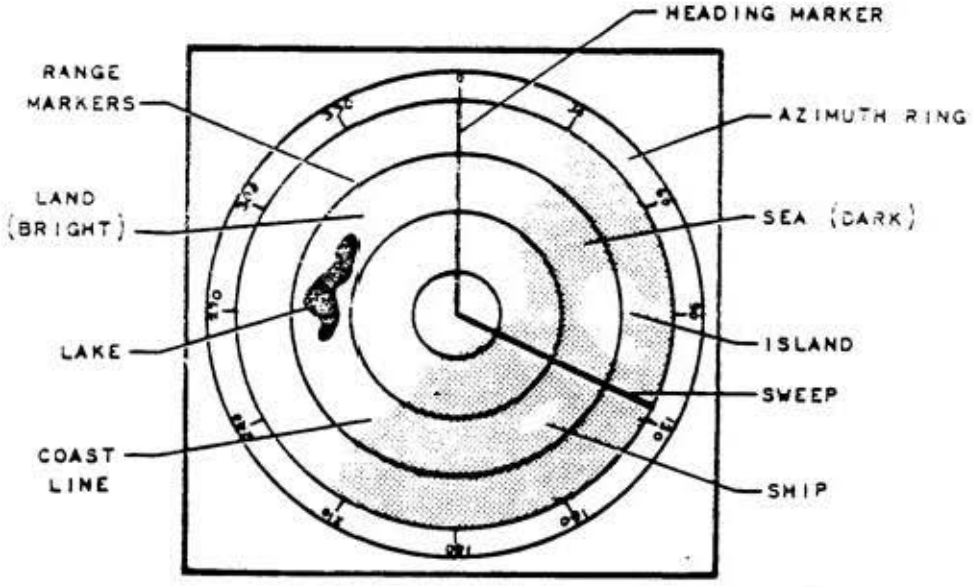
NAVIGATION RADAR

GENERAL

The AN/APN-59B Radar system provides a visual indication of cities, landmarks, shorelines, islands, and ships in the form of an electronic map of the earth's surface below the aircraft. The radar also provides weather warning for plotting cloud formations and weather disturbances and may be used to interrogate ground beacon (RACON) stations as an additional aid to navigation. All information is presented on display indicators at the pilot's and navigator's stations.



RADAR PRESENTATION

AIRCRAFT INSTALLATION

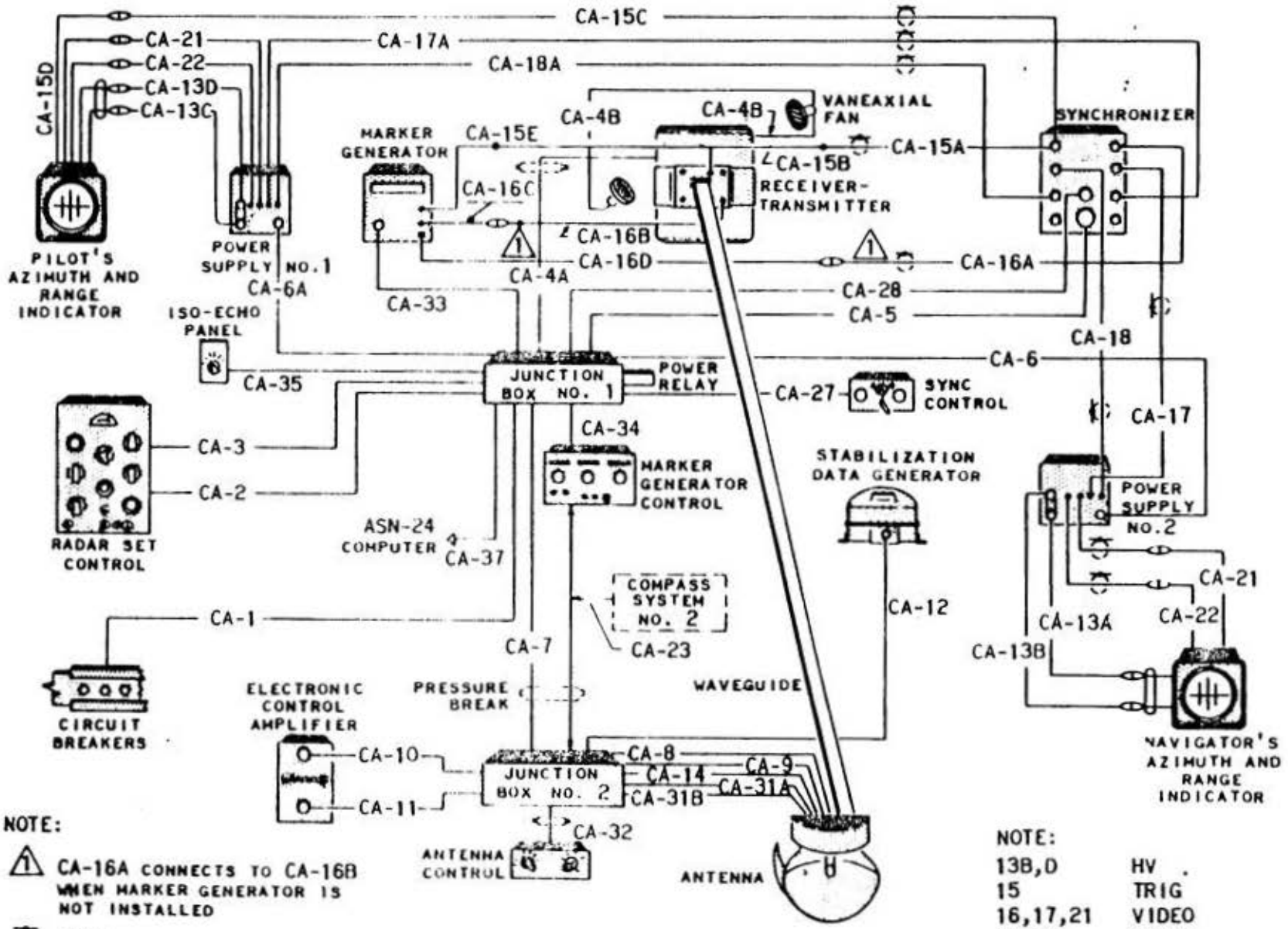
The basic system consists of a Receiver-Transmitter (RT) unit, antenna, stabilization data generator (gyro), Electronic Control Amplifier (ECA), radar set control, synchronizer control, two indicators, two indicator power supply units, two fans, and two radar Junction (J) boxes. Auxiliary components include an antenna control, electronic marker generator, iso-echo control, and a generator control. The antenna, stabilization data generator, ECA, and No. 2 J box are in the radome. The radome is hinged to permit easy access to these units. The control panels and one indicator are at the navigator's station, while the ISO-ECHO control and the second indicator are on the glare shield above the main instrument panel. The synchronizer unit, marker generator unit, and both indicator power supplies are in the center avionics equipment rack. The No. 1 radar J box is located approximately three feet forward of the center avionics equipment rack.

Aircraft power required for system operation is supplied through circuit breakers on the avionics circuit breaker panel above the navigator's station. Power required is 115 volts AC, from the A-C navigation bus No. 1, 115 volts, AC from the A-C avionics bus No. 1, and 28 volts, DC from the main D-C avionics bus No. 1.

Components of the system are shown in the cabling illustration. Each component is designated by the short name normally used by maintenance personnel. The J boxes are part of the aircraft installation, and provide test points as well as interface of the units. Coaxial cables are used for signals such as Video, Main Trigger, and Sweep. A waveguide connects the RT unit to the antenna. A radar pressurization system makes the radar system independent of fluctuations in atmospheric pressure caused by changes in altitude. The system maintains sea level pressure in the RT unit and waveguide to prevent corona and arcing.

SYSTEM OPERATION

The radar system transmits and receives RF energy pulses at a nominal frequency of 9375 megahertz (MHz). The system transmits a pulse of energy and waits to receive echo signals, then transmits another pulse and again waits for echo signals. This transmit and receive cycle (pulse repetition frequency) is repeated many times a second. If the transmitted wave strikes the ground, some of the energy is reflected back to the receiver. If the ground area is large and irregular, a strong echo results. If the area is small or flat, the reflected energy is small and the echo is weak. Since radio waves travel at the speed of light (approximately 162,000 nautical miles per second), there is an extremely short time between transmission and reception. It is possible to measure elapsed time in millionths of a second (microseconds). The time multiplied by velocity of the RF energy provides distance of the displayed signals.



NOTE:

⚠1 CA-16A CONNECTS TO CA-16B WHEN MARKER GENERATOR IS NOT INSTALLED

COAX

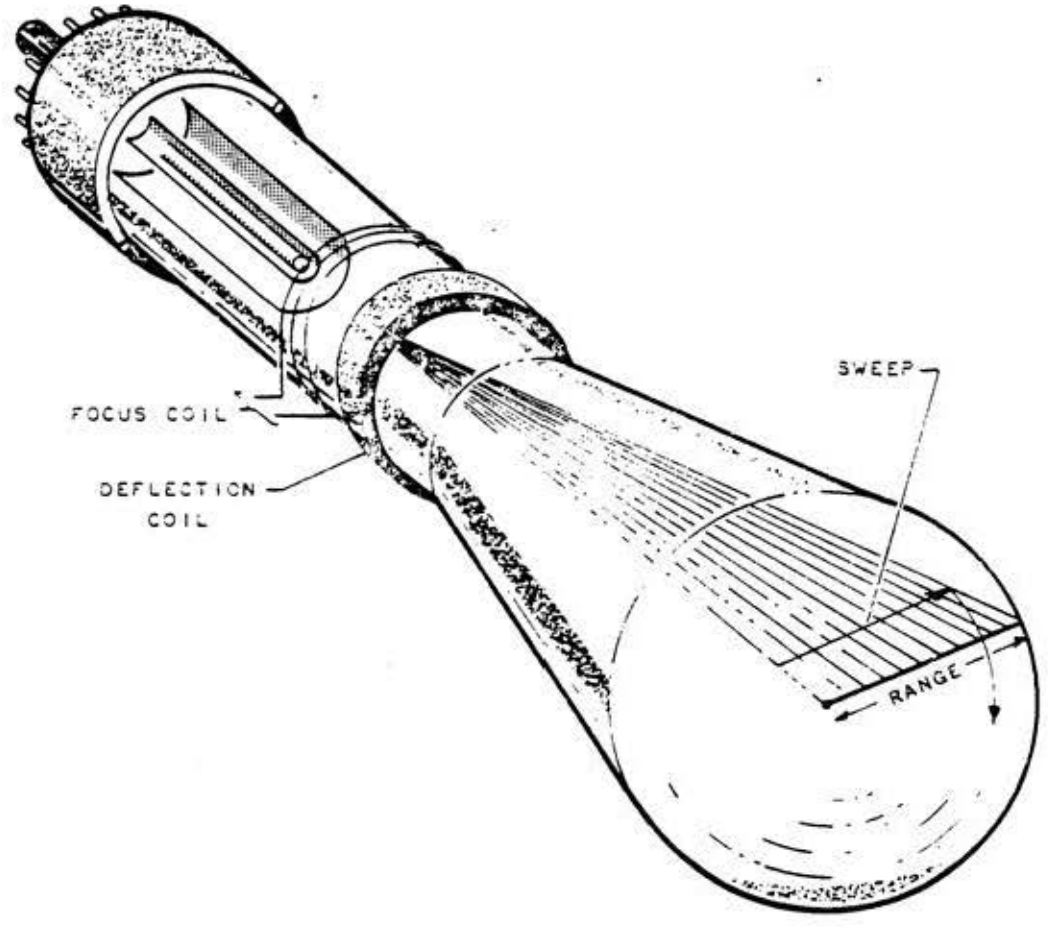
NOTE:

13B,D	HV
15	TRIG
16,17,21	VIDEO
18,22	SWEEP

COMPONENT CABLING

The directional characteristics of the radar antenna provide azimuth angle information. The directional antenna transmits and receives energy in a narrow, sharply defined beam. Therefore, when an echo is received, the direction of the target is determined by the direction of the antenna.

Echo signals are displayed on a Cathode Ray Tube (CRT) in each indicator. For each transmission, an electron beam produces a narrow trace of light on the tube. The trace starts from the tube center and moves to the edge in a straight line. The time required for the sweep to move from CRT center to edge is determined by the range selected for the system. Radio energy travels one nautical mile in 6.18 microseconds (us). Since the energy travels out and back (round trip), the time required to receive an echo from a target one mile away is 12.36 us (2 x 6.18 us). Therefore, if the selected range of the system is 50 nautical miles, the time required for the sweep to move across the face of the CRT would be 618 ms (50 x 12.36 us).



Since the trace starts when transmission occurs, traces or sweeps appear at the Pulse Repetition Frequency (PRF) of the system. As the antenna rotates, the indicator sweep follows the antenna azimuth change. Thus, the series of sweeps represent pulses of energy sent out successively as the antenna rotates. The returning echo signals are applied to the CRT grid and intensity-modulate the CRT beam. In this way, a brightly illuminated map effect of the area covered by the radar beam is displayed. This method of displaying radar information is called a Plan Position Indicator (PPI) presentation.

Range markers are also generated and displayed on the indicator, along with the received echo signals, to give a better indication of distance. The information used to determine sweep lengths can also be used to determine intervals between range marks. When 10-mile range marks are used, the interval between range marks may be found by multiplying the time required for one radar mile by ten (12.36 us x 10 = 123.6 us between markers). These markers also intensity-modulate the CRT beam and appear as bright spots, or circles, when the sweep is rotated.

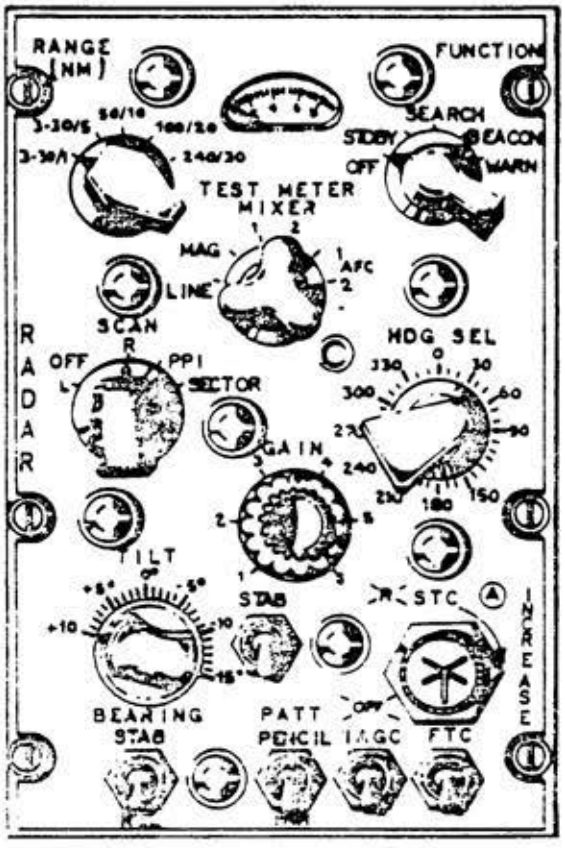
OPERATING CONTROLS

The radar set control panel and the synchronizer control panel contain the primary operation controls. Additional controls are provided on the marker generator control panel and the antenna control panel. Some minor controls are on the indicators. Since control of the radar is the responsibility of the navigator, the control panels are at the navigator's station.

