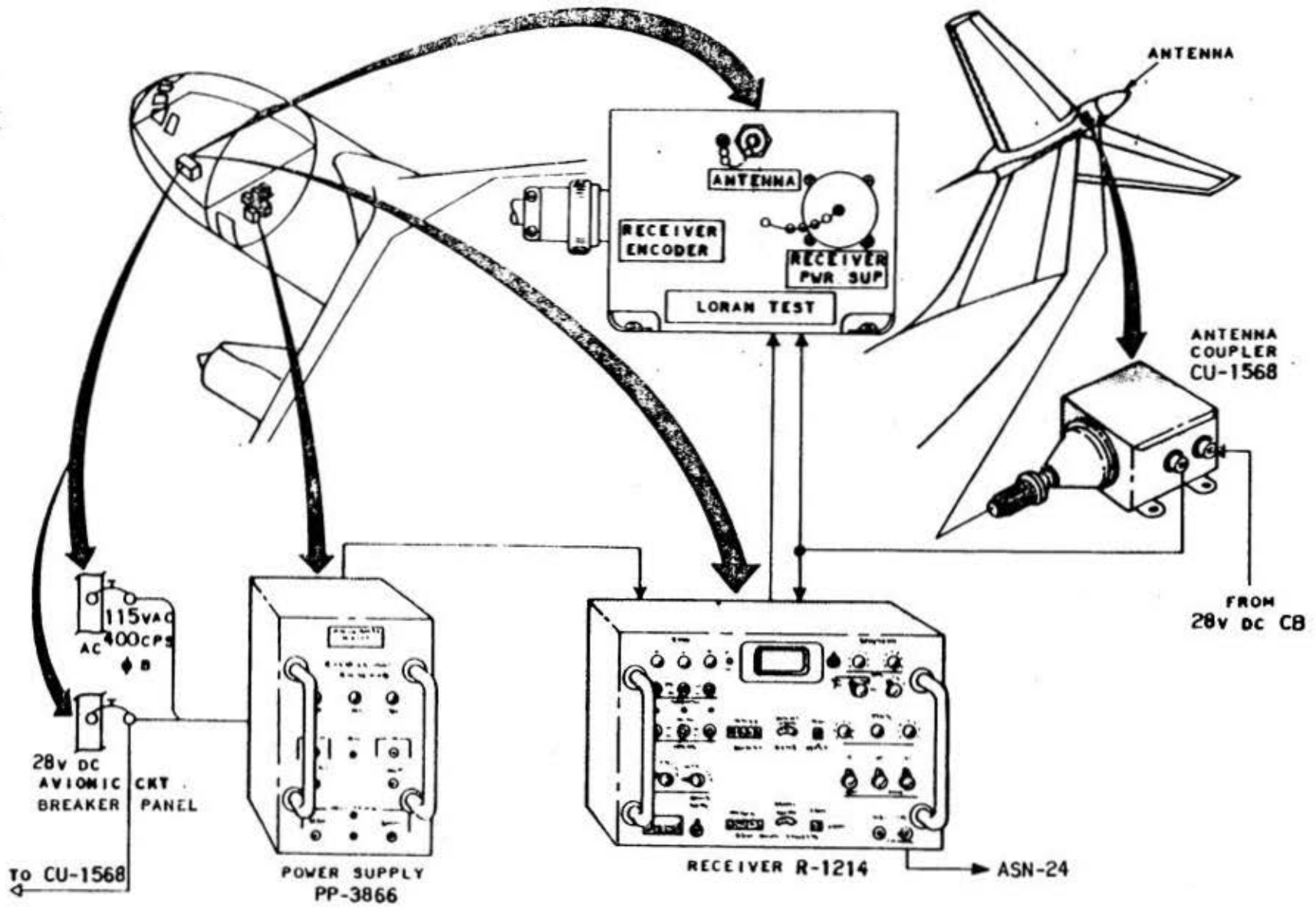
LORAN-C SYSTEM

GENERAL

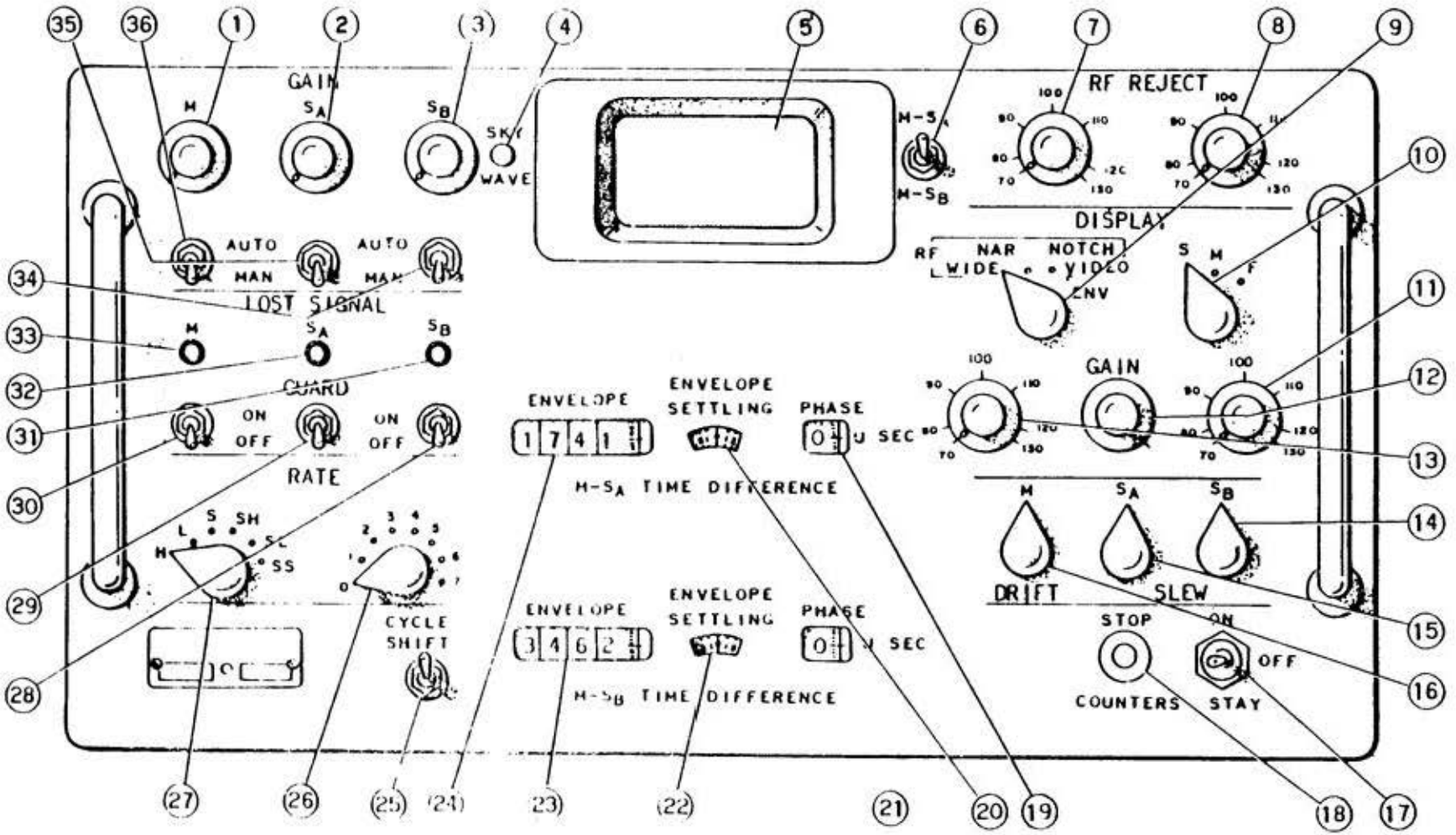
The AN/APN-157 LORAN-C system enables the navigator to accurately determine the geographic position of the aircraft. The LORAN receiver measures and presents, as numerical readouts, time differences in the reception of signals from 100 KHz fixed frequency ground transmitters.

