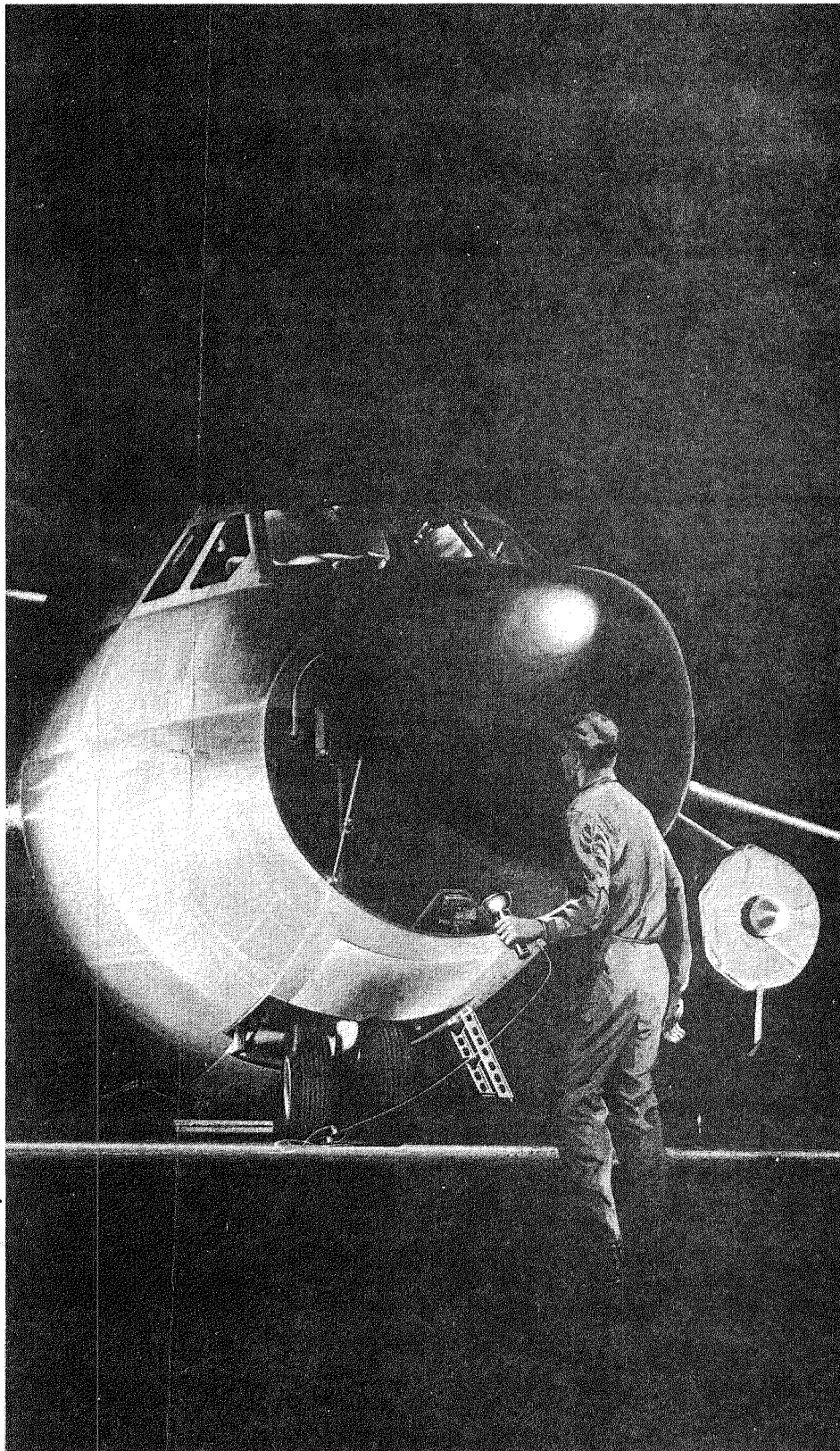


# STARLIFTER TRAINING MANUAL • VOLUME VI



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**AVIONICS**

Customer Training Department • Lockheed - Georgia Company • Marietta, Georgia 30060





# STARLIFTER TRAINING MANUAL

## VOLUME VI

### AVIONICS

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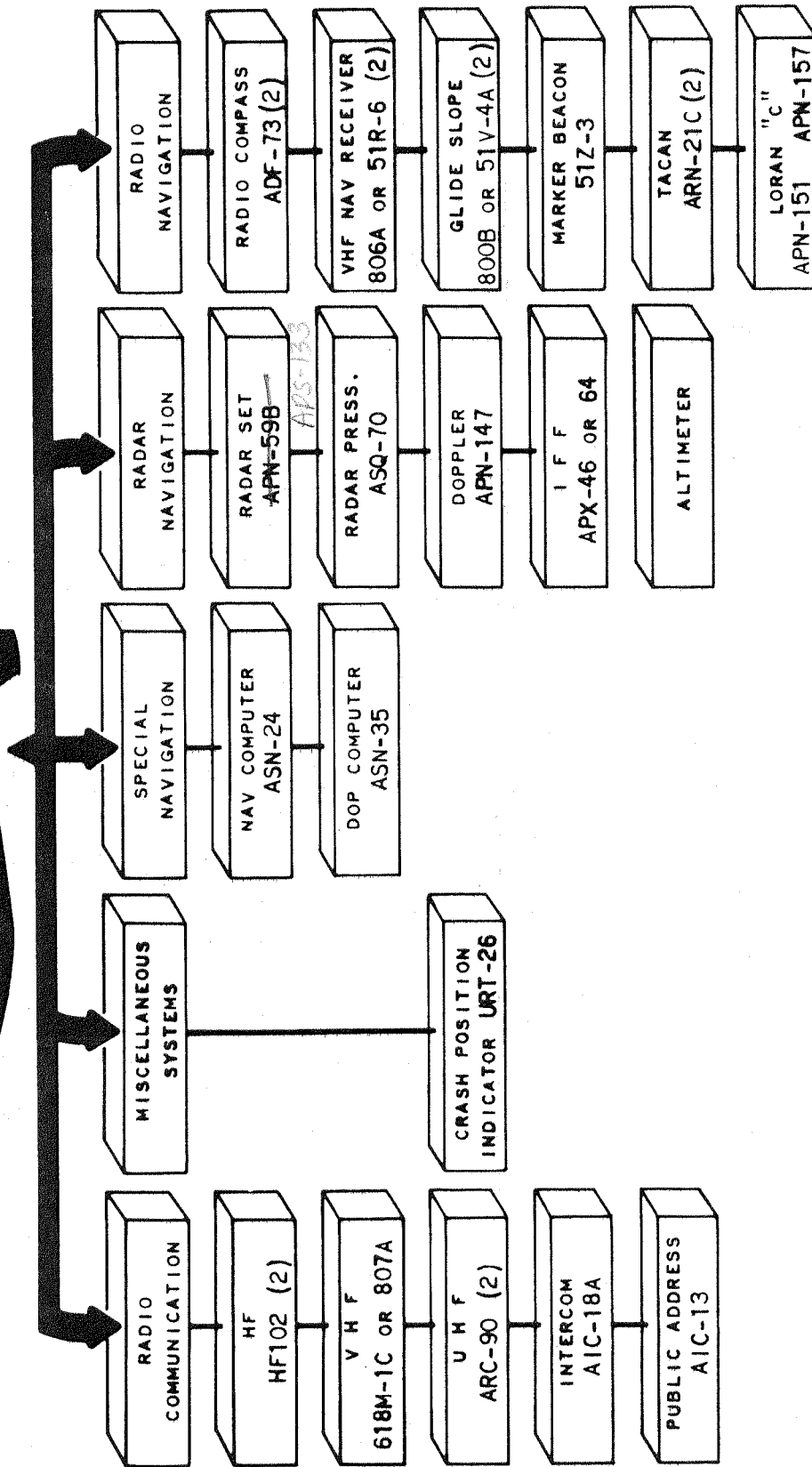
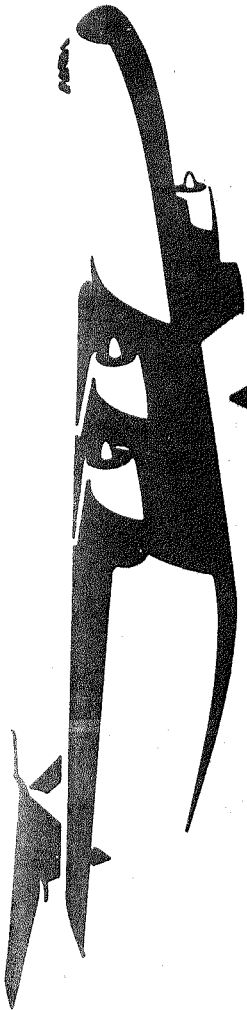
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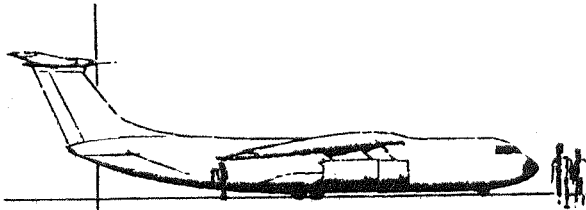
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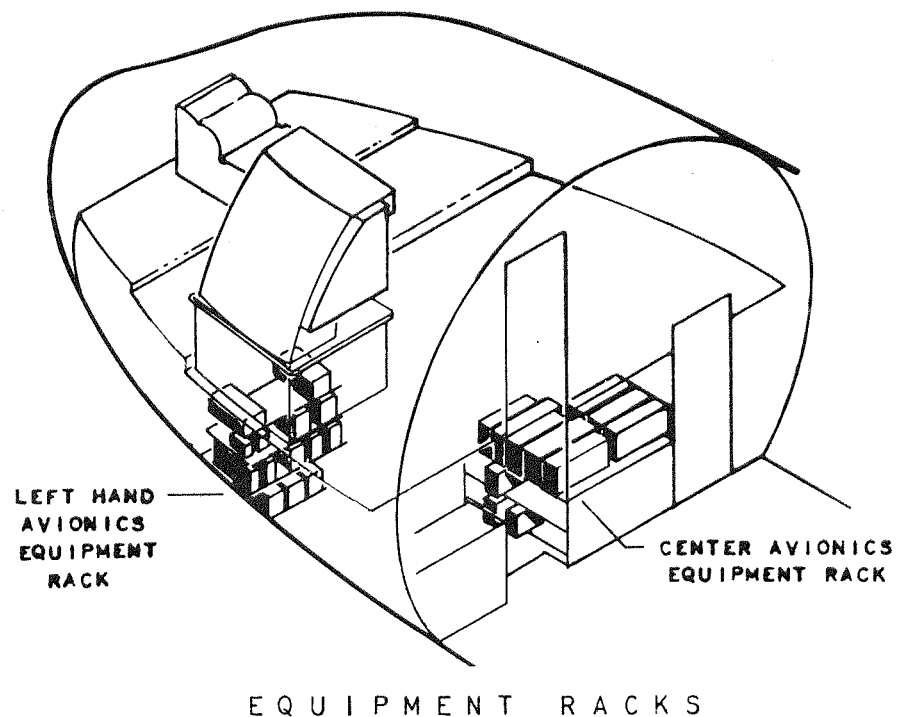
## GENERAL INFORMATION

### INTRODUCTION

Since high-speed, long range operations of modern aircraft require highly specialized and dependable equipment, a wide variety of avionics systems is provided on the StarLifter. This avionics equipment, for the most part, represents the newer generation of solid state electronics equipment developed for the aircraft industry. Use of this equipment has resulted in higher reliability, lighter weight, and reduced electrical power requirements.

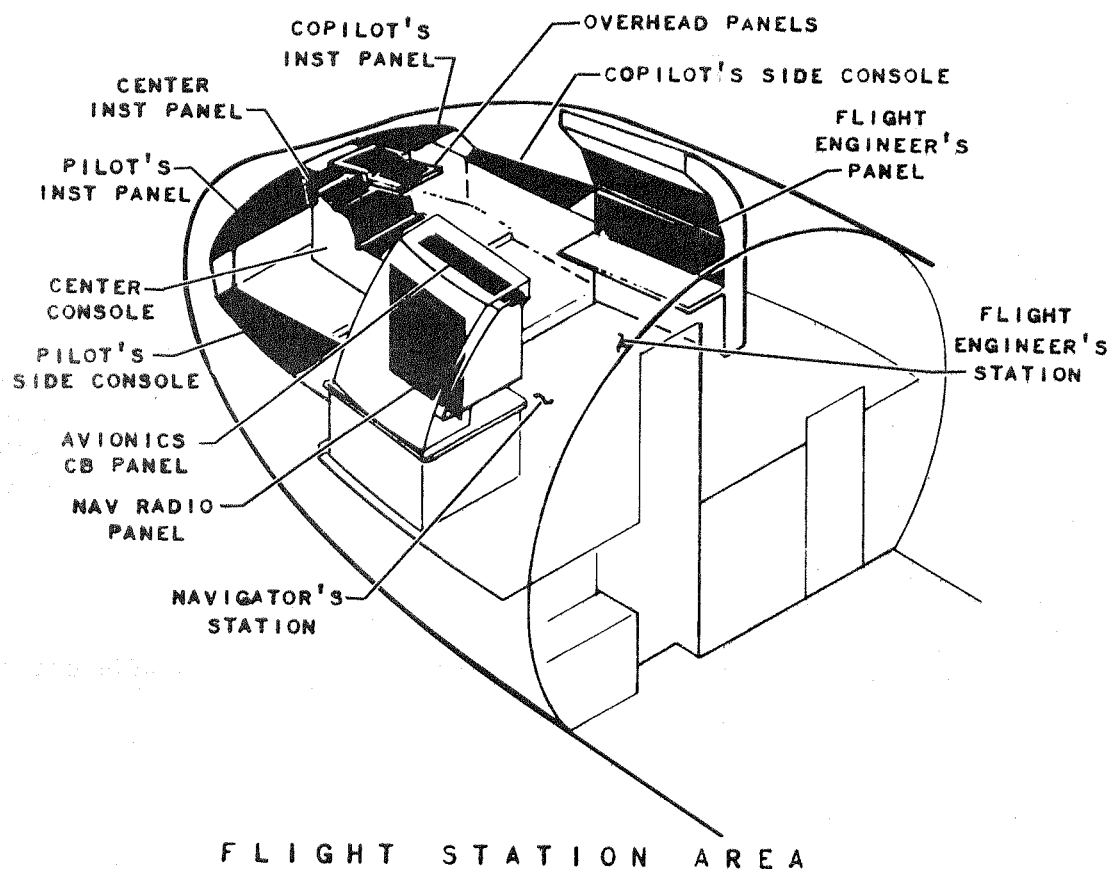
### GENERAL

Equipment location, excluding antennas, is generally confined to the for-



ward sections of the aircraft. Equipment racks are provided under the crew deck area where the majority of the black boxes are located.

Circuit breakers, control panels, and some boxes are located in the flight station area where they are readily accessible to crew members.



The avionics systems can be divided into five basic groups:

- Radio Communications
- Radio Navigation
- Radar Navigation
- Special Navigation
- Miscellaneous Systems

## RADIO COMMUNICATION SYSTEMS

The intercommunications (intercom) system provides communication among the various crew members. It also permits certain crew members to monitor all communication and navigation receivers. Transmission over the radio communication systems is accomplished through the intercom system. It can also be used in conjunction with the Public Address (PA) system to make announcements to crew members and passengers.

The PA system is provided so that instructions or announcements can be heard in the cargo compartment without the use of headphones. The PA system is used during loading and unloading of the aircraft and it can also be used to monitor some of the radio receivers to provide entertainment for passengers during flight.

Two High Frequency (HF) communication systems are installed. These systems provide long-range, Amplitude-Modulated (AM) or Single Sideband (SSB) communication. The SSB mode is limited to Upper Sideband (USB) operation. The HF systems are especially useful in long-range, over-water flights where other communication systems do not provide sufficient range.

For short-range radio contacts, two Very High Frequency (VHF) communication systems are provided. Because of the straight-line radiation characteristics at these frequencies, communication is restricted to line-of-sight distances.

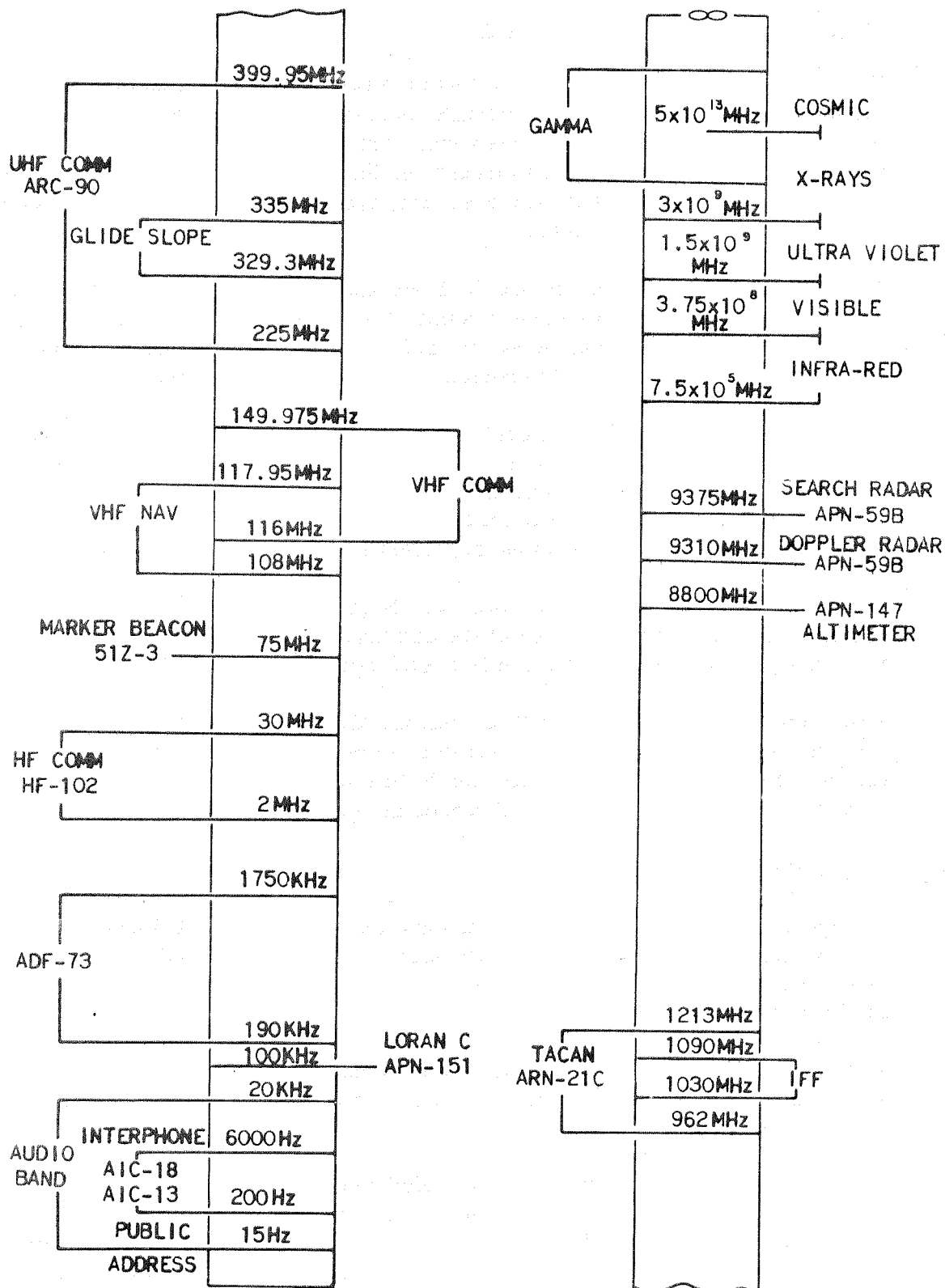
Two Ultra-High Frequency (UHF) communication systems, like the VHF systems, provide short-range communications in air-to-air and air-to-ground operations. Range of these systems is also limited to line-of-sight distances. The range of both the VHF and UHF systems increases as the aircraft altitude increases.

## RADIO NAVIGATION SYSTEMS

The most modern radio navigation aids are installed in the StarLifter. These systems provide aural information for identification to the crew, information for visual display by instruments, and guidance information to the Automatic Flight Control System (AFCS).

Two Automatic Direction Finder (ADF) systems are installed. These systems are used to take bearings on either standard broadcast or low-frequency radio range stations.

Two VHF navigation receivers are provided which may be used for VHF Omnidirectional Range (VOR) or Instrument Landing System (ILS) operation. VOR operation provides visual bearing display to any selected VOR ground station within range of the equipment. ILS operation provides lateral guidance from a runway localizer beam during instrument approaches or landings. Either operation can be coupled into the AFCS to provide automatic radio guidance.



F R E Q U E N C Y   S P E C T R U M



Two glideslope receivers are installed to provide vertical guidance during ILS approaches and landings. The information is visually displayed and can also be coupled to the AFCS for automatic vertical aircraft control during ILS operation.

A single marker beacon receiver provides an indication when the aircraft is directly over any airway or runway marker beacon station.

Two Tactical Air Navigation (TACAN) systems provide indications of bearing and distance to TACAN ground stations. The bearing information can be supplied to the AFCS to fly a selected TACAN course. Bearing and range data are also furnished to the navigation computer.

A Long Range Navigation System (LORAN C) provides all-weather navigation information which enables the navigator to determine a position "fix" at great distances from LORAN ground stations. The LORAN is especially useful during long, over-water flights where other navigation aids are not within range of the aircraft. Data is also supplied to the navigation computer.

#### RADAR NAVIGATION SYSTEMS

A search radar system is installed to provide radar display to the pilot and navigator for weather avoidance, terrain mapping, and ground radar beacon station identification and position. Aircraft position data may be inserted into the navigation computer.

A pressurization system provides needed atmospheric pressure to the search radar to prevent high voltage arcing at high altitudes.

An identification system (IFF) is installed to provide coded replies to interrogations from other stations. The IFF transponder may be used to transmit encoded barometric altitude information as well as selected identification codes.

The installed doppler radar system will provide the navigator with visual indications of aircraft drift angle and ground speed. This radar navigation system operates accurately under varying wind conditions without need for ground stations. Electrical outputs for the doppler computer, navigation computer and compass systems are also provided.

The radar altimeter (low-range) system provides the pilots with an indication of the aircraft's true altitude above the ground. This system also provides altitude data to the All Weather Landing System (AWLS).

#### SPECIAL NAVIGATION SYSTEMS

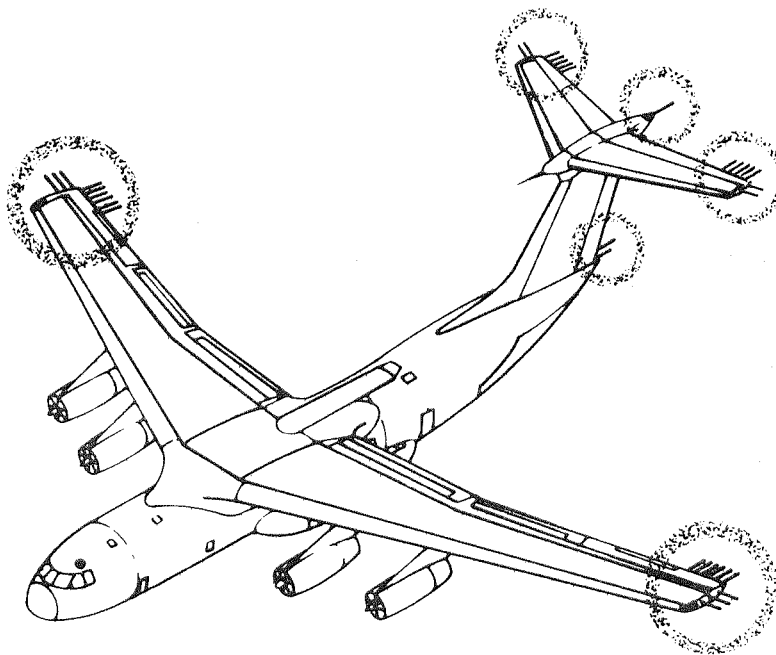
The doppler computer provides present position indications to the air crew such as distance to go along the selected flight path and cross track deviation away

from the selected path. The doppler computer receives the aircrafts actual path and ground speed information from the doppler radar system. Outputs from the doppler computer may be selected as an input to the AFCS for aircraft guidance.

A light-weight, high-speed navigational computer (ASN-24) is installed to assist the navigator and pilot in determining such navigation parameters as distance to a selected destination, present latitude and longitude, ground speed, winds, cross track and along track to selected destinations and celestial navigation data. The outputs are provided from continuously updated dead reckoning computations. Positional accuracy is improved by inputs from various navigational sensors including search radar, TACAN, LORAN C, Doppler radar, gyro compass, and central air data computer. High precision outputs are available for terminal navigation at drop zones. Outputs are also selectable by the pilot's and copilot's flight direction systems.

### STATIC DISCHARGERS

As the airplane moves through the air, a static charge tends to accumulate along the trailing edges of the wing and of the vertical and horizontal stabilizers. This



#### NOTE:

THIRTY FIVE STATIC DISCHARGERS DISSIPATE  
STATIC ELECTRICITY FROM THE AIRCRAFT INTO  
THE ATMOSPHERE REDUCING INTERFERENCE TO  
RADIO RECEPTION.

#### STATIC DISCHARGER LOCATIONS

static charge builds up until it discharges into the air. As the discharge occurs, Radio Frequency (RF) waves are generated which are picked up by the radio receivers as static interference. The amount of interference depends upon the amount of static charge at the time of discharge. If the static charge can be concentrated on small areas, the discharge will occur before the charge becomes very high. As a result, radio interference will be greatly decreased. To accomplish this, static dischargers are provided as shown in the illustration.

### MISCELLANEOUS SYSTEMS

A crash position indicator (CPI), transmitting on an emergency radio frequency, will guide search and rescue aircraft to locate the ditching area. CPI transmission begins with manual or automatic deployment from the StarLifter.

The airborne flight data recorder make a nondestructive record of aircraft altitude, airspeed, heading and vertical velocity. This system provides a precrash history of flight parameters beneficial to accident investigations.

### POWER SOURCES

The power required by the StarLifter is normally supplied by four main engine-driven A-C generators.

Auxiliary power is supplied by a fifth generator driven by an Auxiliary Power Unit (APU). This generator is used for ground checkout of the aircraft systems.

External A-C power can be used for ground checkout of the aircraft systems.

A-C power for the avionics systems is supplied by the main tie bus to the No. 1 and 2 avionics buses, and the isolated A-C avionics bus. Avionics bus No. 1 supplies phase "a" nav. bus 1. Phase "a" nav. bus 2 is supplied by the No. 2 avionics bus.

D-C power is supplied by two T/R units to the No. 1 main D-C avionics bus and No. 2 main D-C avionics bus. The isolated D-C avionics bus can be supplied power in flight from the emergency generator or the battery.