RADAR SET CONTROL

The FUNCTION switch is the master power switch for the radar. In the "OFF" position, the radar is inoperative. In "STDBY", the system is in warmup status. A minimum of three to five minutes warmup period is provided by thermal relays, even if the switch is moved to an operating position. A waveguide shutter protects the receiver in the off or standby conditions.

When the switch is in "SEARCH", the system is operational for electronic mapping. The transmitter produces pulses of RF at 9,375 MHz. Echo signals are received and detected, then displayed on the indicators. In "BEACON" operation, the transmitter pulse width is changed to interrogate ground beacon stations. The stations are sensitive to pulse widths of 2.35 us. When interrogated, the beacon station replies with a series of identification pulses at a frequency of 9,310 MHz. In "BEACON" operation, the receiver does not respond to the search echo signals; therefore, the indicators display only beacon replies. The "WARN" operation is the weather contour, or storm avoidance function. System operation remains the same as "SEARCH", except the transmitter Pulse Width (PW) is longer on short range. The longer pulse width sacrifices signal resolution in order to obtain



RADAR CONTROL PANEL

sufficient reflected signal strength from cloud formations. On long range, "SEARCH" and "WARN" are identical.

The RANGE (NM) switch controls the range and range markers displayed on the indicators. The system is capable of displaying a maximum range of 240 NM. Since the system is airborne, it measures slant range. Four ranges and five sets of range markers are used in determining distances.

The 30-mile range uses either one-mile or five-mile markers. This range is the 3 to 30-mile range, or expandable range, and is variable. The center of the indicator presentation is zero and represents the aircraft position. Range displayed can be 0 to 3 NM, 0 to 30 NM, or any value between 3 and 30 NM. The RANGE 3-30 control on the synchronizer control panel varies the range display. The displayed range is fixed on all other ranges. The 50 NM range uses 10 NM markers; 100 NM range uses 20 NM markers; and the 240 NM range uses 30 NM markers.

The "SCAN" switch controls the azimuth movement of the radar antenna and reflectors. The antenna can rotate 360 degrees in azimuth at approximate speeds of 12 or 45 revolutions per minute (RPM). When the SCAN switch is "OFF", the antenna remains stationary. In "L", the antenna rotates counterclockwise at 12 RPM. In "R", the antenna rotates clockwise at 12 RPM.

In "SECTOR", the antenna will scan back and forth. The width of the sector scan function, as well as the sector to be scanned, are controlled by the antenna control panel. The operation of the antenna control panel will be explained later in this chapter.

The TILT control varies the position of the antenna reflectors. Positioning the reflectors moves the radiated beam up or down from the zero tilt reference position. The TILT operation is capable of positioning the beam up 10 degrees or down 15 degrees.

The PATT (Pattern) switch selects the type of beam to be radiated from the antenna by changing the lower portion of the reflector. The reflector has two lower halves, but only one is used at a time. One reflector provides a reflector provides a beam which is narrow both vertically and horizontally.

The STAB switch is used to gyro-stabilize the antenna reflector with respect to the earth's surface. This allows the antenna reference to remain level with respect to the earth during pitch and roll of the aircraft. The stabilization data generator is a vertical gyro which provides pitch and roll stabilization information to the antenna. The antenna can be stabilized during aircraft maneuvers of 30 degrees roll (left or right) and 15 degrees pitch nose up, and 12 degrees pitch nose down. Beyond these limits, the indicator display will distort due to mechanical limits in the antenna. When the STAB switch is off, the antenna reference is locked to the aircraft.

The BEARING switch selects an azimuth reference for the indicator display. The reference may be "REL" (aircraft heading) or "STAB" (magnetic). During relative operation, the top of the indicator is aircraft heading and the heading marker occurs at zero degrees on the indicator azimuth scale. When the BEARING switch is in "STAB", the display is referenced to the magnetic compass system. The top of the indicator may represent any bearing from 0 to 360 degrees. The exact bearing is determined by the setting of the HDG SEL (heading select) control. This control is used only during bearing stabilized operation and is usually set to zero degrees. The HDG SEL control is marked from 0 to 360 degrees. A small window next to the control provides a fine reading in one-degree increments. When the control reads zero, the top of the indicator is magnetic north and aircraft heading is indicated by the position of the heading marker. If the aircraft is heading east, the marker will occur at 90 degrees on the indicator.

The GAIN controls (coarse and fine) vary the receiver gain. Received signals are detected and amplified in the receiver. The gain of the amplifiers is controlled by the GAIN controls. The coarse control is usually turned clockwise until the echo signals become visible on the indicator. The fine control is used to trim the setting of the coarse control for the best display.

The Instantaneous Automatic Gain Control (IAGC) distorts the signals in the receiver to improve the indicator display. This switch is used as an anti-clutter or anti-jamming control. Large amplitude signals cause bright areas on the indicators. The IAGC decreases the amplitude of these large signals. The effect of the IAGC circuit varies with the receiver gain control setting. When IAGC is selected, the gain should again be varied for best indicator display.

The Fast Time Constant (FTC) switch inserts a fast time constant into the receiver. This circuit distorts long-duration signals to improve the indicator display. Long-duration signals blend together in the display. The FTC circuit breaks up these signals into individual targets as an anti-clutter or anti-jamming control.

The Sensitivity Time Controls (STC) vary the sensitivity of the receiver, starting at the beginning of each sweep. The effect of STC gradually decreases with range. Two controls are provided. The small knob is a switch and variable control. The switch turns STC "on" and varies the STC effective range. Maximum range is approximately 40 NM. The large knob controls the amount of effect STC has on the signals.

The test meter and test meter mixer provides a check of circuit voltages and currents. The meter monitors "LINE" voltage to the radar, which is an indication of the 115 volts, AC from the avionics bus No. 1. It also monitors "MAG", which is an indication of magnetron current. In a radar operating mode, transmitter operation is indicated by magnetron current.

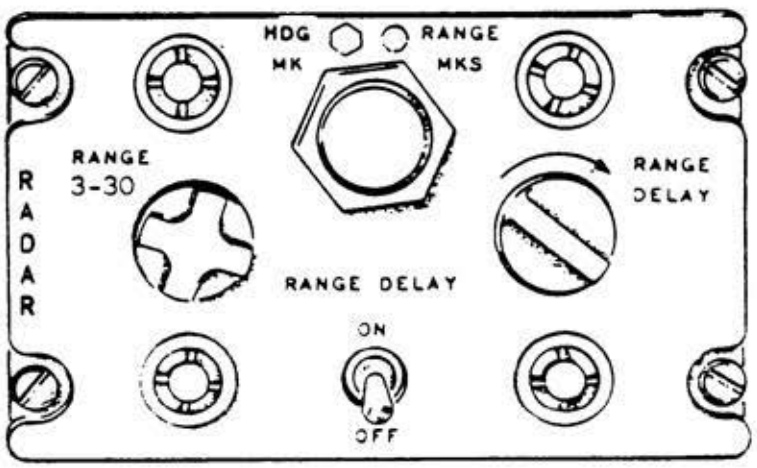
The "MIXER 1 and 2" positions allow monitoring of the receiver crystal currents. The crystals are balanced and should indicate the same current. The "AGC 1 AND 2" positions allow monitoring of the automatic frequency control crystal currents. These are also balanced and should indicate the same current.

All meter readings should be constant when using an operating mode. In ("STBY") operation, the magnetron current is zero since the transmitter is not operating. Crystal current readings cycle from minimum to maximum in standby, due to the local oscillator and AFC circuits. When an operational mode is selected, the readings will stop cycling as the AFC circuits lock on. The TEST METER MIXER switch should remain in the "LINE" or "MAG" position, except during checks.

An auxiliary meter (0 to 1 ma) can be plugged into a fuse box on the RT unit to bypass the control panel meter. This allows meter readings to be made at the RT unit, during ground checks. The TEST METER switch controls the auxiliary meter readings.

SYNCHRONIZER CONTROL

The synchronizer (SYNC) control contains controls which vary the indicator references. The RANGE DELAY control varies delay before start of the indicator sweep. As the control is turned clockwise, a marker, similar to a range marker, moves out from the center of the presentation. This marker is used to select the desired range delay. The indicator range markers are used as references to accurately set the amount of delay.



SYNCHRONIZER CONTROL PANEL

The RANGE DELAY switch turns the delay "ON" or "OFF." When the switch is "ON," the center of the indicator represents the delay set by the range delay control. The indicator then displays the 3-30/5 mile range. The indicator Target Discrimination (TD) lamp and 3-30/5 range lamp turn on in range delay operation.

The RANGE 3-30 control varies the range displayed on the indicator when the 30-mile range is selected, and also in range delay. The indicator displays from 0 to 3 NM when the control is counterclockwise. When the control is turned clockwise, range will increase until 0 to 30 NM is displayed.

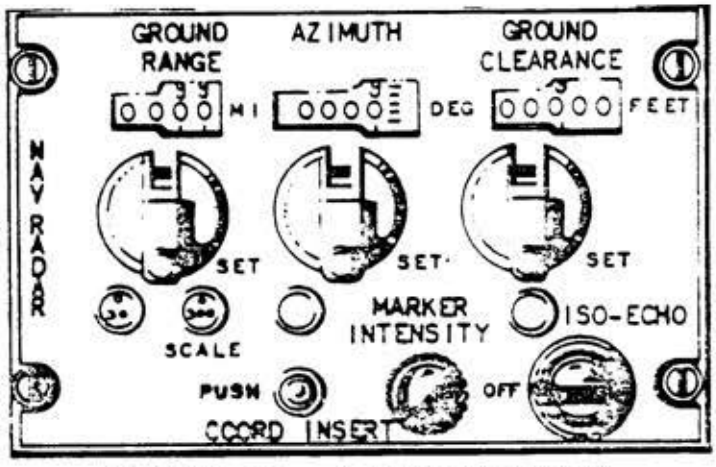
The HDG MK (heading mark) control varies the intensity of the heading marker. When the antenna is facing dead ahead, a switch is actuated in the antenna. This switch causes the heading marker to appear on both indicators. The marker

always represents aircraft heading. When the control is turned counterclockwise, the mark will appear as a flash on the indicator or, if clockwise, the mark will appear as a blank (dark) line on the navigator's indicator.

The RANGE MKS control varies the intensity of the range markers. The marks appear and brighten with clockwise rotation of the control.

MARKER GENERATOR CONTROL

The marker generator control provides variable control of precision markers used to determine the range and azimuth of selected target. This information may be supplied to a dead reckoning computer for navigation.



MARKER GENERATOR CONTROL PANEL

The GROUND RANGE-SET control and counter are used to vary a precision marker on the indicator. The marker appears as a range marker on the indicator display. The counter numerals provide a direct reading of the marked range in nautical miles. This marker can be positioned to a target on the indicator and will indicate either slant range or ground range, dependent upon the GROUND CLEARANCE-SET control.

The GROUND CLEARANCE-SET control and counter also move the range marker. The control is used to supply aircraft altitude, in feet, to the marker position so that the range counter will display ground range. If the GROUND CLEARANCE-SET control is set to the aircraft altitude, and the GROUND RANGE-SET control is turned until the marker is on the indicator target, the GROUND RANGE counter will read the ground range to the target. If GROUND CLEARANCE is not used (positioned to zero), and the marker is positioned to the target with the GROUND RANGE-SET control, the range counter will display the slant range of the target. The combination of the two controls varies the position of the marker. Since slant range is always greater than ground range, the GROUND CLEARANCE setting decreases the GROUND RANGE setting required to position the marker to a target. All range readings should be made directly from the GROUND RANGE counter.

Range lamps indicate the scale of the GROUND RANGE counter. A "0 to 30" lamp and a "0 to 300" lamp are provided for the two scales. The 30-mile scale is used when the radar set is operating on the 30-mile range. On all other ranges, the 300-mile scale is used.

The AZIMUTH-SET control and counter vary a precision azimuth marker on the indicator. This marker appears as a second aircraft heading marker. It is variable through 360 degrees. If the control is positioned until the marker appears across the center of a selected target, the counter will read the target magnetic bearing. Relative bearing can be obtained by comparing the aircraft heading marker and the precision azimuth marker on the indicator display.

A MARKER INTENSITY control varies the intensity of the azimuth marker and precision range marker on the display. Clockwise movement produces bright markers and counterclockwise movement produces dark markers. When the control is centered, no markers are visible.

The COORD INSERT (coordinate insert) push switch is used to transfer the target ground range and azimuth to the AN/ASN-24 dead-reckoning computer. When pressed, the switch completes a relay circuit in the computer. If the switch is held, the data will be transferred to the computer. When the COORD INSERT lamp comes on, the data transfer is complete and the switch can be released.

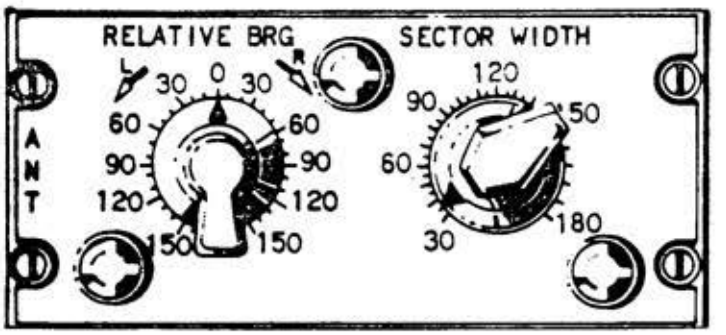
The ISO-ECHO control is used during weather contour operation to locate the center of a storm. When the control is turned CW, blank areas will appear in the cloud formation indicator display. These are the areas of the greatest density of the storm.

A second ISO-ECHO control is on the pilot's instrument panel. It provides the same function as the navigator's control. If the pilot's control is turned clockwise, the same results will occur. In addition, the ISO-ECHO lamp on the marker generator control goes "on" to indicate pilot control of iso-echo. The navigator's control is disabled when the pilot is in control of ISO-ECHO. The capability for ISO-ECHO operation is not provided unless the marker generator and marker generator control box are installed.