Each group of ground transmitters, called a LORAN chain, consists of one master station (M), and two slave stations (Sx and Sy). All station groups transmit a pulse-modulated, fixed frequency 100 KHz signal. Each LORAN-C pulse consists of 20 100 KHz sine waves which rise to a maximum amplitude in 5 cycles. The master station transmits 9 pulses and each slave station transmits 8 pulses in a LORAN-C interval. The LORAN-C chains are distinguished by the pulse recurrance interval, (the time required for a chain to complete its transmission interval). The 100 KHz carrier is phase coded (inverted) in a logic pattern to aid in signal identification and to avoid sky-wave contamination. One numerical read-out on the LORAN-C receiver will indicate the M-Sx time difference, while the other read-out indicates the M-Sy time difference. These time differences represent distance differences, and are used to identify a pair of hyperbolic lines on the LORAN-C navigation chart. The point of intersection of the two hyperbolic lines indicates the aircraft's position.

In addition to the numerical read-outs, the LORAN receiver presents a visual display on a Cathode Ray Tube (CRT) to aid in signal identification and lock-on operation. Another function of the AN/APN-157 receiver is the translation of time differences into digital form. This digital information is fed to the AN/ASN-24 computer.



COMPONENTS LOCATION AND CABLING



LORAN RECEIVER OPERATING CONTROLS

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Ambient operating temperature range	$-54^{\circ}C$ ($-65^{\circ}F$) to $+55^{\circ}C$ ($+131^{\circ}F$)
Type antenna required	Long-wire type. Vertical electrical height greater than two meters.
Frequency Control:	
a. Oscillation frequency	a. 100 KHz $\pm$ 1 ppm
b. Crystal stability with temperature	b. Maximum frequency drift 1 part in 10^7 for a $40^{\circ}C$ change within range of $0^{\circ}C$ ($+32^{\circ}F$) to $+65^{\circ}C$ ($+149^{\circ}F$).
c. Crystal operating temperature	c. $+70^{\circ}C$ ($+158^{\circ}F$) under oven control
d. Frequency accuracy	d. After one hour warmup maximum frequency drift in five-minute period, 3 parts in 10^8. Maximum frequency drift in 24-hour period, 5 parts in 10^8.

The output voltages, regulation percentages, and current values of the PP-3866/APN-157 power supply are as follows:

POWER SUPPLY PP-3866/APN, OUTPUT VOLTAGE AND CURRENT		
VOLTAGE (VOLTS)	REGULATION (PERCENT)	MAXIMUM CURRENT (AMPERES)
DIRECT CURRENT		
-12	0.25	2.0
-55	0.25	0.15
+55	0.25	0.45
-11	5.0	0.8
-30	5.0	0.01
+28*	None	1.5
+15**	None	1.5
ALTERNATING CURRENT (400 Hertzs)		
115*	None	1.5

* Voltage is fed through power supply from aircraft source.

** Peak voltage, full-wave 400-Hertz rectified and unfiltered.

BLOCK DIAGRAM THEORY OF OPERATION

LORAN-C CHAIN

LORAN-C is a hyperbolic navigation system operating on a pulsed 100 KHz carrier frequency. A LORAN-C chain usually consists of one master station and two slave stations. However, the chain is not restricted to two slave stations. The bottom portion of the "Loran-C Chain" illustration shows a star and a square LORAN chain that employs three slave stations. The M-Sx, M-Sy and M-Sz each comprise a LORAN pair. Time difference measurements are made between the signals of any two pairs selected by the airborne receiver operator. The top portion of the "Loran Chain" illustration shows a typical triad LORAN chain arrangement.

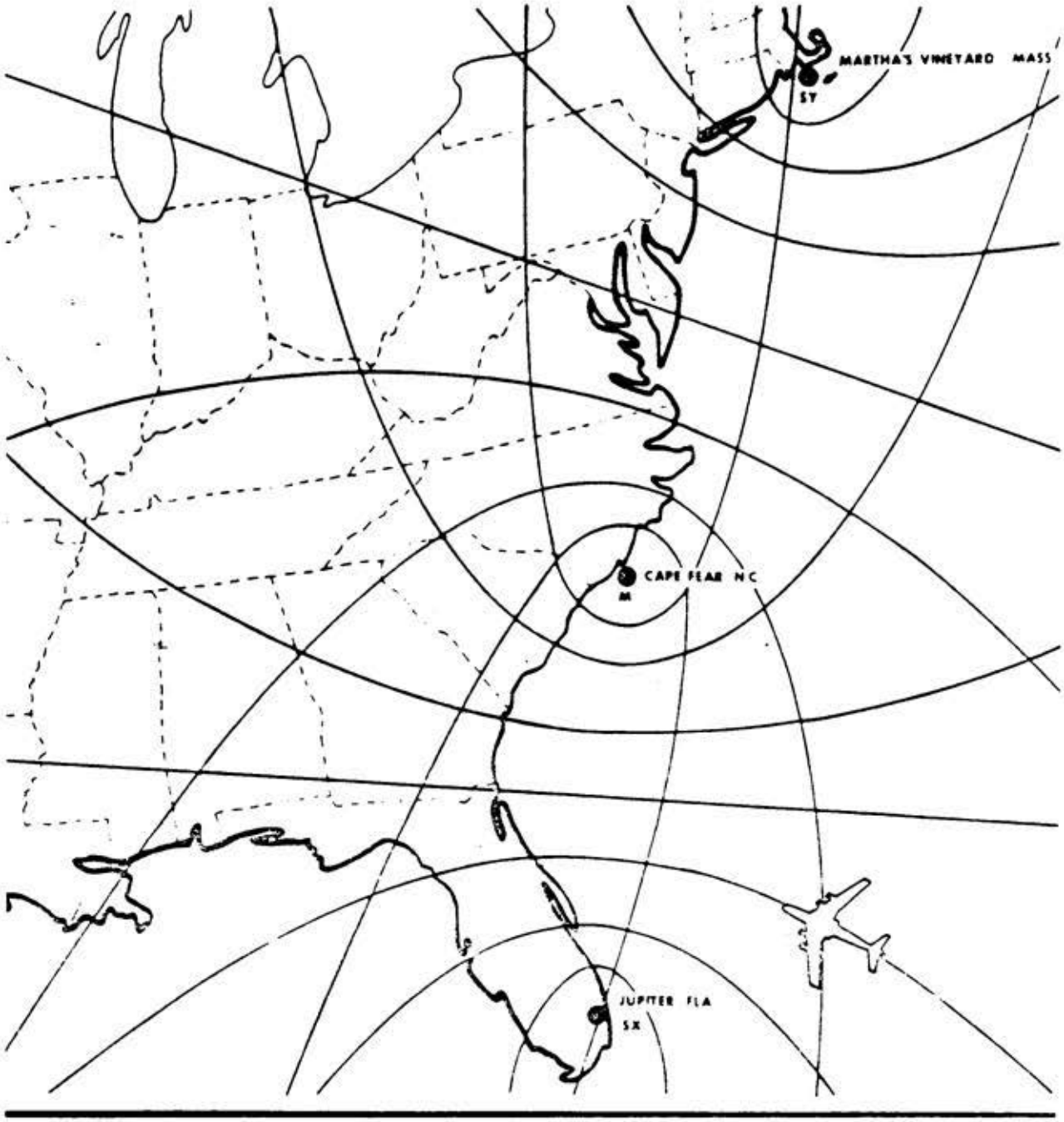
Each hyperbolic line shown in the illustration identifies the RF arrival time difference of LORAN transmitter pairs. The intersection of these hyperbolic lines accurately locates the geometric position of the aircraft up to approximately 1200 nautical miles.

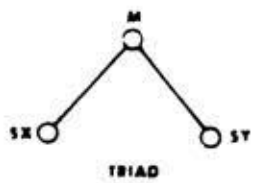
The master station signal, consisting of nine pulses, is always the first transmission in a station group signal cycle. Following this are the pulse groups of slave stations X, Y, and Z (if used) in that order. The time required to complete one LORAN cycle is called the pulse recurrance interval.