### CONTROL PANELS

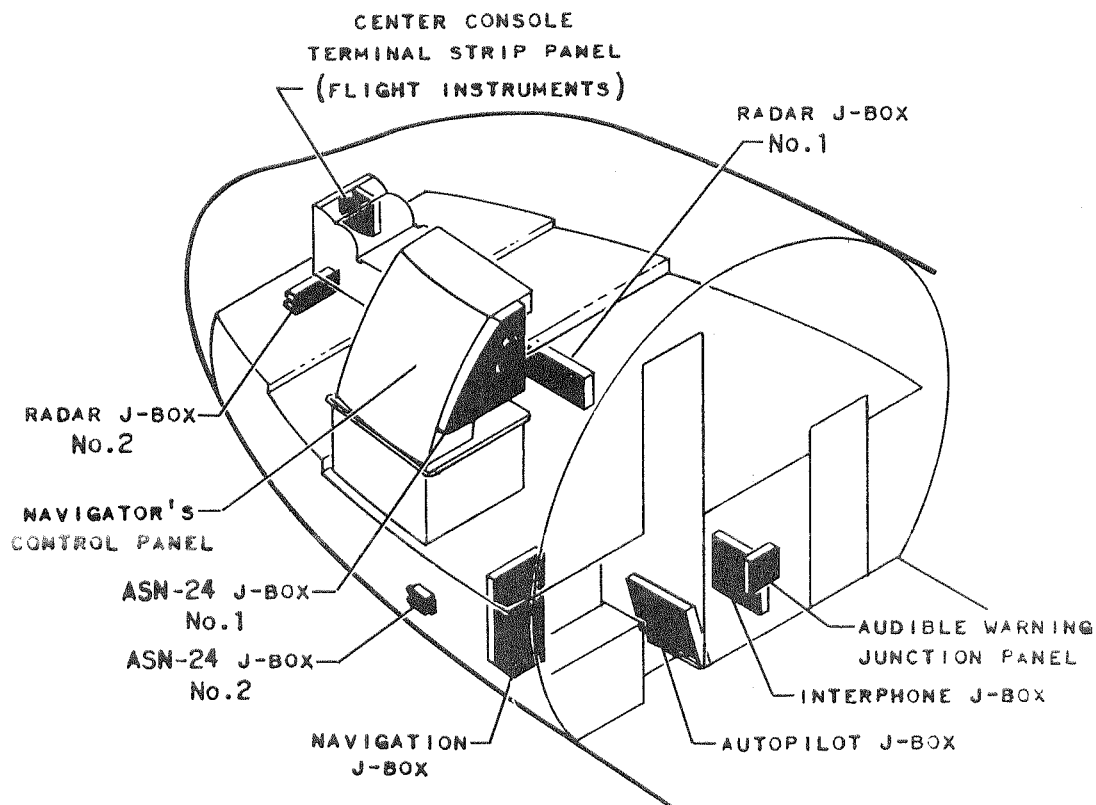
The pilot's and copilot's control panels for the communication and navigation equipment are located on the center console. Each control panel is edgellighted, engroved plastic panel. Only the markings and controls are illuminated. The navigator's and flight engineer's stations have the same style illuminated panels.

## EQUIPMENT RACKS

The major avionics equipment is located under the flight deck floor on racks. These racks are the left hand avionics equipment rack and the center avionics equipment rack. The left hand avionics equipment rack is approached by entering the left underdeck passageway. The center avionics equipment rack is located between the two underdeck passages.

## JUNCTION BOXES

There are seven major Junction (J) boxes on the airplane. These J boxes serve as interconnection points among the radar, communication, and navigation equipment. The seven J boxes are the autopilot, interphone, navigation, two ASN-24, and two radar. These locations are shown on the illustration.



AVIONICS JUNCTION (J) BOXES

## AVIONICS TEST RECEPTACLES

Three avionics test receptacles are installed in the forward area of the aircraft. They are intended to supply D-C and single-phase A-C power to ground support test equipment used in checkout and troubleshooting of various avionics systems. One receptacle is located in the nose wheel well under the radar receiver-transmitter. The other two are located on either side of the avionics underdeck rack, slightly aft of the forward wheelwell box.

## ANTENNAS

The majority of the electronics systems' antennas are of the following types: flush-mounted (cavity), blade (stub), or long-wire.

## TECHNICAL ORDERS

A complete series of Air Force technical orders is available. Several of these manuals contain information which directly concerns the avionics systems. These manuals are as follows:

### T.O. 1C-141A-1 Flight Manual:

The Flight Manual contains information for safe and efficient operation of the airplane. The manual includes a section on the location of components with operating procedures for the electrical and avionic systems, and includes range and limitations due to installation.

### T.O. 1C-141A-2-7 Electrical Systems:

This Manual covers the description, operation, checkout, troubleshooting, removal and replacement of components, and adjustment procedures for the entire electrical systems of the C-141A airplane.

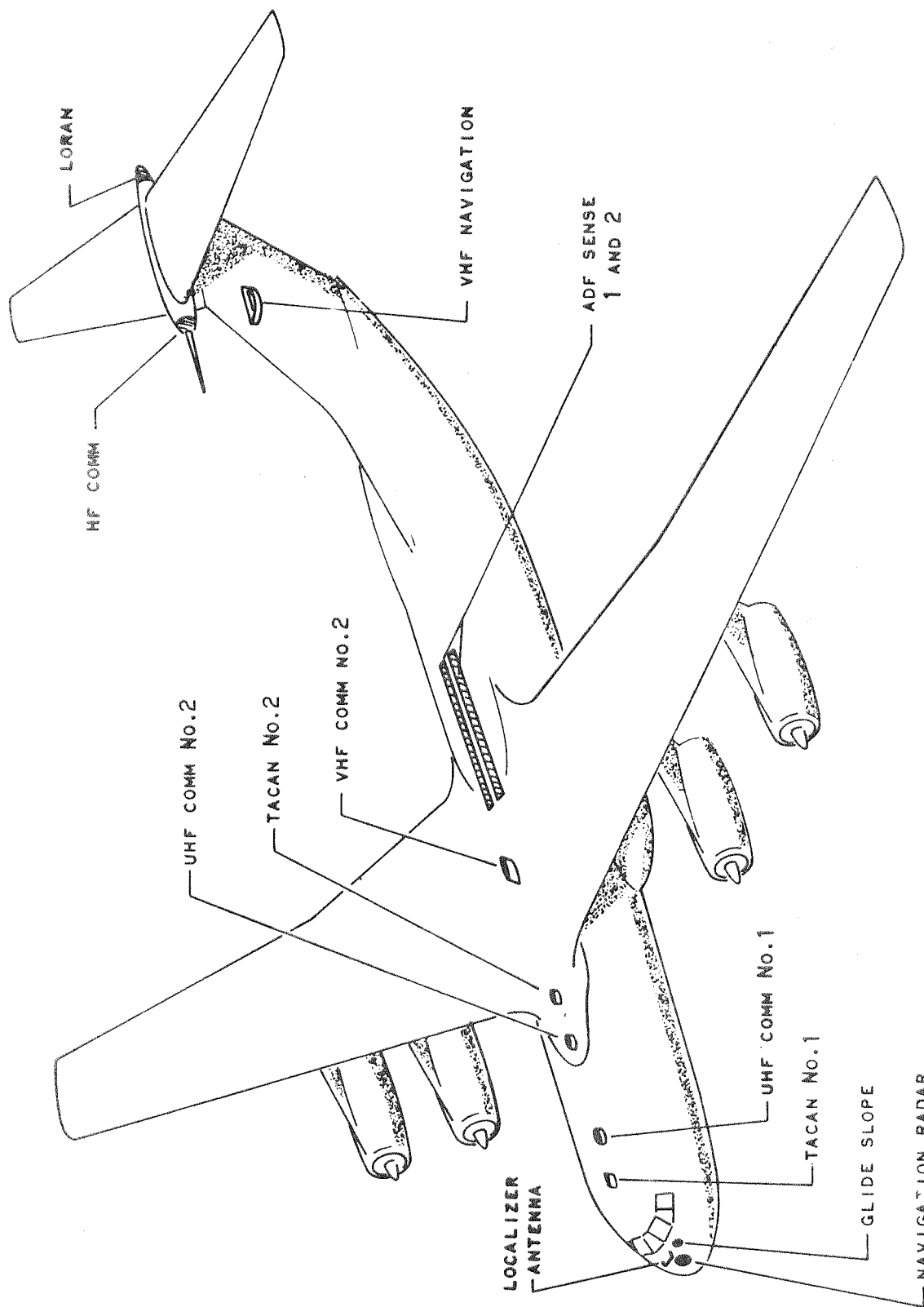
### T.O. 1C-141A-2-8 Radio/Communications and Navigation Systems:

This manual covers the operation, checkout, troubleshooting, removal and replacement of components, and adjustments of the components of the avionic system of the C-141A airplane. Included are wiring diagrams of all the systems, and an item list of all the systems components by name and part number.

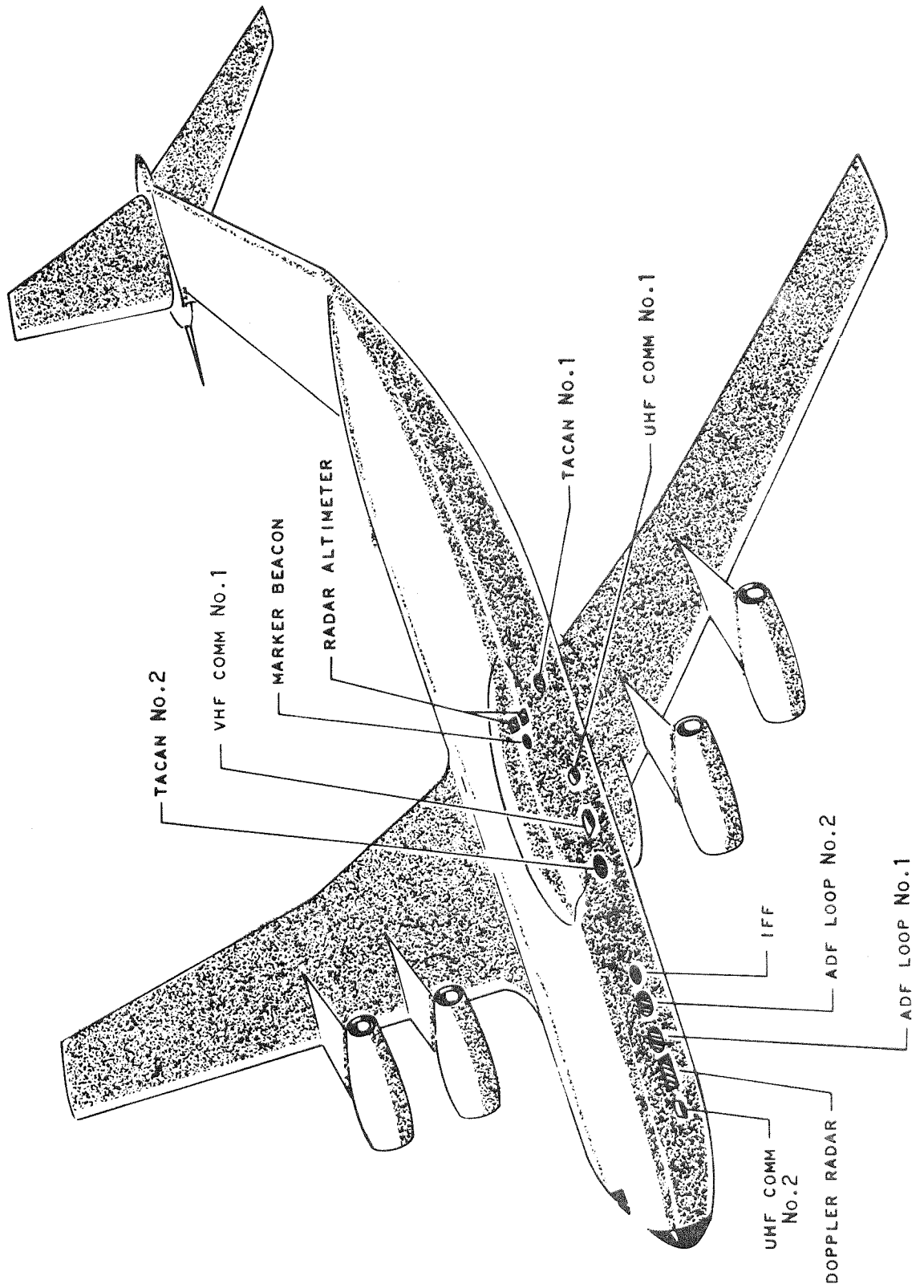
### T.O. 1C-141A-2-11 Airplane Wiring Diagrams:

This manual contains an item list of the electrical system components and wiring diagrams of the electrical systems of the airplanes. For detailed information on a specific system, refer to the Air Force Systems Technical Order or manufacturer's handbook on the specific system or unit. T.O. 1C-141A-01 is a T.O. index of applicable T.O.'s used with the C-141A airplanes.



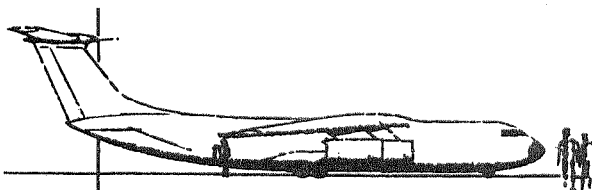


ANTENNA LOCATIONS (TOP)



ANTENNA LOCATIONS ( BOTTOM )





## INTERCOMMUNICATIONS SYSTEM

### GENERAL

The intercommunications system (interphone) provides voice communication facilities between aircrew members, aircrew and ground crew members and provides transmission, reception and monitoring of selected radio communication system. Monitoring of radio navigation systems is also provided. The interphone may be used in conjunction with the Public Address (PA) system for loud speaker announcements to passengers in the cargo area.

Pilot's audio signals, as well as a warning tone in case of aircraft engine fire or overspeed, may be heard through the flight station loudspeaker.

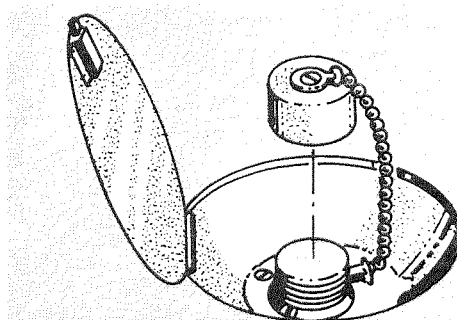
### AIRCRAFT INSTALLATION

There are ten interphone stations located in the aircraft.

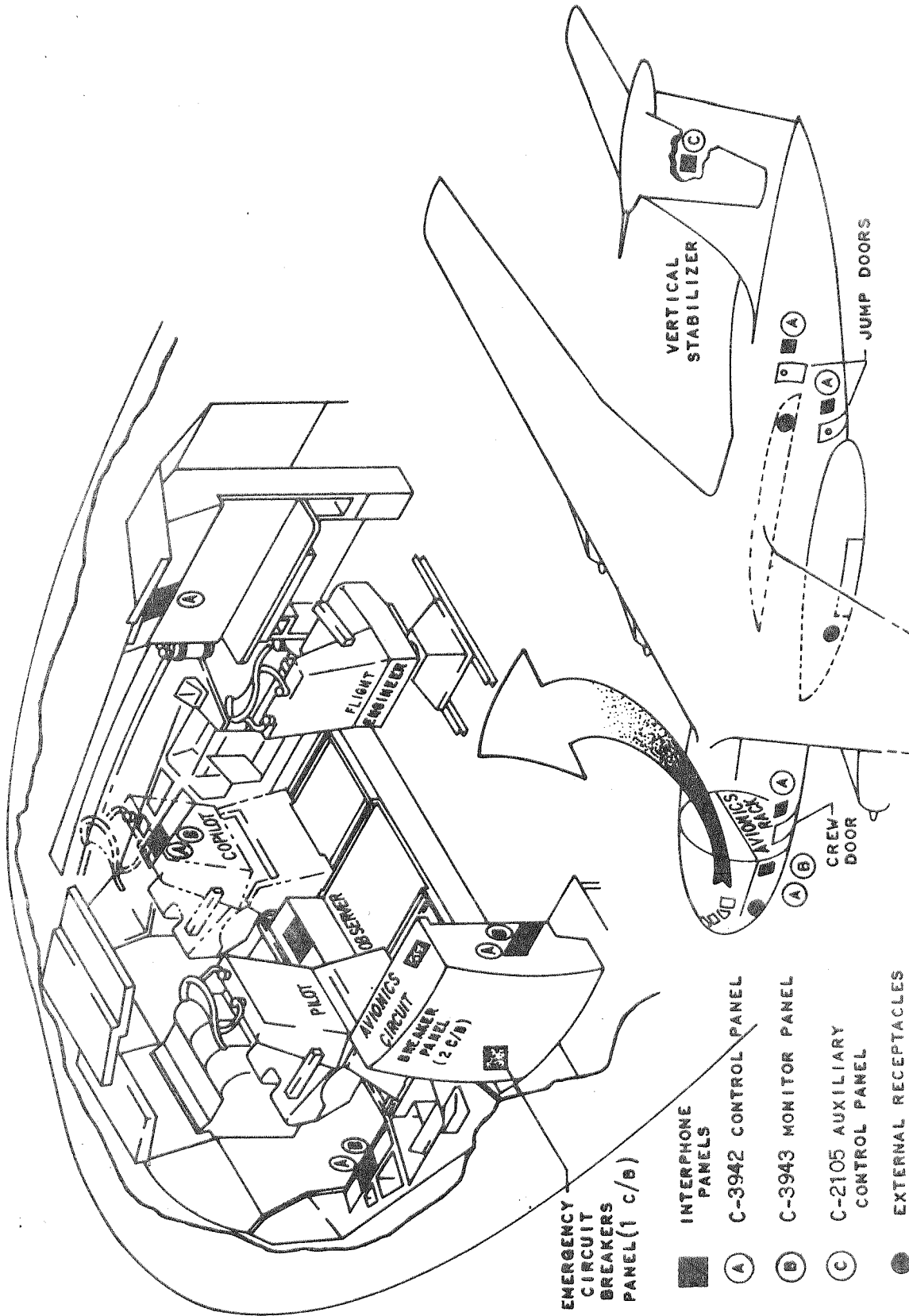
The panel locations drawing shows the five crew member interphone stations in the flight station, the avionics rack station, the three cargo area stations, and the vertical stabilizer station.

The drawing also shows the external interphone receptacle locations. However, receptacle locations may vary depending on aircraft number and modifications. The forward fuselage receptacle is electrically connected to the avionics rack control panel. The wheel well area receptacles are connected to the jump door control panels.

The interphone system overall diagram shows general interconnection of the interphone stations. Notice that the "INTER" (INTERPHONE), "CALL" and "HOT MIC" wires interconnect.

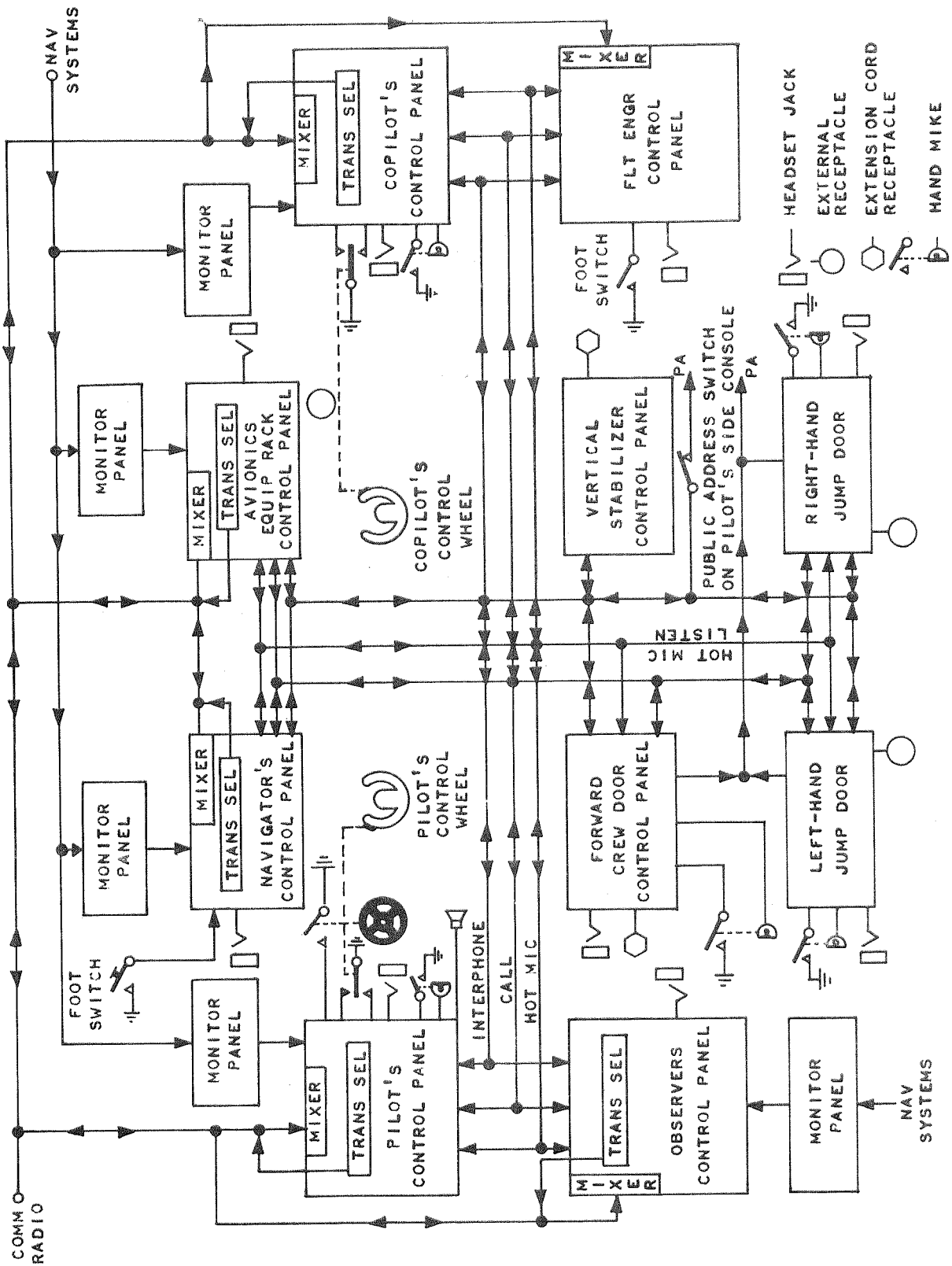


EXTERNAL  
INTERCOMMUNICATION  
RECEPTACLE



PANEL LOCATIONS





INTERPHONE SYSTEM OVERALL DIAGRAM

all control panels except the vertical stabilizer panel.

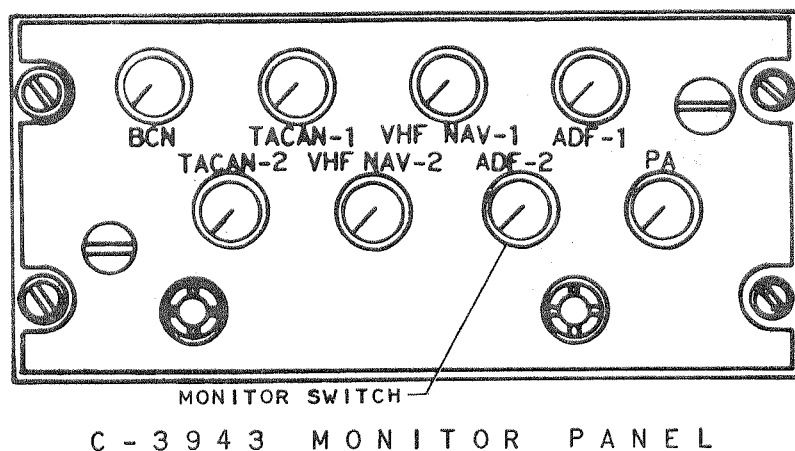
Three circuit breakers supply 28-volt D-C power. The pilot's and flight engineer's stations are supplied from the emergency D-C bus through a circuit breaker located aft of the pilot's side console. The remaining stations are supplied through circuit breakers on the avionics circuit breaker panel at the navigator's position. The main D-C bus No. 1 supplies the observer, avionics equipment rack, left jump door, and vertical stabilizer stations. The main D-C bus No. 2 supplies the copilot's, navigator's, forward crew door, and right hand jump door stations. The interphone system does not have an ON-OFF switch. The system operates when the buses are energized and the circuit breakers are closed.

Microphone switches are located at each interphone station to provide keying of the selected system. The pilot and copilot switches are located on the control wheels. These switches are three-position switches springloaded to the center ("OFF") position. The other two positions are "MIC" position for transmitting by a selected radio and "INTER" for transmitting over the interphone system. All other positions have mic switches in the extension cord adapters that connect to the headsets. The pilot and copilot headset cords do not have mic switches. The navigator and flight engineer also have a foot switch in parallel with the headset cord mic switch.

a 75 foot extension cord is provided for use with external receptacles. This cord is stored near the forward crew door.

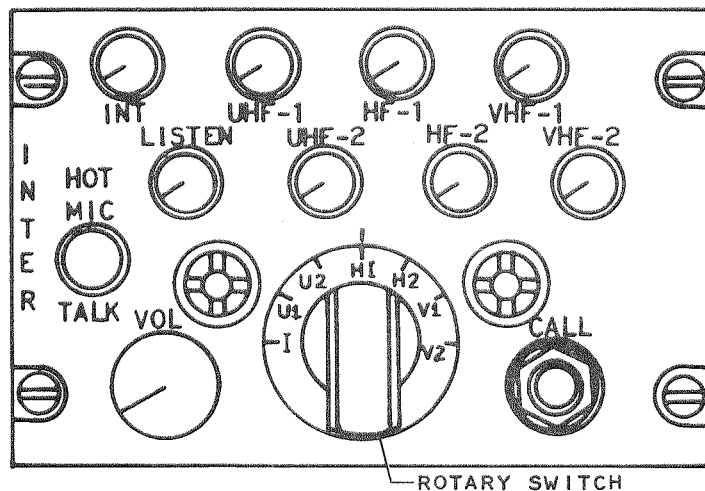
#### SYSTEM OPERATION

When aircraft power is activated, the interphone system will be operational. For crew members with monitor panels to monitor a navigational radio the



desired navigation system must be operational and the desired system switch on monitor panel must be pulled out and adjusted (volted) for proper volume. The signal will be fed through the control panel headset amplifier to the headset. Up to seven navigational radios and the PA system can be monitored at one time through the monitor panel.

Crew members with control panels can "interphone" or monitor the communications radio by pulling the desired monitor switch on the control panel and adjusting (rotating) the volume. To transmit over interphone or a communications radio, the control panel rotary selector switch is set for the desired system. With the mic button pressed, the mic audio signal will be fed through the interphone system to the selected radio for transmission.