ANTENNA CONTROL

The antenna control box allows the sector width and relative bearing to be varied when the radar set control scan switch is in the "SECTOR" position. The SECTOR WIDTH control varies the width of the sector to be scanned by the antenna. The center of this sector is the relative bearing, set by the RELATIVE BRG control. Aircraft heading may be sectored by placing the RELATIVE BRG control at 0 degrees. Sector width is variable from a minimum of 30 degrees (15 degrees left and right of center) to a maximum of 180 degrees (90 degrees

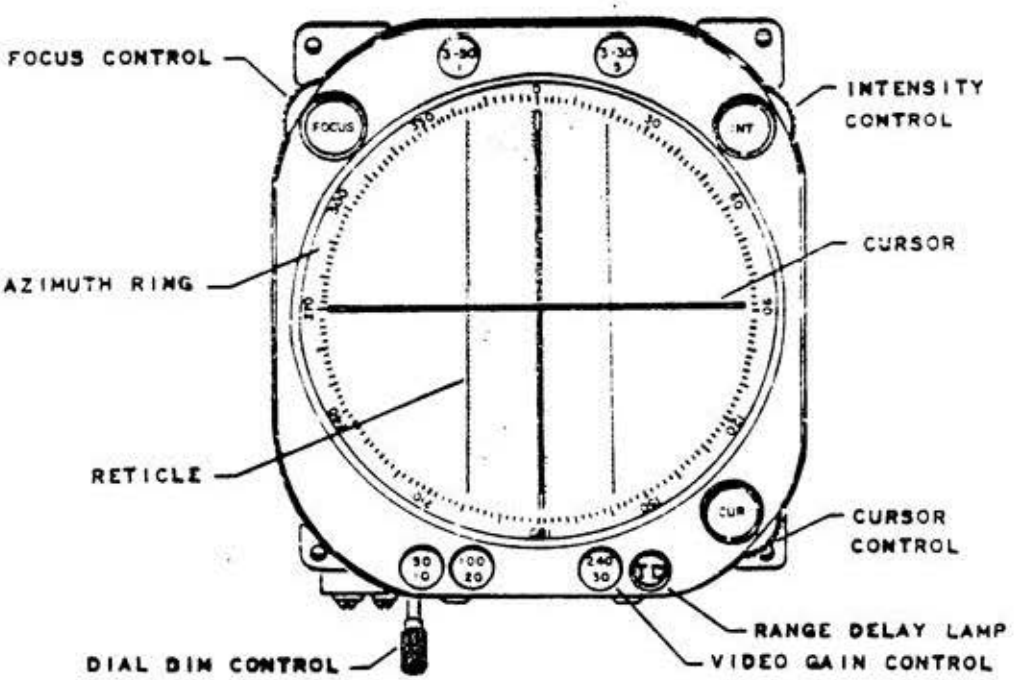
left and right of center). The center of the area to be sectored is variable 180 degrees left and right, or a total of 360 degrees.



ANTENNA CONTROL PANEL

NAVIGATOR'S INDICATOR

The navigator's indicator receives amplified video signals from the synchronizer and displays them in a PPI presentation. A stationary azimuth ring and a rotatable cursor are used to determine target bearing. A transparent reticle strip may be positioned horizontally for offset tracking of targets. A heading marker appears each time the antenna points dead ahead of the aircraft. In addition to the heading marker, a variable azimuth mark may appear due to the AZIMUTH-SET control on the marker generator control. A precision range mark, supplied from the marker generator may also be used.

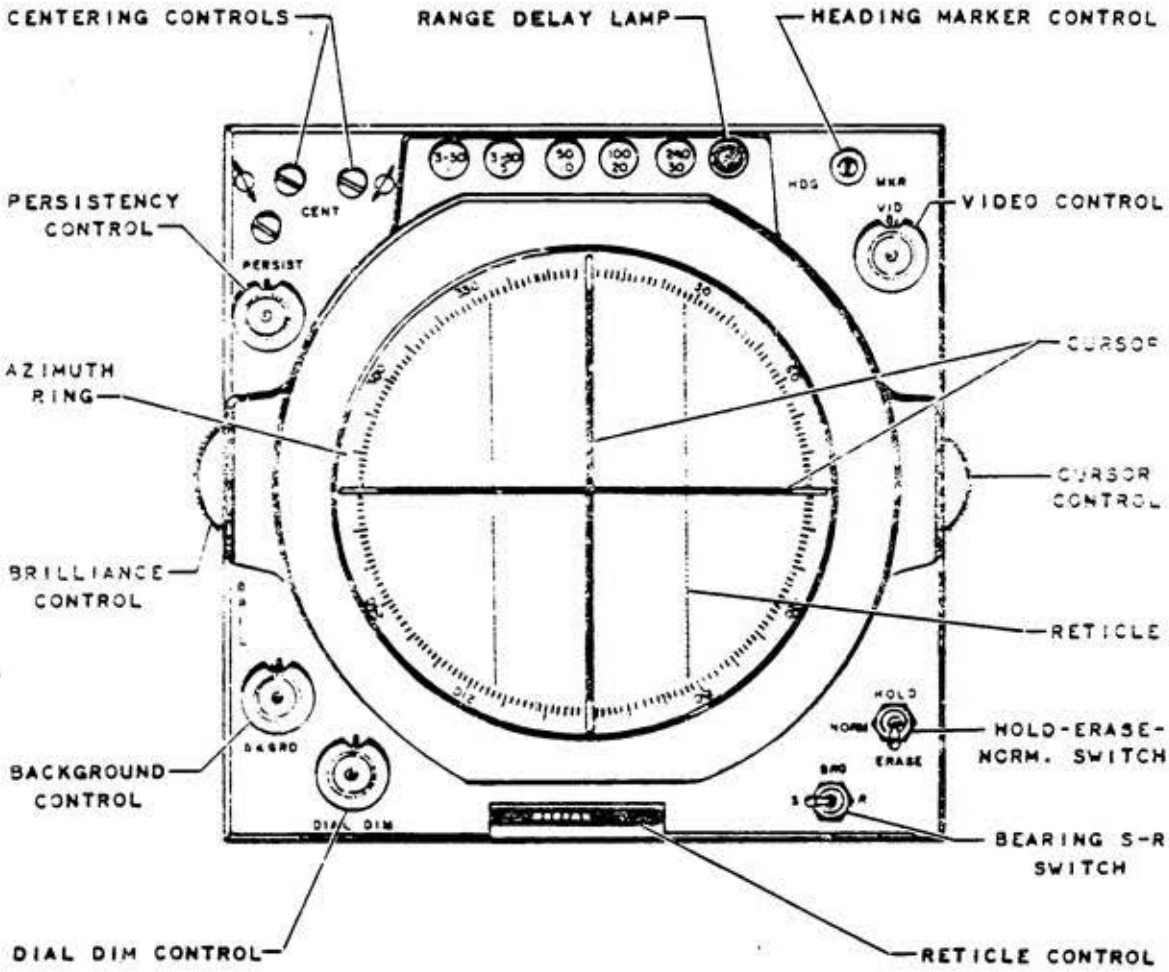


NAVIGATOR'S INDICATOR

Azimuth reference for the navigator's indicator presentation can be aircraft heading (relative) or stabilized. In stabilized operation, the reference is the magnetic compass. Five range lights indicate which of the ranges and range markers are in use, and a sixth light (TD) indicates range delay operation. An INT (intensity) control varies brightness of the presentation, and a FOCUS control varies sharpness. Screwdriver adjustments may be used for video gain control and intensity limit. The dial-dim control is used to set brightness of the edge lights around the indicator face.

PILOT'S INDICATOR

The pilot's indicator receives and displays information identical to that of the navigator's indicator. The pilot's indicator also has an azimuth ring, a rotatable cursor, and a reticle. Five range lights show the range and range markers in use. A TD light indicates range delay operation.



PILOT'S INDICATOR

Two screwdriver adjustments (CENT controls) permit centering of the display on the face of the indicator. Vertical adjustment is from upper left to lower right; horizontal adjustment is from upper right to lower left. The HDG MKR screwdriver control may be used to supplement a similar control on the synchronizer control box. Clockwise rotation of the VID control is used to increase the brightness of video and range markers. The BKGRD control may be used to vary background intensity and to intensify display, and the BRILL control operates a polaroid filter for viewing in a dark environment.

The HOLD-ERASE-NORM switch allows for normal display or complete erasure. In "HOLD", the display will be retained for a minimum of 60 seconds. In "ERASE", all previous information is removed from the display and in "NORM", indicator displays will be normal. A PERSIST (persistency) control permits a variable erase function. Counterclockwise rotation of the control allows maximum erasure, minimum time of display; clockwise rotation of the PERSIST knob allows a target persistence of at least one PPI scan.

By use of the BRG S-R switch, the pilot's indicator may be referenced in azimuth to the relative heading of the aircraft, or it may be slaved to display the azimuth reference of the navigator's indicator.

OPERATING FREQUENCIES

- Transmitter = 9375 $\pm$ 40 MHz
- Receiver = 9375 $\pm$ 40 MHz (radar) and 9310 MHz (Beacon)
- Intermediate Frequency = 30 MHz
- Power Output = 50 kilowatts of peak power (minimum)
- Pressurization = Antenna and Waveguide: 15 pounds per square inch (Minimum).

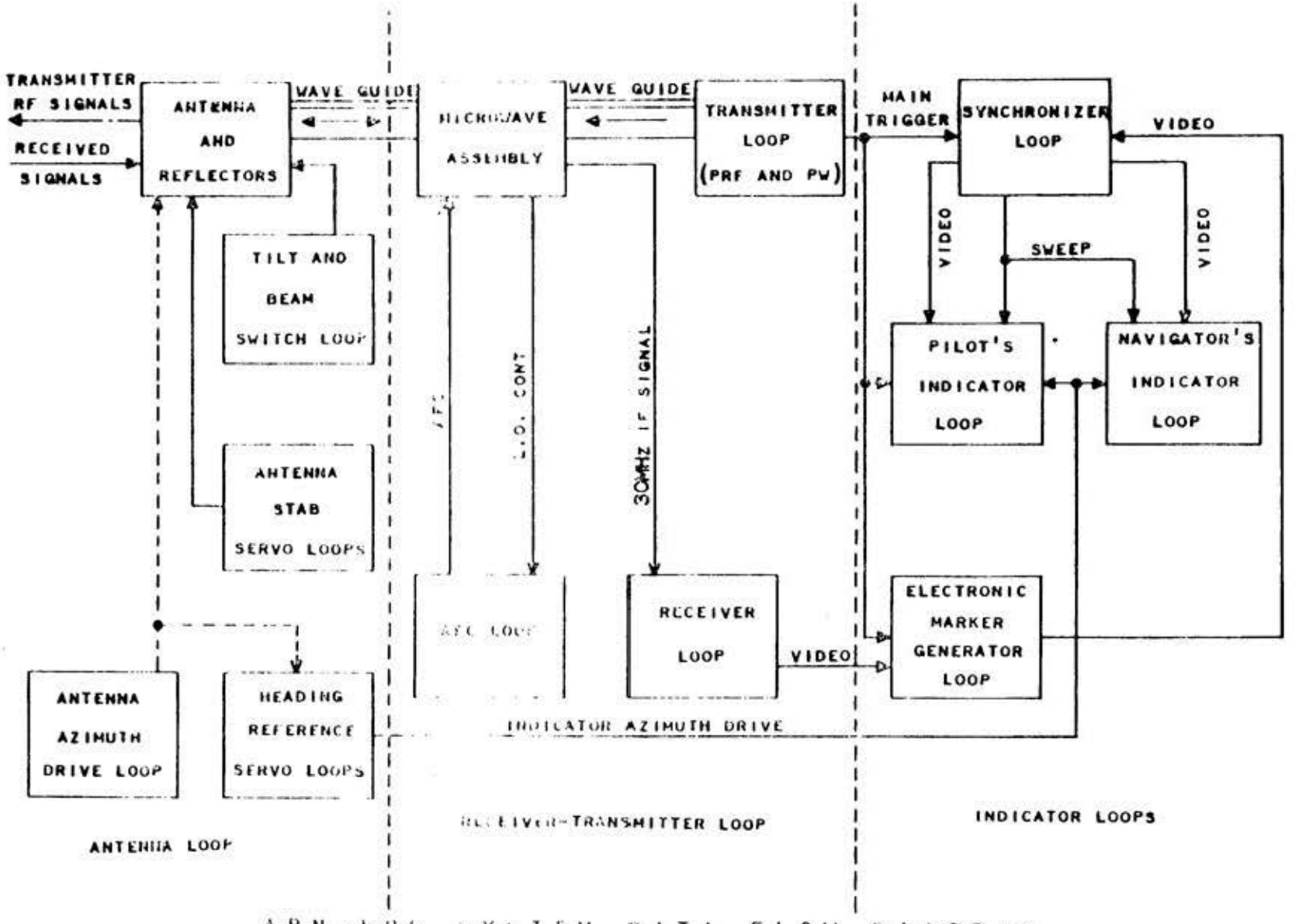
PULSE CHARACTERISTICS

Range	3-30 NM		50 NM		100 NM		240 NM	
Function	PRF	PW	PRF	PW	PRF	PW	PRF	PW
Search	2000	0.35 us	1025	0.8 us	180	4.5 us	180	4.5 us
Warning	180	4.5 us	180	4.5 us	180	4.5 us	180	4.5 us
Range Delay	180	4.5 us	180	4.5 us	180	4.5 us	180	4.5 us
Beacon	350	2.35 us	350	2.35 us	350	2.35 us	180	2.35 us
Beacon (Range Delay)	180	2.35 us	180	2.35 us	180	2.35 us	180	2.35 us

ANTENNA OPERATING LIMITS

- PPI Scan = continuous full rotation at 11 to 16 or 49 $\pm$ 7 rpm. Speed of rotation is dependent upon range and operation mode of the radar.
- Sector Scan = continuously variable from 30 degrees to 180 degrees in width at 11 to 16 rpm. Center of sector selective over any bearing.
- Beam Shape = Pencil: 3 degrees wide, 5 degrees high (conical)
  Fan: 3 degrees wide, 40 degrees high (approximately)
- Slant Range = from 80 yards to 240 nautical miles.
- Reflector Stabilization = Pitch: from 12 degrees nose down to 15 degrees nose up

  Roll: $\pm$ 30 degrees
- Beam Tilt = from 10 degrees up to 15 degrees down



APN-509 SYSTEM DATA FLOW DIAGRAM

BLOCK DIAGRAM THEORY OF OPERATION

RECEIVER-TRANSMITTER UNIT

The receiver-transmitter consists of the transmitter, microwave and AFC, receiver, and power supply circuits. The transmitter generates the RF pulse which is fed to the antenna via the microwave assembly. The microwave assembly receives echo signals or beacon ground station transmissions. These signals are mixed with a Local Oscillator (LO) frequency to produce a 30 MHz IF signal. The receiver processes the IF and provides a video output to the synchronizer. The Automatic Frequency Control (AFC) samples the transmitter and LO frequencies and varies the LO frequency to maintain the 30 MHz IF. The circuits used for AFC and receiver are part of the Electrical Frequency Control (EFC) subassembly in the RT unit.