A total of 48 repetition rates are available in the APN-157 system, as shown in the "Repetition Rate" illustration.

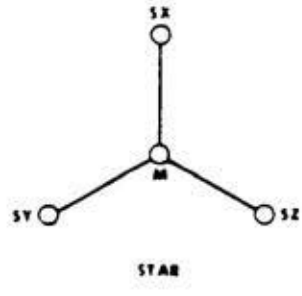
PULSE REPETITION RATES (MICROSECONDS)						
SPECIFIC RATE SELECTION	BASIC RATE SELECTION					
	SS	SL	SH	S	L	H
0	100,000	80,000	60,000	50,000	40,000	30,000
1	99,900	79,900	59,900	49,900	39,900	29,900
2	99,800	79,800	59,800	49,800	39,800	29,800
3	99,700	79,700	59,700	49,700	39,700	29,700
4	99,600	79,600	59,600	49,600	39,600	29,600
5	99,500	79,500	59,500	49,500	39,500	29,500
6	99,400	79,400	59,400	49,400	39,400	29,400
7	99,300	79,300	59,300	49,300	39,300	29,300

Note that the time required to complete one LORAN cycle at PRR 50 is 50,000 microseconds. Thus the ground transmitters will repeat the sequence of pulse groups 20 times in one second.

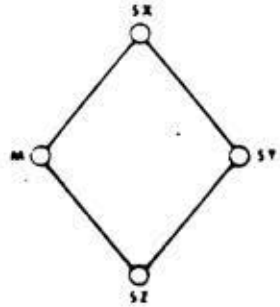




TRIAD



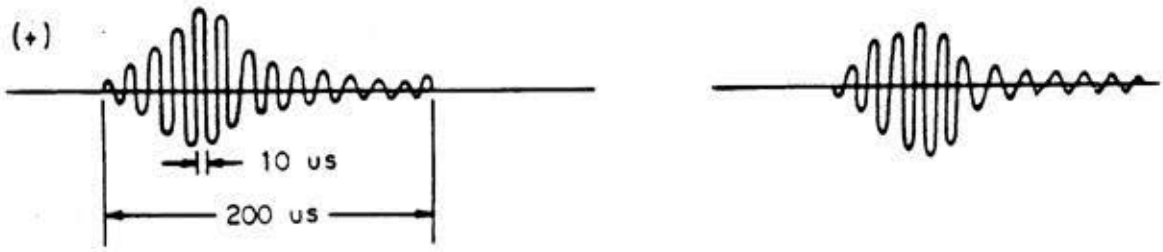
STAR



SQUARE

LORAN-C CHAIN

In addition to being patterned in timing and sequence, the LORAN signals are also phase coded. The 100 KHz RF carrier has a 180 degree phase difference relationship between the phase code designated plus and the phase code designated minus. Individual pulses with 180 degree phase differences are shown in the "Phase Coding Sequence" illustration.



PHASE CODING SEQUENCE		
LORAN CYCLE	MASTER	SLAVE
FIRST CYCLE	++--+-+-	+++++--+
SECOND CYCLE	+--++++	+-+-++--

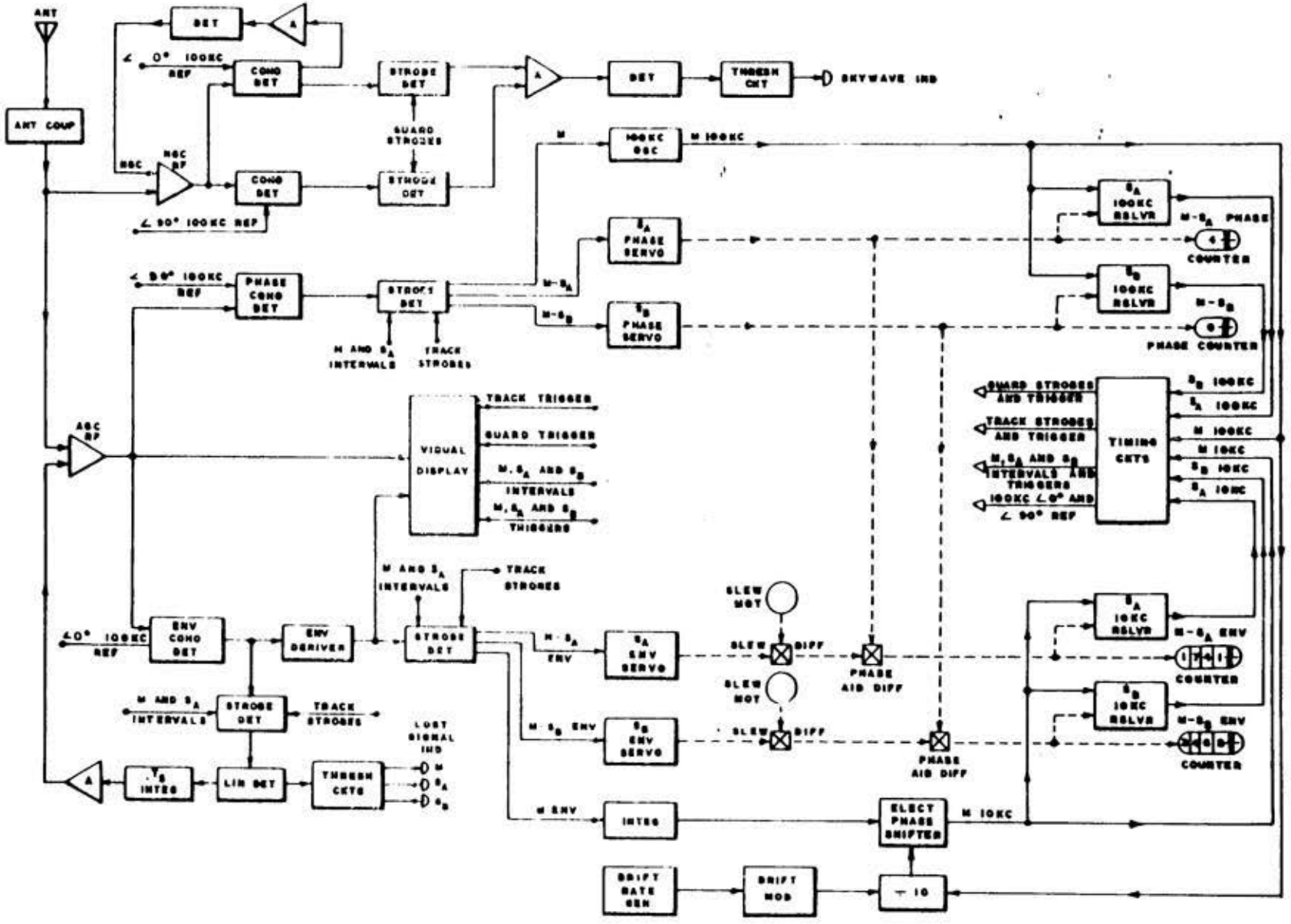
The LORAN chain has two phase coding patterns. The ground transmitters alternate between these two patterns. The phase coding for Sx, Sy, and Sz is the same for any one LORAN cycle. Phase coding is used to prevent sky-wave contamination of the LORAN signals.

LORAN RECEIVER

The basic function of the R-1214/APN-157 LORAN-C receiver is to measure the RF arrival time difference of two master-slave pairs. For increased accuracy the receiver measures both envelope and phase time difference. The envelope time difference (coarse) and the phase time difference (fine) comprise the numerical readouts.

A functional diagram of the LORAN receiver is shown on page 12. The time difference readings produced by the receiver are developed by the action of two primary servo loops, each of which consists of three sub loops. The subloops of the envelope servo loop are as follows:

- Master envelope servo loop
- Slave A envelope servo loop
- Slave B envelope servo loop



FUNCTIONAL DIAGRAM

The sub-loops of the phase servo loop are as follows:

- Master phase servo loop
- Slave A phase servo loop
- Slave B phase servo loop

The function of the master envelope servo loop is to shift the phase of a master 10 KHz reference signal along the time axis. The slave A and slave B envelope servo loops drive envelope counters.