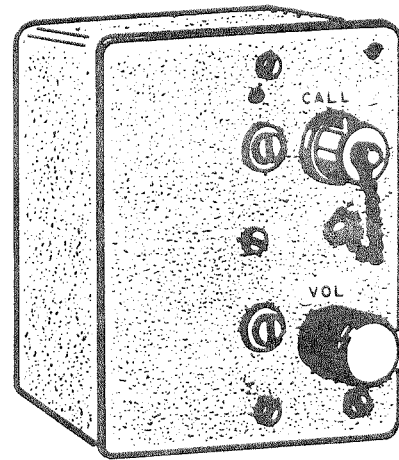
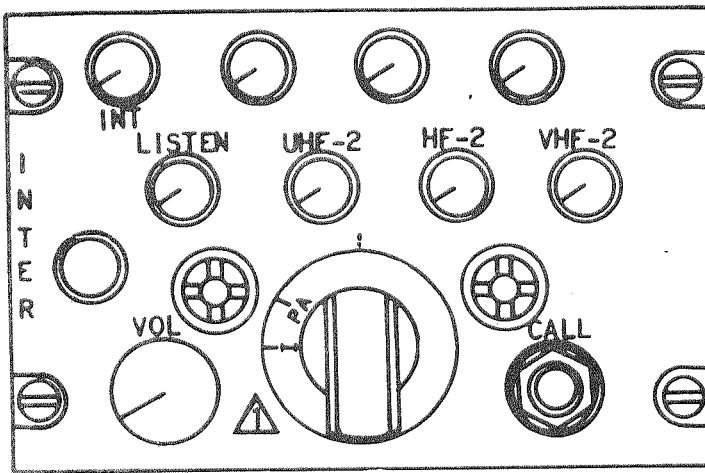


C - 3 9 4 2 C O N T R O L P A N E L

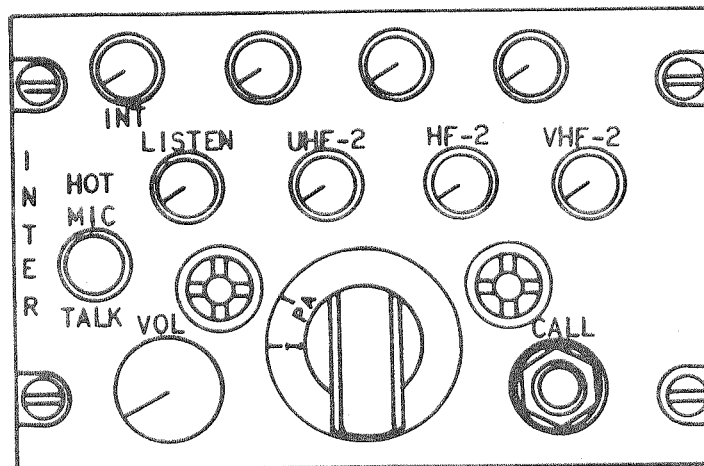
Reception from the same selected system is provided by releasing the mic button. For "HOT MIC" operation the HOT MIC TALK button is pulled. This allows communication over the interphone system without pressing a mix button. The "HOT MIC" talk volume is not adjustable.

To monitor hot mic talk the HOT MIC LISTEN button must be pulled and rotated for volume. To use the "CALL" (emergency interphone) function, the CALL button is pressed. This is a springloaded button that will return to the "OFF" position when released. To talk over the PA system from the flight station the pilot's INTER-INTER PA switch must be in "INTER PA" position. To use the PA system from the cargo station when the pilot's switch is not in "INTER PA" position, the cargo control panel rotary selector switch has to be in the "PA" position.

Control panels located in the cargo compartment have only two positions, "I" and "PA", on the rotary selector switches and only one monitor switch position, "INT". On modified aircraft the crew door panel will have "HOT MIC



"TALK" and "LISTEN". The selector switch at the flight engineer's position has no provisions for radio transmissions.



The vertical stabilizer station has only interphone capability.

# SPECIFICATIONS

## AIC-18 INTERCOMMUNICATIONS SYSTEM

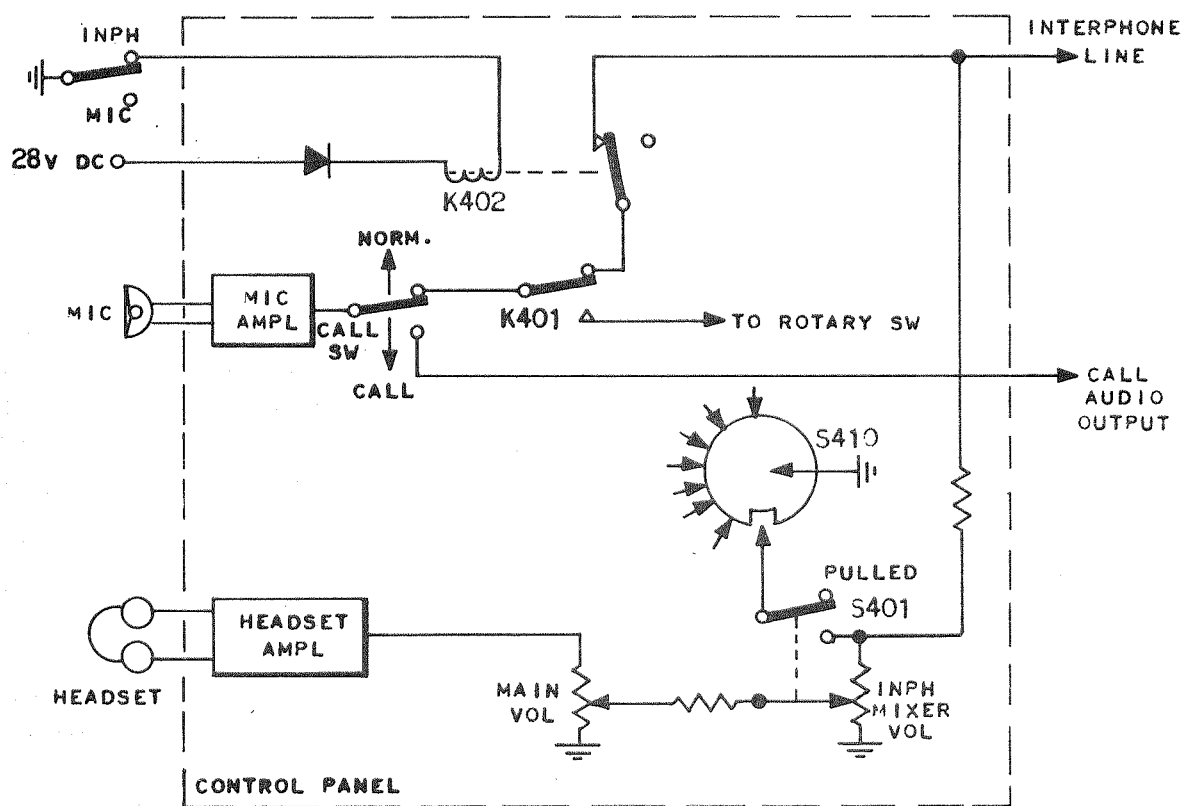
CHARACTERISTIC	SPECIFICATION
<p>MIC Amplifier AM-1964</p> <p>Input source impedance</p> <p>Output load impedance</p> <p>Output voltage</p>	<p>5 ohms</p> <p>150 ohms</p> <p>2.0v RMS approximately</p>
<p>HEADSET Amplifier AM-1965</p> <p>Input source impedance</p> <p>Output load impedance</p> <p>Auxiliary output winding</p> <p>Output Power</p>	<p>150 ohms</p> <p>9.5 ohms for headphone</p> <p>for loudspeaker(s)</p> <p>1.0-watt, maximum</p>
Call exalt	6 db approximately
Volume Control range	31 db nominal
Monitor volume control ranges	18 db nominal
D-C Power Source: range	24.0 to 30.0 volts, DC
Nominal	27.5 volts, DC
Emergency	12.0 volts, DC
Operation	
NOTE:	
Intercommunication Set Control	
C-3942 and	
C-3943 panel lamp source:	
Nominal	6-volt AC or DC
Power requirement	
Intercommunication Station	
No relays energized	3.6 Watts, nominal
Relays energized	5.3 Watts, nominal
Intercommunication Set Controls	
No relays energized-less lamps	3.6 Watts, nominal
One relay energized-less lamps	5.3 Watts, nominal
Panel lamps-nominal	2.4 Watts, nominal
Monitor Panels	
Panel Lamps-nominal	2.4 Watts, nominal C-3943



Radio transmission sidetone is returned from the selected radio through S410. The mixer and main volume controls affect the audio level. An alternate sidetone path is through the monitor switch. However with the rotary switch on the selected system the monitor need not be "on."

Radio reception is provided by releasing the mic switch allowing the selected system to switch from transmit to receive. The receive audio follows the same paths as sidetone shown on the radio transmit diagram. Each rotary switch radio position and the interphone position has an independent matching monitor switch circuit as shown on the radio transmit diagram. Therefore, interphone and any number of radios may be listened to simultaneously. Since the monitor panel is an audio mixer for the navigation radio receivers, with a single line to the control panel headset amplifier, any number of navigation systems and PA can be listened to simultaneously.

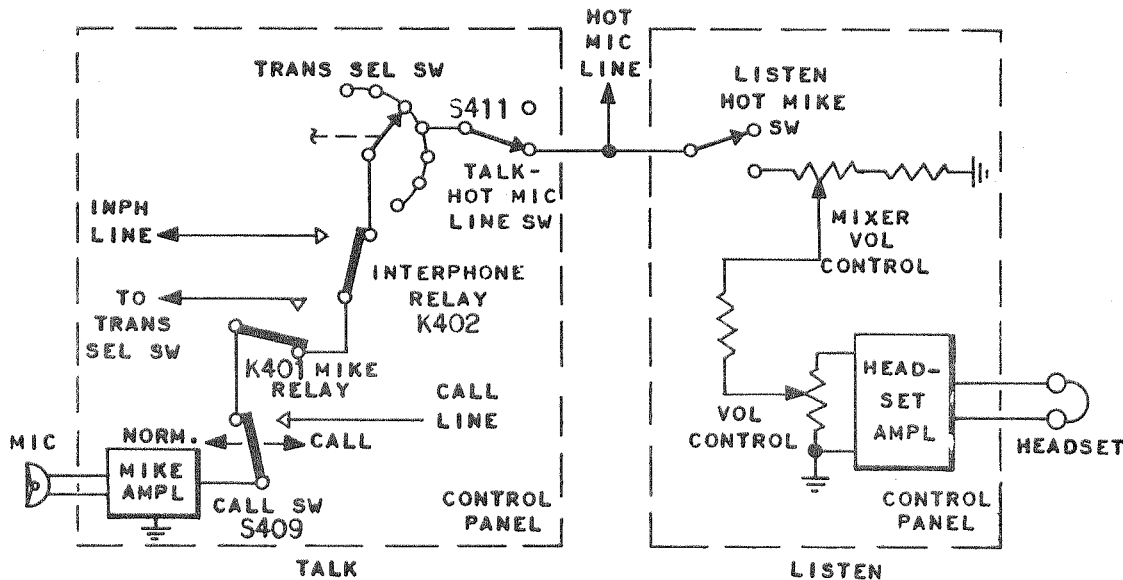
The pilot and copilot can transmit interphone without use of the rotary switch. By pressing their mic buttons to "INPH" their mic audio signals are coupled by



PILOT'S AND COPILOT'S MAIN PANEL

the energized relay (K402) directly to the interphone line. With the interphone monitor (S401) pulled or the rotary switch (S410) set to interphone the shorting ground is removed and the operator can hear his interphone sidetone.

If "CALL," "MIC," or "INTERPHONE" is not activated the operator can talk HOT MIC by pulling S411. He can listen to "HOT MIC" by pulling the HOT MIC LISTEN switch (S405).

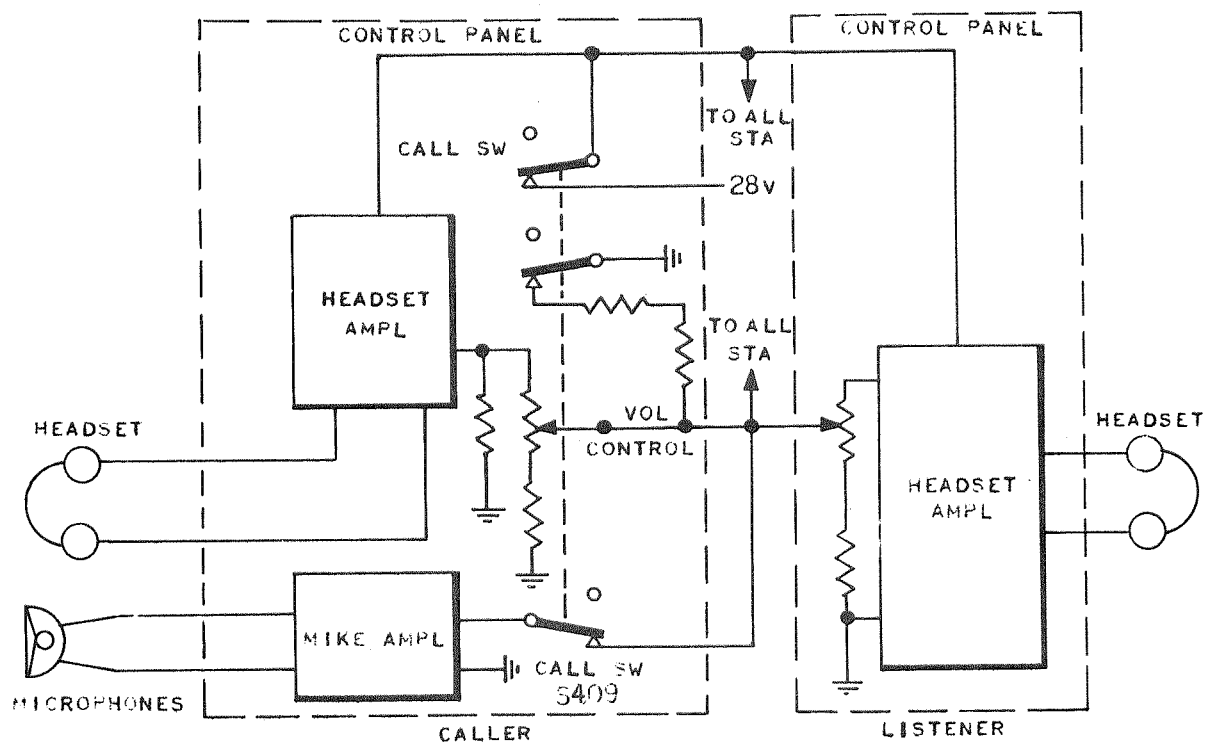


HOT MIC TALK AND LISTEN

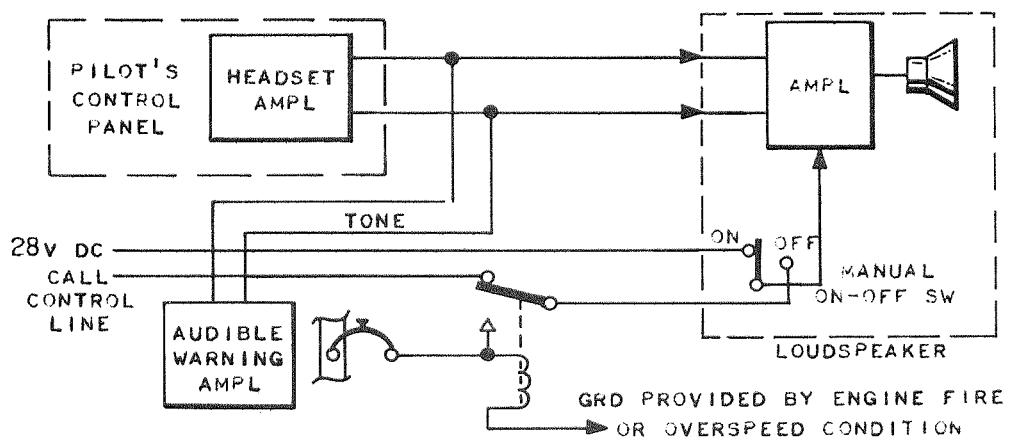
When the CALL button (S409) is pressed the mic audio is routed through the call audio line to all call capable stations. The caller hears his sidetone through his volume control. The pressed CALL button also applies 28-volt, DC to all stations activating headset amplifier Automatic Gain Control (AGC) circuits. Since call audio level is greater than the other signals the AGC circuits reduce the gain of the amplifiers resulting in CALL sounding normal with all previously selected signals being lower in volume. S409 also connects a shunt resistor circuit to the headset amplifier input reducing the callers sidetone. This will cause his sidetone to be about the same level that other listeners hear. This compensates wire losses between stations.

When a CALL button is pressed, 28-volt, DC on the call control line activates the flight station loudspeaker. When the fire or overspeed relay energizes the loudspeaker is also activated. The crew may turn the loudspeaker power switch "ON" for continual operation. When the loudspeaker is "ON" pilot's headset signals may be heard through the speaker. Engine fire or overspeed warning is provided by a tone in the speaker.