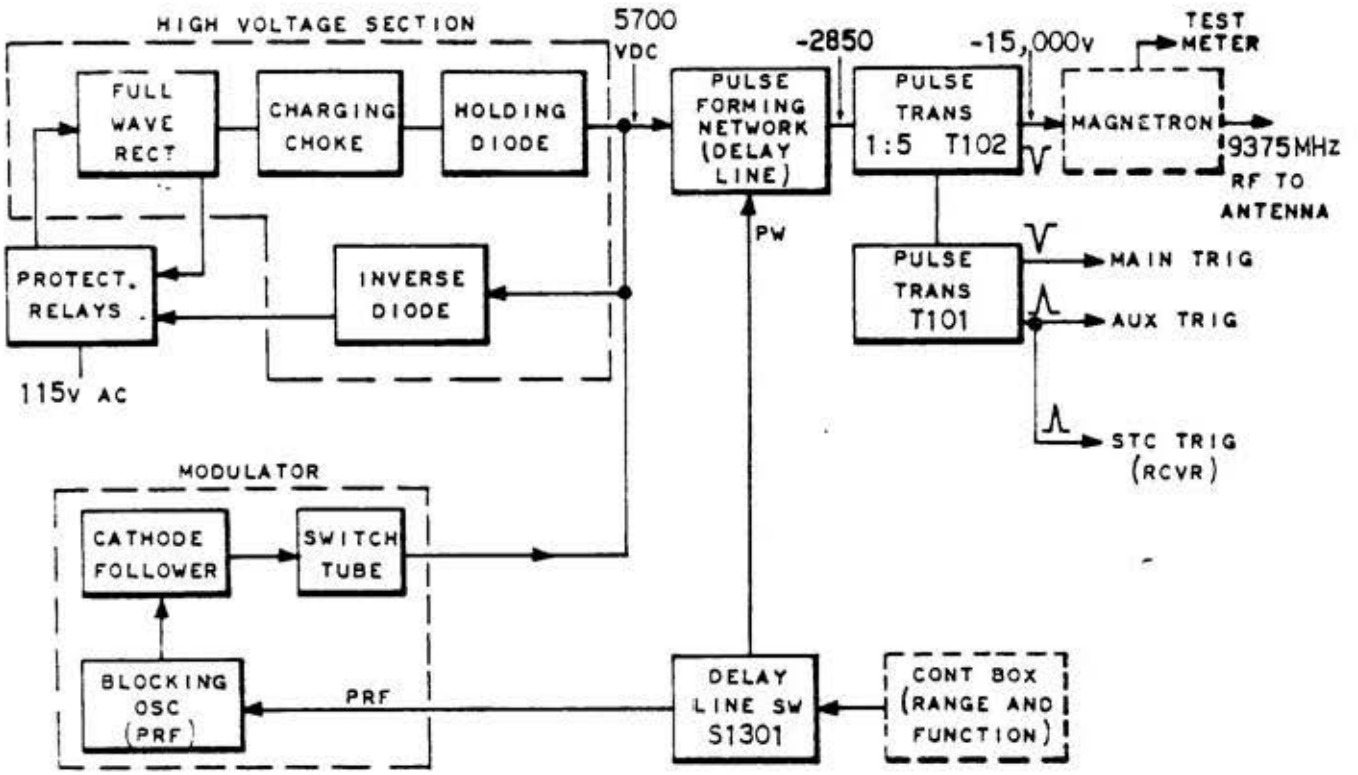
The low voltage power supply provides operating voltages for the radar system. These voltage outputs can be checked from the fuse box. The power supply also provides a 230-volt interlock voltage, which is used to interlock the high voltage section of the transmitter to power supply operation. The high voltage power supply provides a negative D-C voltage for the TR tube in the microwave assembly. This voltage ensures that the tube will remain partially ionized, providing receiver protection. The high voltage power supply also provides the line voltage meter reading for the test meter.

TRANSMITTER SUBASSEMBLY

The transmitter produces the Pulse Repetition Frequency (PRF) and the Pulse Width (PW). The modulator section of the transmitter contains a free-running blocking oscillator which serves as the master oscillator. The primary functions of the transmitter are to generate the RF pulse to be transmitted and to synchronize the indicator presentations to this transmission.

A-C power is applied to the high voltage section of the transmitter through relays which protect against circuit overloads. Relays also prevent the application of high voltage until an operating mode is selected and the thermal time delay is over. The high voltage section changes the AC to 3,000 volts, DC which is used to charge a delay line through a choke and a holding diode. The choke raises the delay line voltage to approximately 5,700 volts, DC due to the collapse of its field. The holding diode prevents discharge of the delay line.

The delay line, referred to as a Pulse Forming Network (PFN), is divided into four sections. The first section produces a 0.35 us pulse width; the first and second sections in series produce a 0.8 us pulse width; the first three sections produce a 2.35 us pulse width; and all four sections produce a 4.5 us pulse width. A delay line switch, controlled by range and function selected, changes the PRF and delay line sections.



TRANSMITTER SUBASSEMBLY

The Blocking Oscillator (BO) produces pulses at one of four PRF's, dependent upon range and function selected. The PRF is a continuous series of pulses which establish timing of the radar. The BO frequency is changed by varying resistance in the grid circuit.

The BO pulses are applied to a cathode follower for circuit isolation. The output triggers a thyratron switch tube. The switch tube conducts, shorting the delay line to ground. The delay line voltage (5,700 volts, DC) decreases as the delay line discharges through pulse transformers. An inverse diode prevents reverse polarity on the delay line which might occur if an impedance mismatch existed between the delay line and pulse transformers.

When the delay line discharges, a negative step voltage is applied to the primary of the pulse transformer. The secondary of the transformer provides a negative 15,000 volt pulse to the cathode of the magnetron. During the width of this pulse, the magnetron oscillates at 9,375 MHz producing a power of 50 kilowatts peak, minimum (approximately 45 dbm). This output is coupled into the microwave assembly.

The discharge current of the delay line also passes through the low impedance primary of a second pulse transformer. The secondary winding is center-tapped to provide two small trigger pulses, identical and synchronized to the magnetron trigger pulse. The negative trigger is the "main trig" output of the RT unit. The positive trigger is the "aux trig" output, used in checking the PRF and PW. The positive trigger is also supplied to the receiver STC circuit.

MICROWAVE ASSEMBLY

The function of the microwave assembly is to perform electronic switching required to permit the use of a single antenna for transmitting and receiving. The switching is accomplished in a duplexer by TR and Anti-TR (ATR) tubes. These tubes have spark gaps in cavity resonators, broadly tuned to the transmitter frequency. The tubes are filled with gas to allow a lower voltage breakdown.

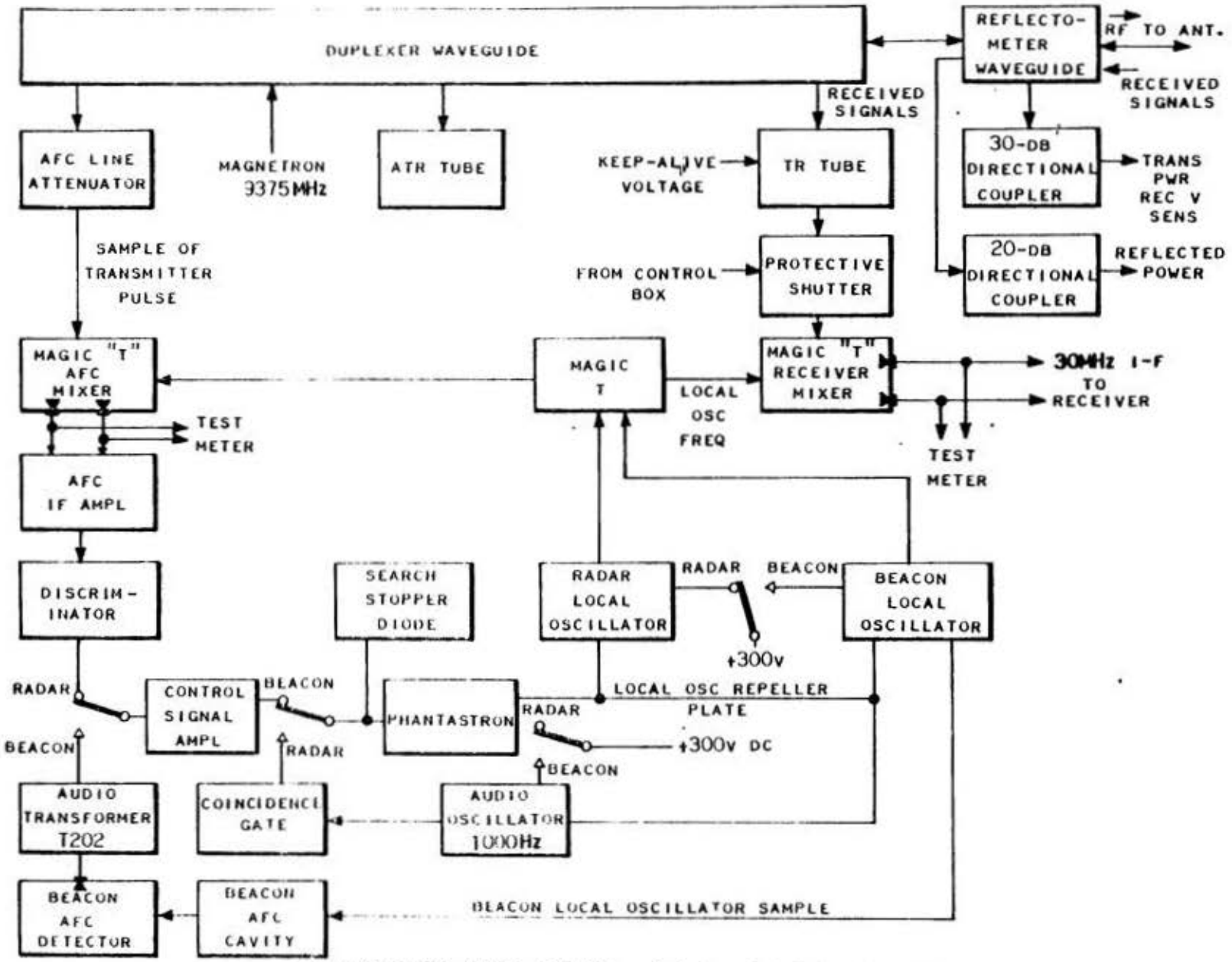
The TR tube is in the receiver waveguide and is slightly ionized by a "keep-alive" voltage. When a pulse is transmitted, the TR tubes fire immediately, blocking the pulse from entering the receiver. The ATR tube is also fired by the transmitter pulse. These tubes effectively close the wall of the duplexer waveguide, providing a low impedance RF path into the reflectometer, waveguide, and antenna.

The reflectometer consists of an output waveguide which has two directional couplers. The output waveguide directs the transmitter pulses to the antenna, and the directional couplers provide test receptacles. One receptacle is used to check transmitter power output and receiver sensitivity. Both receptacles are used in conjunction to check Voltage Standing Wave Ratio (VSWR).

AFC CIRCUITS

When the magnetron is transmitting, a sample pulse is fed to the AFC mixers. This pulse is mixed with the output of the radar LO to produce a 30-MHz, IF. The signals are mixed and detected by balanced crystals in a "Magic T" which provides isolation between input signals. The IF signal is amplified and fed to a discriminator. If the frequency of the LO is correct (30 MHz above magnetron frequency), the IF will be 30 MHz. If the oscillator frequency is high, the signal will exceed 30 MHz and, if low, will be less than 30 MHz.

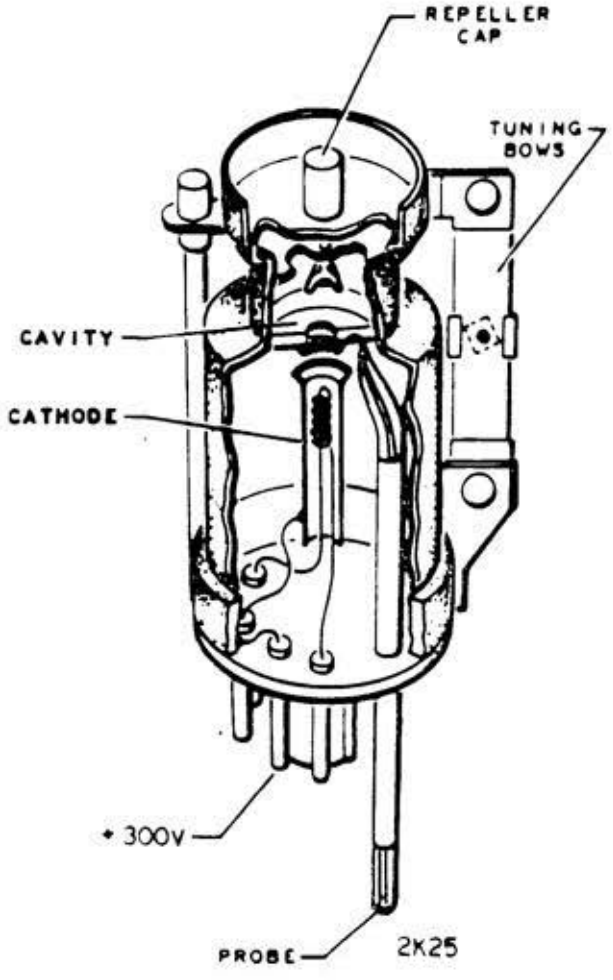
The discriminator output is amplified, inverted, and fed to a search stopper diode and phantastron oscillator. A negative pulse has no effect on the diode and the phantastron continues to oscillate. The phantastron output is a negative sawtooth waveform which sweeps the LO to a higher frequency by varying repeller plate voltage.



MICROWAVE AND AFC CIRCUITS

When the LO reaches a frequency that produces an IF slightly above 30 MHz, the discriminator output becomes a negative pulse. The negative pulses are amplified, inverted, and applied to the search stopper diode. The diode develops a negative bias for the phantastron which then stops oscillating. The phantastron then applies a steady DC to the repeller plate to maintain the correct LO frequency.

In BEACON operation, the beacon relay energizes. An audio oscillator then produces a 1,000 Hz signal which is fed to the beacon LO and a coincidence tube. The beacon LO is tuned to 9,280 MHz, which is 30 MHz below the received beacon station signal. The LO frequency is modulated by the audio oscillator signal and phantastron sweep. The resultant frequency modulated output of the LO is fed to the beacon AFC cavity which is sharply tuned to 9,280 MHz.



REFLEX KLYSTRON LOCAL OSCILLATOR

If the beacon LO frequency is low, the phase of the 1,000-Hz modulation signal is shifted 180 degrees by the cavity. This signal is detected by the beacon AFC detector, stepped up and phase shifted 180 degrees by a transformer, and applied to the control signal amplifier. The amplifier shifts the phase of the modulation signal 180 degrees, and the output has the same phase as the original output of the beacon cavity. The coincidence tube compares this signal against the 1,000-Hz signal from the audio oscillator. Since the two signals are 180 degrees out of phase, the tube does not conduct, permitting the phantastron to continue oscillation.

When the LO frequency is slightly above 9,280 MHz, the beacon cavity does not reverse the phase of the 1,000-Hz modulation signal. The inputs to the coincidence tube are now in phase and the tube conducts, applying a positive pulse to

the search stopper diode. The diode develops a negative bias which converts the phantastron from an oscillator to a D-C amplifier. The phantastron output maintains this LO frequency.

RECEIVER CIRCUITS

Echo signals or ground beacon signals are fed through the reflectometer to the duplexer. These low-energy signals are insufficient to fire the ATR or TR tubes. The received energy passes through the TR tube into the receiver mixer. When the radar is not in use and the TR tube is not functioning, a protective shutter is inserted into the waveguide to protect the crystals.