The function of the master phase servo loop is to shift the phase of a master 100 KHz reference oscillator. The slave A and slave B phase servo loops drive phase counters.

The incoming RF is applied to the sky-wave guard circuits and to the AGC RF amplifiers. The AGC RF amplifiers have outputs to the two primary servo loops and to the visual display. The AGC and lost signal circuits sample the RF energy in the envelope servo loop.

Receiver time sharing permits the use of common circuits. The "Basic Timing Waveforms" drawing illustrates the timing waveforms that enable time sharing. The master interval starts the LORAN cycle of the receiver. Note that the slave A interval begins at the end of the master interval and the slave B interval begins with the end of the slave A interval. The period of the LORAN cycle is determined by the PRR setting. Three identical divide-by-ten counters in the timing circuits are used to produce timing pulses from the master 10 KHz signal. The basic counting device in each circuit is a magnetic beam switching tube that produces one output signal from any particular terminal for every ten input pulses. The timing pulses are fed to the basic and specific rate switches located on the receiver front panel. The output of these switches resets the counting decades so that another LORAN cycle may begin.

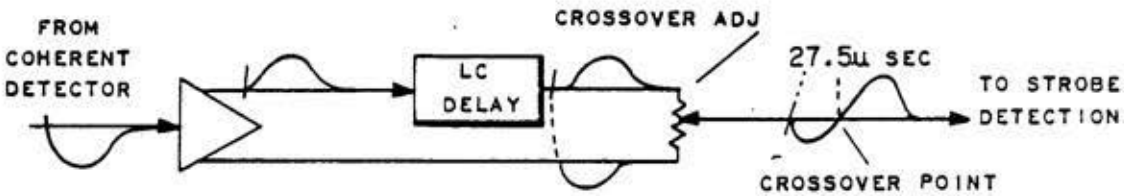
The master, slave A, and slave B gates shown in the "Basic Timing Waveforms" illustration control a multipulse generator. The pulses out of this generator are spaced 1,000 microseconds apart and are used to develop track and guard strobes, as well as inputs to the phase code logic circuits. The output of the phase code logic circuits determines the phase inversion pattern of the master 100 KHz reference signal.

MASTER ENVELOPE SERVO LOOP

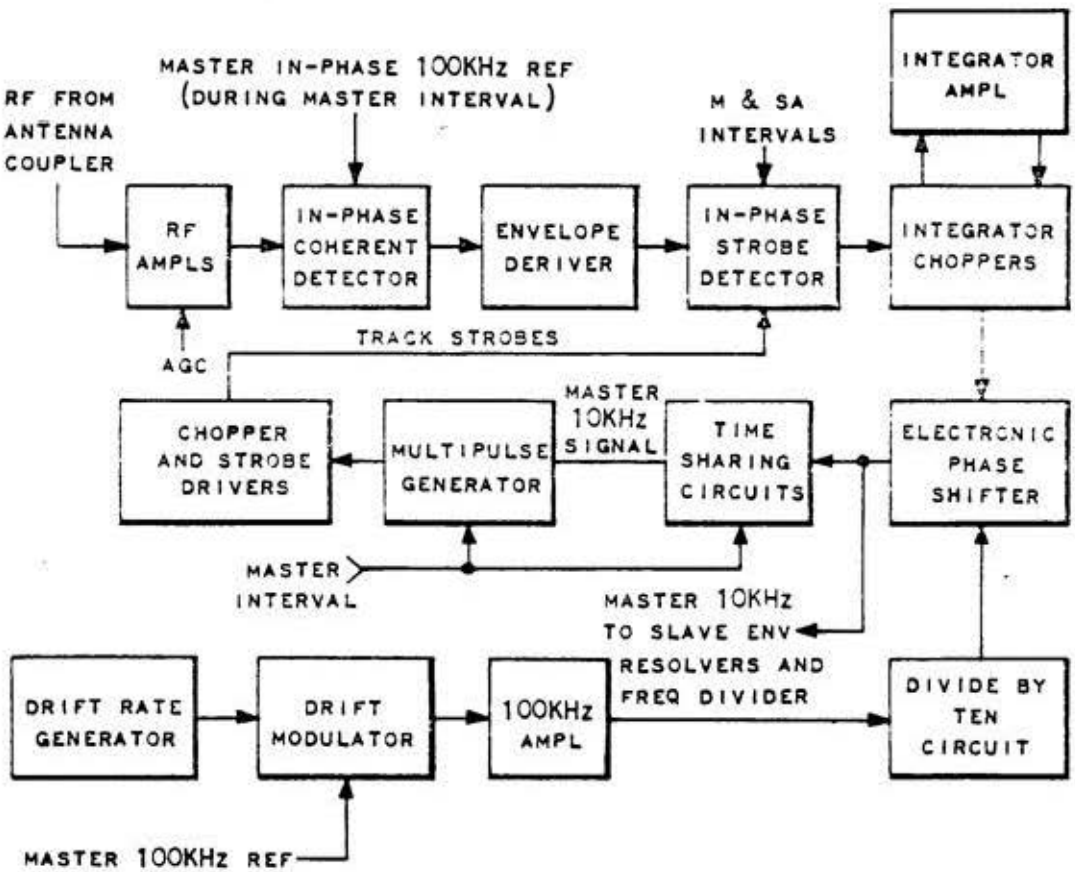
The master envelope servo loop causes time synchronism between the receiver generated master track strobe and the received master station pulses. The in-phase coherent detector compares the two signals, removes the 100 KHz carrier, and produces a negative-going envelope. The envelope deriver produces a cross-over, or null, 27.5 microseconds after the beginning of the envelope. The negative polarity video envelopes are coupled to a paraphase amplifier. The positive

BASIC TIMING WAVEFORMS

going envelope taken from the collector of the paraphase, (phase splitter), amplifier is delayed by a LC network. The in-phase envelope and the delayed inverted envelope are added across a potentiometer to produce a derived envelope. The potentiometer is adjusted to give a crossover point 27.5 microseconds after the start of the envelope. The derived envelopes are fed to the in-phase strobe detector (coincidence circuit) which has as a second input track strobes from the strobe driver. The track strobes are pulses with a 10 microsecond width and occuring at a 1 KHz rate. The function of the in-phase strobe detector is to sense any displacement of the track strobes from the crossover of the derived envelope. Any displacement develops an average D-C voltage, the polarity and



ENVELOPE DERIVER



MASTER ENVELOPE SERVO LOOP

amplitude depend on the direction and amount of displacement. The D-C voltage is integrated and applied to an electronic phase shifter. The master 10 KHz reference used to develop track strobes is phase shifted along the time axis until the strobes align with the crossover points of the derived video.

The drift rate generator and modulator are used in initial lock-on to shift the phase of the master 100 KHz reference signal. Divide-by-ten circuits convert the 100 KHz to a master 10 KHz reference that is applied to the electronic phase shifter.

SLAVE ENVELOPE SERVO LOOP

The slave envelope servo loop is identical for slave A and slave B; only slave A will be discussed. The RF amplifiers, in-phase coherent detector, envelope deriver, and strobe detector are the same circuits used in the master envelope servo loop. Multiple use of the circuits is possible because of time sharing.

