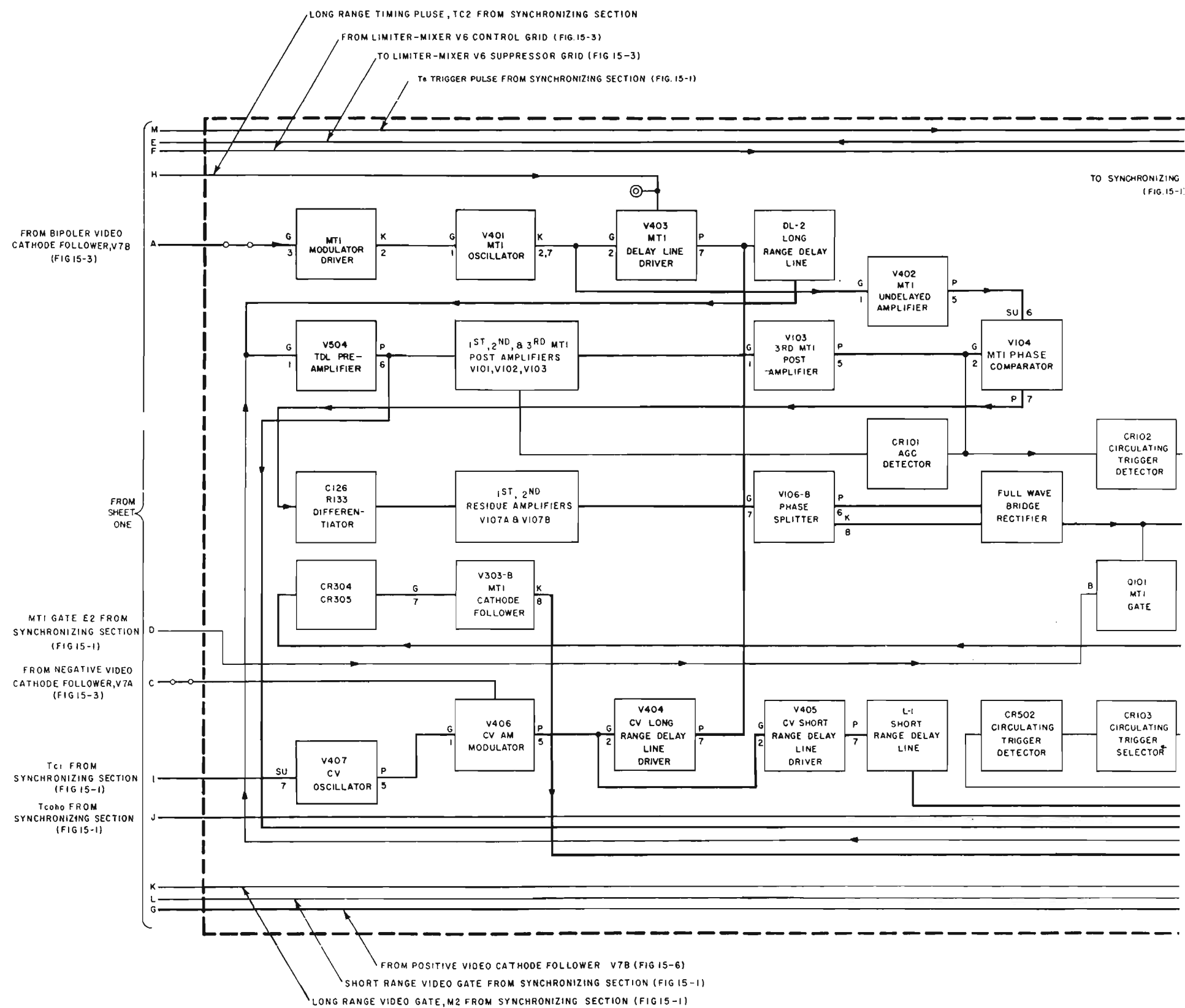


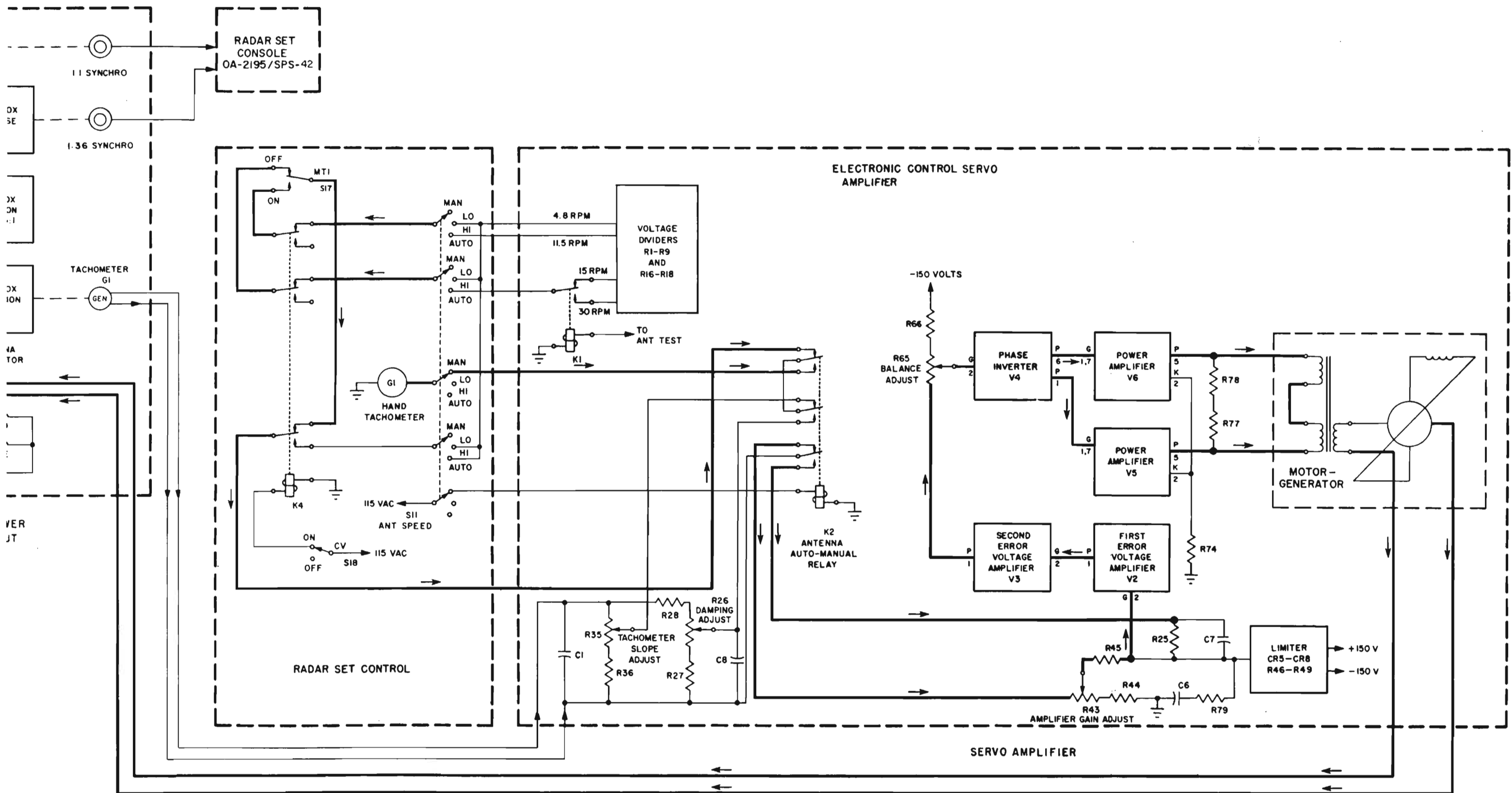
1M POSITIVE VIDEO CATHODE FOLLOWER V78 (FIG 15-6)

NGE VIDEO GATE FROM SYNCHRONIZING SECTION (FIG 15-1)

EO GATE, M2 FROM SYNCHRONIZING SECTION (FIG 15-1)

Figure 15-7.—Moving target indicator. ^{032.272}





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Figure 15-10.—Antenna positioning section, block diagram.