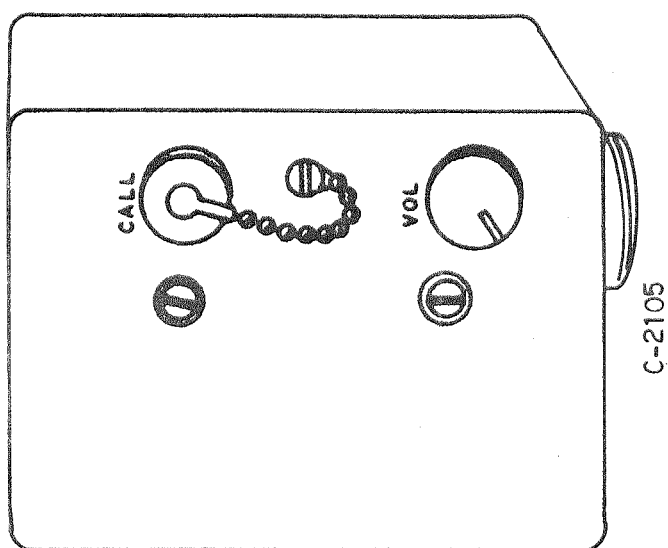




CALL FUNCTION

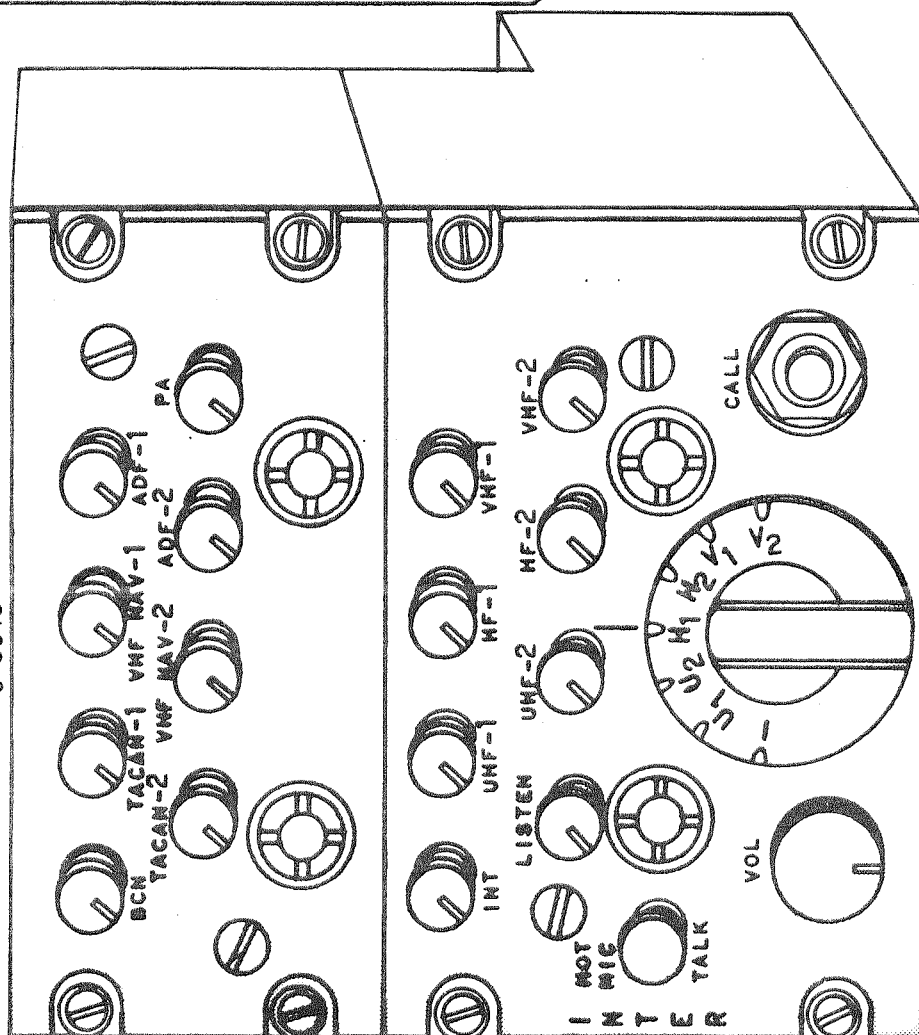


VERT STAB



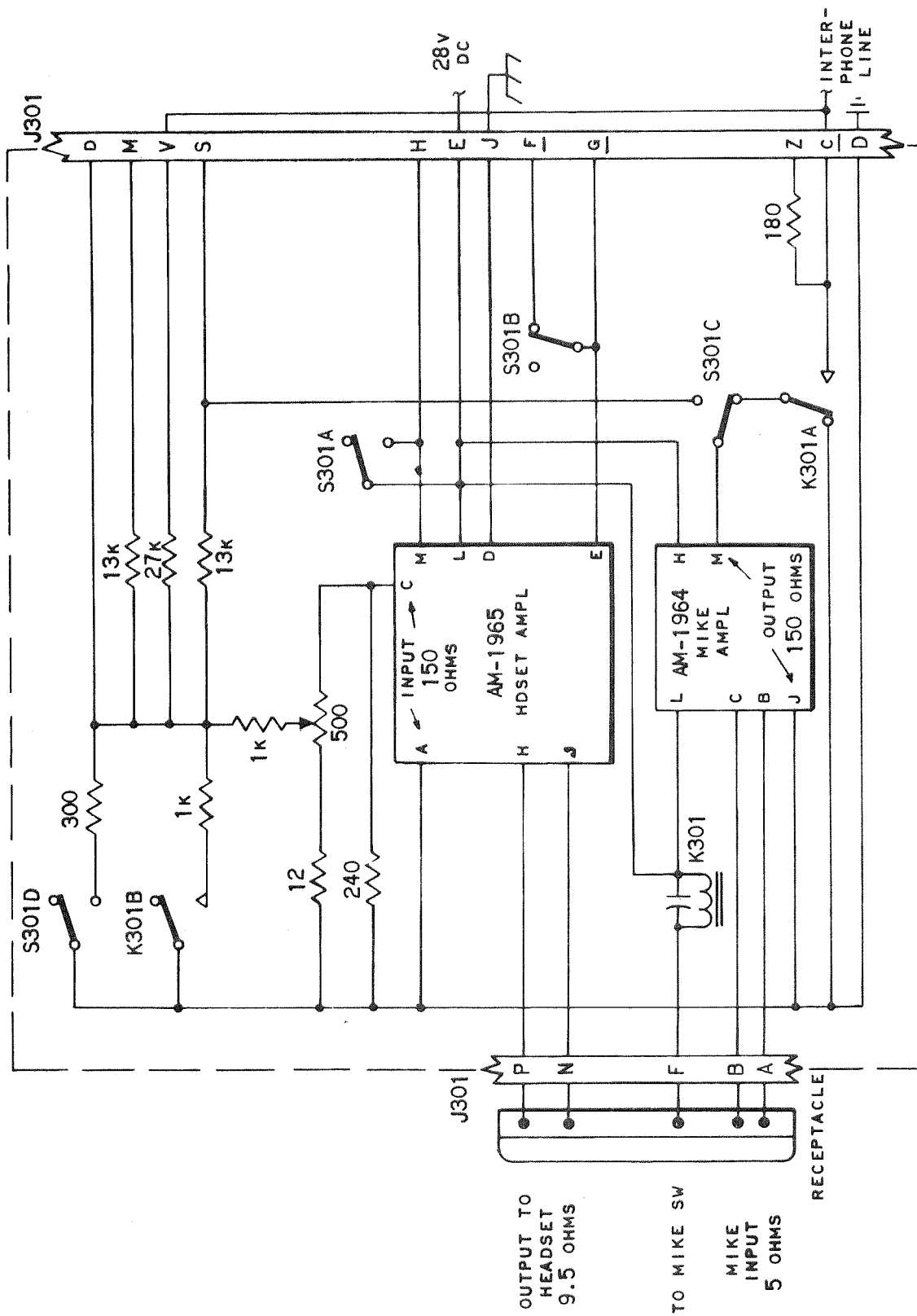
TYPICAL MAIN PANELS

C-3943

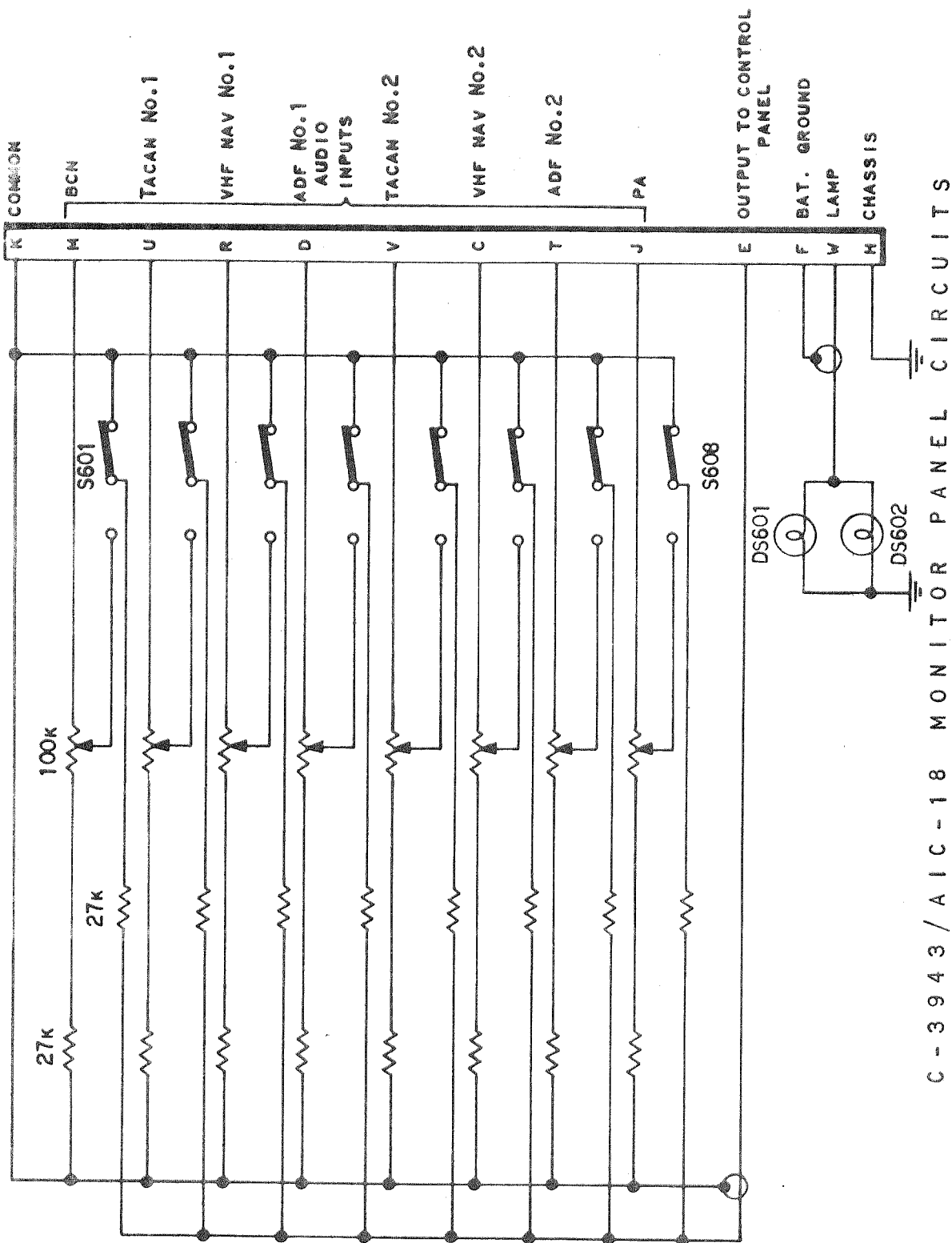


C-3942

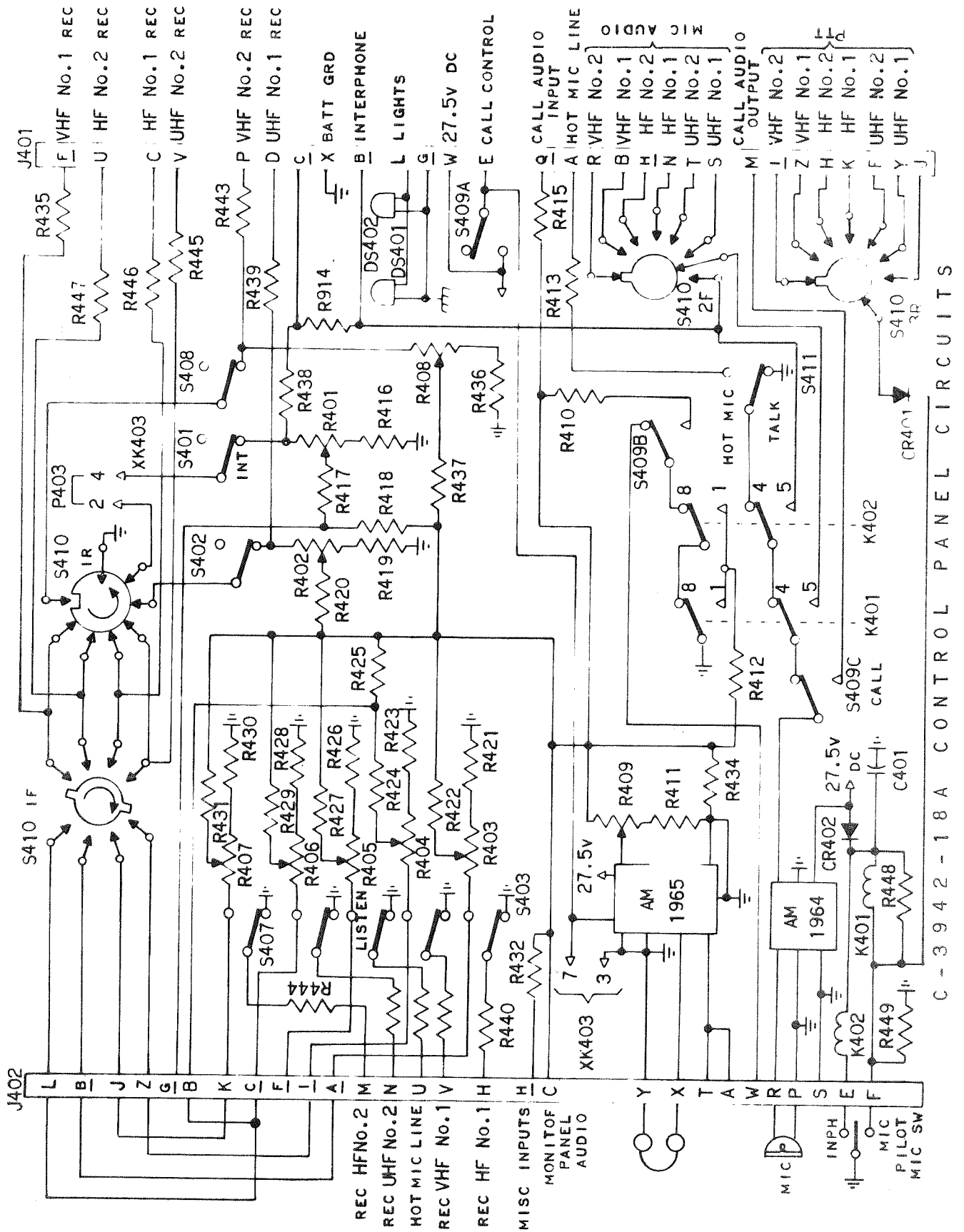
A I C - 1 8 A C O N T R O L P A N E L S



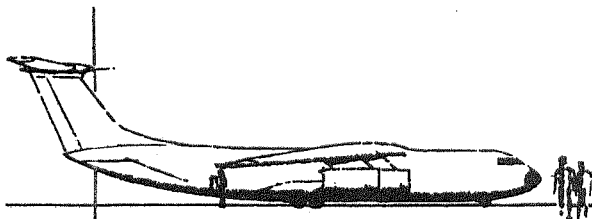
C-2105/AIC-18A CONTROL PANEL SCHEMATIC



C-3943 / AIC-18 MONITOR PANEL CIRCUITS







## PUBLIC ADDRESS SYSTEM

### GENERAL

The public address (PA) system is provided so messages or instructions from any interphone station may be heard in the cargo compartment with the use of loudspeakers. It can also be used to monitor standard radio broadcasts for entertainment purposes.

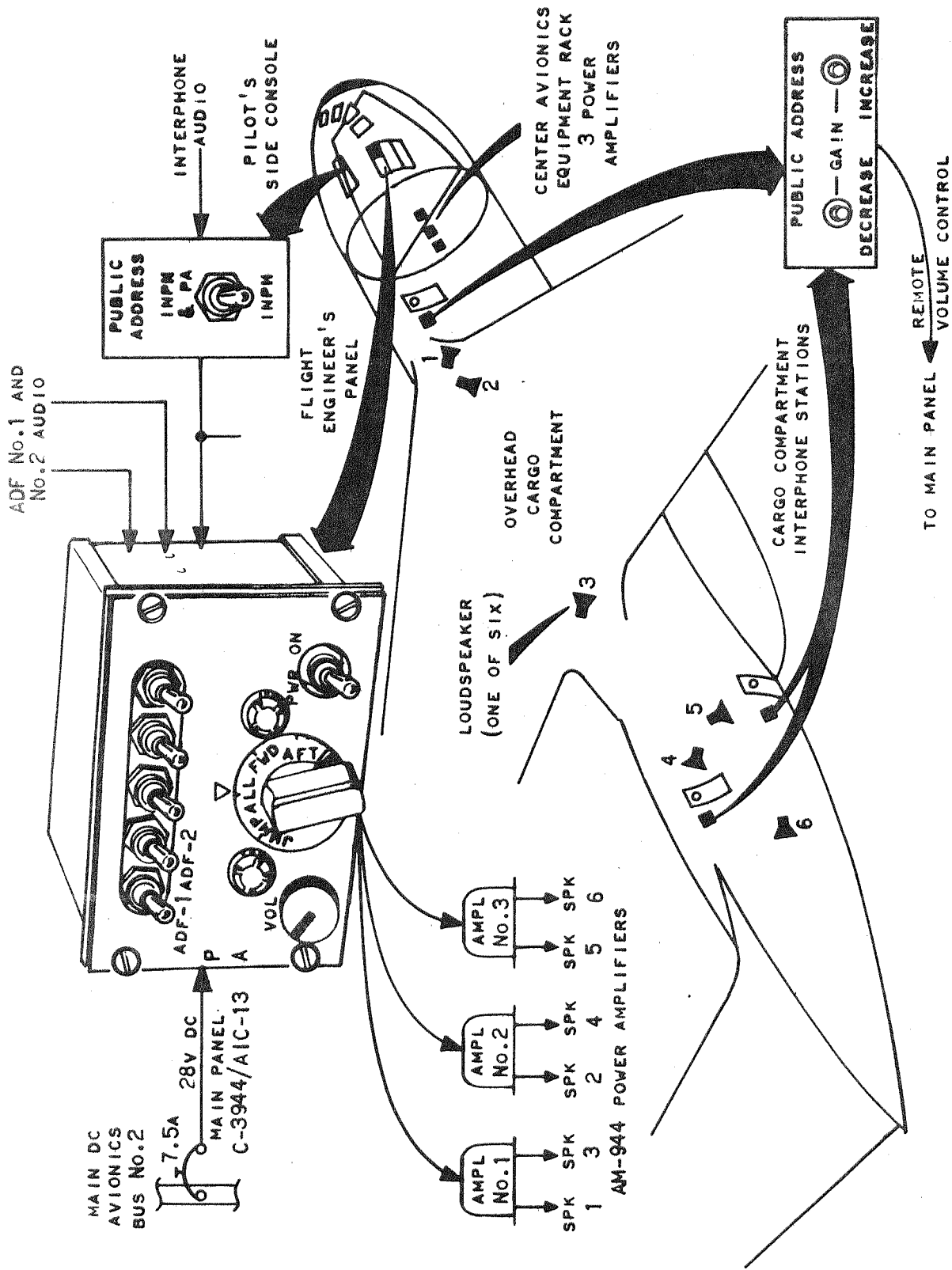
### AIRCRAFT INSTALLATION

The main control panel, C-3944/AIC-13, is located at the flight engineer's station. Three auxiliary control panels are located at the cargo compartment interphone stations. Three amplifiers, AM-944/AIC-13, are installed in the center avionics equipment rack. Six speakers, LS-211/AIC-13, are located overhead in the cargo compartment. The relays associated with the PA system are located on the interphone junction box. The INTERPHONE-INTERPHONE PA switch is located on the pilot's side console. All amplifiers are transistorized and require 28-volt DC for operation. The required voltage is supplied through a circuit breaker on the avionics circuit breaker panel, from the main D-C avionics bus No. 2.

### SYSTEM OPERATION

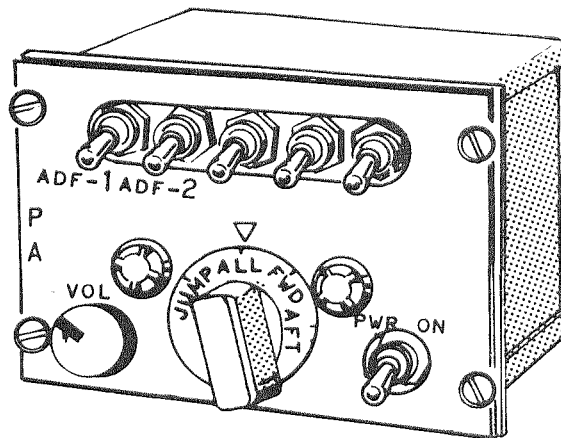
When the system is energized by placing the PWR switch, on the main control panel, "ON" and with the pilot's switch in "INPH & PA" position, interphone transmissions by any station will be heard through the selected cargo loudspeakers.

In addition, when the rotary selector switch on any interphone control panel in the cargo compartment is set to the PA position, a crew member at that station may talk over the PA system regardless of the pilot's switch position. Two push button switches at each of the cargo panels enable volume (gain) to be increased or decreased.



# AIRCRAFT INSTALLATION

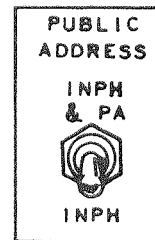




MAIN CONTROL PANEL

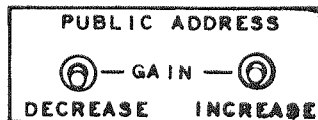
Volume is manually controlled at the main control panel by rotation of the volume control knob. The main control panel contains all other facilities necessary for system operation and control.

When the pilot's switch is set to "INPH" the interphone line is not connected to the PA system. With the pilot's switch set to "INPH" and no PA transmissions are being made from the cargo stations the Automatic Direction Finder (ADF) receivers may be heard, through the cargo loudspeakers, as they are selected at the main control



PILOT'S SWITCH

panel. This provides music listening for passenger entertainment. Speaker selection is also made at the main control panel. With the main control panel



rotary switch set to "JUMP" only the two speakers facing the jump doors will operate. In the "ALL" position all speakers operate. Only the forward speaker operates with the rotary selector set to "FWD". When "AFT" is selected only the speaker over the ramp area will operate.

## SPECIFICATIONS

### PUBLIC ADDRESS SYSTEM AIC-13

CHARACTERISTIC	SPECIFICATION
OVERALL	
Nominal power input voltage required	27.5 volts, DC
Maximum current required (at 17 watts output with 12 decibels of clipping)	1.0 amperes
Effective frequency range	500 to 5000 Hz
CONTROL PANEL UNIT	
Input impedance (all but auxiliary input)	Suitable to bridge a 150 ohm line (one 39,000 and five 47,000-ohm bridging type inputs)
Input impedance (auxiliary input)	Varies between 10 to 500 ohms depending on the setting of volume control
Output impedance	150 ohms
Gain (all but auxiliary input)	10 decibels
Gain (auxiliary input)	60 decibels with volume control maximum
Frequency response (nominal)	300 60 6000 Hz
Distortion at maximum output (300 Hz at 11 volts across 150-ohm line)	12 percent
Signal input voltage for full output	1.0 volts
AMPLIFIER UNIT	
Input No. 1 impedance	150 ohms
Input No. 2 impedance	200 ohms
Output impedance	4, 8 and 16 ohms
Input No. 1 gain	35 decibels
Input No. 2 gain	21 decibels

## SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
<b>AMPLIFIER UNIT (continued)</b>	
Frequency Response (nominal	300 to 6000 Hz
Distortion at maximum output (300 Hz at 18 volts across 16-ohm load)	9 percent
Input No. 1 signal voltage for full output at clipping threshold (1000 Hz)	0.9 volts
Input No. 2 signal voltage for full output at clipping threshold (1000 Hz)	2.8 volts
Input No. 2 signal voltage for full output with 12 decibels of clipping (1000 Hz)	11.0 volts
<b>LOUDSPEAKER UNIT</b>	
Frequency Range	500 to 5000 Hz
Input impedance	16 ohms
Power handling capacity	25 watts

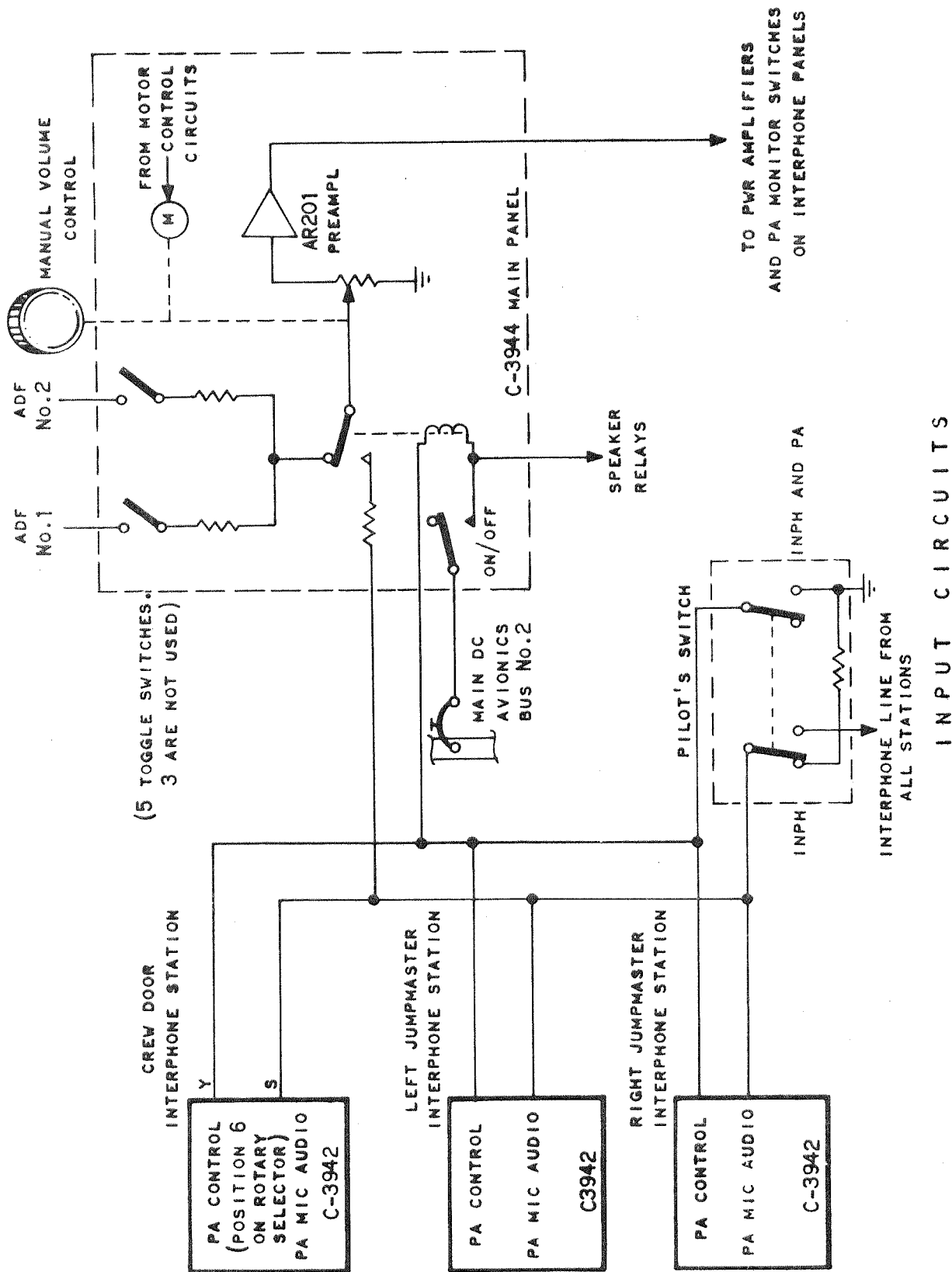
## BLOCK DIAGRAM THEORY OF OPERATION

It can be seen from the "Input Circuits" diagram, with the power switch "on," that if the pilot or any cargo station operator has not selected "PA" the main panel relay will be deenergized allowing the selected ADF receiver to pass to the volume control and be amplified by the main panel preamplifier.

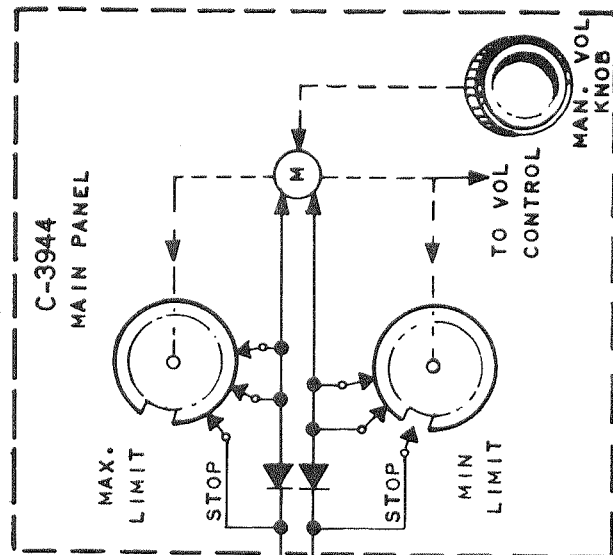
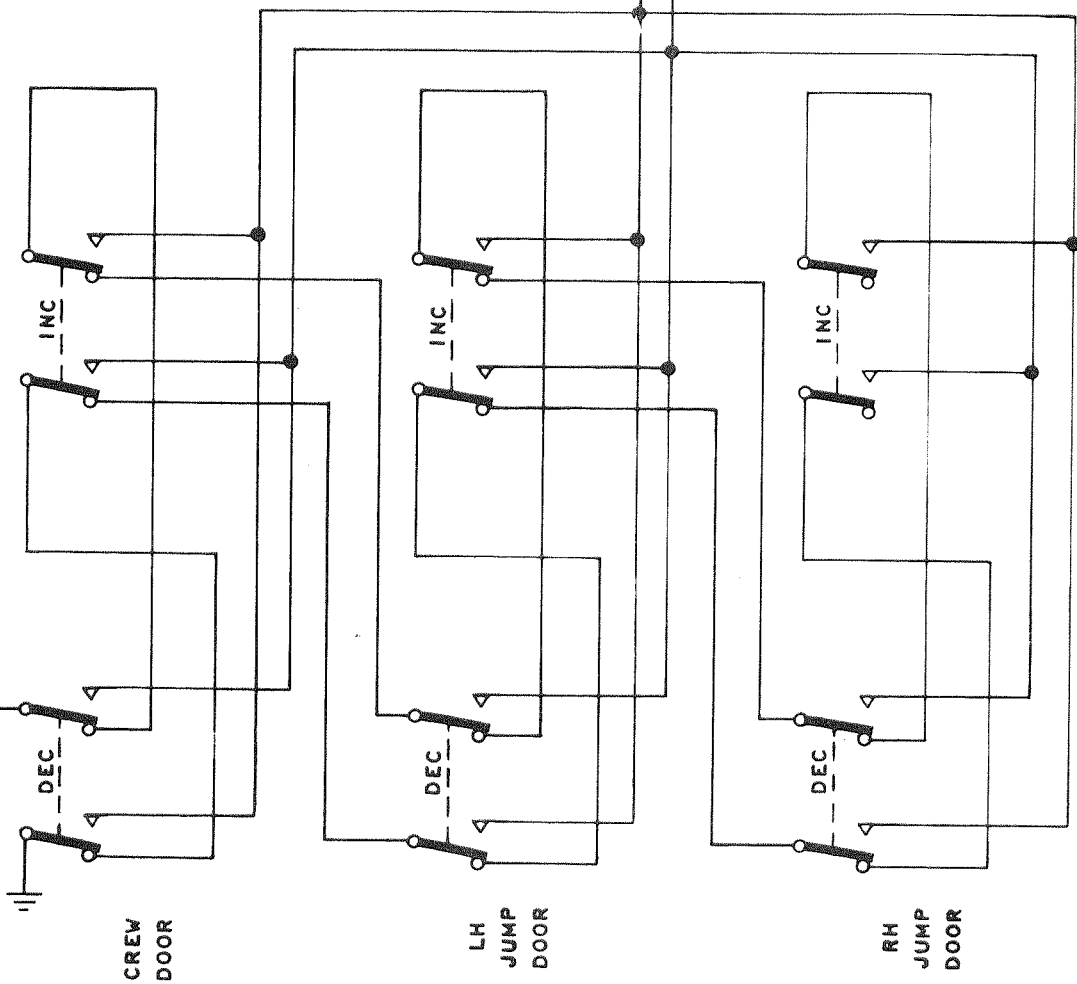
If the pilot selects "INPH & PA" a ground will energize the relay. The same occurs when the cargo operators select "PA." With the relay energized it is seen that the cargo PA mic line or the interphone line is connected to the PA input. The volume control can be adjusted manually at the main panel or turned by the remotely controlled motor.

The volume control motor is 28-volt, D-C operated. Whether the motor increases or decreases volume depends on the polarity of the DC applied.

The volume control diagram is shown in the minimum volume position. If any cargo INCREASE GAIN button is pressed it is seen that ground is applied to the motor through the bottom diode bypassing the open contact of the minimum limit switch. Power of +28-volt, DC is applied through the closed contacts of the



28V DC  
FROM ON-OFF



VOLUME CONTROL CIRCUITS

maximum limit switch to the motor. The motor will turn the volume control until the maximum limit switch, rotating clockwise, opens circuits at the maximum limit stop contact. The motor will not drive pass this point.

Now picture the maximum limit switch open and the minimum limit switch closed. Operating "DECREASE GAIN" will apply ground to the motor through the top diode bypassing the open contact of the maximum limit switch. Power of +28-volt, DC is applied through the closed contacts of the minimum limit switch to the motor. The motor will turn the volume control until the minimum limit switch, rotating counterclockwise, open circuits at the minimum limit stop contact.

Close examination of the volume control circuit will show that the left jump door panel has priority over the right jump door panel and that the crew door panel has highest priority. "DECREASE GAIN" has priority over "INCREASE GAIN."

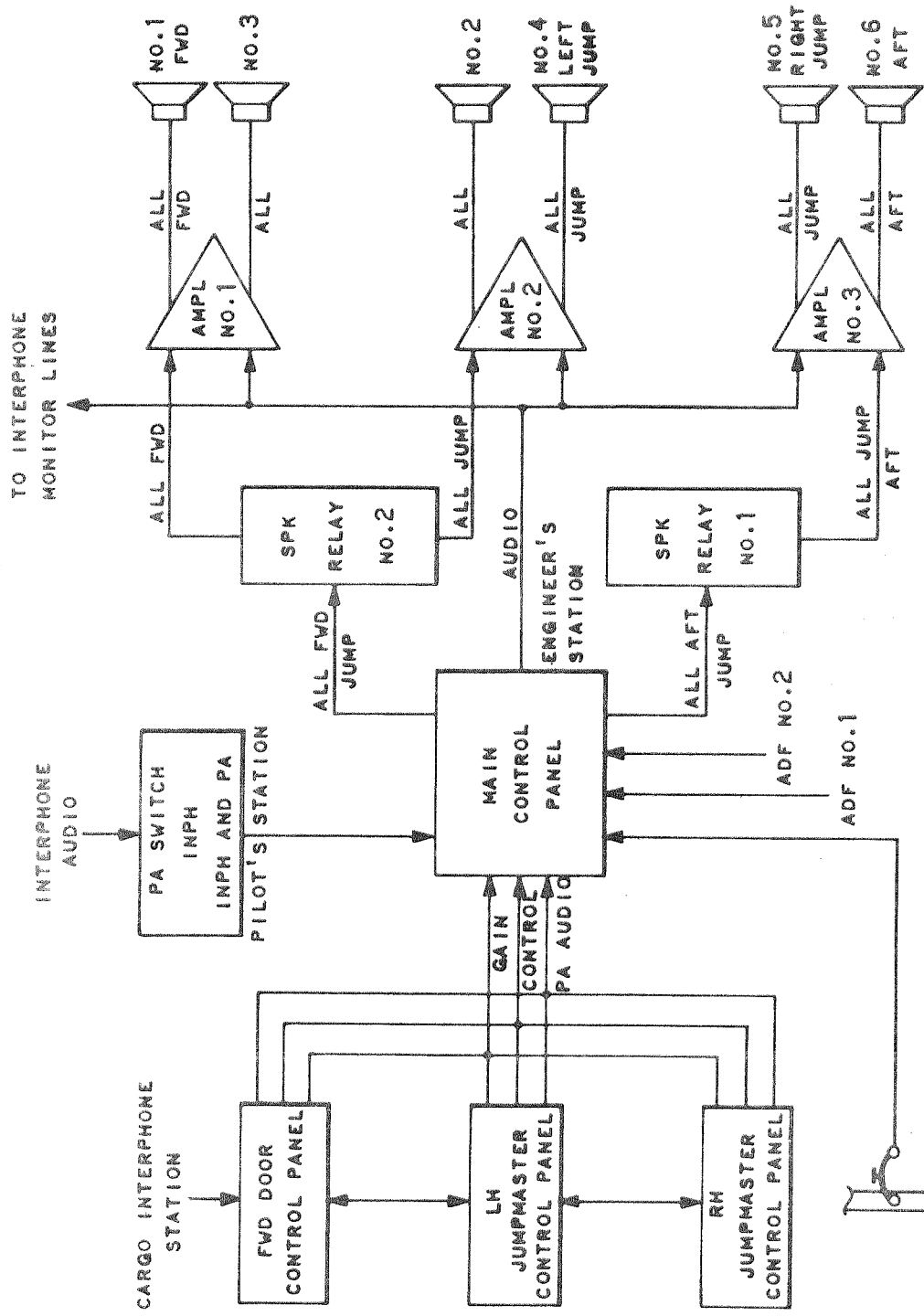
The three power amplifiers receive the selected input audio signal from the main control panel preamplifier. The power amplifiers raise the level of the signal sufficiently to drive the loudspeakers.

Referring to the output circuits diagram it is seen that each power amplifier drives two speakers.

Placing the speaker selector switch in the "ALL" position results in both speaker selector relays remaining deenergized. Operating voltage is applied to all amplifiers and relay No. 1 in all amplifiers is energized.