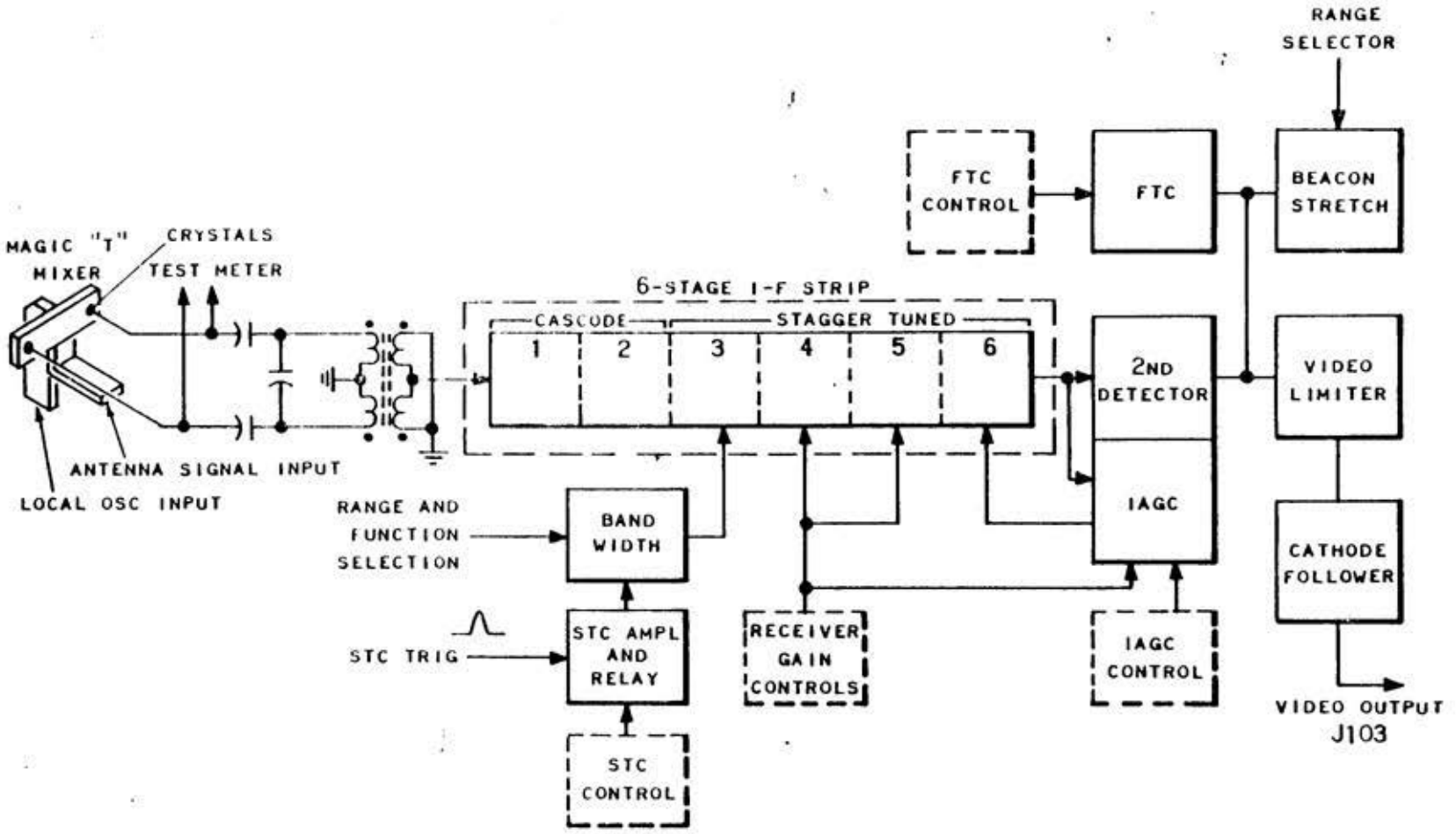
In beacon operation, the 9,280-MHz output of the beacon LO is fed to the receiver mixer with the received 9,310-MHz beacon signal to produce a 30 MHz-IF signal. In search or warning operation, the 9,405-MHz output of the radar LO is fed to the receiver mixer, with the 9,375-MHz received echo signals, to produce a 30-MHz IF signal. The 30-MHz IF is fed into the receiver.

The receiver consists of IF amplifiers, detector, amplifier-limiter, and cathode follower. The IF signal is amplified by stagger-tuned IF amplifiers and fed to the detector. The detector rectifies the IF signal and develops a negative video output. The video is amplified, limited, and fed through a cathode follower to the marker generator units. In addition to the basic circuits, the receiver contains bandwidth, STC, LAGC, FTC, beacon stretch, and gain control circuits, which are used to alter the characteristics of the receiver. The overall receiver sensitivity is approximately negative 101 dbm.

The bandwidth circuit increases receiver sensitivity on long range. With the radar in 30 or 60-mile search operation, or in beacon operation, narrow pulses are transmitted. Under these conditions, the receiver bandwidth of 5 MHz allows the high-harmonic content of the narrow width pulses to pass. In 100 or 240-mile search operation or in all ranges of warning, longer pulses of 4.5 us duration are used. Under these conditions, the receiver bandwidth is reduced to 0.75 MHz, increasing sensitivity.

The function of the Sensitivity Time Control (STC) circuit is to reduce indicator clutter due to large amplitude signals at short range. Clutter interference appears on the indicator presentation as a bright area around the center of the CRT. In order to reduce blocking by signals of this type, the STC circuit reduces receiver gain at close range and allows gain to increase to normal with range.

The STC range control closes a switch to connect the circuit into the receiver. The circuit consists of an amplifier, capacitor, and two variable resistor controls. A positive trigger from the transmitter is applied to the grid of the amplifier, causing it to conduct and charge the capacitor. At the end of the pulse,



RECEIVER CIRCUITS

the tube cuts off and the capacitor discharges, applying a negative bias to the third IF amplifier. Discharge path of the capacitor is through the STC range control. Varying this control regulates the discharge rate of the capacitor and range at which normal amplification is restored. The second variable resistor controls gain of the STC amplifier and amount of discharge.

The Instantaneous Automatic Gain Control (IAGC) circuit is primarily an anti-jamming device used to reduce receiver IF saturation by applying a negative bias to the sixth IF amplifier. This would be the first stage saturated in case of jamming. The bias is applied only if signals exceed a level set by the GAIN control.

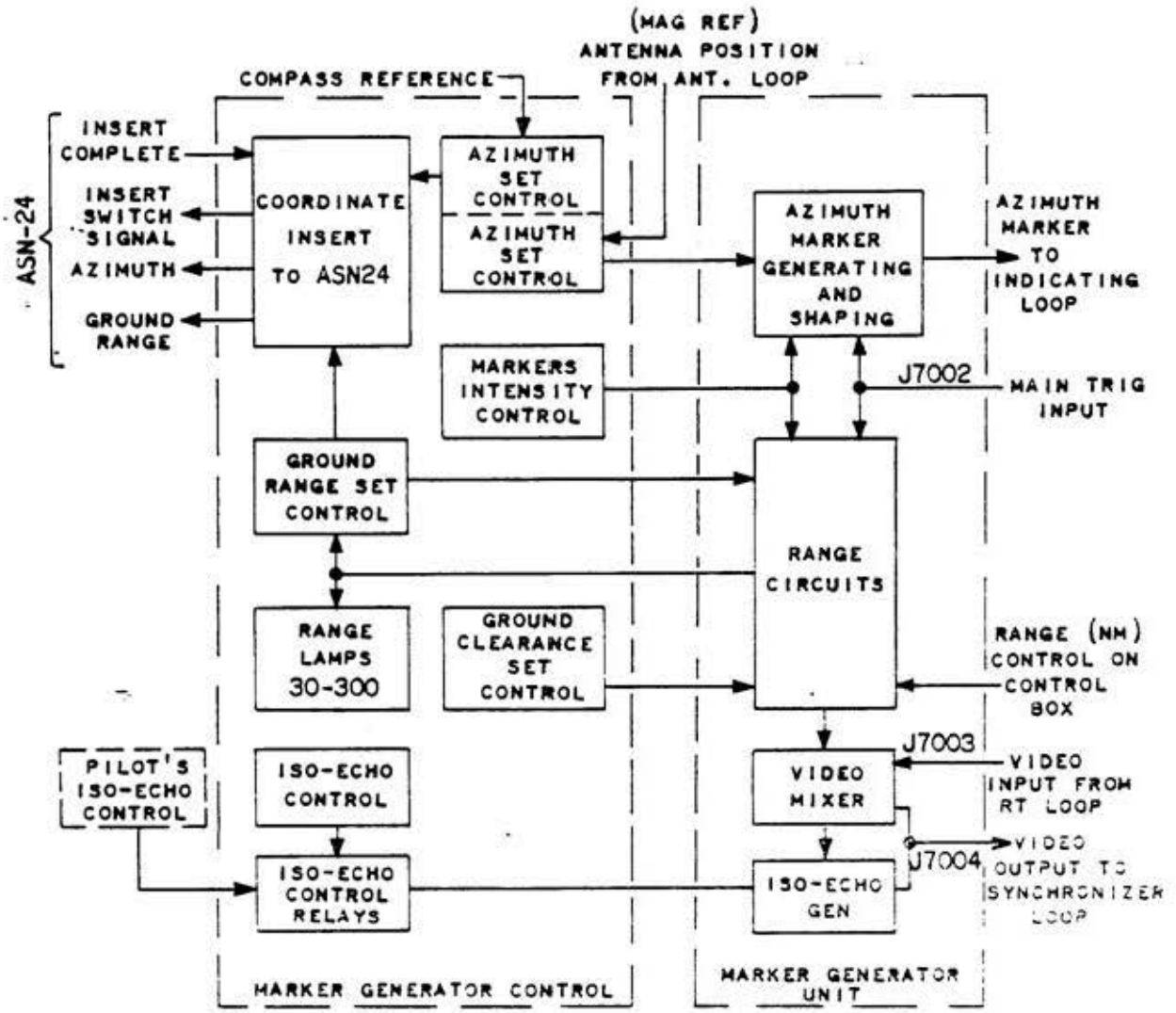
The circuit uses a rectifier, resistor, and filter. When the IAGC switch is placed in the "ON" position, a relay is energized which permits the IAGC circuit to function. The setting of the RECEIVER GAIN control determines the normal signal amplification of the sixth IF amplifier. When a signal of high amplitude appears at the detector, the IAGC rectifier produces a negative voltage across the resistor which is fed back to the grid of the sixth IF amplifier, temporarily decreasing gain. The circuit permits observation of target details which would otherwise be lost.

The beacon-stretch circuit makes the received signals more discernible on long range operation. On the 100 or 240-mile range, a relay is energized which inserts an additional resistor in series with the load resistor of the detector, elongating the video pulses during each sweep.

The Fast Time Constant (FTC) circuit is connected between the second detector and video amplifier. It serves an an additional aid in minimizing the effects of clutter and jamming. When the switch is placed in the "ON" position, a relay is energized which disconnects one capacitor from the grid coupling circuit of the video amplifier-limiter and adds a resistor in parallel with the grid resistor of the tube. The RC time constant input to the amplifier-limiter is reduced, causing pulses to be differentiated. Differentiation removes the greater portion of long duration blocking signals, permitting the desired signals to be observed.

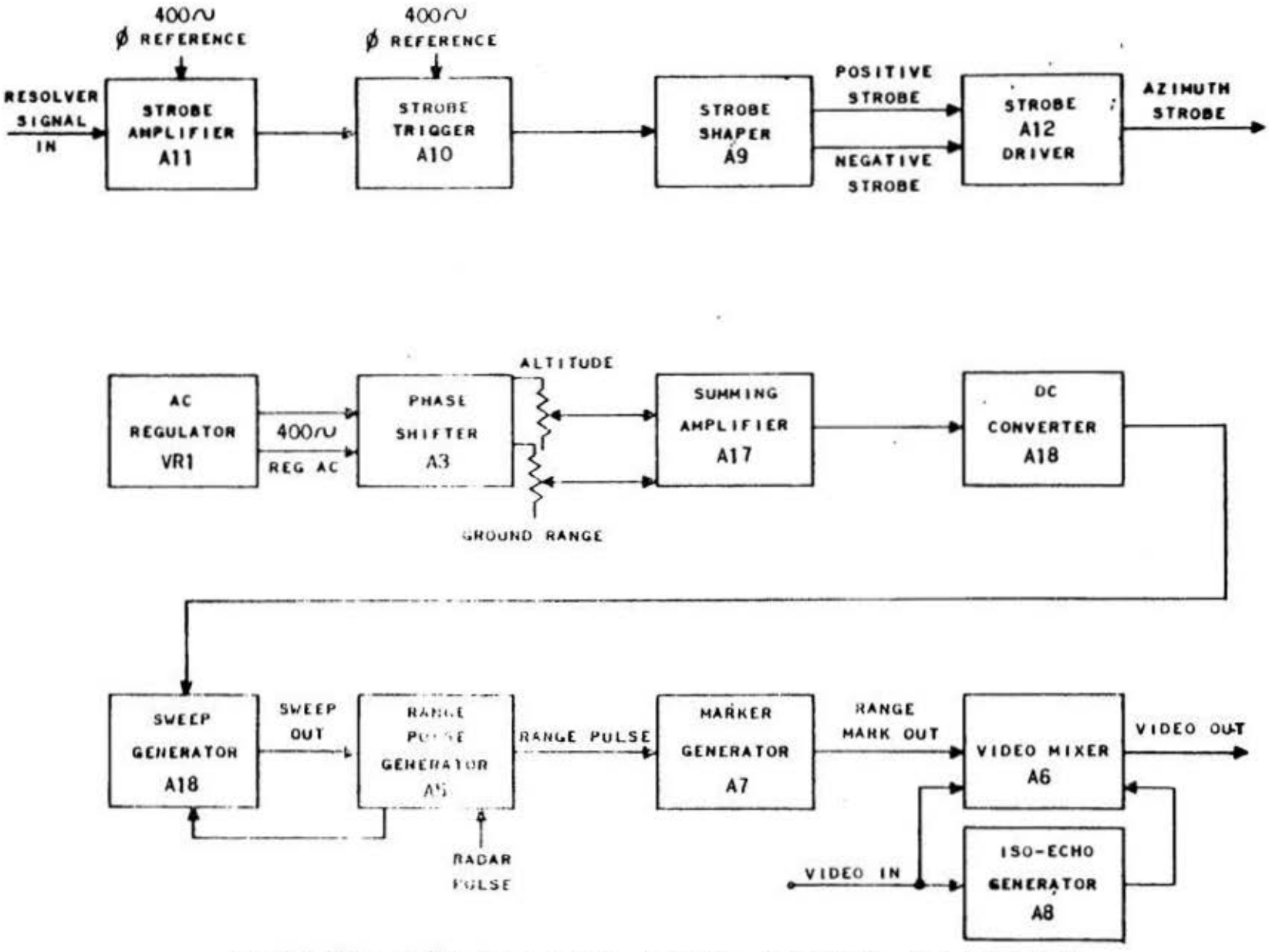
MARKER GENERATOR

The marker generator unit contains a low-voltage power supply, an A-C voltage regulator, and switching functions. Video signals from the receiver are processed by the marker generator unit for application to the synchronizer unit. Four circuit modules are used for the generation of the precision azimuth mark (strobe); two modules develop the precision range marks; two modules are used for video mixing; and one module generates the iso-echo function.