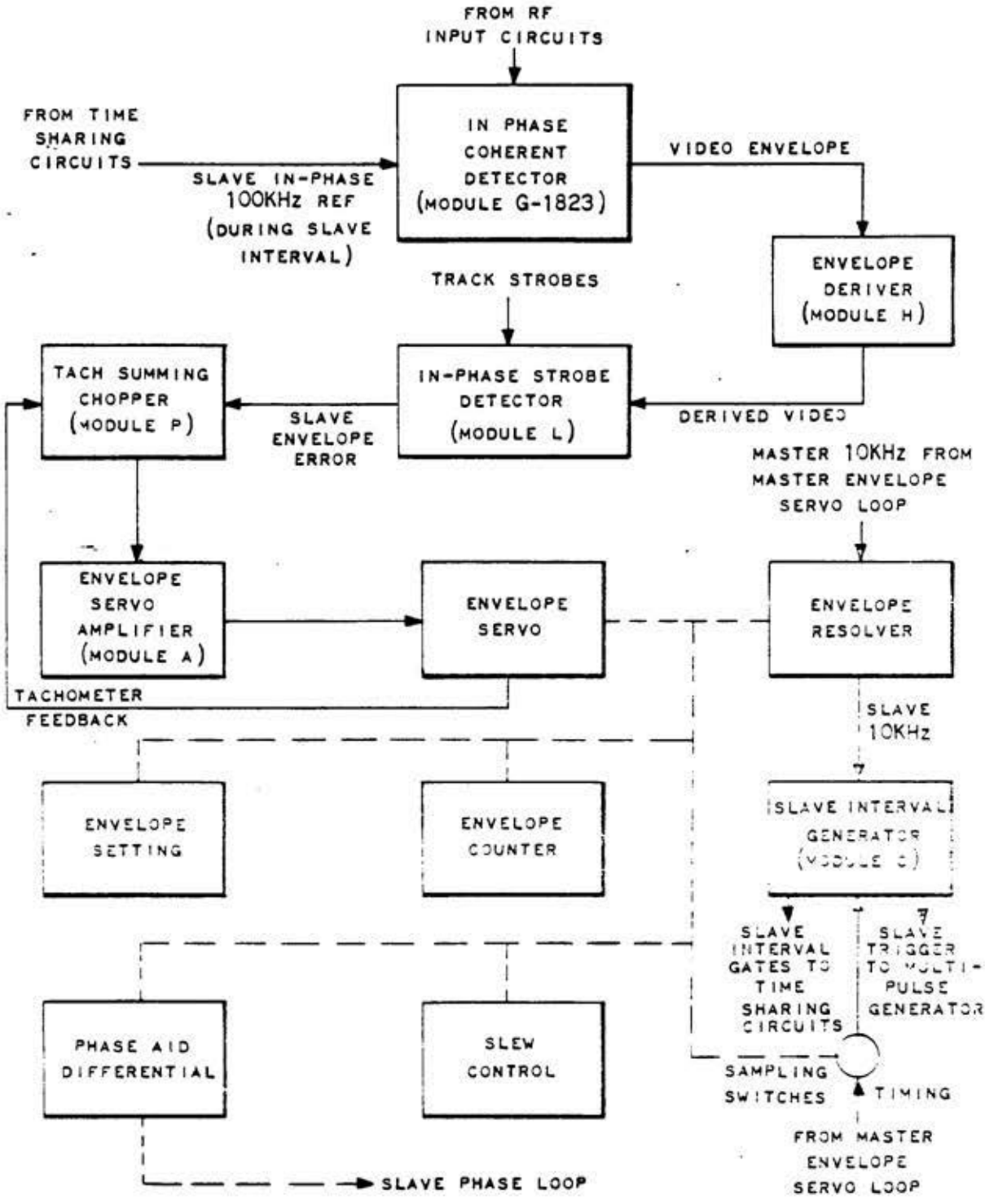
Operation of the coherent detector and the envelope deriver is the same as the master envelope loop. However, the in-phase strobe detector, in addition to developing the error between the track strobes and derived envelope, stores the slave A error signal. Within the same module, the slave A error voltage and the master error voltage are compared. Any voltage difference is fed to the tach summing chopper where the M-SA error voltage develops the 400 Hz signal that is needed to drive the slave A servo motor and amplifier. Since the envelope servo is referenced to the 10 KHz from the master envelope servo loop (through the envelope resolver), the amount of slave envelope shaft rotation required to null the loop is a measure of the time difference between the master and slave RF pulses. The envelope counter is calibrated to read time difference in micro-seconds.

The envelope servo generates a rate feedback to the tach summing circuits for the prevention of overshoot. The servo also drives three rotary sampling switches that furnish digital inputs to the slave interval generator. The slave interval generator develops all timing waveforms affecting operations of the slave A signals.

The slew control enables the operator to drive the servo loop along the time axis during initial signal lock-on. Since the accuracy of the envelope time difference measurements is limited by the width of the track strobes (10 micro-seconds), phase-aid from the slave phase servo loop drives the envelope loop to finer resolution.

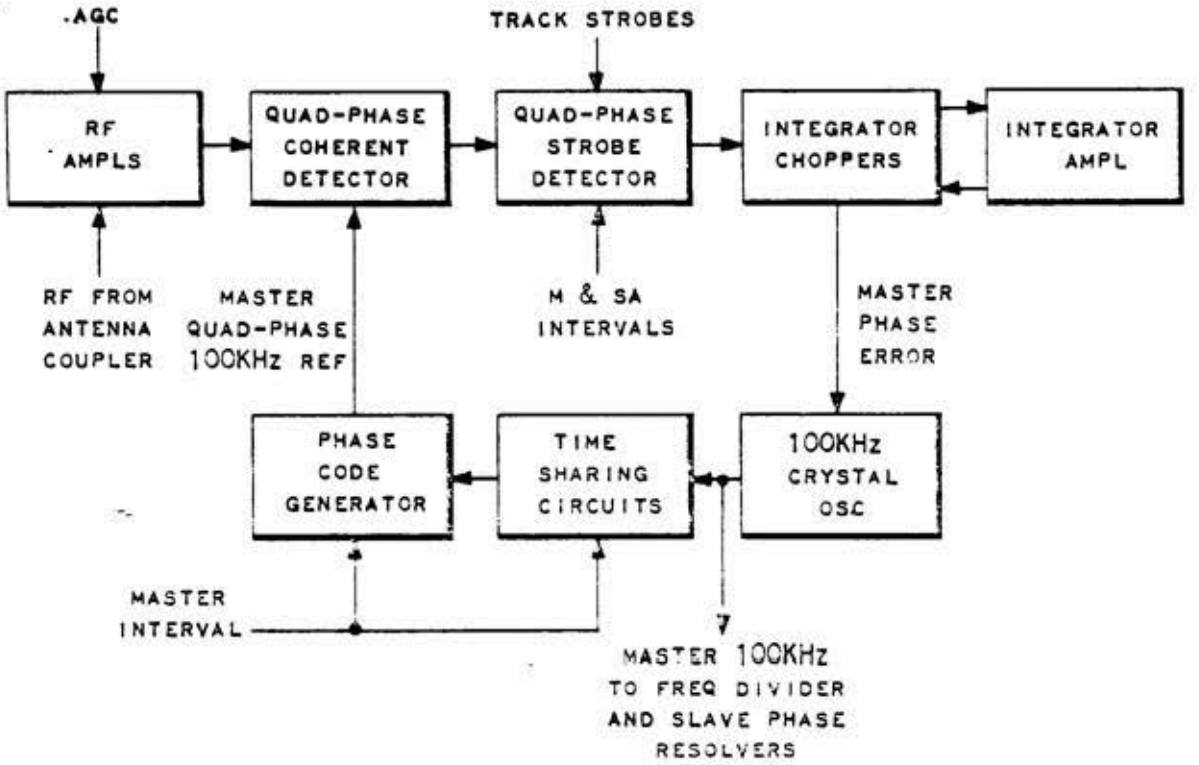
MASTER PHASE SERVO LOOP

The master phase servo loop functions as an automatic frequency correcting and



SLAVE ENVELOPE SERVO LOOP

phase correcting device. It maintains a 90 degree (quadrature) phase relationship between the 100 KHz carrier and the quad phase 100 KHz reference signal from the timing and phase code circuits. Phase comparison is accomplished by the quad-phase coherent detector. If the two signals are out of quadrature, an