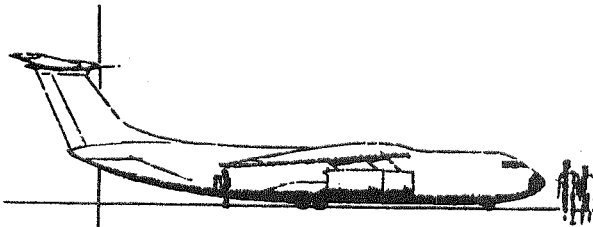
The output of each amplifier is connected to two parallel speakers; therefore, all six PA speakers are operational. When the SPEAKER SELECTOR switch is placed in the "JUMP" position both speaker selector relays are energized. Operating voltage is applied to amplifiers No. 2 and 3. Both relays in each amplifier are deenergized, and each amplifier output is coupled to one speaker. Amplifier No. 2 drives the left jump door speaker (speaker No. 4) and amplifier No. 3 drives the right jump door speaker (speaker No. 5). Placing the SPEAKER SELECTOR switch in the "AFT" position, energizes speaker selector relay No. 1. Operating voltage is applied to amplifier No. 3 amplifier. The No. 2 amplifier relay is energized to connect the No. 3 amplifier output to the aft speaker (speaker No. 6). Placing the SPEAKER SELECTOR switch in the FWD position energizes speaker selector relay No. 2. Operating voltage is applied to amplifier No. 1. Both amplifier relays are deenergized to connect the amplifier output to the forward speaker (speaker No. 1).





A I C - 1 3   B L O C K   D I A G R A M





## HF COMMUNICATION

### GENERAL

Two High Frequency (HF) radio systems are used to transmit and receive voice communications. They are used primarily for long range communications outside the range of other systems. Long range communication is possible since this system is not limited by line-of-sight characteristics. This system not only provides the conventional Amplitude Modulation (AM) method of voice communications but also the more recent Single Sideband (SSB) method. This too enhances the longer range capability of the system.

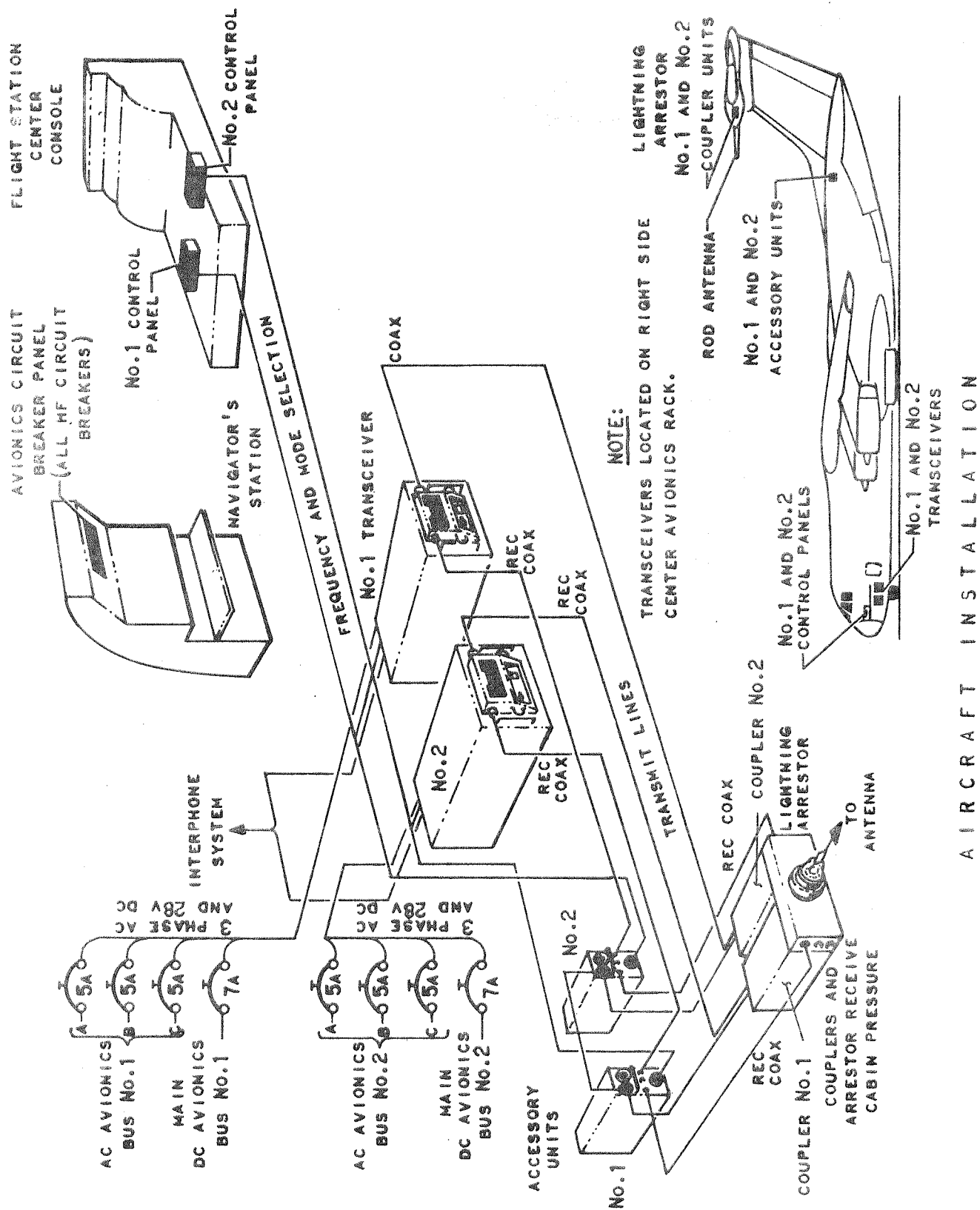
### AIRCRAFT INSTALLATION

Each system consists of a Model 618T-2 transceiver, a Model 180 R-4A antenna coupler, a 309A-1A coupler accessory unit, a 452A-1A lightning arrester relay unit, a Model 714E-2A Control Panel, and one rod type fixed antenna shared by both systems.

The transceivers are in the center avionics equipment rack. The control panels are on the center console; the coupler accessory units are in the vertical stabilizer base; and the lightning arrester relay unit and antenna couplers are in the horizontal stabilizer bullet. The antenna is mounted in the forward bullet fairing of the empennage.

Primary power necessary for system operation is 28-volt D-C power and 3-phase AC, 208 volts, phase-to-phase. Four circuit breakers for each system are on the avionics circuit breaker panel. System No. 1 is supplied from the A-C avionics and main D-C avionics No. 1 busses. No. 2 HF is supplied in an identical manner from the No. 2 busses.

Keying interlock between the two HF systems is provided by relays in the coupler accessory units and the lightning arrester relay unit. The interlock circuits prevent both transceivers from being keyed simultaneously, and provide the necessary switching to enable one antenna to be used by both systems.



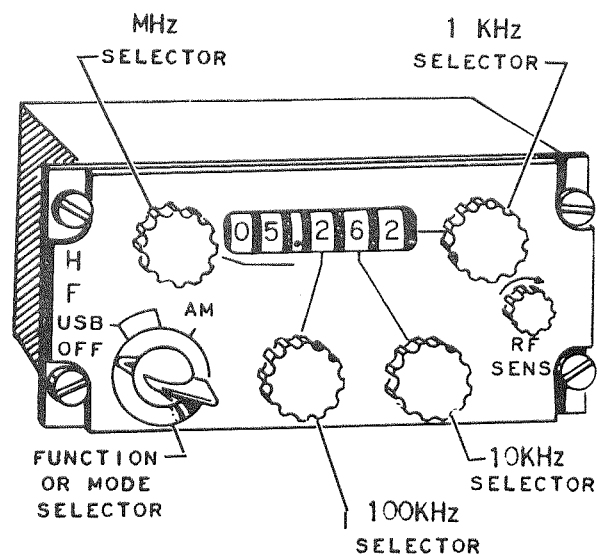
## SYSTEM OPERATION (only one system is discussed)

The function, or mode of operation is selected by a four-position rotary switch. In the "USB" position, the system operates using SSB with carrier suppression. Only the Upper Sideband (USB) is transmitted. The next position is also "USB". LSB need not be labeled on the control panel since this mode is disabled in the aircraft wiring.

In "AM" operation, the carrier and upper sideband are transmitted. This is also SSB operation, but the carrier is also transmitted. When the switch is in the "OFF" position, the equipment is deenergized.

The frequency selected may be read directly from the control panel. Frequency is determined by dialing the four frequency knobs until the desired operating frequency appears in the panel window. The antenna tuning system automatically tunes the antenna for each transmitter frequency in order to obtain maximum power transfer from the transmitter to the antenna.

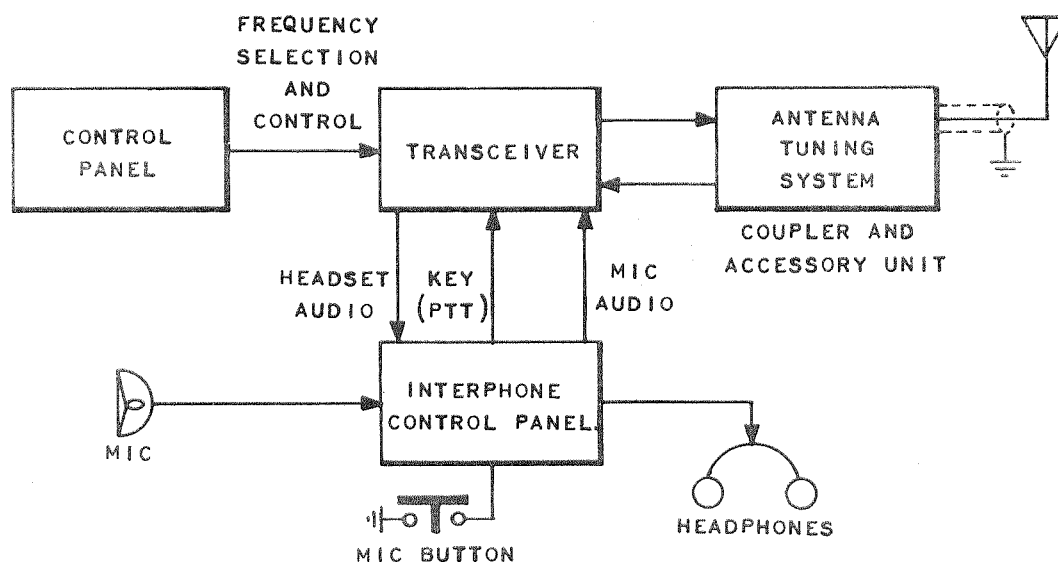
In order to transmit and receive from an HF system, the desired system must be selected on the interphone control panel rotary selector. If reception only is desired, the HF mixer switch should be turned on. The volume level of the HF audio should be controlled by the interphone volume controls only.



C O N T R O L   P A N E L

The transmitter can be keyed by pressing the microphone button on the headset cord or on the control wheel. Audio signals will be supplied from the microphone to the transmitter. RF energy from the transmitter is applied to the tuning system and antenna. Sidetone audio will be heard in the headphones during transmission. When the microphone button is released, the antenna is connected to the receiver input. Received signals are amplified, detected, and then routed to the interphone system. Best received signal to noise ratio is adjusted by the RF sensitivity control.

When each new frequency is selected and the transmitter is first keyed, the antenna tuning system will tune. The tuning cycle is indicated to the operator



SYSTEM BLOCK DIAGRAM

by a 1 KHz tone in the headphones. The average tuning time of the tuning system is five seconds. When tuning is complete, the tone will cease. Keying the transmitter the second time will provide full power transmission. This operation is known as "Radio Silence" meaning that the transmitter is not on the air for tuning purposes until the transmitter is first keyed. This reduces needless transmissions that cause interference when new receive frequencies are selected. If the system fails to tune in 75 seconds, a thermal cutout will disable the tuning cycle and prevent transmission. After allowing cooling time, a new frequency must be selected and the mic button pressed in order to initiate the tuning cycle again.

During receive operation, the antenna is connected directly to an amplifier in the accessory unit, bypassing the tuning circuits in the coupler used during tuning and transmit operations. The amplifier output is supplied to the receiver.

## SPECIFICATIONS

### COLLINS 618T-2

CHARACTERISTIC	SPECIFICATION
Altitude range	Pressure equivalent of 30,000 feet with externally supplied cooling air.
Power requirements	115 volts (line to neutral), 3-phase, 400 Hz. 1000 watts 115 volts, 400 Hz. single phase. 160 watts, 27.5 volts, DC, 120 watts
Frequency range	2.000 to 29.999 MHz
Frequency channels	28,000.
Frequency stability	0.8 part per million per month.
Time required to change channels	8 seconds average (independent of external antenna tuner).
Transmit Characteristics.	
RF power output	SSB: 400 watts pep. $\begin{smallmatrix} +2 \\ -1 \end{smallmatrix}$ db.  AM: 125 watts carrier $\pm 1$ db.  CW: 125 watts, locked key $\pm 1$ db.
RF output impedance	52 ohms.
Audio input impedance	80 ohms unbalanced and 600 ohms balanced.
Audio-frequency response	5 db peak-to-valley ratio from 300 to 3000 Hz.
Distortion	SSB: Third-order distortion products down at least 30 db.  AM: Less than 20 percent at 80 percent modulation with 1000 Hz.

SPECIFICATIONS (Continued)

COLLINS 618T-2

CHARACTERISTIC	SPECIFICATION
Receive Characteristics.	
Sensitivity	SSB: 1 microvolt for 10 db S+N/N ratio.  AM: 3 microvolts modulated 30 percent 1000 Hz for a 6 db S+N/N ratio.
Selectivity	SSB: 2.85 KHz, 6 db down. 6.0 KHz, 60 db down.  AM: 5.5 KHz, 6 db down. 14.0 KHz, minimum, 60 db down.
AGC characteristic	Maximum variation of audio putput is 6 db for input signals from 10 to 100,000 microvolts. No overload below 1-volt signal input.
IF and image rejection	80 db, minimum.
Audio output power	100 milliwatts into 300 ohm load.
Audio distortion	Less than 10 percent with 1000-micro- volt input, modulated 80 percent at 1000 Hz.
Audio-frequency response	5 db peak-to-valley ratio from 300 to 3000 Hz.
Image rejection	60 db minimum below desired frequency relative to 5 microvolt input.

## MODULE COMPLEMENT

MODULE	FUNCTION
A1	Frequency divider
A2	RF oscillator
A3	IF translator
A4	Kilohertz-frequency stabilizer
A5	Low-voltage power supply
A6	Electronic control amplifier
A7	3 phase AC high-voltage power supply
A9	AM/audio amplifier
A10	Megahertz-frequency stabilizer
A11	Power amplifier
A12	RF translator
A12A1	Autopositioner (submodule)
A12A2	Variable-frequency oscillator (VFO submodule)

## BLOCK DIAGRAM THEORY OF OPERATION

### SINGLE SIDEBAND CONCEPT

The need for SSB communication systems has arisen because commercial and military services need the long-range propagation characteristics obtainable in the high frequency band. Since HF spectrum space is limited, the best possible use of available frequencies requires communication systems with minimum bandwidth. An AM signal is composed of three parts: an RF carrier frequency, upper sideband, and lower sideband. All of the audio (Voice) information is contained in each sideband. Each sideband merely duplicates the information of the other. The carrier contains no information. If one sideband and the carrier are eliminated, a SSB signal results. The SSB signal is half the bandwidth of an AM signal. A SSB signal therefore requires only half the spectrum space for transmission of information.

The principal advantages of SSB are high energy carrier elimination and narrow frequency bandwidth. A SSB transmitter provides full rated power output in one sideband while an AM transmitter provides one-fourth of its rated power in each of two sidebands. A SSB transmitter with much less power than an AM transmitter will give equal performance. For the advantages of SSB communication to be fully realized, attention must be given to frequency stability, filter selectivity, and low distortion linear power amplification.

The maximum frequency error which can be tolerated in an SSB system used for voice communication is approximately 100 Hertz (Hz). Noticeable distortion occurs at 50 Hz or greater. Another consideration in airborne SSB equipment is Doppler shift, due to relative motion between transmitter and receiver. At an operating frequency of 20 MHz when transmitting from a modern jet aircraft to ground, the frequency shift is approximately 20 Hz. This represents approximately one-half the frequency error at which noticeable distortion occurs, placing additional restrictions on the maximum allowable frequency error of the SSB equipment.

To enable SSB equipment to meet frequency and stability requirements, it is necessary to use a stable master oscillator, by which other variable frequency oscillators are stabilized. This is accomplished by comparing their output frequency with a frequency derived from the master oscillator.

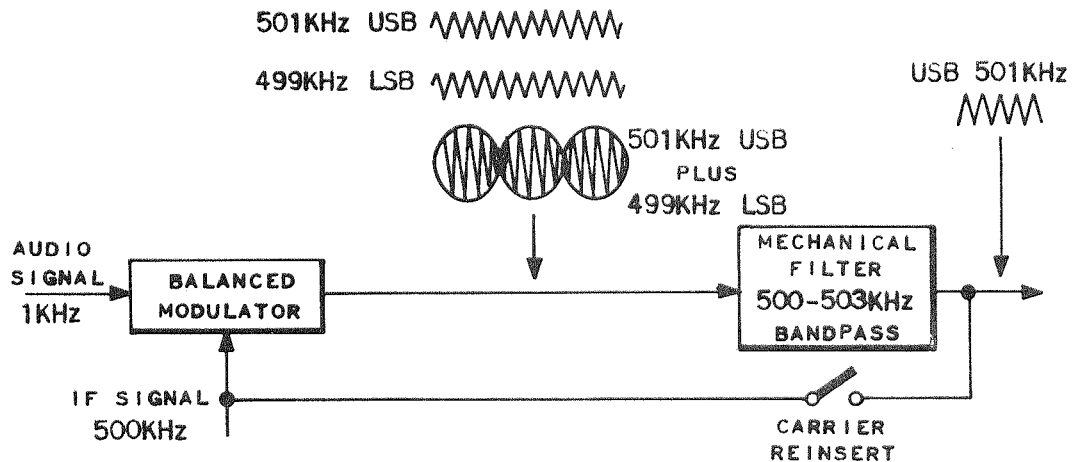
In SSB transceivers, the signal bandwidth must be narrow to reject interference and the unwanted sideband. The filter used, therefore, must have a very narrow and flat bandpass. These filter requirements are met by mechanical filters which operate at a frequency of 500 KHz. These filters provide a much higher Quality (Q) than is possible in LC circuits.

Because the SSB signal is a translated audio spectrum, it must be amplified linearly like an audio signal in order to prevent excessive distortion. In addition, linear amplification essentially eliminates the generation of harmonics, thereby



preventing adjacent channel interference. Class C RF amplifiers, like those used to amplify AM signals, therefore, cannot be used in SSB transmissions. The RF amplifiers and drivers are usually pentode vacuum tube stages operating class A.

The SSB signal is generated in the HF communication system by a filter-type SSB generator, consisting of a balanced modulator and a very selective bandpass filter. The output amplitude of the balanced modulator depends on the audio input amplitude. When there is no audio input, the balanced modulator has no output.



Using a 500 KHz signal as the carrier frequency and a 1000 Hz audio tone as inputs, the output of the balanced modulator consists of the upper and lower sidebands, one on each side of 500 KHz, just as in an AM modulator. Unlike an AM modulator output however, the balanced modulator contains no appreciable amount of the 500 KHz carrier component. Thus, the carrier has been suppressed.

The double-sideband, suppressed-carrier signal (501 KHz and 499 KHz) from the balanced modulator is fed to an upper sideband (USB) mechanical filter. The bandwidth of the filter is 3 KHz; wide enough to pass only the modulating spectrum. Therefore, only the upper sideband will be passed (501 KHz). Note that the SSB signal is a sine wave, constant in amplitude, when a single-tone audio signal is used for modulation. This SSB signal is displaced from its original carrier frequency by an amount equal to the frequency of the modulating audio signal. This modulated signal is heterodyned in several mixers until the selected transmitter frequency has been developed.

To recover the audio signal at the receiver, the SSB signal must be mixed with a carrier frequency which is generated at the receiver. The mixer that performs this demodulation is called a product detector. In the example given, combining 501 KHz with 500 KHz (carrier signal) in the product detector produces a difference frequency of 1 KHz, which is the audio signal.

Remember that in the transmitter, the carrier is suppressed and the sideband is transmitted. In the receiver, the sideband is received and the carrier reinserted.

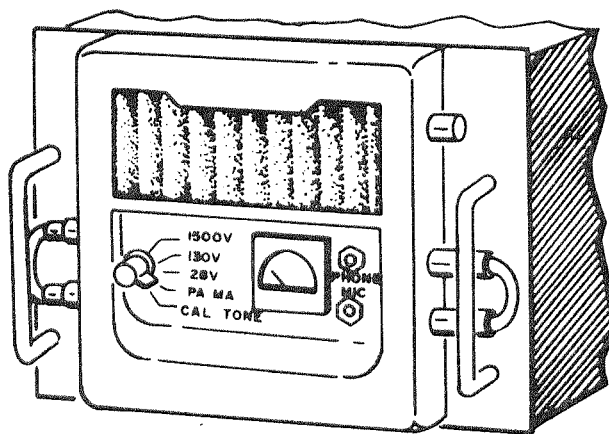
## TRANSCEIVER GENERAL

The transceiver is the major unit of the system. The unit is composed of 11 plug-in modules, including an interchangeable internal high voltage power supply. The Model 618T-2 uses a 3-phase, A-C high voltage power supply.

## MODULES

The functions of the modules are summarized below.

**MODULE A1.** The frequency divide module transforms a 100 KHz signal from the RF oscillator module to a 10 KHz pulse and a 1 KHz spectrum which is centered at 550 KHz. These outputs are used for VFO frequency stabilization in the kilohertz frequency stabilizer module. A 1 KHz cal tone is also provided.



T R A N S C E I V E R

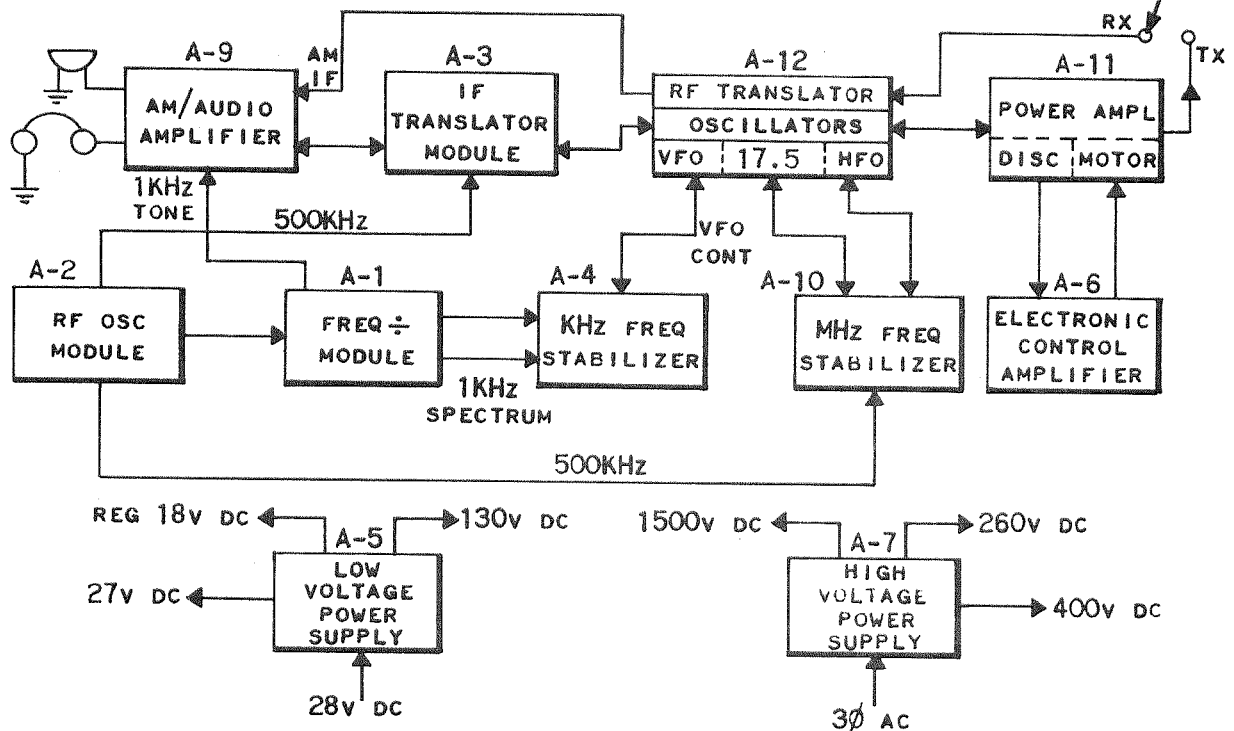
**MODULE A2.** The radio frequency oscillator module contains the 3 MHz RF oscillator, which is the stable master oscillator of the system. This oscillator is used to produce three output signals: a 500 KHz signal to the IF translator for communications, a 500 KHz signal to the Megahertz (MHz) frequency stabilizer to be used in stabilization of the HF and 17.5 MHz oscillators, and a 100 KHz signal to the frequency divide module.

**MODULE A3.** The IF translator receives the microphone audio from AM/audio module and a 50 KHz signal from the RF oscillator module and generates a 500 KHz SSB or AM signal in the transmit mode. This module also contains SSB IF amplifiers and a product detector which are used in the SSB receive mode.

**MODULE A4.** In the KHz frequency stabilizer, the VFO frequency is phase-locked in 1 KHz steps with the RF oscillator reference frequency from the frequency divide module. This action of the KHz frequency stabilizer provides a D-C tuning voltage for tuning the voltage-sensitive capacitors in the VFO tuned circuits.

**MODULE A5.** The low voltage power supply contains a transient blanker circuit which protects transistors in the transceiver from line voltage surges, an 18-volt voltage regulator which provides transistor supply voltage, and a rectifier

filter which produces 130 volts DC from a 115-volt, 400 Hz input. Voltage inputs are 28 volts, DC, and 115 volts, AC.



618T-2 MODULE BLOCK DIAGRAM

MODULE A6. The electronic control amplifier receives an error signal from the power amplifier phase discriminator. This signal is amplified and applied to a servo motor. The motor drives a variable inductor used in tuning the power amplifier's output network.

MODULE A7. The high voltage power supply supplied vacuum tube filament voltages, 260 volts, DC for the tubes in the RF translator module, 1500 volts, DC for the power amplifier module, and TGC control voltages. Voltage input is 3-phase AC, 208 volts, phase-to-phase.

MODULE A9. The AM/audio module provides audio amplification of the microphone signal in transmit mode in both AM and SSB operation. In the AM receive mode, the module provides AM/IF amplification and audio amplification. In the SSB receive mode, audio amplification is provided.

MODULE A10. The megahertz frequency stabilizer module stabilizes the frequency of the 17.5 MHz and HF oscillators in the RF translator by phase locking them to the 500 KHz reference signal derived from the RF oscillator.

MODULE A11. The power amplifier module amplifies the selected operated frequency to 400 watts PEP in the SSB mode or 125 watts carrier power in the AM mode.

MODULE A12. The RF translator contains the VFO and 17.5 MHz and HF oscillators with their associated transmit and receive mixers. These circuits are used in translating the 500 KHz modulated IF signal to the selected operating frequency in the transmit mode and translating the received RF signal into the 500 KHz IF signal in the receive mode.