MARKER GENERATOR BLOCK DIAGRAM

Synchro information from the antenna circuitry is sent to a synchro-differential-resolver (transolver) in the marker generator control. Information required for the precision-marker-generation is taken from the transolver and applied to the strobe amplifier. The signal from the transolver is amplified and fullwave-phase demodulated by the strobe amplifier. The signal is amplified so that the synchro null is more easily detected. The 400-Hz line voltage is used as the phase reference for demodulation. The demodulated signal is sent to the strobe trigger circuit, where it is full-wave rectified.



MARKER GENERATOR LOOP BLOCK DIAGRAM

The full-wave rectifier in the strobe trigger circuit produces an output which is used to excite a Schmitt trigger. This produces a pulse at the null points. Because there are two null points for each antenna revolution, an AND gate is developed to block the second pulse. The AND gate consists of a second Schmitt trigger which receives excitation from the alternate phase of the transolver. Since this alternate signal and the signal applied to the strobe amplifier are 90 degrees out of phase, the AND gate is produced only during the first null. Therefore, only the first azimuth pulse is sent to the strobe shaper.

The strobe shaper contains two bistable multivibrator stages. The first bistable stage is activated by the azimuth pulse from the strobe trigger. The second bistable stage is triggered by the first radar trigger after the azimuth pulse occurs. The next radar trigger turns the second bistable stage off. The trailing edge of the resultant square wave is differentiated and turns off the first bistable stage, completing a cycle. This cycle repeats with the next azimuth pulse. Both negative and positive strobes are sent from the second bistable stage to the strobe driver.

In the strobe driver, the positive strobe is clipped to a level determined by the position of the MARKER INTENSITY control. After passing through an emitter follower and an amplifier stage, where it is amplified and inverted, this strobe is sent to the marker polarity relay as the "white strobe". The negative strobe is differentiated and the resultant pulse activates a monostable stage which generates the "black strobe". The "black strobe" is coupled through an amplifier stage to the marker polarity relay. By action of the marker polarity relay, both strobes are directly coupled to the cathodes of the pilot's and navigator's indicators.

The range measurement circuits are initiated by the A-C regulator which develops two 400-Hz, 12.5-volt (rms) signals, 180 degrees out of phase. These signals are sent to a phase shifter which produces a 90-degree phase difference between the two signals. These signals, corresponding to ground range and ground clearance, pass through precision variable resistors in the generator control to the summing amplifier. The summing amplifier adds the two signals vectorially, producing a 400-Hz signal, the amplitude of which is proportional to slant range. This signal goes to a D-C converter stage where it becomes an equivalent D-C level which is used as a reference for the range pulse generator.

The sweep generator is made up of a bistable multivibrator, which is activated by the radar trigger; a transistor switch; and a boot-strap sweep generator. When the bistable stage is activated, the transistor switch is opened, allowing the boot-strap circuit to produce a linear sweep. This sweep is applied to the range pulse generator. Two sweep lengths are available: one for short range, 30 miles (approximately 400 us), and one for long range, 300 miles (approximately 4,000 us).

In the range pulse generator, when the amplitude of the sweep from the sweep generator equals the D-C reference level, a regenerative spike is produced. This spike activates a blocking oscillator which generates the precision range marks and terminates the sweep by resetting the bistable stage of the sweep generator. Two pulse widths are available: for short range, 0.35 - 0.65 us; for long range, 3.5 - 4.5 us. The range pulse is applied to the marker generator circuit.

The marker generator circuit contains two transistor amplifiers, a clippling stage, and a transistor switch. When the MARKER INTENSITY control on the marker control panel is fully counterclockwise, the range pulse bypasses the first transistor amplifier and goes directly to the second transistor amplifier. This pulse is fixed in amplitude and causes a black mark to appear on the pilot's indicator storage tube (CRT). When the MARKER INTENSITY control is rotated clockwise, the transistor switch energizes a relay which causes the range pulse to be applied to the first transistor amplifier. The output pulse of the first transistor amplifier is clipped at a level determined by the setting of the MARKER INTENSITY control. This signal is applied to the second transistor amplifier and appears as a white variable mark on the storage tube. These marks, as well as the iso-echo output, are sent to the video mixer.

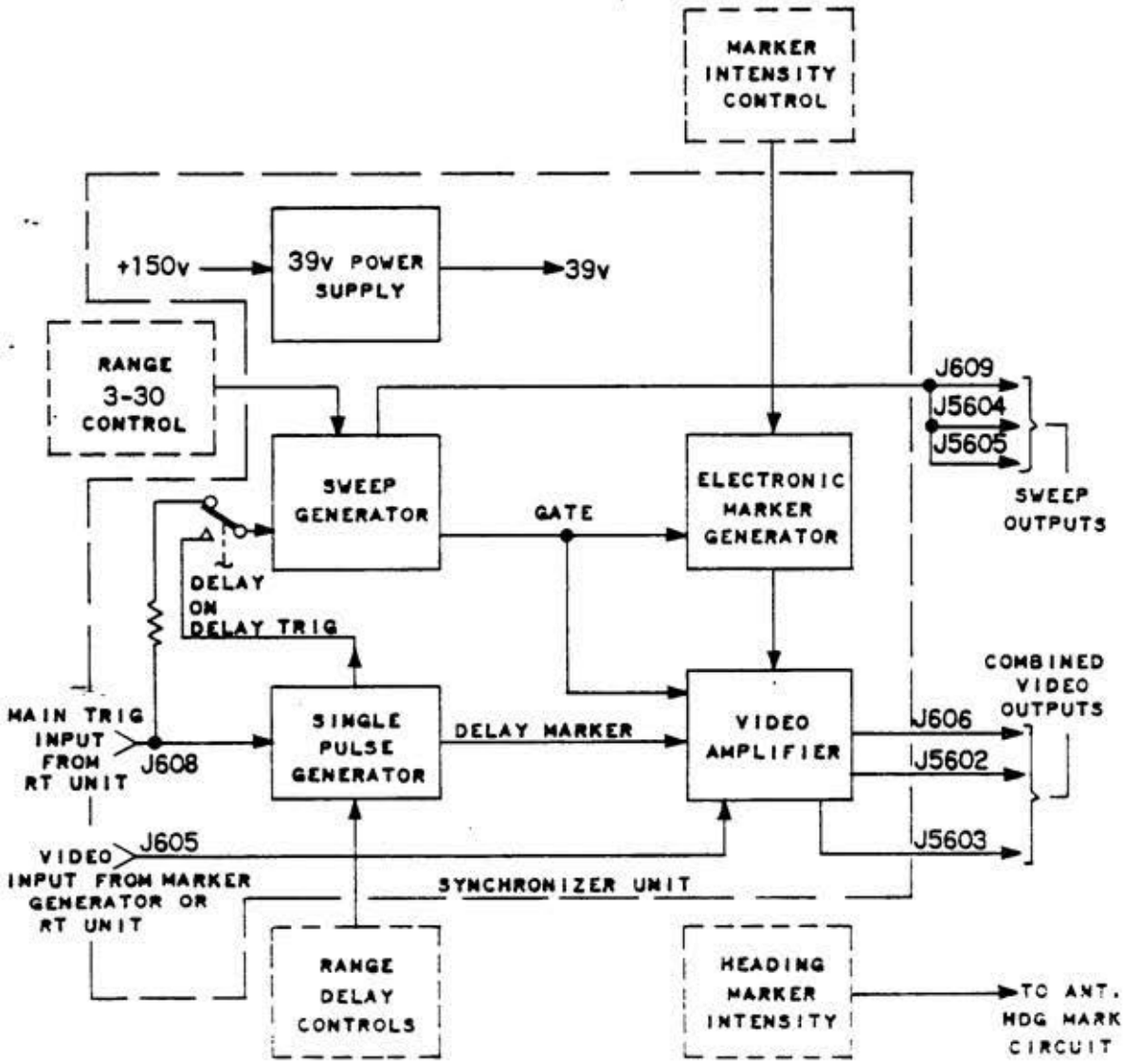
The iso-echo generator receives the video signal through an emitter follower stage. The output of the emitter follower passes through a reverse-biased diode, at a level determined by the setting of the ISO-ECHO control(s). Signals which exceed the bias voltage are amplified, inverted, and sent to the video mixer.

The video mixer consists of a two-stage transistor amplifier and an emitter follower. Video and iso-echo are mixed at the first transistor amplifier stage, and range marks are inserted at the second stage. The video output is taken from the emitter follower and sent to the synchronizer. Iso-echo signals appear as a hole (black spot) on the indicators.

SYNCHRONIZER CIRCUITS

The sync unit contains a sweep generator, electronic marker generator, single pulse generator, video amplifier, and power supply. The unit is completely transistorized.

The sweep generator input is the "main trigger" from the RT unit, or the "delay trigger", from the single pulse generator. The trigger starts the main gate waveform. The main gate starts the sweep and the sweep, when completed, ends the main gate. The main gate is fed to the video amplifier and electronic marker generator. The sweep output is fed to connectors on the synchronizer for the two indicators. A third connector may be used for test.



SYNCHRONIZER BLOCK DIAGRAM

The single pulse generator provides a delay marker, or delay trigger. With the RANGE DELAY switch in the "OFF" position, the output is a variable delay marker which is fed to the video amplifier. The position of this marker on the indicator display can be varied with the RANGE DELAY control. The marker denotes the starting point of the sweep when the RANGE DELAY switch is "ON". The indicator display will then be variable from 3 to 30 miles beyond this range.

The electronic marker generator receives the main gate from the sweep generator. Range marks of 1, 5, 10, 20, or 30 nautical miles are generated during the gate. Brightness of the markers is varied by the RANGE MKS intensity control. The marker output is applied to the video amplifier for processing. Only the 1

and 5-mile range marks are produced directly. Countdown circuits are used for the 10, 20 and 30-mile markers.

The video amplifier combines the delay marker from the single pulse generator, range markers from the range mark generator, main gate from the sweep generator, and combined video from the marker generator unit. These signals are processed and presented as two combined video outputs of the synchronizer. A third video output may be used for test.

The D-C voltage for the transistors is provided by the +39-volt regulator. The board for this regulator also contains the circuits which control the sweep lengths (time) of the 30, 50, 100, and 240-mile ranges. The sweep lengths can be adjusted from outside the synchronizer. The +39-volt regulated supply is derived from the +150-volt supply of the RT unit. Other voltages necessary for synchronizer operation are provided by the RT unit.

ANTENNA CIRCUITS

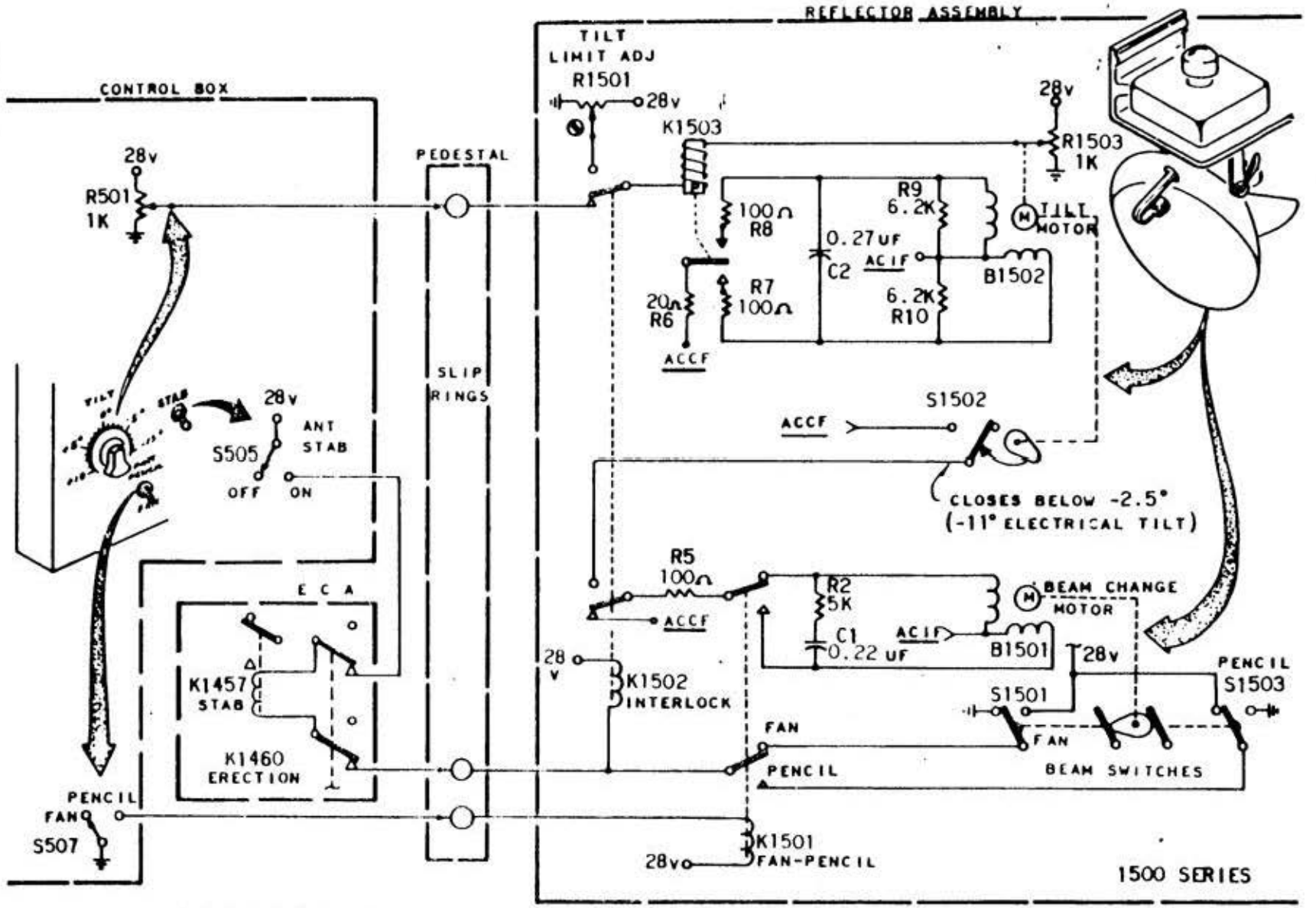
The antenna consists of tilt and beam-change, azimuth drive, antenna stabilization, and heading reference circuits, in addition to the waveguide and antenna reflector assembly. The heading reference circuits provide azimuth drive signals for the indicators. The remaining circuits control the antenna reflectors.

The tilt and beam change circuits are controlled by the PATT switch and TILT control to shape and tilt the radiated beam. The tilt circuit consists of a variable resistance bridge, a polarized relay, and two-phase A-C motor. The relay is connected between the bridge potentiometers and is energized when the tilt control potentiometer is moved, unbalancing the bridge. The A-C motor is turned on through relay contacts, and drives the antenna reflectors and potentiometer until the bridge is again balanced.