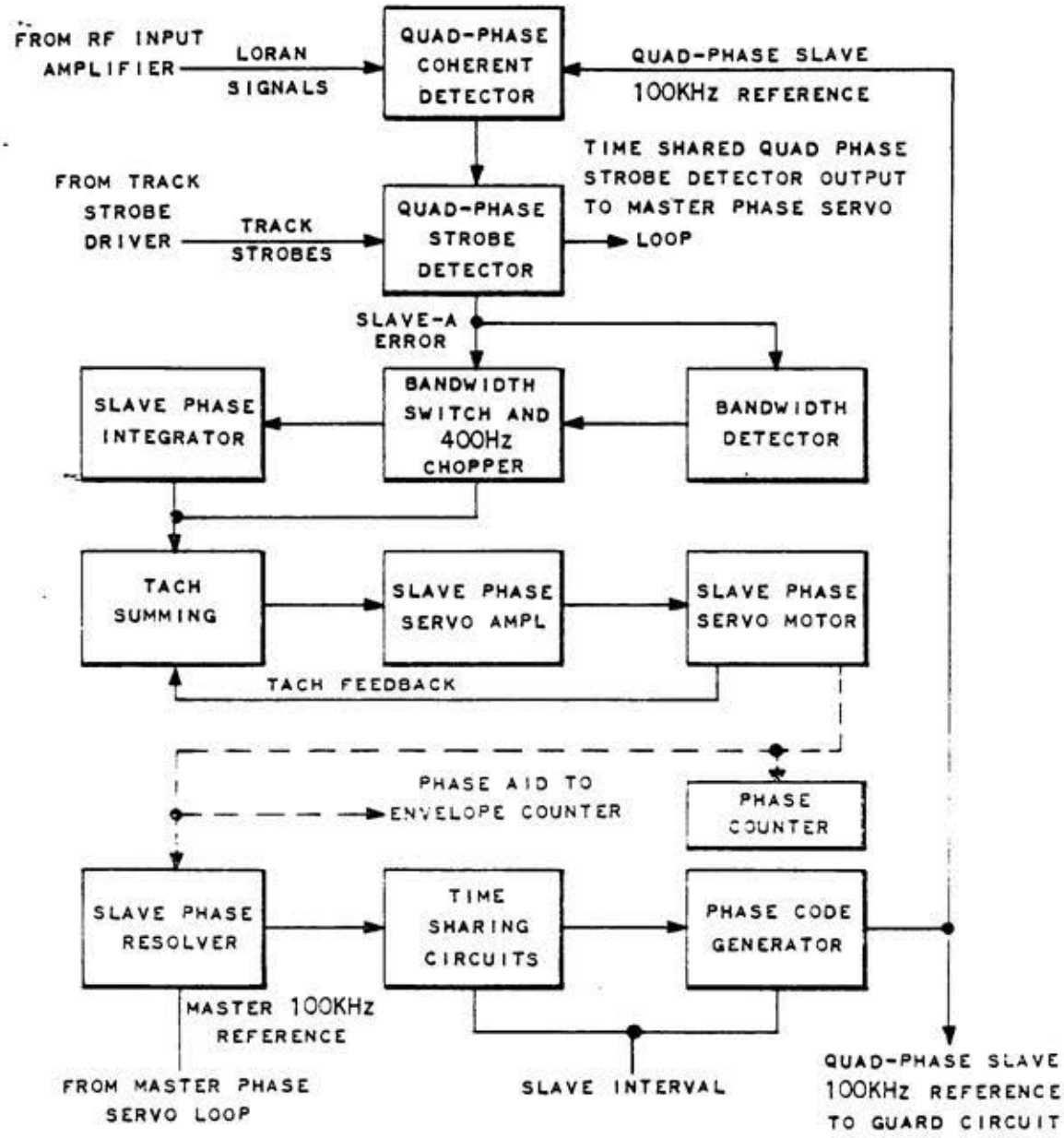


MASTER PHASE SERVO LOOP

error D-C voltage is developed which is proportional to the phase error. The quad-phase strobe detector is essentially a sampling circuit that is gated on by the track strobes. The error voltage is integrated and then used to shift the phase and frequency of the 100 KHz master oscillator. Thus the internally generated 100 KHz is frequency and phase locked to the incoming RF signal. Feedback for the servo loop is through the time sharing circuits and the pahse code generator.

SLAVE PHASE SERVO LOOP

The slave phase servo loop is identical for slave A and slave B operation. Only the slave A loop will be discussed below. The slave phase servo loop has two functions: it increases the accuracy of the time difference measurement, and it gives mechanical aid to the slave envelope servo. This servo uses the same quad-phase coherent detector and the same quad-phase strobe detector as the master phase loop through time sharing.



SLAVE PHASE SERVO LOOP

The error signal out of the strobe detector goes to a bandwidth detector which functions as a threshold device. If a large error signal is present, the bandwidth detector causes a relay in the bandwidth switch to energize. The energized relay reduces the time constant of the slave phase integrator, causing the servo loop to move at a fairly rapid rate. As the error voltage decreases, the relay in the bandwidth switch deenergizes and the servo loop moves at a slow rate. Therefore the bandwidth switch serves to smooth servo response. The tach summing circuits act as a speed control to minimize overshoot as the servo approaches a null position. The slave phase resolver takes the master 100 KHz reference, shifts the phase according to the angular shaft position from the mechanical drive, and produces an output to the time sharing circuits and the phase code generator. The output of the phase code generator becomes the slave quad-phase reference. The resolver will shift the phase until the error signal is nulled.