Color coded test points located on the modules permit general troubleshooting without removing modules from the chassis. Each module is equipped with plug-in connectors and can be quickly removed since there are no mechanical linkages between any of the modules. Many of the potentiometer adjustments are also accessible without removing modules from the unit. Headset and microphone jacks, meter, and meter selector switch are located on the front panel. Four meter selector switch positions are used to check power supply voltages and power amplifier plate current. A fifth position, "CAL TONE", is used to compare the frequency of the Model 618T-2 with WWV. A 400 Hz blower is also located on the front panel to provide forced-air cooling.

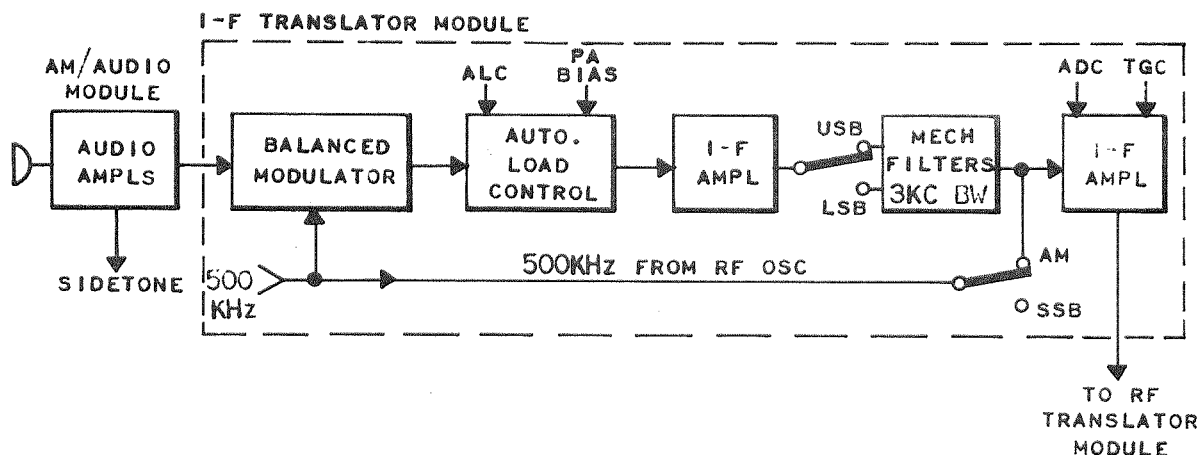
#### TRANSMITTER BLOCK DIAGRAM

The amplified microphone signal from the interphone system is fed into the AM/audio module (A9) where it is amplified through three audio amplifiers. The amplifiers provide a sidetone output for monitoring the audio. This differs from most radio communication equipment in that sidetone is usually developed in the transmitter output stage, or antenna circuits, and indicates that the transmitter is radiating power. Developing a sidetone signal in the antenna circuits of the transceiver is not possible due to the characteristics of SSB modulation. Therefore, a portion of the power amplifier output signal is rectified and used to energize a relay in the sidetone circuits. The closed contacts of the relay couple the sidetone signal to the interphone system. Without sufficient RF voltages from the power amplifier, the relay remains deenergized and no sidetone will be heard in the operator's headset. This indirectly provides a check of transmitter RF output.

The amplified MIC audio from the AM/audio module is fed to a balanced modulator in the IF translator module where it is combined with a 500 KHz signal from the RF oscillator. The balanced modulator output is the upper and lower sidebands with no appreciable 500 KHz carrier signal.

The two sidebands are fed to the Automatic Load Control (ALC) IF amplifier. The gain of the amplifier is controlled by a feedback signal from the grid of the power amplifier. If the grid of the power amplifier is overdriven, it will draw grid current and produce a negative voltage which is fed back to the ALC amplifier. The gain of the ALC is thereby reduced lowering the drive to the power amplifier. The power amplifier bias voltage is used also as B+ for the ALC amplifier thus assuring no PA grid signal without bias.

The two sideband signals are further amplified by a second IF amplifier and fed through a mechanical filter tuned to the Upper Sideband (USB) or Lower Sideband (LSB) depending on the mode selected on the control panel (disregard LSB which is disabled in the aircraft wiring).



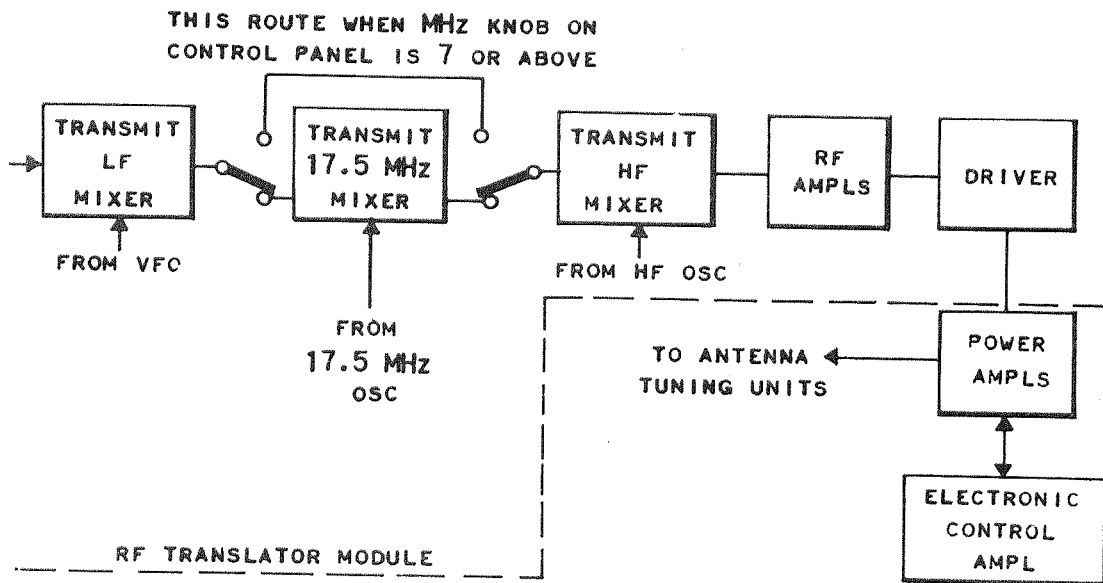
AUDIO TO IF TRANSLATION SCHEME  
( TRANSMIT )

When the transceiver is operated in the AM mode, the upper sideband is passed and a 500 KHz carrier from the RF oscillator module is reinserted at the filter output producing an amplitude-modulated RF envelope.

The signal is amplified further by a third IF amplifier. The gain of this amplifier is controlled by feedback signals from the power amplifier. This is accomplished by a D-C amplifier. If excessive RF power amplifier plate-voltage-swing occurs, the Automatic Drive Control (ADC) will reduce the gain of the third IF amplifier (Q4). ADC voltage is developed by rectifying a portion of the amplifier plate signal. If excessive power amplifier plate current flows, the Transmitter Gain Control (TGC) will also reduce the gain of the third IF amplifier. These feedback steps are taken to insure that the power amplifier will have a linear output.

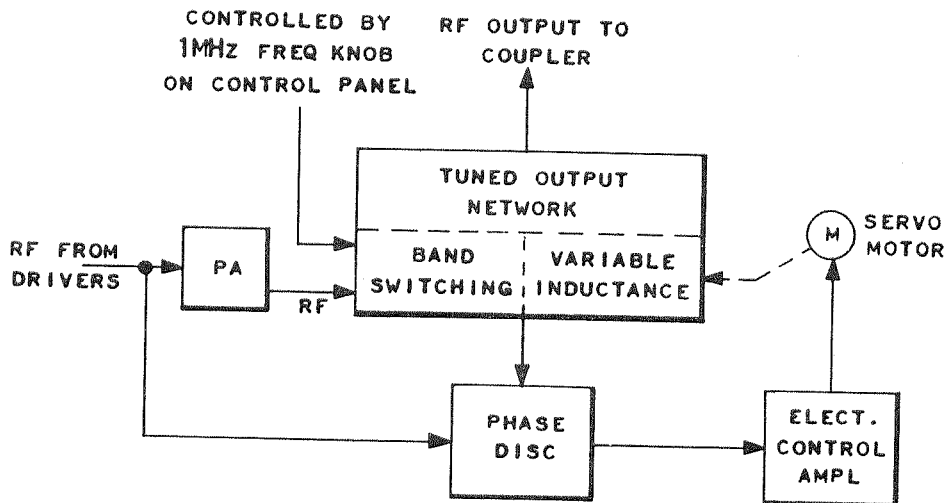
The output of the IF translator is sent to the RF translator module where it is translated into the selected operating frequency. This is accomplished by combining the IF signal with the signal of three oscillators.

The output of the RF translator is fed to the RF amplifier and then to the driver. The signal output is fed to the power amplifier module where it is amplified to 400 watts, PEP in SSB mode, or 125 watts of carrier power in the AM mode.



IF TO RF TRANSLATION AND RF POWER  
SCHEME (TRANSMIT)

The power amplifier has an output network which is automatically tuned as new operating frequencies are selected. A band switch motor, controlled by the 1 MHz bandchange mechanism of the RF translator, provides coarse tuning by switching LC elements. These elements are switches in eight steps, or bands, to encompass the frequency range of the system.



POWER AMPLIFIER TUNING

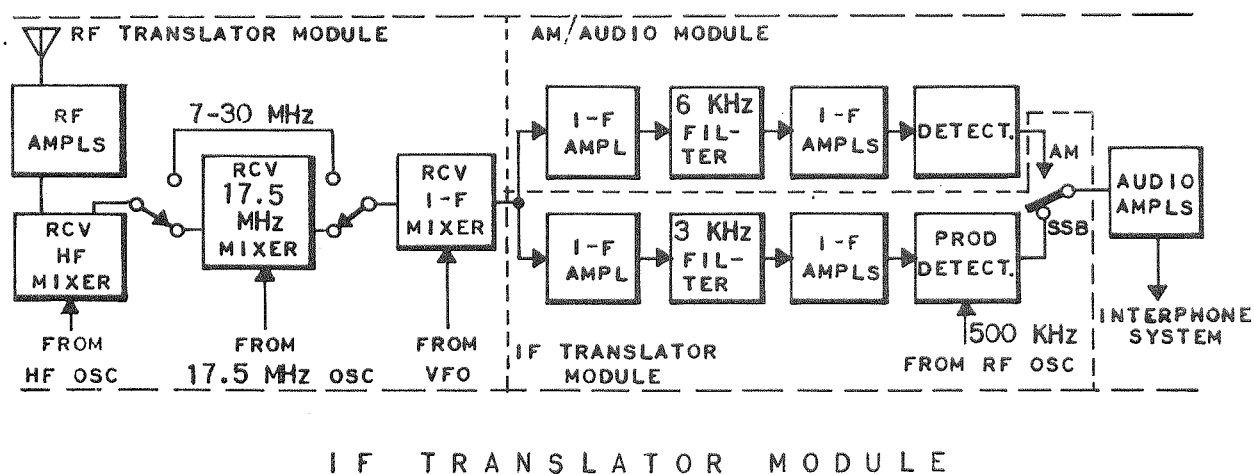
A servo loop, composed of a phase discriminator, a servo amplifier, and an A-C motor, provides fine tuning. The discriminator compares the phase of the RF current in the tuned network to the phase of the PA grid signal voltage and produces a D-C error signal. This error signal is applied to the Electronic Control Amplifier (ECA), converted to an A-C signal, amplified, and applied to an A-C motor. The motor drives a variable inductor, fine tuning the power amplifier output network. This provides resonance in the output of the power amplifier. The output network couples the signal from the power amplifier to the antenna, providing a 1000-ohm load for the power amplifier. The antenna coupler matches the input impedance of the antenna (which varies with frequency) to the output impedance of the transmitter.

## RECEIVING

The received signal is coupled from the antenna to the same RF amplifier used in the transmit mode. The output is applied to the receive mixers. The tuned circuits of the receive mixers are the same circuits that tune the transmit mixers, and the injection signals come from the same oscillators used in the transmit mode, however, the process is now reversed. The RF translator takes a received RF signal and translates it to a 500 KHz IF signal. The input frequency of the receive mixers is the same as the transmit mixer output frequency. Each succeeding mixer therefore produces a new frequency until a 500 KHz IF signal is developed at the receive IF mixer output.

The IF signal is fed to both the IF translator module A3 (SSB IF), and the AM/audio module A9 (AMIF).

In SSB mode, the IF signal is injected into the same IF circuits used in transmitting. The ALC and balanced modulator circuits are not used.



The IF output is fed to a product detector, where a 500 KHz signal from the RF oscillator is mixed with the IF signal (injecting a carrier). The detector produces a difference frequency, which is the audio signal. This signal is supplied to the AM/audio module where it is amplified and sent to the interphone system.

In the AM mode, the IF signal developed by the RF translator is applied to the AMIF strip in the AM/audio module. The signal is then coupled to a mechanical filter. The filter has a bandpass of 6 KHz to pass both upper and lower sidebands. The filter output is amplified by three IF amplifiers. The signal is then applied to a diode detector, amplified, and coupled to the interphone system.

## FREQUENCY GENERATION

Generating the selected operating frequency is accomplished by heterodyning signals from four oscillators.

The RF oscillator, located in the RF oscillator module, generates a constant frequency, 3 MHz signal, which is reduced to 500 KHz by regenerative dividers. This is the first signal in the frequency generating process.

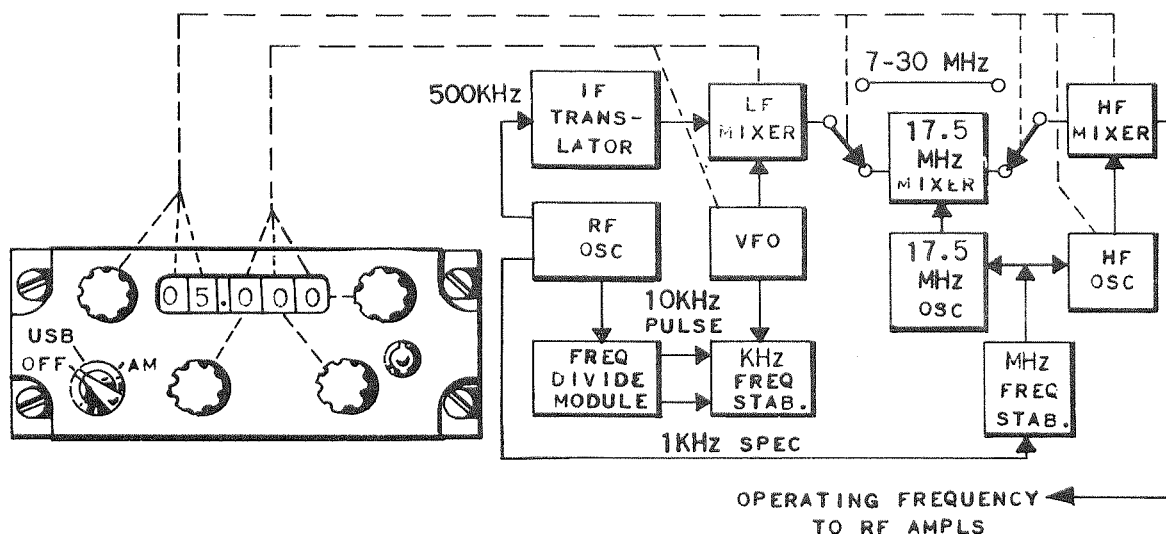
The 17.5 MHz oscillator in the RF translator module also generates only one signal, 17.5 MHz and is used at operating frequencies below 7 MHz.

The two remaining oscillators, also located in the RF translator module, are variable frequency oscillators. The HF oscillator varies from 8.5 through 16 MHz in 500 KHz steps, and is tuned by a band switch motor controlled from the 1 MHz frequency control knob on the control panel. The Variable-Frequency Oscillator (VFO) varies from 3500 through 2501 in 1 KHz steps and is tuned by the autopositioner which is supplied tuning information by the 100 KHz, 10 KHz, and 1 KHz frequency control knobs on the control panel.

When an operating frequency of 5.000 MHz is selected on the control panel, the following signals are generated. A 500 KHz signal from the RF oscillator module is modulated in the IF translator module. From the IF translator, the modulated 500 KHz signal is sent to the RF translator module where it is mixed with the VFO output in the IF mixer. The VFO output in this case is 3.5 MHz (the VFO frequency = 3500 KHz - last three digits in control panel window, 3.5 MHz - .xxx). The mixer output is therefore the difference frequency (3.5 MHz minus 0.5 MHz equals 3 MHz). Since the selected operating frequency is below 7 MHz, the output of the low frequency mixer is applied to the 17.5 MHz mixer. The signal is mixed with the output of the 17.5 MHz oscillator. The difference frequency, 17.5 MHz minus 3 MHz, equals 14.5 MHz. This signal is applied to the HF mixer.

In the HF mixer, the 14.5 MHz is mixed with the output of the HF oscillator. With a control panel frequency setting of 5 MHz the output of the HF oscillator is 9.5 MHz. Combining 9.5 MHz with 14.5 MHz results in a 5 MHz signal, completing the frequency generating process. The selected operating frequency is then





F R E Q U E N C Y   S E L E C T I O N   S C H E M A T I C

generated and is ready to be amplified by RF amplifier, driver, and power amplifier and radiated by the antenna. When the control panel MHz knob setting is 7 or above, the HF oscillator output is 3 MHz plus the MHz knob setting. When the setting is 6 or less, the setting must be subtracted from 14.5 MHz to find the oscillator output.

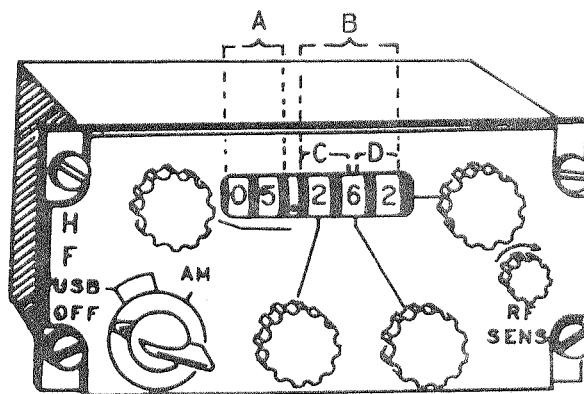
### MECHANICAL TUNING

The MHz frequency selector on the control panel controls a band switch motor in the RF translator. This motor, with the associated ganged switches, changes the LC tuning elements which coarse tune the HF oscillator, mixer, RF amplifier, and driver stages.

The autopositioner (an automatic electrical positioning device) tunes the VFO by mechanically driving a variable inductor in the VFO tank circuit. The mechanical action of the autopositioner also tunes a 2-3 MHz variable IF strip in the output circuit of the IF mixer. Fine tuning for the RF amplifier and driver stages is also provided as the autopositioner varies reactive elements in the tuned circuits of these stages.

An electrical control system is part of each autopositioner. This control consists of 100 KHz, 10 KHz, and 1 KHz control switches in the control panel, and electrically similar seeking switches that are driven by the autopositioner shaft in the RF translator module. The control system is the open circuit seeking type. Whenever the control switches and seeking switches are not set to the same electrical position, the autopositioner is energized and drives.

## FREQUENCY RULES



1. VFO OUTPUT = 3.5 MHz - B
2. VIF = 3.0 MHz - B
3. A12 BAND PASS FILTER SIGNAL = 14.5 MHz + B (NOT USED WHEN A IS 7 OR ABOVE)
4. HF OSCILLATOR OUTPUT = A + 3 MHz (WHEN A IS 7 OR ABOVE)
5. HF OSCILLATOR OUTPUT = 14.5 MHz - A (WHEN A IS 6 OR BELOW)
6. HF OSCILLATOR INPUT =  $\frac{A + 3 \text{ MHz}}{2}$  (WHEN A IS 14 OR ABOVE. OTHERWISE INPUT AND OUTPUT FREQUENCIES ARE EQUAL)
7. 1 KHz SPECTRUM FREQUENCY LAST DIGIT = D (THIS ANSWER MUST BE IN THE RANGE OF 546-555 KHz)
8. DIGIT OSCILLATOR OUTPUT LAST DIGIT = D (THIS ANSWER MUST BE IN THE RANGE OF 296-305 KHz)
9. A4 KEYED OSCILLATOR SPECTRUM CENTER FREQUENCY = 4.05 MHz - C  
OR (4.05 MHz - C) - 0.01 MHz WHEN D IS 6 OR ABOVE
10. A4 1ST MIXER OUTPUT SPECTRUM CENTER FREQUENCY = 0.55 MHz + D OR  
(0.55 MHz - 0.01 MHz) + D WHEN D IS 6 OR ABOVE
11. A4 2ND MIXER OUTPUT SPECTRUM CENTER FREQUENCY = 0.250 MHz (WHEN D IS 5 OR BELOW) OR 260 MHz - 0.01 WHEN D IS 6 OR ABOVE
12. A4 2ND MIXER OUTPUT SPECTRUM CENTER FREQUENCY = 0.250 MHz (WHEN D IS 5 OR BELOW) OR 260 MHz - 0.01 WHEN D IS 6 OR ABOVE

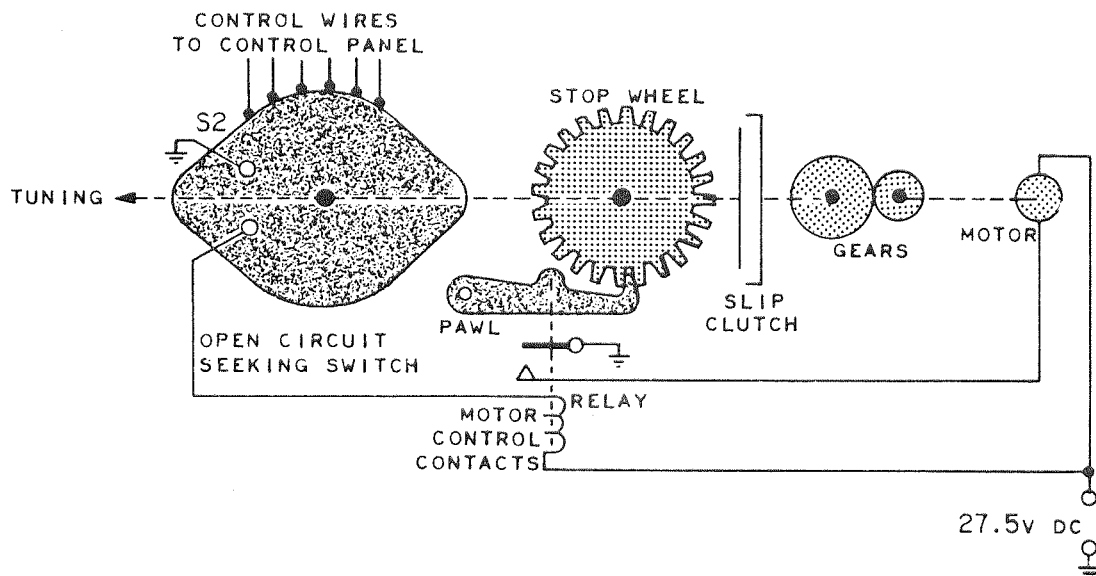
## FREQUENCY SCHEME

## AUTOPOSITIONER CYCLE OF OPERATION

When the frequency selector switch is changed, a ground for the relay is provided by the control system. Energizing the relay lifts the pawl out of the stopwheel notch and closes the ground circuit of the motor. The motor drives the autopo- sitioner shaft and seeking switches. When the seeking switches reach a point corresponding to the new position of the frequency selector switch, the relay cir- cuit is opened and the pawl drops into a stopwheel notch, stopping shaft rotation. The motor circuit opens and the motor coasts to a stop, dissipating kinetic energy in the slip clutch.

The output shaft of the autopo- sitioner is mechanically coupled to a variable induc- tor in the tuned circuit of the VFO. Ten turns of the output shaft tunes the VFO through the 1 MHz frequency range 2501 to 3500 KHz.

There are three seeking switches in the autopo- sitioner system: the 100 KHz, 10 KHz, and 1 KHz seeking switches. For the selected VFO frequency to be set up, all three seeking switches must be properly positioned. Since each of the three switches has ten positions, there are 1000 possible switch combinations, or shaft positions.



## SIMPLIFIED AUTOPOSITIONER SYSTEM

The 100 KHz seeking switch is geared to the output shaft of the autopositioner so that it is moved one position for each rotation (100 KHz) of the output shaft. The 10 KHz seeking switch and stopwheel are coupled to the output shaft. The stop- wheel has ten notches, making each notch position 10 KHz apart in frequency. The 100 KHz and 10 KHz seeking switches are both driven by the same motor.

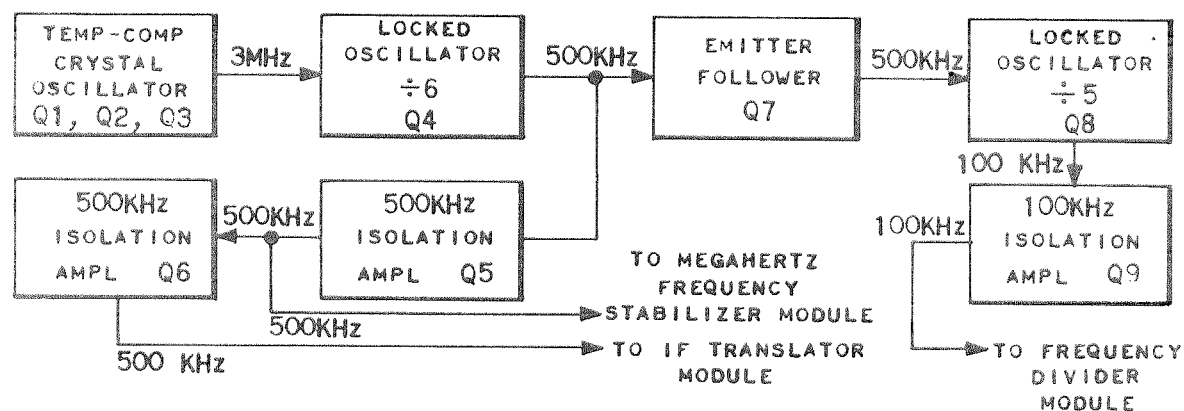
The 1 KHz seeking switch is driven by a separate motor. This motor also drives a gear and cam arrangement which turns the output shaft to ten intermediate positions between each notch on the stopwheel. Each of the ten positions is a 1 KHz step. These ten positions, together with the 100 notch positions furnished by the ten rotations of stop wheel, give the required 1000 positions.

The autopositioner mechanically tunes the VFO to within 2 KHz of the selected operating frequency. In addition, precision resistive dividers which are ganged to the seeking switches in the autopositioner submodule furnish voltage information to the KHz frequency stabilizer module. Within this module, stabilizing circuits will phase lock the VFO at the correct 1 KHz frequency point.

## FREQUENCY STABILIZATION

The extremely high frequency stability required by the transceiver is obtained by using a crystal-controlled master oscillator in the RF oscillator module. This master oscillator is used to stabilize all other oscillators in the frequency generating process.

The oscillators in the RF translator module, which are used to develop operating frequencies, are phase-locked to the master oscillator. This is accomplished by the KHz frequency stabilizer and the MHz frequency stabilizer. The KHz frequency stabilizer locks the VFO to the master oscillator. The 17.5 MHz oscillator and the HF oscillator are controlled by the MHz frequency stabilizer, again phase-locking to the master oscillator which is the frequency standard of the system. The operating frequency is therefore as stable as the crystal oscillator, which is accurate to within 0.8 part per million per month.