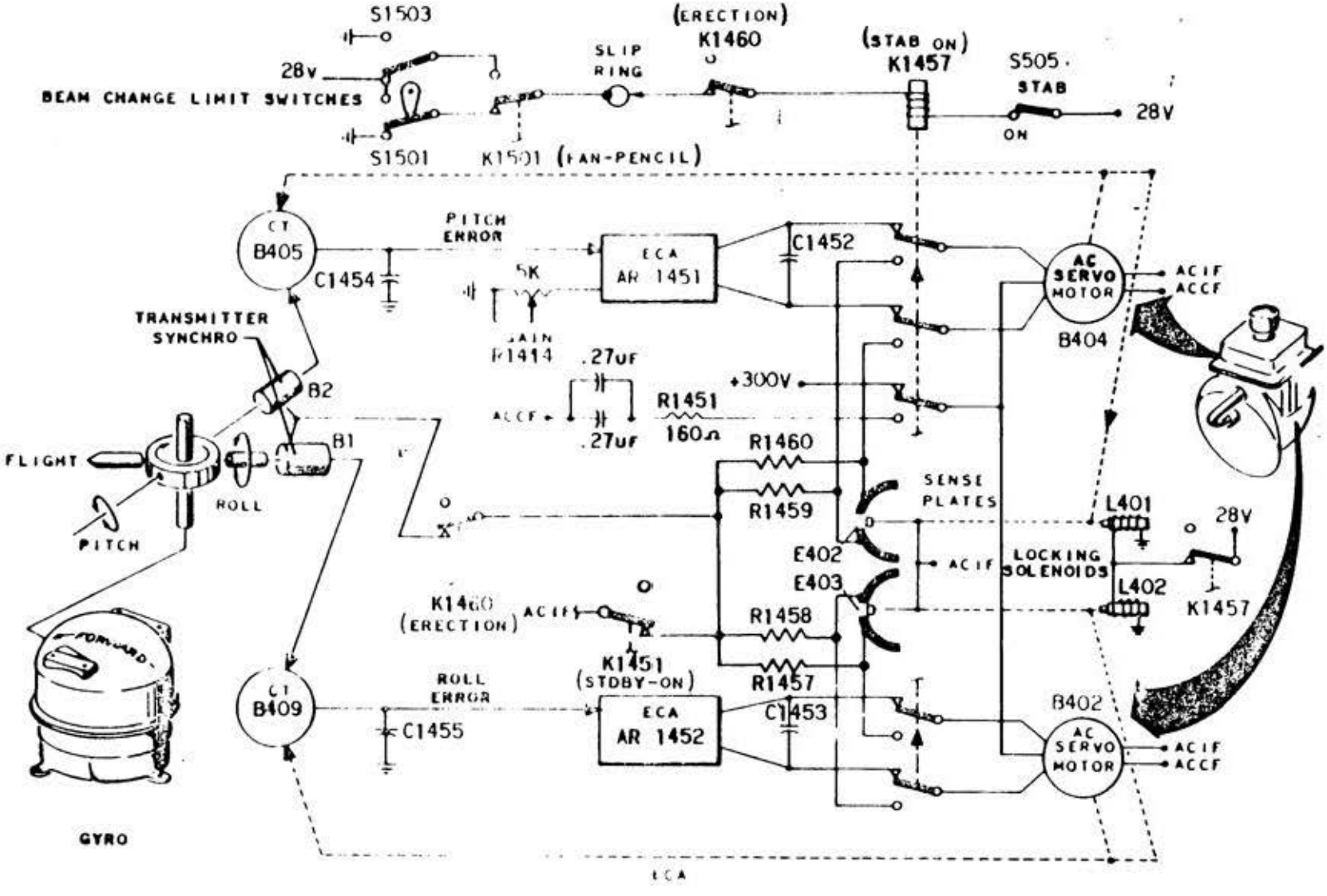
The beam change circuit consists of relays, microswitches, and a two-phase A-C motor. The motor is normally stalled while operating, to hold the lower reflector against mechanical stops. This keeps the reflectors in alignment at all times.

When the "PATT" (pattern) switch position is changed, the relays reverse the connections of the A-C motor, causing it to drive in the opposite direction. The motor again stalls against the mechanical stops when the reflectors are aligned. Before a beam change can be accomplished, the tilt circuit must drive to "tilt clearance" and antenna stabilization must turn off. Interlock of these circuits for proper sequence is accomplished by microswitches and relays in the antenna.

Antenna stabilization is accomplished by two servo loops. One loop controls the pitch axis and the other controls the roll axis. A platform in the antenna pedestal is the reference for the reflectors. When STAB is "off", the platform is locked (zero) to the antenna housing. When STAB is "on", the platform is positioned in pitch and roll to remain level with the earth's surface.



ANTENNA TILT AND BEAM CHANGE CIRCUITS



ANTENNA STABILIZATION SERVO LOOPS

The stabilization data generator provides a pitch and roll signal to Control Transformers (CT) in the antenna. The CT output is supplied as position error information to servo amplifiers in the ECA unit. The amplified error voltage is supplied back to the antenna servo motors. The pitch and roll servo motors position the platform and CT rotor to null the error voltage. Continuous operation of these servo loops maintains the level platform position. During a beam change, or when stabilization is turned off, the platform is driven to zero by the servo motors and locked in position by solenoids.

Azimuth drive of the antenna is accomplished by a dual armature, reversible D-C motor. Speeds of 12 rpm or 45 rpm are provided by using both armatures connected in series (12 rpm), or one armature only (45 rpm). The polarity of the DC voltage to the motor determines the direction of rotation. Fast speed is used only in "SEARCH", "30 or 50 NM RANGE", with "PPI" scan selected. Fast scan will be clockwise rotation, due to the polarity of the D-C motor voltage.

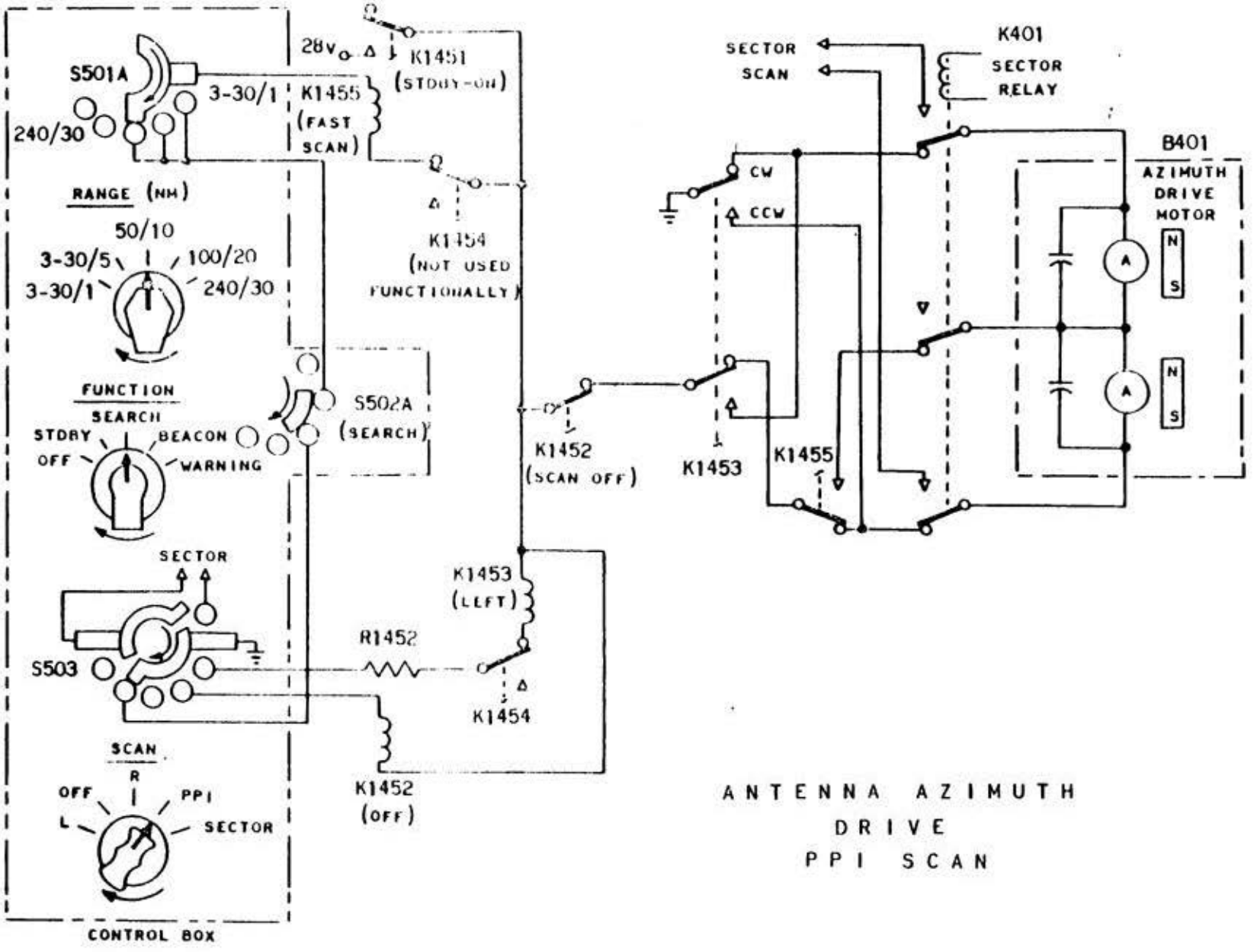
Relays accomplish the switching necessary to allow 12-rpm clockwise rotation, 12-rpm counterclockwise rotation, or 45-rpm clockwise rotation. Sector scan relays reverse the motor voltage, causing the scan to reverse after the degrees of travel, as preset by the antenna control unit settings have been traversed.

The heading reference circuits control the azimuth reference of the indicator display. The navigator can select relative (aircraft heading) or stabilized (magnetic) reference by the BEARING switch on the radar control panel. The relative reference is provided by a fixed rotor synchro in the ECA unit. Magnetic reference is supplied by the aircraft magnetic compass system.

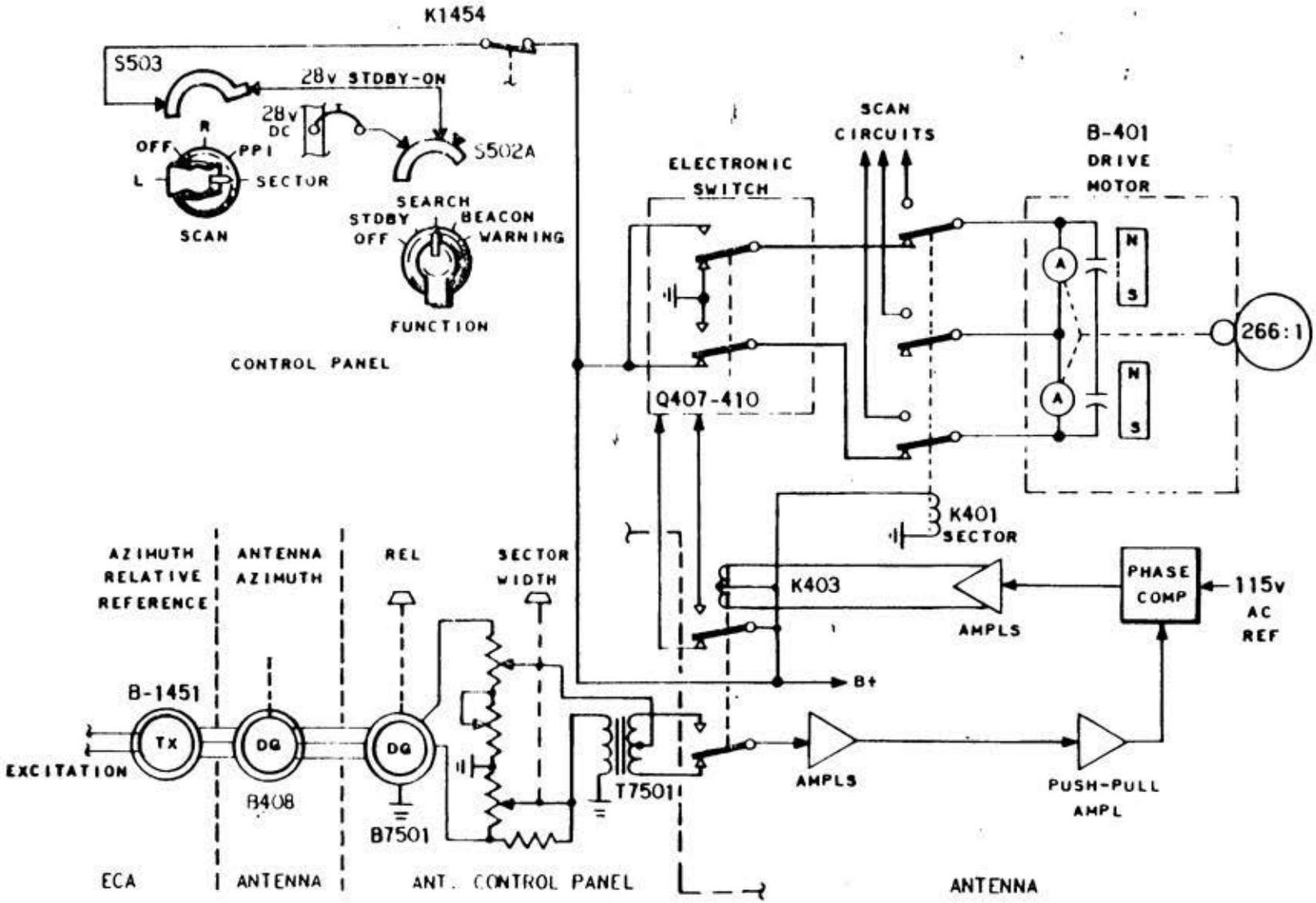
The synchro reference is supplied to the differential synchros in the antenna, then to indicator servo loops, which position CRT deflection coils to track antenna azimuth changes. The indicators contain a control transformer and servo motor. The servo amplifiers are in the indicator power supply units.

The antenna synchro is driven by the antenna azimuth drive motor. This synchro signal, representing antenna position, is supplied to the control transformer. The control transformer error output is amplified and used to drive the servo motor. The motor positions the deflection coil, and also turns the control transformer to null.