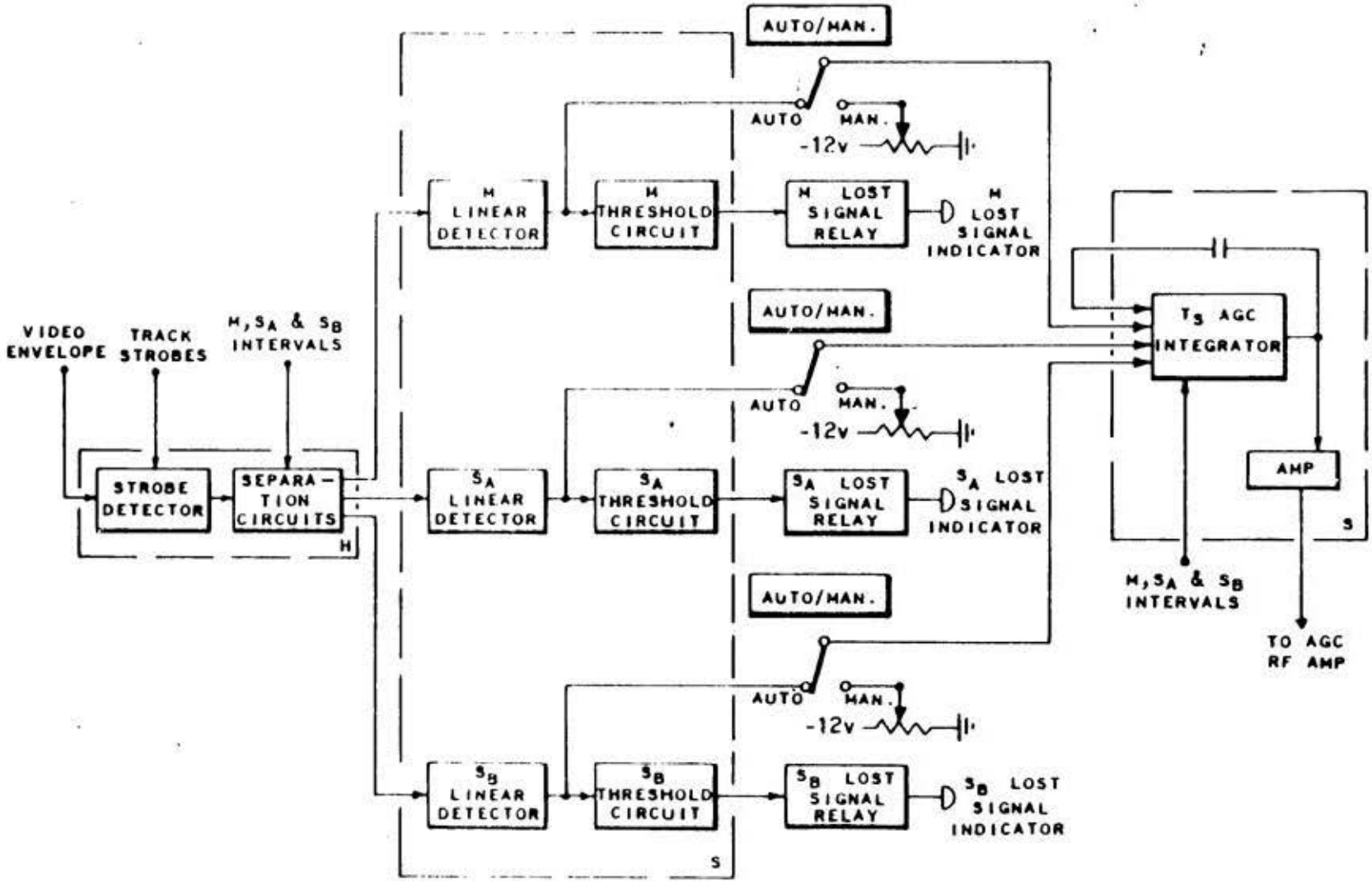
AGC AND LOST SIGNAL CIRCUITS

The circuits shown in the "Lost Signal Block Diagram" illustration have a dual function. First, the amplitude of the video envelopes is processed to produce an Automatic Gain Control (AGC) voltage for the master, slave A, and slave B intervals. The second function is the triggering of lost signal indications when the RF amplitude is below a threshold level. The video envelope input to the AGC strobe detector is taken from the in-phase coherent detector of the envelope servo loops. The AGC strobe detector is time shared for the three intervals.

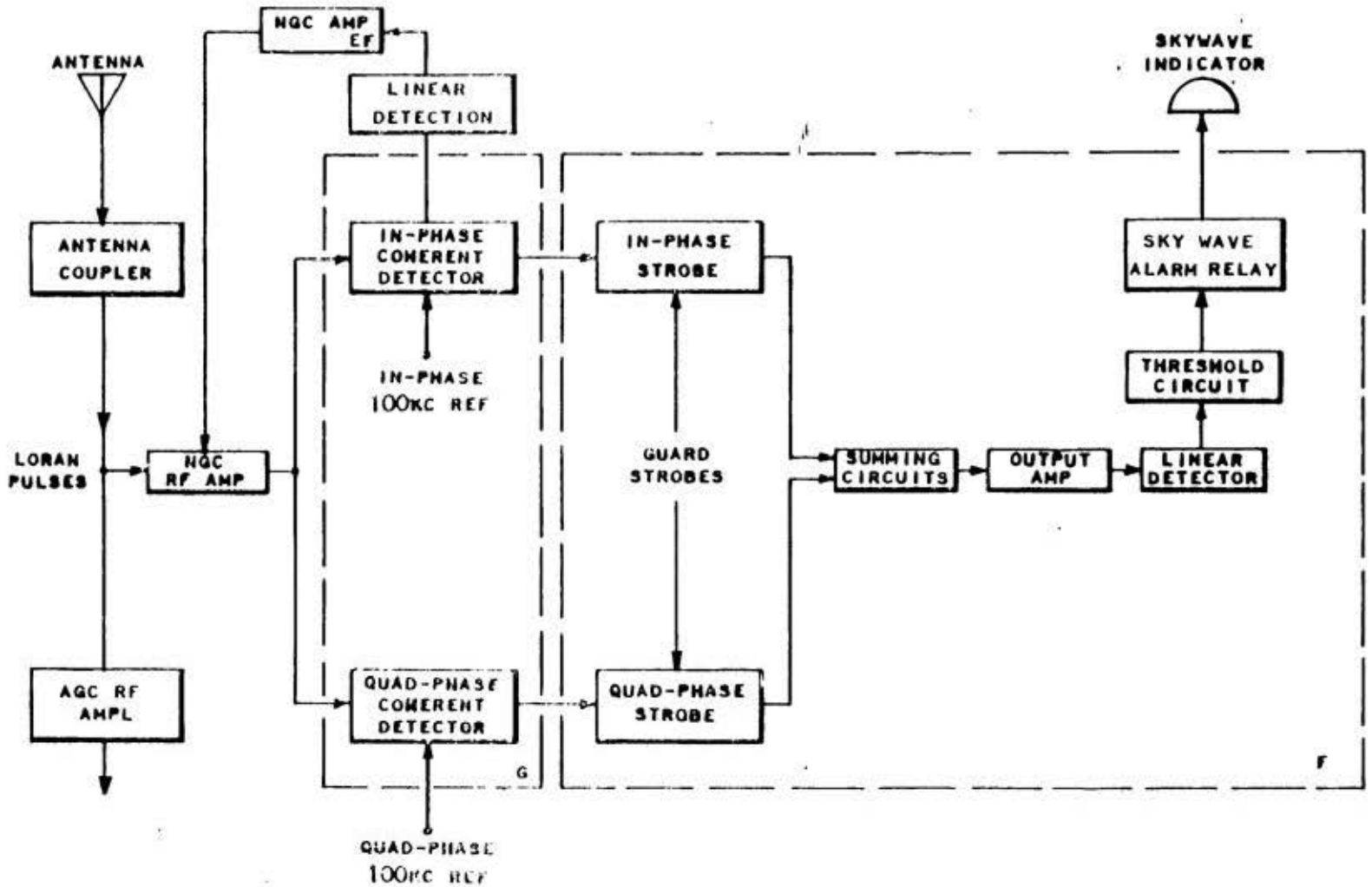
The negative-going track strobes gate the strobe detector which produces a D-C voltage proportional to the amplitude of the video envelope. This chopped D-C voltage is applied to separation circuits where outputs are selected according to the respective intervals. The separation circuits have outputs to the master, slave A, and slave B linear detectors. The linear detectors produce a D-C voltage that is proportional to the average signal input.

The detected AGC voltage for each interval is coupled to the time-shared integrator and at the same time to the three threshold circuits. The integrator compares individual D-C levels with a reference voltage. The time shared difference voltage out of the integrator adjusts the RF amplifier gain so that the LORAN signal level in each interval remains the same. Manual gain is enabled when the LORAN receiver front panel AUTO/MAN switches are set to the "MAN" position.

Three identical threshold circuits are used for lost signal detection. Loss of signal switches a tunnel diode which in turn deenergizes the lost signal relay. The deenergized relay causes the LOST SIGNAL lamp to illuminate.



AGC AND LOST SIGNAL BLOCK DIAGRAM



SKYWAVE GUARD BLOCK DIAGRAM

Sky waves occur when the ionsphere reflects LORAN pulses toward the earth. These sky waves lag the ground waves by 30 to 50 microseconds. The LORAN receiver generates guard strobes 40 microseconds ahead of the track strobes; therefore coincidence of guard strobes with ground waves indicate that the track strobes are locked on sky-waves. The guard coherent detectors as shown in the "Skywave Guard Block Diagram" remove the 100 KHz carrier and the video envelope is coupled to the strobe detectors. Both strobe detectors act as sampling circuits that are gated on by the guard strobes. The output signals are summed, amplified, and applied to a linear detector. If the D-C voltage produced by the linear detector is of high amplitude, a tunnel diode in the threshold circuit will switch to its high resistance state. The sky wave alarm relay will then be deenergized and the SKY WAVE lamp will illuminate.