RF OSCILLATOR MODULE (A2)  
BLOCK DIAGRAM

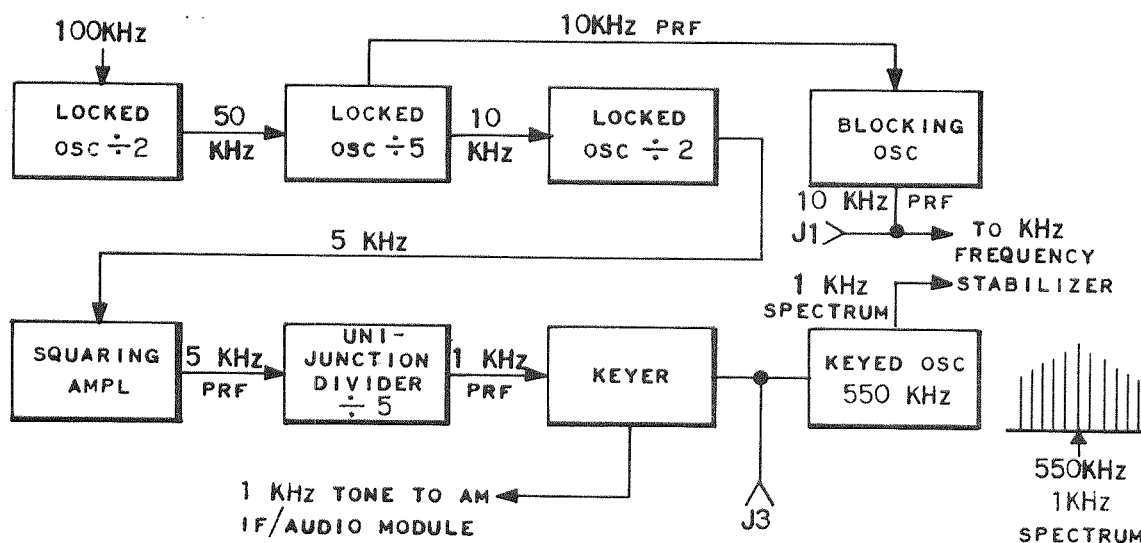
## RF OSCILLATOR MODULE

The master oscillator is a 3 MHz crystal controlled oscillator. The 3 MHz output of the master oscillator is applied to a 500 KHz locked oscillator. Output of the 500 KHz locked oscillator is applied to two 500 KHz isolation amplifiers and through an emitter follower to a 100 KHz locked oscillator. An output is taken from the first 500 KHz amplifier for use by the megahertz frequency stabilizer module. Output of the second 500 KHz amplifier is routed to the IF translator module. The output of the 100 KHz locked oscillator is amplified and applied to the frequency divide module.

## FREQUENCY DIVIDE MODULE

This module transforms the 100 KHz sine wave input into a 10 KHz pulse and a 1 KHz spectrum centered at 550 KHz. These signals are used in the kilohertz frequency stabilizer module to phase lock the VFO to a signal developed from the RF oscillator.

The 10 KHz pulse is developed as follows: The 100 KHz input is reduced to 50 KHz by a locked oscillator. A second locked oscillator divides the 50 KHz by five to produce a 10 KHz output. A portion of this 10 KHz sine wave is differentiated to produce a 10 KHz pulse. This pulse is used to trigger a blocking oscillator whose output provides the 10 KHz pulse which is coupled to the KHz frequency stabilizer.



FREQUENCY DIVIDE MODULE (A1)  
SIMPLIFIED BLOCK DIAGRAM

The remaining 10 KHz sine wave is reduced to 5 KHz by a divide-by-two locked oscillator. This 5 KHz is converted to a square wave in a saturated amplifier. The square wave is used as the input signal to a unijunction transistor divide-by-five stage, producing a 1 KHz pulse. The 1 KHz pulse is used to trigger a monostable multivibrator. The multivibrator output keys an oscillator on and off at 1 KHz rate. The frequency of the oscillator is 550 KHz. The oscillator output is therefore a 1 KHz spectrum-centered at 550 KHz. This spectrum is sent to the kilohertz frequency stabilizer module along with the 10 KHz pulse to be used in stabilizing the RF translator VFO.

The VFO frequency is varied in 1 KHz steps. To keep the VFO frequency as stable as the RF oscillator frequency, it is necessary to reduce the RF oscillator output to a 1 KHz spectrum so that the two signals can be phase-locked.

A spectrum of frequencies is simply many frequencies spaced at equal intervals over a frequency range. A short rectangular wave with a repetition rate of 1 KHz for example, is composed of a series of sine waves (harmonics) with frequencies, each spaced exactly 1 KHz apart, of 2 KHz, 3 KHz, 4 KHz, 5 KHz, etc. The amplitude of these harmonics (spectrum points) decreases as the frequencies get farther away from the fundamental.

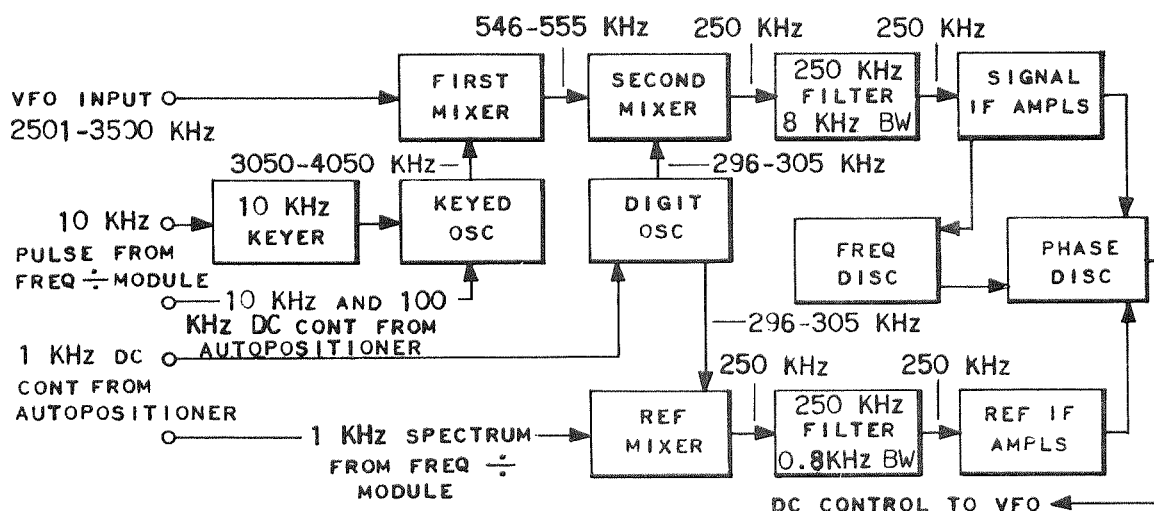
In some instances, it is desirable to use spectrum points that are so far from the fundamental that their amplitude is too small to be useful. Suppose the 1 KHz spectrum points around 550 KHz (550th harmonic) were needed. It is possible to increase the amplitude of the spectrum points around 550 KHz by using a rectangular 1 KHz pulse to key a free-running oscillator tuned to oscillate at approximately 550 KHz. It is not necessary for the free-running frequency of the keyed oscillator to be exactly 550 KHz. The 550th harmonic of the 1 KHz rectangular wave will force the oscillator to lock exactly at 550 KHz. The free-running oscillator frequency does not appear in the spectrum. It merely determines the frequency about which the amplitude of the spectrum points will be greatest. The amplitude of the spectrum points decreases farther from 550 KHz.

It is important to remember that each spectrum frequency (or harmonic) is as stable and exact as the original 1 KHz keying frequency which is developed from the RF oscillator. The frequency of the RF oscillator would have to vary by 3 KHz to produce a 1 Hz change in the 1 KHz keying pulse, which shows that the RF oscillator is the determining factor in the stability of the selected operating frequency.

#### KILOHERTZ FREQUENCY STABILIZER MODULE

A voltage-sensitive capacitor in the tuned circuit of the VFO fine tunes the VFO according to the D-C tuning voltage developed by the kilohertz frequency stabilizer frequency and phase discriminators.

The inputs to the phase discriminator are two 250 KHz IF signals. One is the VFO frequency that has been heterodyned to 250 KHz (signal IF). The other is the RF oscillator frequency that has been heterodyned to 250 KHz (reference IF).



K H z F R E Q U E N C Y S T A B I L I Z E R M O D U L E ( A 4 )  
S I M P L I F I E D B L O C K D I A G R A M

The phase discriminator output is a D-C error signal. This error signal "pulls" the VFO frequency, by tuning the voltage sensitive tuning capacitors in the VFO tuned circuits, until the two signals are phase locked.

To develop the 250 KHz signal, the VFO signal is mixed with a spectrum of frequencies 10 KHz apart which is centered approximately 550 KHz higher in frequency than the VFO. As the VFO is varied from 3500 to 2501 KHz, the center of the 10 KHz spectrum moves from 4050 to 3050 KHz. This 10 KHz spectrum is derived from the 10 KHz pulse, from the frequency divide module, from which a multivibrator produces a rectangular pulse to key an oscillator. The free-running frequency of the keyed oscillator is approximately 550 KHz higher than the VFO. The keyed oscillator is tuned by a D-C voltage applied to a voltage-sensitive capacitor. The tuning voltage is varied by the auto-positioner as the 10 KHz and 10 KHz frequency control knobs on the control panel are varied. A regulated D-C voltage is applied to a precision resistance bridge which serves as the source of tuning voltage for the keyed oscillator. Rotary switches, driven by the autopositioner, select different voltage points on the bridge as the selected operating frequency is varied. 100 D-C voltages are possible to tune the keyed oscillator to any one of 100 possible operating frequencies between 3.05 and 4.05 MHz. The operating frequency of the keyed oscillator can be determined by subtracting the 100 KHz and 10 KHz knob digits on the control panel from 4.05 MHz. ( $KO = 4.05 \text{ MHz} - 0.XX0$ ).

In the example previously used, when an operating frequency of 5,000 MHz is selected on the control panel, the VFO frequency is 3500 KHz and the keyed oscillator spectrum is centered at 4050 KHz.

Mixing the VFO output and the keyed oscillator signals produces a spectrum output from the first mixer containing frequencies spaced 10 KHz apart and centered around 550 KHz. This signal is combined in a second mixer with a signal from a free-running digit oscillator. The digit oscillator output is a single frequency which is varied by the 1 KHz frequency control knob on the control panel.

The digit oscillator is also tuned by a voltage-sensitive capacitor. The tuning voltage is derived from another precision resistive divider in the autopositioner. The oscillator generates ten signals which are 1 KHz apart, from 296 to 305 KHz. The last digit on the control panel always matches the last digit of digit oscillator frequency within its range. With 5.000 MHz selected on the control panel, the digit oscillator output frequency is 300 KHz. The 550 KHz spectrum from the first mixer is combined with this signal in the second mixer. The mixer output is another spectrum of frequencies spaced 10 KHz apart but centered around 250 KHz. This signal is passed through a mechanical filter. The filter has a band pass of 8 KHz to insure that the 250 KHz spectrum point will be passed, and spectrum points 10 KHz away will not pass since the filter bandwidth extends only 4 KHz on each side of 250 KHz.

Variations of the signal IF frequency result from VFO frequency changes. After amplification by IF amplifiers, the 250 KHz signal is supplied to the frequency discriminator. The frequency discriminator output pulls the VFO signal, bringing the signal IF frequency closer to 250 KHz and within the capture range of the phase discriminator. The VFO is pulled to within  $\pm 200$  Hz of the exact frequency by the frequency discriminator.

To provide a reference IF signal for the phase discriminator, the 1 KHz spectrum centered at 550 KHz from the frequency divide module is mixed with the digit oscillator output of 300 KHz in the reference mixer. The mixer output is a 1 KHz spectrum centered around 250 KHz. This signal is passed through a crystal filter which has a bandwidth of 0.8 KHz. The mixer output frequency of 250 KHz is passed, but spectrum points 1 KHz away do not pass since the filter bandwidth extends only 400 Hz on either side of 250 KHz.

The digit oscillator does require stabilization. Any digit oscillator error is cancelled since the oscillator output is common to both the reference IF and the signal IF. However, the digit oscillator must not vary more than  $\pm 200$  Hertz from its proper frequency for the signal IF to function properly. If these limits are exceeded, the frequency discriminator will see the error and correct the VFO erroneously.



There are now two 250 KHz IF signals to be applied to the phase discriminator. These signals are the reference IF developed from the RF oscillator signal and the signal IF developed from the VFO signal. The 250 KHz signal IF is first applied to the frequency discriminator. If a large frequency error exists, the D-C error signal developed by the frequency discriminator tunes the VFO, bringing the signal IF frequency within range of the phase discriminator. The phase discriminator control voltage overrides the frequency discriminator control voltage to phase-lock the VFO to the RF oscillator signal.

The HF oscillator and the 17.5 MHz oscillator also have voltage-sensitive capacitors in their tuned circuits. The tuning voltage for the capacitors comes from a diode detector. The signal into the diode detector is a combination of three 1 MHz IF signals obtained by mixing the oscillator outputs with a 500 KHz spectrum. This spectrum is derived from a 500 KHz signal from the RF oscillator module. The amplitude of the sum of these three 1 MHz signals is proportional to the phase error of the oscillator. Since each oscillator has similar control circuit, stabilization of only the 17.5 MHz oscillator is described here.

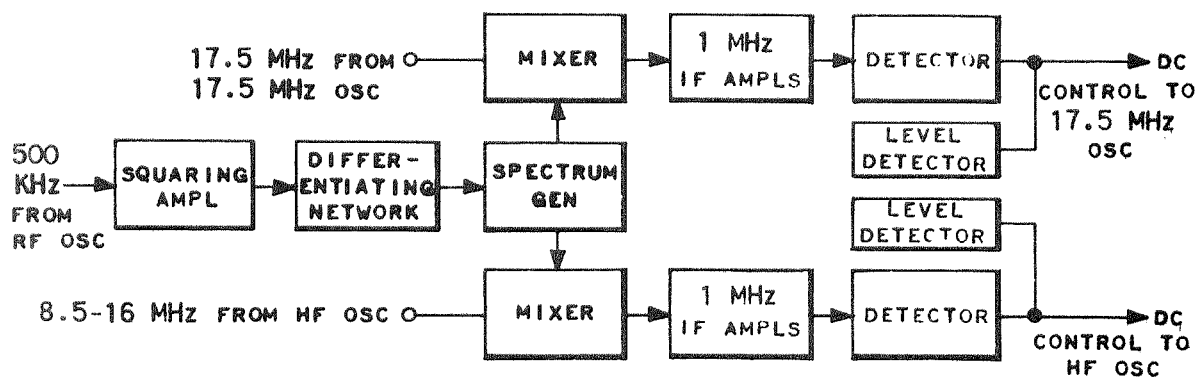
**DEVELOPING THE 500 KHz SPECTRUM.** A square wave is developed from the 500 KHz signal from the RF oscillator. A differentiating network produces a pulse from the square wave. This pulse is used to trigger a spectrum generator. A ringing circuit in the output of the spectrum generator produces a 500 MHz spectrum centered at approximately 7 MHz and extending from 500 KHz to 25 MHz and beyond.

When this spectrum is mixed with the 17.5 MHz oscillator output, the mixer output will contain a 1 MHz signal derived from the 1 MHz spectrum frequency (2nd harmonic) of the input spectrum. Since the spectrum extends from 0.5 to 25 MHz, a second 1 MHz IF signal is obtained by mixing the oscillator frequency (17.5 MHz) with the 16.5 MHz spectrum frequency. The third 1 MHz IF results from mixing the oscillator frequency (17.5 MHz) with the 18.5 MHz spectrum frequency. If the oscillator frequency varies from 17.5 MHz the frequency of the second and third IF signals change by the same amount.

If, for example, the oscillator frequency increases by 200 Hz, mixing the oscillator output with the 16.5 MHz spectrum point will produce an IF signal of 1.0002 MHz. Mixing the oscillator output with the 18.5 MHz spectrum point results in an IF signal of 0.9998 MHz.

Combining the first IF signal (1 MHz) with the two developed by mixing will result in a varying amplitude signal which is somewhat similar to amplitude modulation. The output of the diode detector will therefore vary, causing the frequency of the 17.5 MHz oscillator to vary because the detector output tunes the voltage sensitive capacitor in the oscillator tuned circuit. The oscillator frequency will tend to swing back and forth above and below its lock-in frequency.

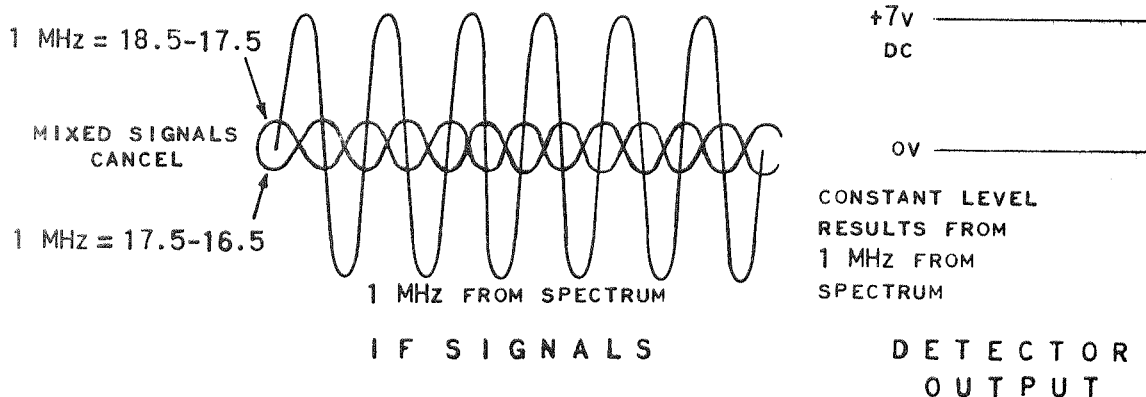
This action will occur regardless of whether the oscillator frequency increases or decreases, since spectrum frequencies above and below the oscillator frequency result in one IF signal increasing in frequency as the other decreases.



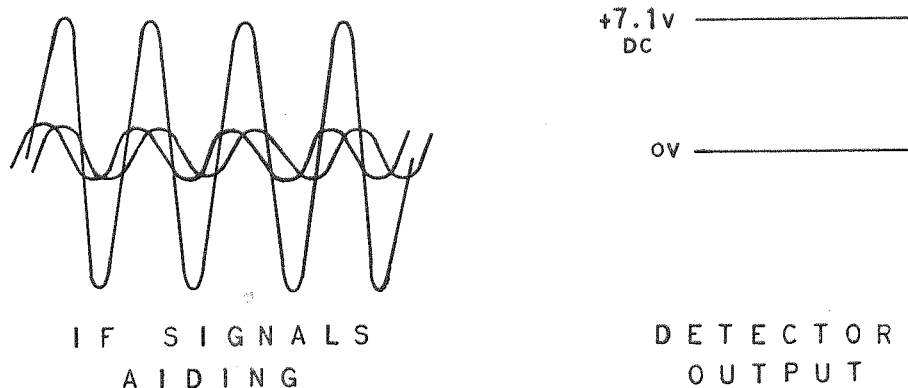
MEGAHERTZ FREQUENCY STABILIZER MODULE  
(A 10) SIMPLIFIED BLOCK DIAGRAM

When the oscillator is on frequency (phase-locked), the three signals are all 1 MHz. The vector sum is therefore a constant-amplitude signal, producing a steady D-C voltage as the detector output, keeping the oscillator tuning and frequency constant. However this example is exaggerated for simplicity. The term "phase-locked" implies the oscillator cannot drift even in degrees.

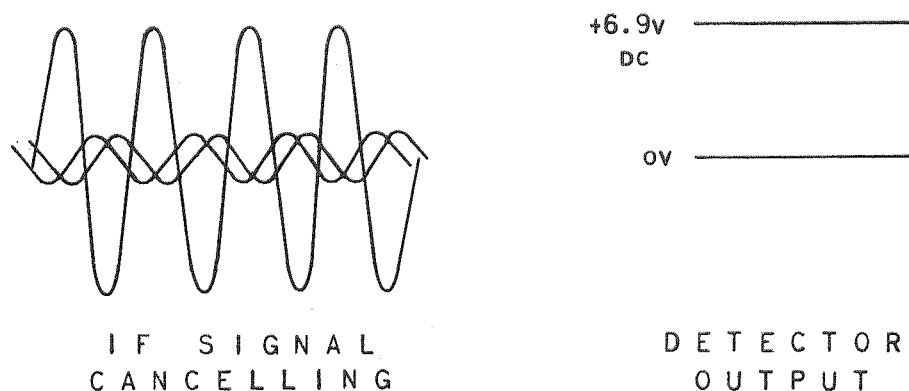
When the 17.5 MHz oscillator is exactly on frequency (phase locked) the three IF signals are as shown with the mixed signals 180 degrees out of phase.



When the oscillator drifts a few degrees in one direction the mixed signals add to the spectrum 1 MHz signal causing the detector output to increase, providing correction to the oscillator. Opposite oscillator drift causes the composite IF signal to reduce in amplitude reducing the detector output providing correction to the oscillator.



A unijunction transistor is placed across the output of the detector. If the detector output exceeds a certain value (this will occur when the oscillator has a very large frequency error), the transistor conducts, shorting the detector output to zero. This permits the detector output to build up again, resulting in a sawtooth recycle voltage at a frequency of approximately 2 KHz until the oscillator locks in.



The recycle voltage insures that the oscillator will sweep across its lock-in point during periods of oscillator unlock.

#### ANTENNA TUNING SYSTEM

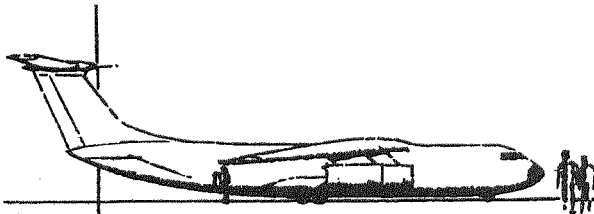
The antenna coupler and accessory unit form an antenna tuning system to automatically tune the tail-cap-type antenna for each operating frequency. The tuning system cancels antenna reactance and matches the impedance of the antenna to the transmitter. The system selects the proper capacitive or inductive reactance necessary to cancel the capacitive or inductive reactance of the antenna. This changes (tunes) the electrical length of the antenna until it appears resistive. When the reactive components have been cancelled, the system then matches (loads) the antenna impedance to the output impedance of



the transmitter. When system No. 1 is keyed, a ground is applied to the coil of a keying relay in the coupler accessory unit No. 1. The relay coil is supplied 28-volt, D-C power through contacts of the deenergized interlock relay in coupler accessory unit No. 2. Contacts of the keying relay supply 28-volt, D-C power to transmit relay No. 1 in the lightning arrestor unit. The transmit relay contacts connect the transmitter RF signal from system No. 1 to the antenna. The relay also completes the coil circuit of the interlock relay in the antenna accessory unit No. 1. Contacts of the interlock relay open the key line of system No. 2 to prevent simultaneous keying of the systems.

The interlock relay contacts also open the coil circuits of the No. 1 and No. 2 receive relays in the lightning arrestor relay unit. The receive relays disconnect the antenna from the receivers and ground both receiver inputs. This prevents the high-level transmitter RF energy from entering the receiver circuits. When the key line ground is removed, the relays of accessory unit No. 1 deenergize and power is applied to the receive relays in the lightning arrestor relay unit. The relays energize to remove the ground from the receivers and connect the antenna. This permits simultaneous use of the receivers. The interlock circuits for system No. 2 operate in a similar manner, using the relays of accessory unit No. 2.





## VHF COMMUNICATION

### GENERAL

Two Very High Frequency (VHF) radio communication systems are used to transmit and receive voice communications. They are used primarily to contact airport control towers for takeoff and landing instructions and for enroute reporting. They are capable of communications over line-of-sight distances only, therefore, range for air-to-ground communications is limited by aircraft altitude.

### AIRCRAFT INSTALLATION

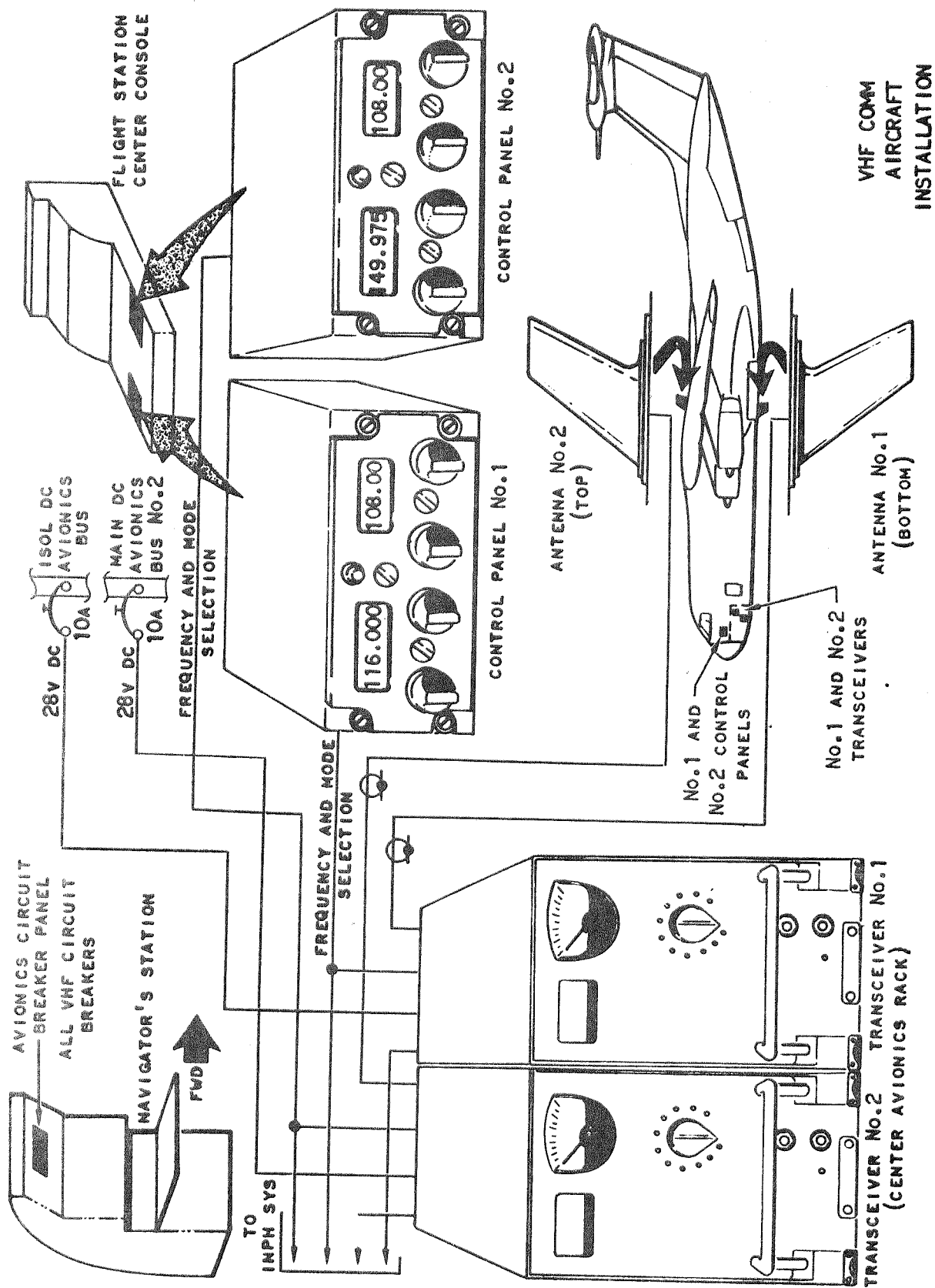
Power requirements and locations are shown on the aircraft installation drawing.