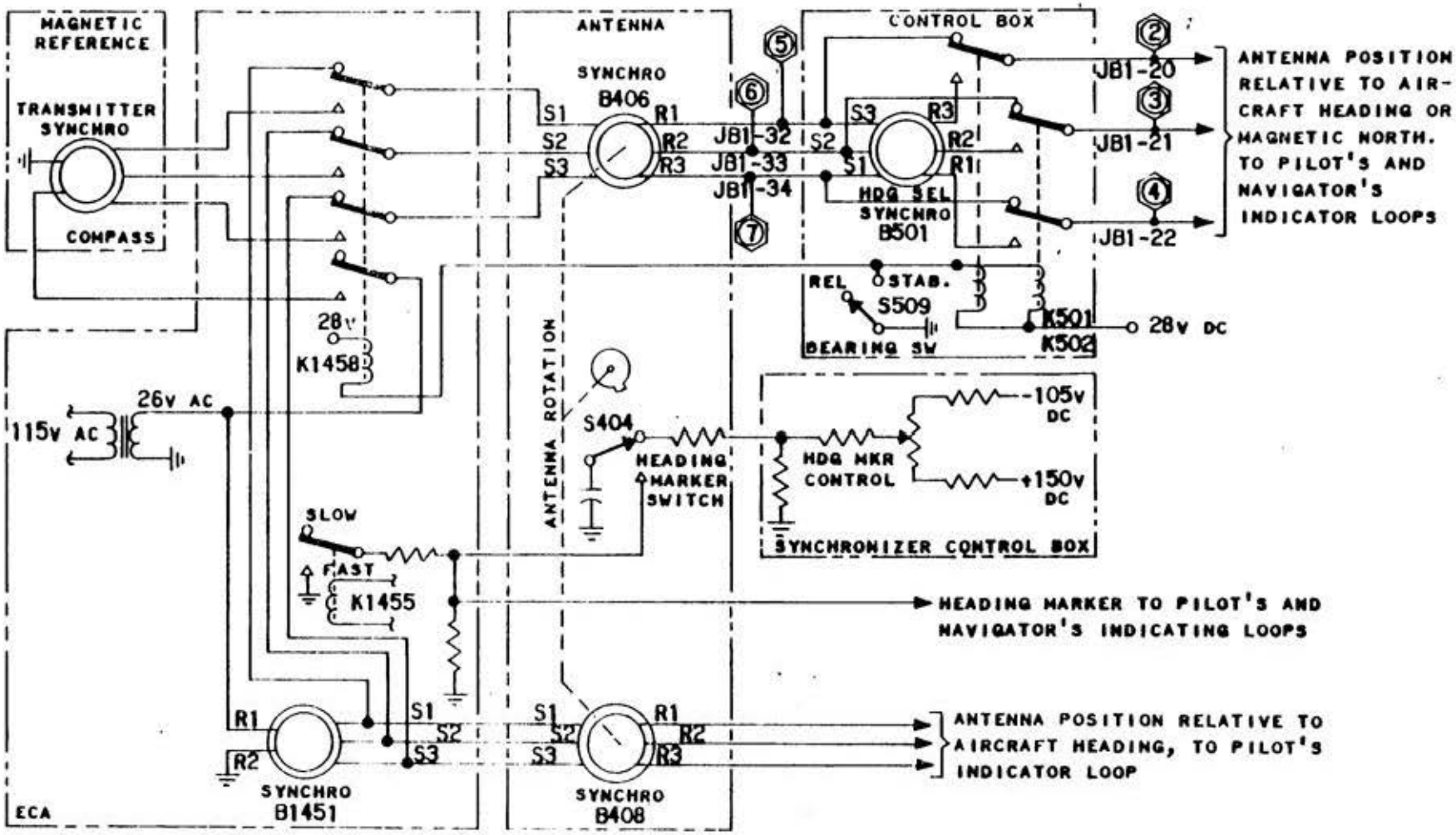
The reference for the navigator's indicator is determined by the BEARING switch on the radar control panel. When "BEARING STAB" is selected on the radar control panel, the navigator's reference is magnetic. The reference can be varied manually by positioning the heading select control. This control positions a differential synchro in the servo loop and allows selection of any magnetic heading as a reference. If the BEARING switch is turned "off", the reference will be the relative synchro in the ECA.



ANTENNA AZIMUTH DRIVE PPI SCAN



ANTENNA SECTOR SCAN BLOCK DIAGRAM



HEADING REFERENCE BLOCK DIAGRAM

The pilot's indicator reference is the relative synchro when the S-R switch is in the "R" position, and the same as the navigator's reference in the "S" position.

POWER SUPPLY AND INDICATOR

Video signals are supplied from the synchronizer to the video amplifier in each indicator. A gain control varies the amplitude of these signals into each amplifier. The signals are amplified sufficiently to intensity-modulate the PPI display, then applied to each CRT control grid.

The intensity control on the navigator's indicator, adjusts the average D-C potential on the grid to determine the brightness of the display. A D-C restorer holds the grid at a constant D-C level, as set by the intensity control. This function is controlled by the BKGRD control on the pilot's indicator.

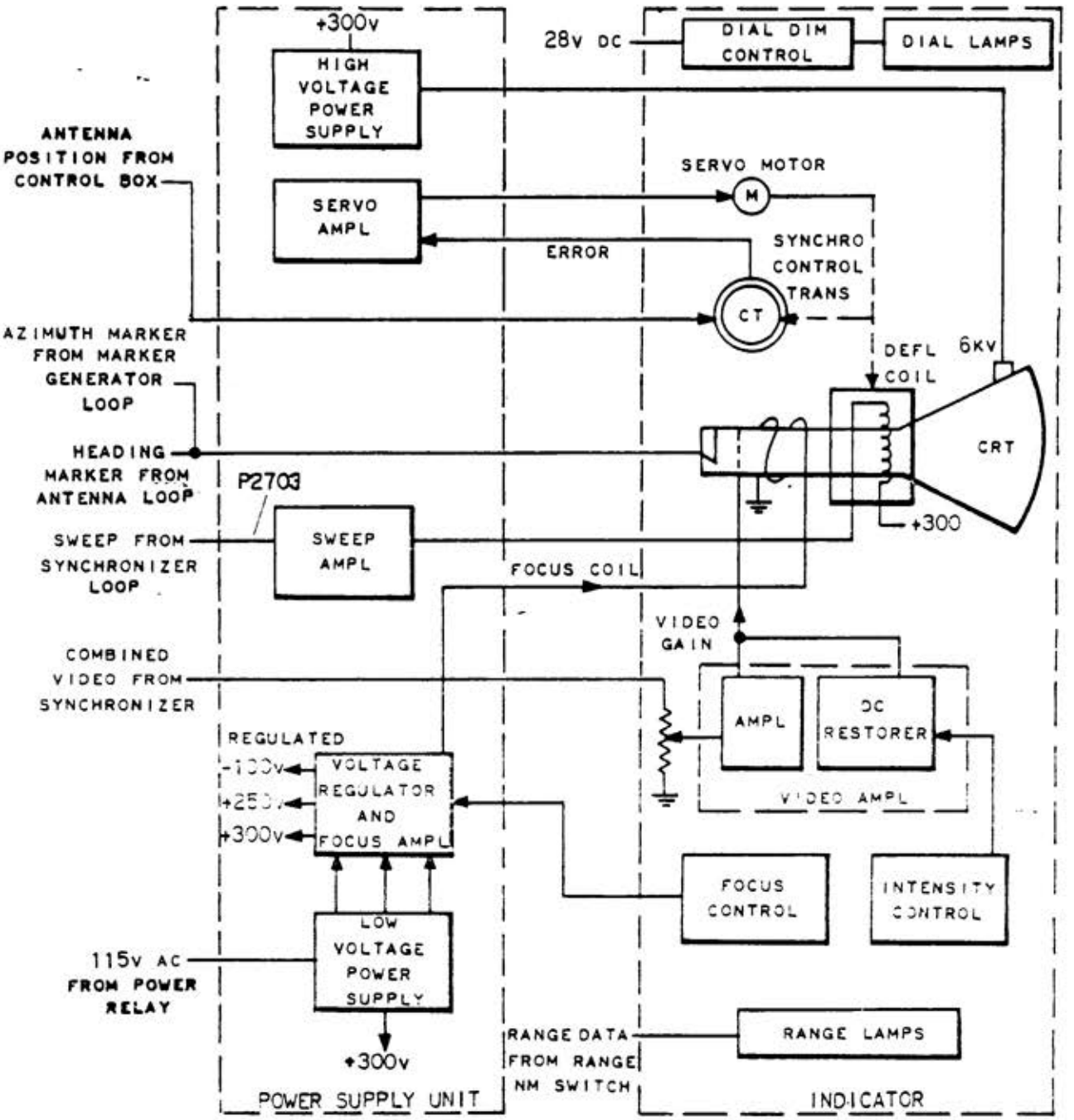
The sweep generated in the synchronizer is amplified in the power supply unit by the sweep amplifier subassembly. The amplified trapezoidal output is applied to the CRT deflection coil. The sweep output causes the electron beam to move from the center to the outside of the CRT during each sweep. The deflection coil is positioned around the neck of the CRT to determine the direction of the beam movement. Positioning is accomplished by the heading reference servo loop.

The heading marker from the antenna is applied to the cathode of the navigator's CRT and to a gated amplifier in the pilot's indicator. After being mixed with video signals from the synchronizer, the pilot's indicator heading mark is applied to the control grid of the CRT. Each time the antenna rotates past the aircraft lubber line, a switch is closed. The switch causes a capacitor to discharge, providing the marker. The heading mark control on the synchronizer control box varies the polarity and amplitude of the capacitor charge, thereby varying the brightness (or blanking) of the marker.

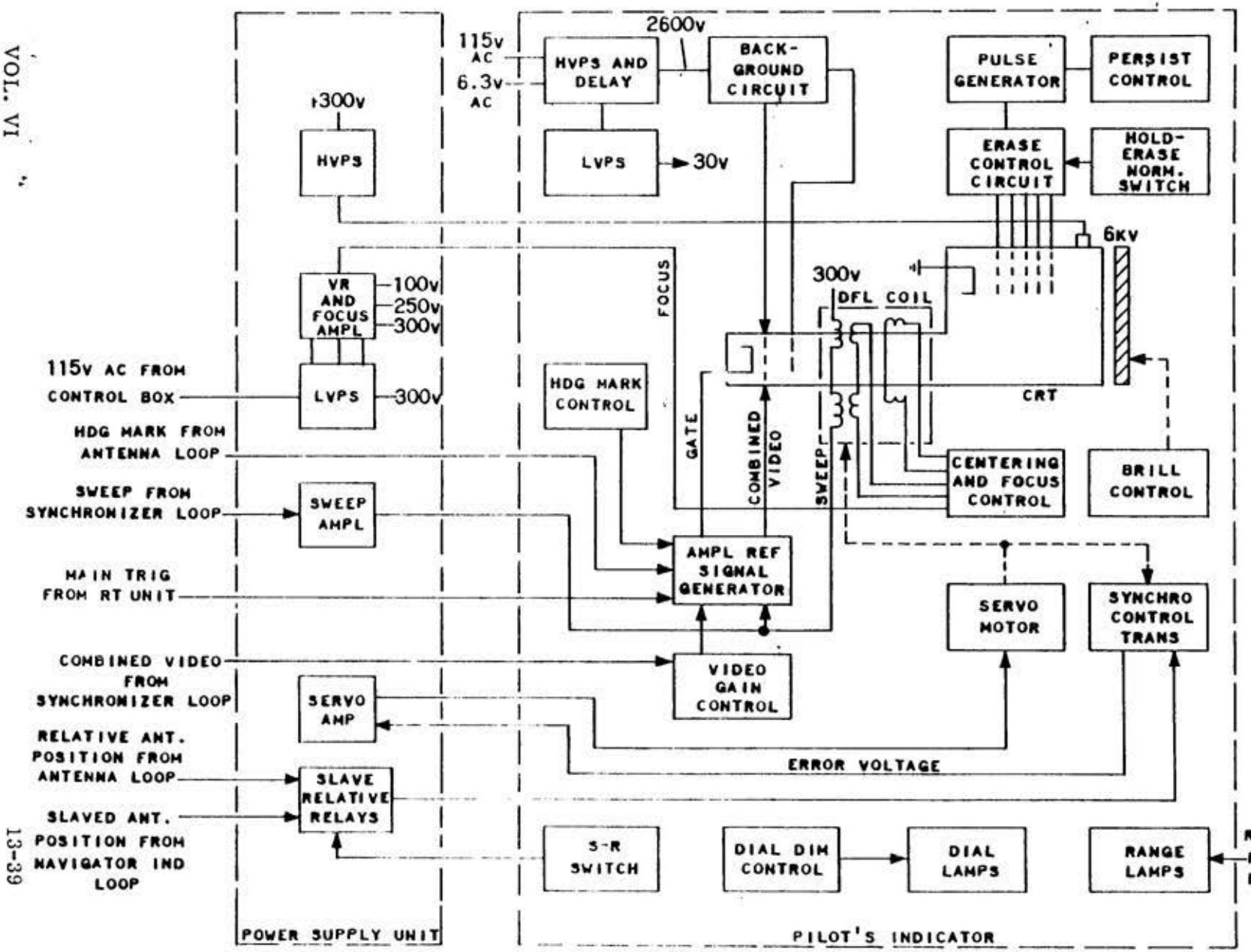
NOTE: Brightness only is varied on the pilot's indicator.

The power supply units contain a low voltage power supply, voltage regulator, sweep amplifier, servo amplifier, and high voltage power supply. These subassemblies provide the operating voltages and amplifiers for the indicators.

The voltage regulator contains a focus amplifier which amplifies the effect of the indicator focus control. The amplifier output is supplied to the CRT focus coil. A high voltage power supply changes 300 volts, DC into approximately 6,000 volts, DC potential for the CRT anode. The high voltage cable is mechanically interlocked to the power and control cable between the power supply and indicator. If either cable is disconnected, the other cable must also be disconnected. An electrical interlock in the indicator removes the high voltage in case an indicator is removed. This is accomplished by de-energizing an interlock relay in the power supply unit.



NAVIGATOR'S INDICATOR AND POWER SUPPLY BLOCK DIAGRAM



PILOT'S INDICATOR AND POWER SUPPLY BLOCK DIAGRAM

The pilot's indicator contains a direct view storage tube which has an unusually bright display. It has the ability to hold a display for an extended period of time, the length of which is determined by the setting of the PERSIST control. The direct view storage tube essentially consists of two electron guns in one CRT envelope (a writing gun and a flood gun).

The writing gun receives video signals and functions in the same manner as the normal CRT except that the electron beam is scanned across a storage mesh instead of the phosphor. The storage mesh is a part of the flood gun and consists of a conducting mesh, coated with an insulating material.

As the electron beam leaves the writing gun, it strikes a portion of the storage mesh causing secondary emission of electrons, resulting in the storage mesh having a net positive charge. The amount of charge is dependent upon the beam intensity and/or the total instantaneous video signal. The flood gun emits and collimates (directs) a low-velocity electron beam which approaches the storage mesh with a uniform charge density. This causes the storage mesh to function as a control grid. A given group of low-velocity electrons will pass through the storage mesh and be accelerated sufficiently to strike the phosphor screen. A positively-biased collector mesh is used to collect secondary-emission electrons from the storage mesh.

Without a means of removing the positive charge from the storage mesh, the PPI display would remain on the face of the viewing screen indefinitely, causing the presentation to smear as the aircraft target moves. To eliminate this, highly positive sawtooth pulses are applied to the conducting element of the storage mesh. These pulses (erase pulses) attract electrons to the storage mesh, leaving a net negative charge until the electron beam from the writing gun strikes again. The width of the erase pulse is varied by rotating the PERSIST control. Clockwise rotation causes the pulse width to be narrowed, increasing the amount of time it takes to erase the charge on the storage mesh.

When the HOLD-ERASE-NORM switch is placed in the "HOLD" position, neither video signals nor erase pulses are applied to the storage mesh. In this instance, the PPI display will remain. When the switch is placed in the "ERASE" position, a constant D-C potential is applied to the storage mesh, while video signals are blocked. In this condition, the entire PPI display is erased.