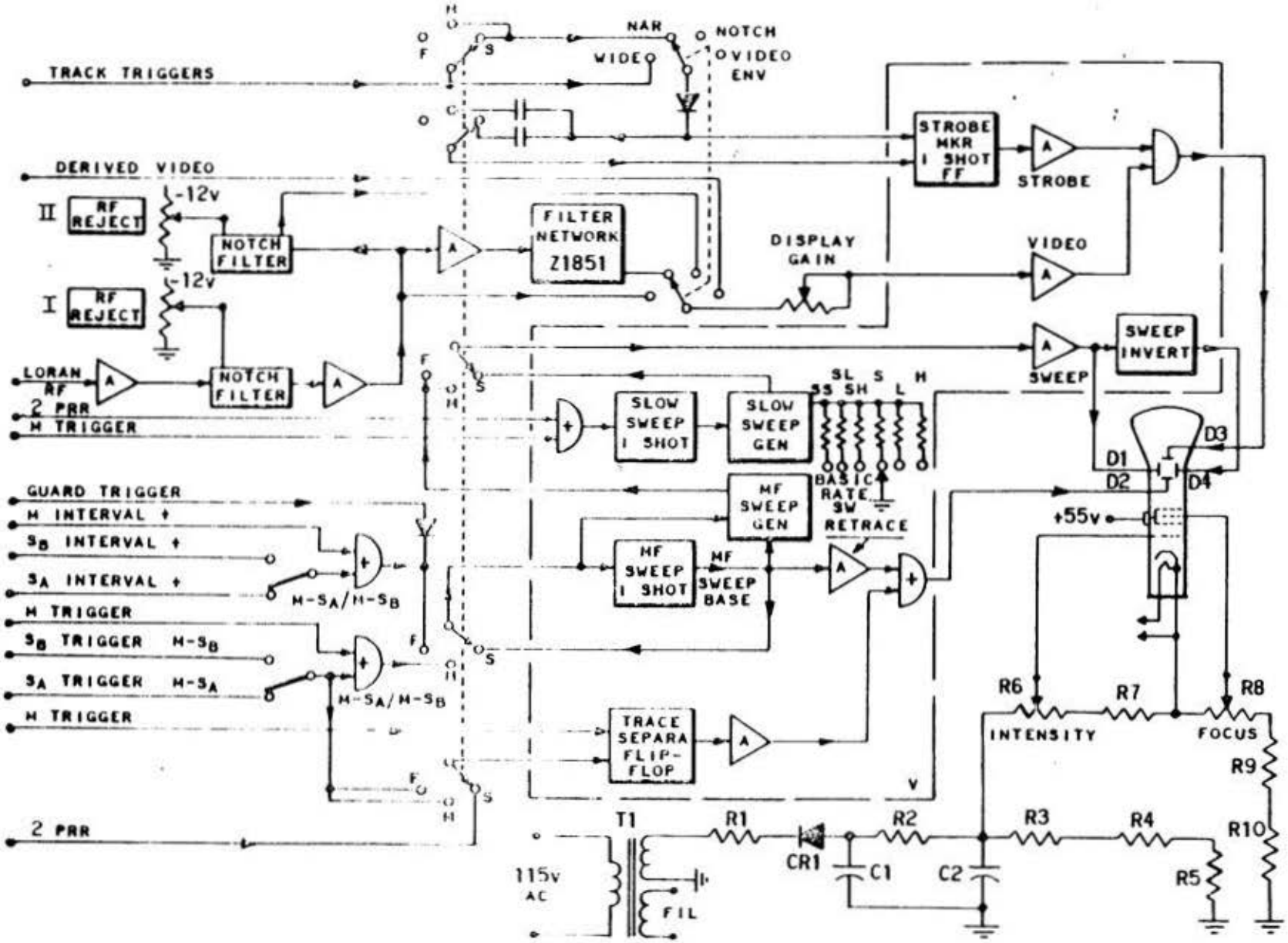
The guard circuit is gain controlled by the Noise Gain Control (NGC) circuits. Pulse envelopes are taken from the in-phase coherent detector and applied to a linear detector. The detector produces a D-C output proportional to the average amplitude of the envelopes. The gain control voltage is amplified and then applied to the first two stages of the NGC RF amplifier.

VISUAL DISPLAY

The visual display system as shown in the "Visual Display Diagram" presents the received LORAN signals along with the internally generated track strobes on an oscilloscope mounted on the receiver front panel. In the lock-on procedure this display is used to align the receiver tracking circuits.

Three sweep speeds are used, slow (S), medium (M), and fast (F). In the slow sweep a complete LORAN cycle (master and both slave signals) is presented on a split trace. The master and part or all of the slave A signals are on the top trace and the slave B signals are on the bottom trace. Medium sweep speed displays the nine master pulses on the top trace and either the eight slave A or the eight slave B pulses on the bottom trace. Fast sweep displays eight master pulses superimposed on the top trace and either the eight slave A or the eight slave B pulses superimposed on the bottom trace.

Two horizontal sweep generators are used to produce the three separate sweep speeds. In slow sweep operation the M (master) trigger starts the top portion of the trace and the negative 2 PRR starts the bottom portion. The slow sweep one shot multivibrator triggers the slow sweep generator. The duration of the linear sweep output of this generator is determined by the basic rate switch on the receiver front panel. The sweep voltage is applied to deflection plate D1 of the CRT. Push-pull deflection is accomplished by inverting the linear sweep and applying it to D2.



VISUAL DISPLAY DIAGRAM

In the medium sweep the M trigger starts the top trace and the slave A or slave B trigger starts the bottom trace. In fast sweep the top portion of the trace is started by the master interval and the bottom trace is started by the slave A or slave B interval. The duration of the linear sweep of the medium-fast sweep generator is determined by the position of the S-M-F switch on the receiver front panel.

Trace separation is accomplished by applying two different voltage levels to deflection plate D3. The retrace amplifier applies a high voltage step to D3 during flyback to deflect the electron beam off the screen.

The video selection circuits are shown in the top portion of the "Visual Display" illustration. The inputs to the video section include LORAN RF, track triggers, and the derived video envelope. With the RF/VIDEO switch positioned to "WIDE", the LORAN RF signals are fed directly to the video amplifier. With the switch in the "NAR" position, greater selectivity is achieved by placing filter network Z 1851 in the RF line. Two notch filters are used to reject unwanted CW interference. With the RF/VIDEO switch in the "NOTCH" position the CRT will display the maximum CW interference from notch filter No. 2. These signals, along with the video envelope, may be selected and coupled through the gain control to the video amplifier. The output of the video amp is combined with strobe markers and applied to vertical deflection plate D4.

ENCODERS

The four encoders in the R-1214/APN-157 receiver translate the mechanically driven readouts (analog) into digital information for use by the ASN-24 airborne computer. The M-SA and M-SB envelope servos, along with the M-SA and M-SB phase servos drive the four encoders. The encoders give an output upon reception of a "Q" (trigger pulse) from the ASN-24. The angular position of the encoders produce a digital pulse train output.

POWER SUPPLY

The PP-3866/APN-157 power supply provides all voltages necessary for LORAN operation with the exception of the 6.3 volts, AC needed for receiver front panel illumination. Both the 115-volt, AC and 28-volt, DC from the aircraft power source are fused in the power supply. The output voltages of the power supply are shown in the "Specifications" section.

Three series regulators provide -12 volts, DC, -55 volts, DC, and +55 volts, DC. Voltage dividers are employed to produce the -11 volts, D-C and the -30 volts, D-C outputs. The unregulated +15 volts, DC is fused within the power supply and is the power source for the servo amplifiers in the receiver.

Sensing leads connected at the receiver provide a monitor for the three regulators. Any deviation from normal voltage levels will be coupled to the series regulators. Each regulator is overload protected to prevent fuse blowing by excessive load currents. When the load of any one regulated line exceeds 50 percent of its rated value, the output voltage of that line is dropped to about 20 percent of its normal value. In addition, the -55 volts, D-C and +55 volts, D-C lines are dropped to 10 volts if the -12 volts, D-C line is shorted on overloaded. This prevents transistor damage in the receiver. Overload lamps on the front of the PP-3866 illuminate when a line draws too much current.

If the 28 volts, D-C, 115 volts, A-C or the 15 volts, D-C fuse blows, lamps on the power supply front panel illuminate. This is accomplished by placing the lamps in parallel with the fuses, thus an open fuse will cause a large amount of current to pass through the lamp.

ANTENNA COUPLER

The CU-1568/APN-157 antenna coupler amplifies and filters the RF signal and matches the impedance of the 50 ohm line to the receiver. The coupler is tuned to a bandwidth of 30 KHz. The signal gain is 15-20 DB while noise is attenuated by approximately 30 DB. A lightning arrestor with a breakdown potential of 4300 volts prevents damage to the RF input circuits.