The primary components are as follows:

- |                 |                  |
|-----------------|------------------|
| ● Transceiver   | WILCOX 807       |
| ● Control Panel | WILCOX 97650-100 |
| ● Antenna       | TRANSO 23070-5   |

Interchangeable components are as follows:

- |                 |                      |
|-----------------|----------------------|
| ● Transceiver   | COLLINS 618M-1C      |
| ● Control Panel | COLLINS 313N2        |
| ● Antenna       | COLLINS 522-1135-012 |

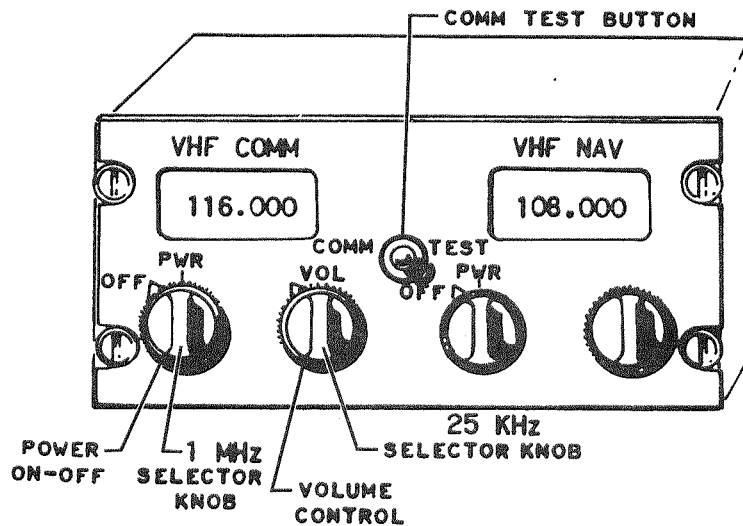


# VHF COMM AIRCRAFT INSTALLATION



## SYSTEM OPERATION (only one system is discussed)

The combination VHF COMM/VHF NAV control panel provides the necessary controls for operation of the VHF communication equipment. These controls are power (PWR) on-off, frequency selection, received audio volume control, and communications (COMM) test.



The power switch activates the system. Frequency selection is made by the 1 MHz and 25 KHz selector knobs. The selected frequency appears in the dial window. The headset volume is adjusted by the volume control. The COMM TEST button, when pressed, allows noise to appear in the headsets. This provides a go-no-go check of the receiver.

With the system activated and the proper frequency selected, transmission is provided by selecting the desired system on the interphone rotary selector and pressing the mic button. Reception is provided by releasing the mic button.

## SPECIFICATIONS

WILCOX 807

CHARACTERISTIC	SPECIFICATION
Power requirements	27.5V DC + 10 percent; - 20 percent
Frequency Range	
Transceiver	116.00 to 149.975 MHz
Number and spacing of channels	
Transceiver	1360 channels 25 KHz apart
Channeling time	Less than 4 seconds
Frequency selection	ARINC (2 out of 5 wire)
Output impedance	52 ohms
Transmitter output power	25 watts, minimum
Type of emission	A3, A0
Type of modulation	Amplitude, high level
Audio input impedance	100 ohms
Sidetone level	100 MW into 200 or 500 ohms at 100 percent modulation
Sensitivity	3 microvolts for 6 db at 1000 Hz 30 percent modulation

# SPECIFICATIONS

## COLLINS 618M-1 ( )

CHARACTERISTIC	SPECIFICATION
Power requirements	27.5 V DC + 10 percent; - 20 percent
Frequency range	
618M-1	118.00 to 135.95 MHz
618M-1A	116.00 to 149.95 MHz
618M-1B	118.00 to 135.975 MHz
618M-1C	116.00 to 149.975 MHz
618M-1D	116.00 to 135.95 MHz
Number and spacing of channels	
618M-1	360 channels 50 KHz apart
618M-1A	680 channels 50 KHz apart
618M-1B	720 channels 25 KHz apart
618M-1C	1360 channels 25 KHz apart
618M-1D	400 channels 50 KHz apart
Channeling time	Less than 4 seconds
Frequency selection	ARINC (2 out of 5 wire)
Output impedance	52 ohms
Transmitter output power	25 watts, minimum

## SPECIFICATIONS (continued)

COLLINS 618M-1 ( )

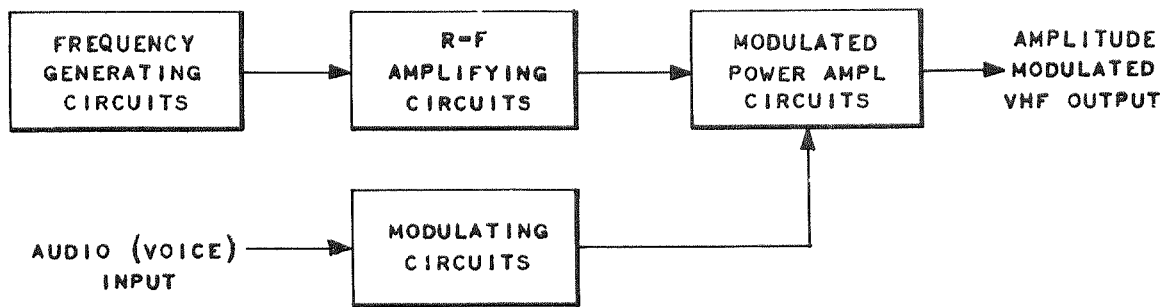
CHARACTERISTIC	SPECIFICATION
Type of emission	A3, A0
Type of modulation	Amplitude, high level
Audio input impedance	150 ohms
Audio output impedance	600 ohms
Sidetone level	100 MW 90 percent modulation
Sensitivity	4 microvolts for 6 db at 1000 Hz

## BLOCK DIAGRAM THEORY OF OPERATION

### TRANSMITTER

A multi-channel VHF transmitter consists of a number of oscillators, mixers, and amplifiers. Combinations of oscillator frequencies provide all possible transmit frequencies. The selected operating frequency signal level from the final mixer stage will be raised by RF amplifiers to the specified power output.

An audio modulating signal is supplied from a microphone through the interphone system to the transmitter modulator circuits. The modulator circuits provide the signal amplification necessary to fully modulate the Radio Frequency (RF) carrier. The modulated RF carrier output is routed through a low pass filter, which suppresses harmonics and prevents transmission of spurious signals, to the antenna for radiation. A portion of the modulated RF output is detected, amplified, and routed to the interphone system as sidetone. The sidetone signal gives the operator an indication of transmitter operating condition.



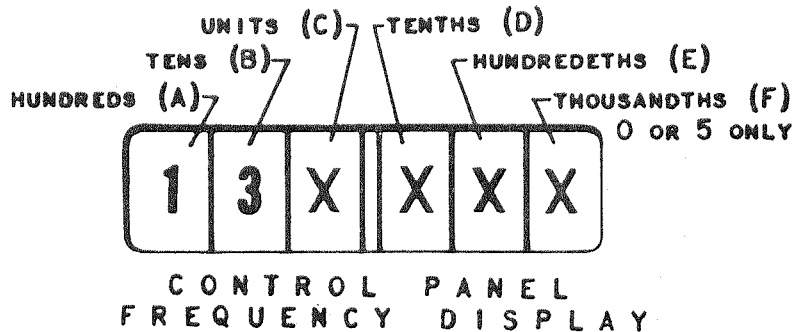
### BASIC TRANSMITTER

There is always definite relationships between the operating frequency, selected at the control panel, and the transmitter oscillators and mixers output frequencies. These relationships can be stated as simple rules. The WILCOX 807 transceiver series will be used as a typical example to demonstrate the frequency selection scheme. The 807 transmitter section uses five crystal-controlled oscillators, a frequency doubler, an injection amplifier, and three mixers in its frequency generating system. Frequency selection is accomplished by switching diodes controlled by the remote control panel using the 2 out of 5 wire grounding scheme per ARINC wiring specifications. The injection and RF amplifier stages are tuned to the correct frequencies by varactors (voltage variable capacitors). Output of the frequency generation system (carrier frequency) is amplified in succession by the RF amplifier, RF exciter amplifier, driver amplifier, and power amplifier. The output of the power amplifier (25 watts minimum) is applied to the antenna. Voice input signals used to modulate the transmitter carrier are amplified to the required level by the modulator amplifier stages and used to modulate the RF carrier at the power amplifier stages. The transmitter output is filtered by the low-pass filter and monitored by the integral sidetone circuit.

The "Transmitter Block Diagram" shows ranges of frequencies for the oscillators and mixers. However, for a particular transmitter channel, only one specific frequency within each range is present at each point in the frequency synthesis scheme.

For transmitter frequency synthesis, frequency selection is accomplished by switching the tens oscillator "on" or "OFF," switching between the two units oscillators (high and low), and by switching crystals in each active units, tenths, and hundredths OSCILLATORS. Crystal switching functions are performed by diodes acting as solid state switches. A total of 35 crystals are used in the transmitter frequency synthesis

The tens oscillator output is 10 MHz in transmit operation. It is "on" when the selected transmit frequency is 11X.XXX (X's denote insignificant digits) or 14X.XXX MHz. It is OFF when the selected frequency is 12X.XXX or 13X.XXX MHz.



Rule 1 - Tens oscillator output equals 10.0 MHz when B is 1 or 4.

Rule 2 - Tens oscillator "OFF" when B is 2 or 3.

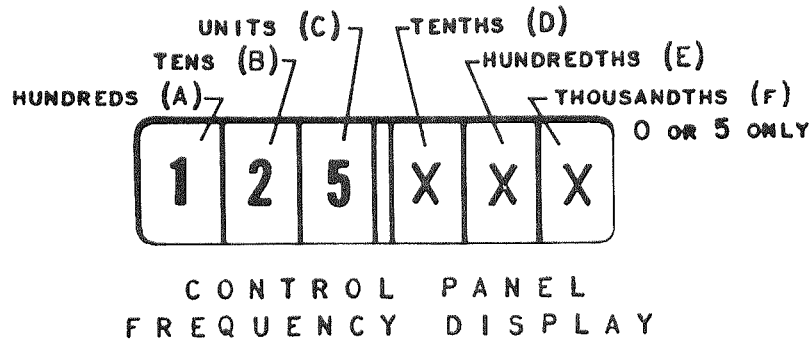
Either the high units or the low units oscillator is selected for operation, dependant upon the frequency selected at the control panel. For selected frequencies between 11X.XXX and 12X.XXX, the low units oscillator is active. Even though either the high or low units oscillator is activated by the tens digit (B), their actual frequency is determined by the units digit (C).

Rule 3 - Low units oscillator output equals  $52.45 \text{ MHz} + C/2$  when "B" is 1 or 2.

Rule 4 - Low units oscillator "OFF" when B is 3 or 4.

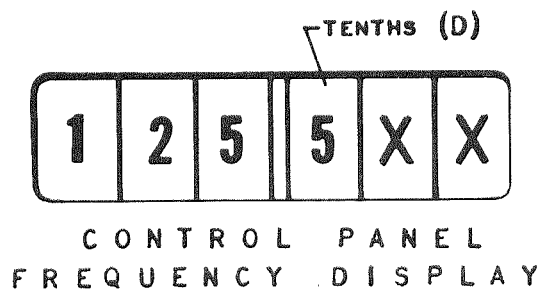
Rule 5 - High units oscillator output equals  $57.45 + C/2$  when "B" is 3 or 4.

Rule 6 - High units oscillator "OFF" when B is 1 or 2.



The active units oscillator frequency is doubled and applied to the first injection mixer where it is mixed with the tens oscillator output. The output of the first injection mixer is applied to a tracked filter, which is varactor tuned to select the difference frequency when "B" is 1, to select the doubled units oscillator frequency when "B" is 2 or 3, and to select the sum frequency when "B" is 4. The frequency selected by the tracked filter is amplified and applied to the third injection mixer.

The tenths oscillator operates at one of ten crystal controlled frequencies over a range of 19.70 to 20.6 MHz in 100 KHz steps. The frequency of this oscillator is controlled by the tenths digit (D).

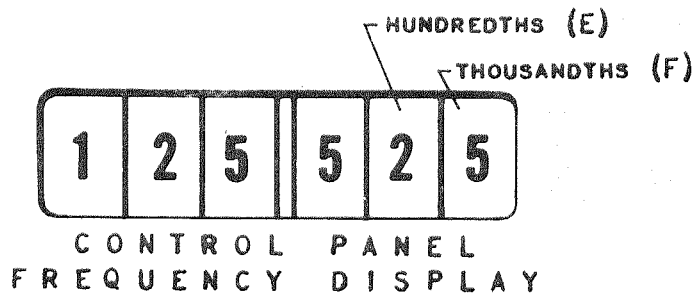


Rule 7 - Tenths oscillator output equals  $19.7 + D$ .

Example:  $19.7 + .5$  equals 20.2 MHz.

The output of the tenths oscillator is applied to the second injection mixer.

The hundredths oscillator operates at one of four crystal controlled frequencies over a range of 4.525 to 4.600 MHz in 25 KHz steps. The frequency is controlled by the last two digits (E hundredths and F thousandths) of the selected operating frequency.



Rule 8 - Hundredths oscillator output equals  $4.6 - EF$

Example:  $4.6 - .025$  equals 4.575 MHz.

The output of the hundredths and tenths oscillators are mixed in the second injection mixer. A varactor controlled tracked filter in the mixer output selects the difference frequency which is applied to the third injection mixer where it is mixed with the combined outputs from the tens and units oscillators. The sum of the two signals is selected by a tracked filter and is within the frequency range of 116.00 to 149.975 MHz (the selected operating frequency). The carrier frequency is then amplified by the RF amplifiers, voice modulated, and transmitted.

#### RECEIVER.

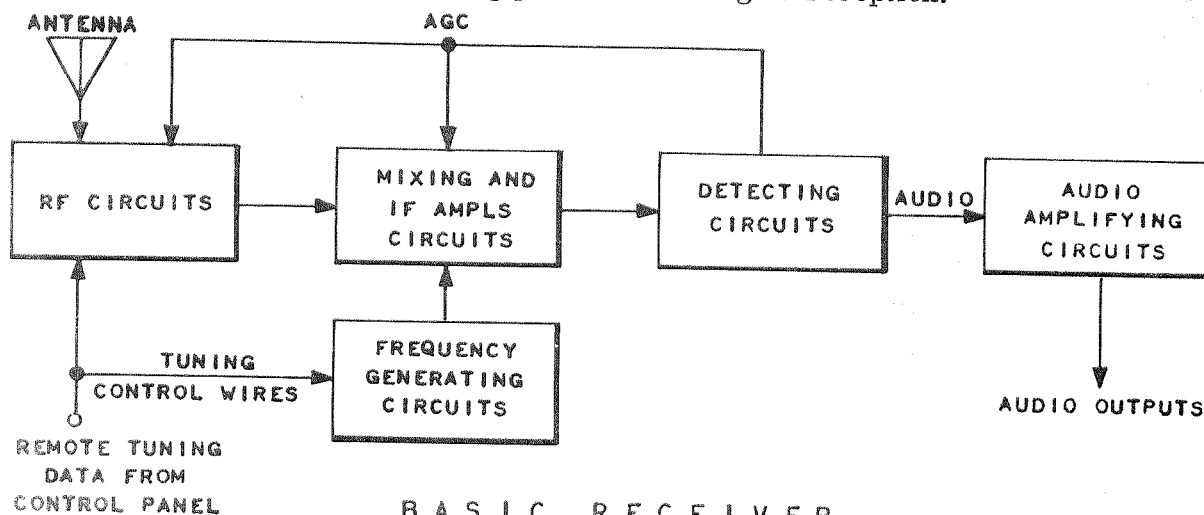
A VHF superhetrodyne receiver must have amplifiers, oscillators, mixers, and a demodulator. The oscillator injection frequency must be offset from the received frequency by an amount equal to the Intermediate Frequency (IF). This offset can be accomplished with one or more oscillators and mixers (single conversion, dual conversion, etc.). Because of this offset, the receiver frequency scheme must differ from the transmitter frequency scheme.

The received signal from the antenna, in a typical multi-channel VHF receiver, is applied to the RF circuits where it is filtered, amplified, and sent to the first mixer. Also into the first mixer is an injection frequency, from a tunable oscillator, that is offset from the received frequency by some amount (IF). Most receivers use two or three frequency conversion stages, thus two or three IF's, for image frequency rejection. The output of each mixer goes through frequency selecting filters and one or more stages of IF amplification. The IF filter and amplification stages determine the receiver bandpass (selectivity). The output of the final IF stage is demodulated and the resulting audio is amplified and routed through the control panel volume control to the interphone and/or headphones or loudspeakers. The output of the final IF stage is also detected to create a D-C voltage, proportional to received signal strength, which is used as degenerative feedback to the RF and IF amplifier





stages, to control overall receiver gain. This signal is called Automatic Gain Control (AGC). Communication receivers generally have quietening (sequelch) circuits to eliminate noise during periods of no signal reception.



### BASIC RECEIVER

As with the transmitter, there is always definite relationships between the operating frequency, selected at the control panel, and the frequency of the receiver's oscillators and mixers. These relationships can also be stated in rules. The receiver portion of the Wilcox 807 transceiver series will be used as a typical example.

The 807 receiver section is a crystal controlled, triple conversion receiver. To achieve triple conversion, it uses six crystal controlled oscillators (a total of 36 crystals are used in the receiver), a frequency doubler, an injection amplifier, and five mixers. The conversion system produces a Variable IF (VIF) of 15.1 to 16.075 MHz, a fixed IF of 3.5 MHz, and a second fixed IF of 455 KHz. Following the conversion circuits are three IF amplifiers, an audio detector, AGC control circuit, sequelch circuit and noise limiter, and a three stage audio amplifier.

For receiver frequency synthesis, the oscillator crystal selection is accomplished by two-out-of-five wire digital binary (ARINC wiring specification) information controlling diodes which act as solid state switches.

Basically the receiver injection frequency generating scheme is the same as the transmitter carrier frequency generating scheme. The tens oscillator is switched "on" or "OFF", either the high or low units oscillator is active, crystals are switched in each of the active units, tenths, and hundredths oscillators. Varactor tuned filters, rather than mechanical tuning capacitors, are used in the RF and injection stages. The rules for the receiver frequency scheme are the same as the rules for the transmitter. However, the actual frequencies involved will be different to account for the required IF offset. With reference to the selected frequency on the control panel we see that

there are the following frequency rules:

Rule 1 - Tens oscillator output equals 9.999 MHz when "B" is 1 or 4.

Rule 2 - Tens oscillator "OFF" when "B" is 2 or 3.

Rule 3 - Low units oscillator output equals 52.45 MHz + C/2 when "B" is 1 or 2.

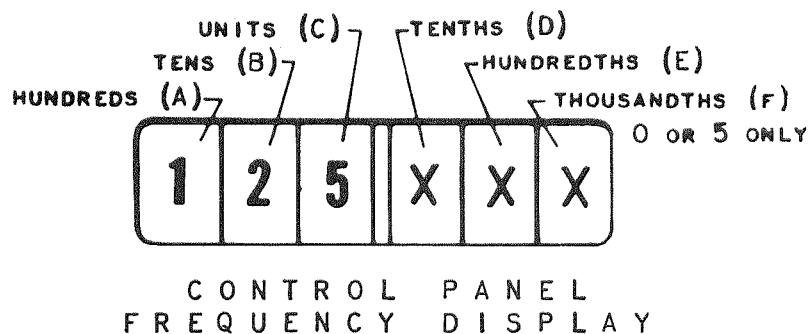
Rule 4 - Low units oscillator "OFF" when "B" is 3 or 4.

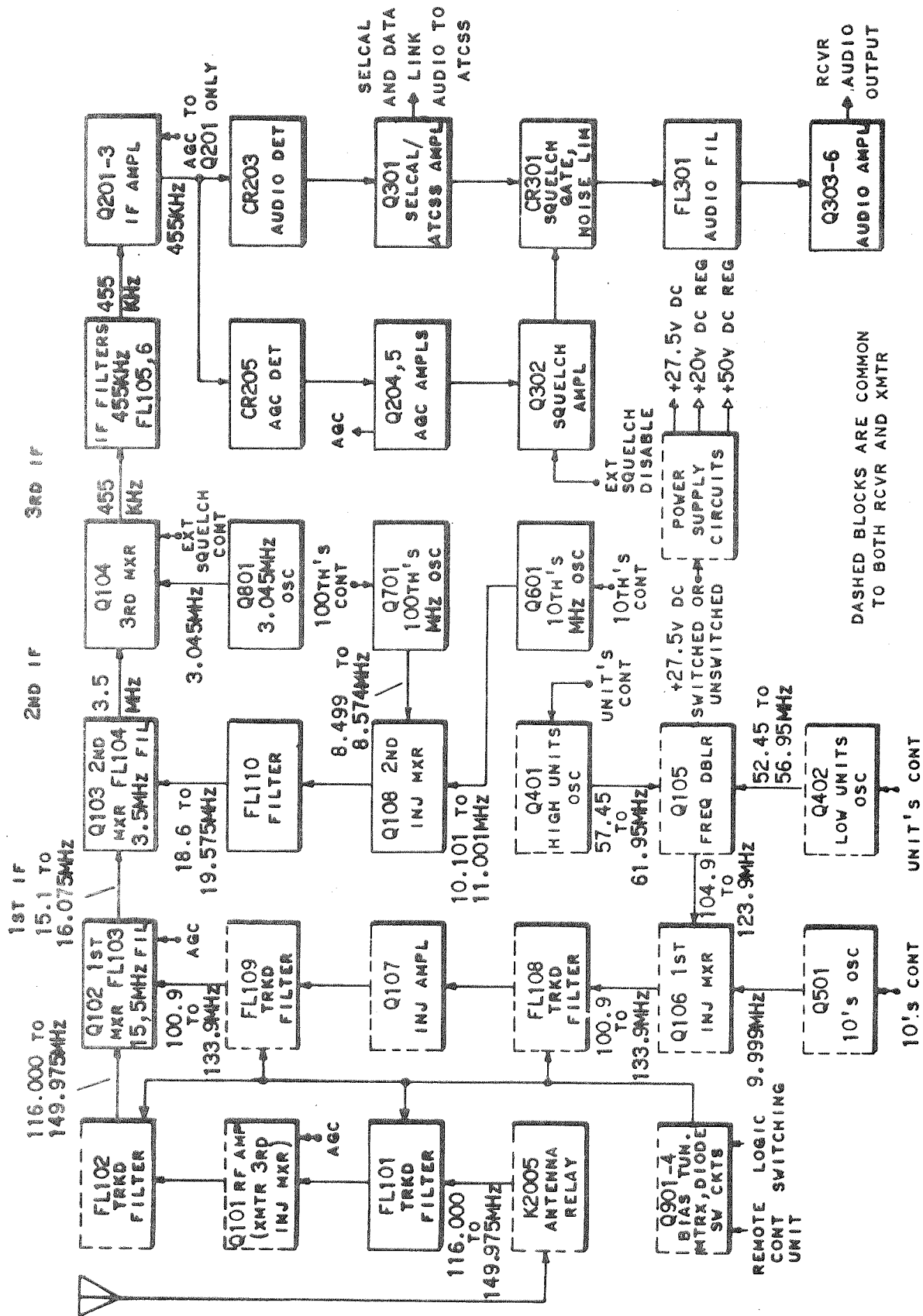
Rule 5 - High units oscillator output equals 57.45 MHz + C/2 when "B" is 3 or 4.

Rule 6 - High units oscillator "OFF" when "B" is 1 or 2.

Rule 7 - Tenths oscillator output equals 10.101 MHz + "D".

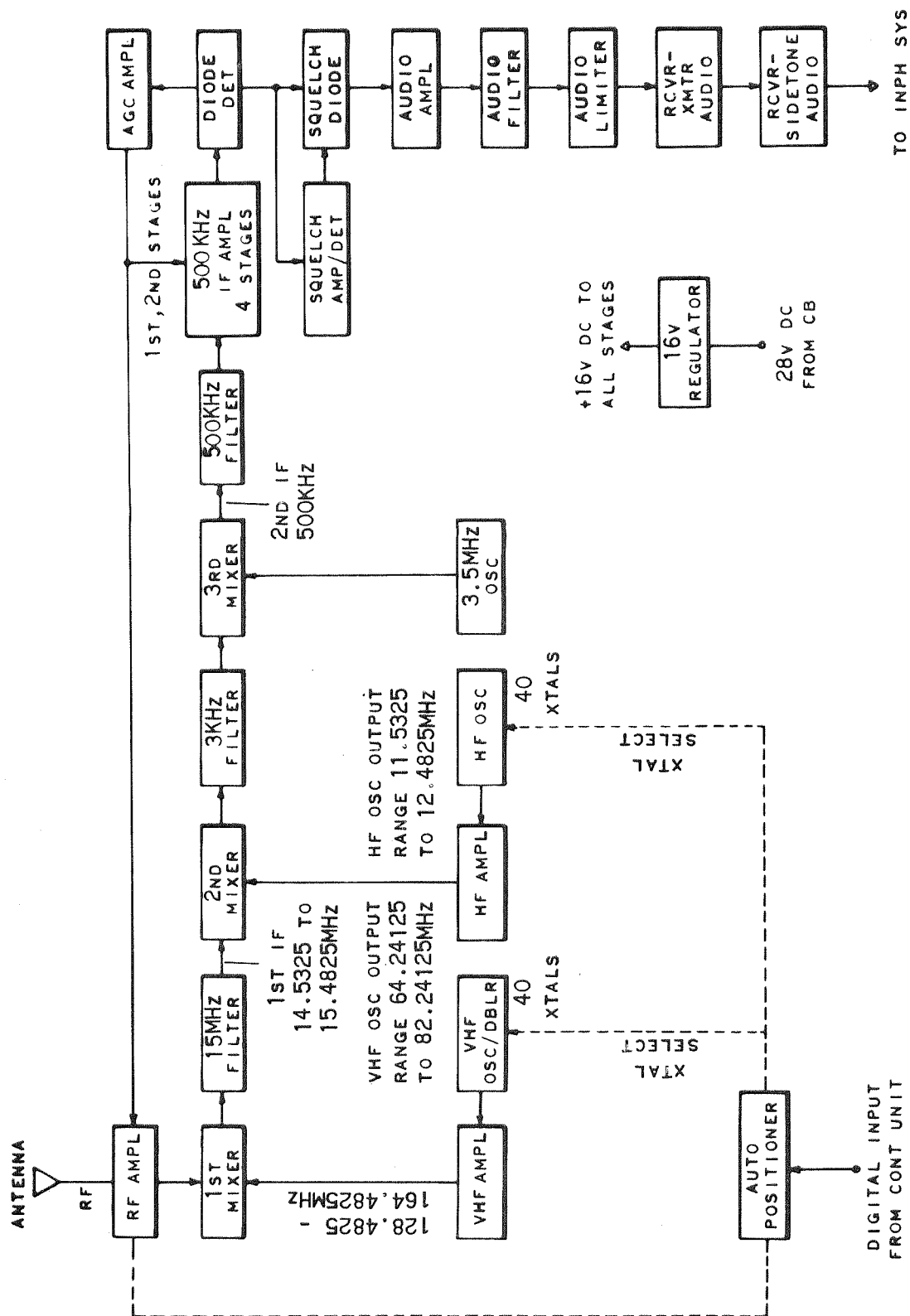
Rule 8 - Hundredths oscillator output equals 8.499 MHz + "EF".

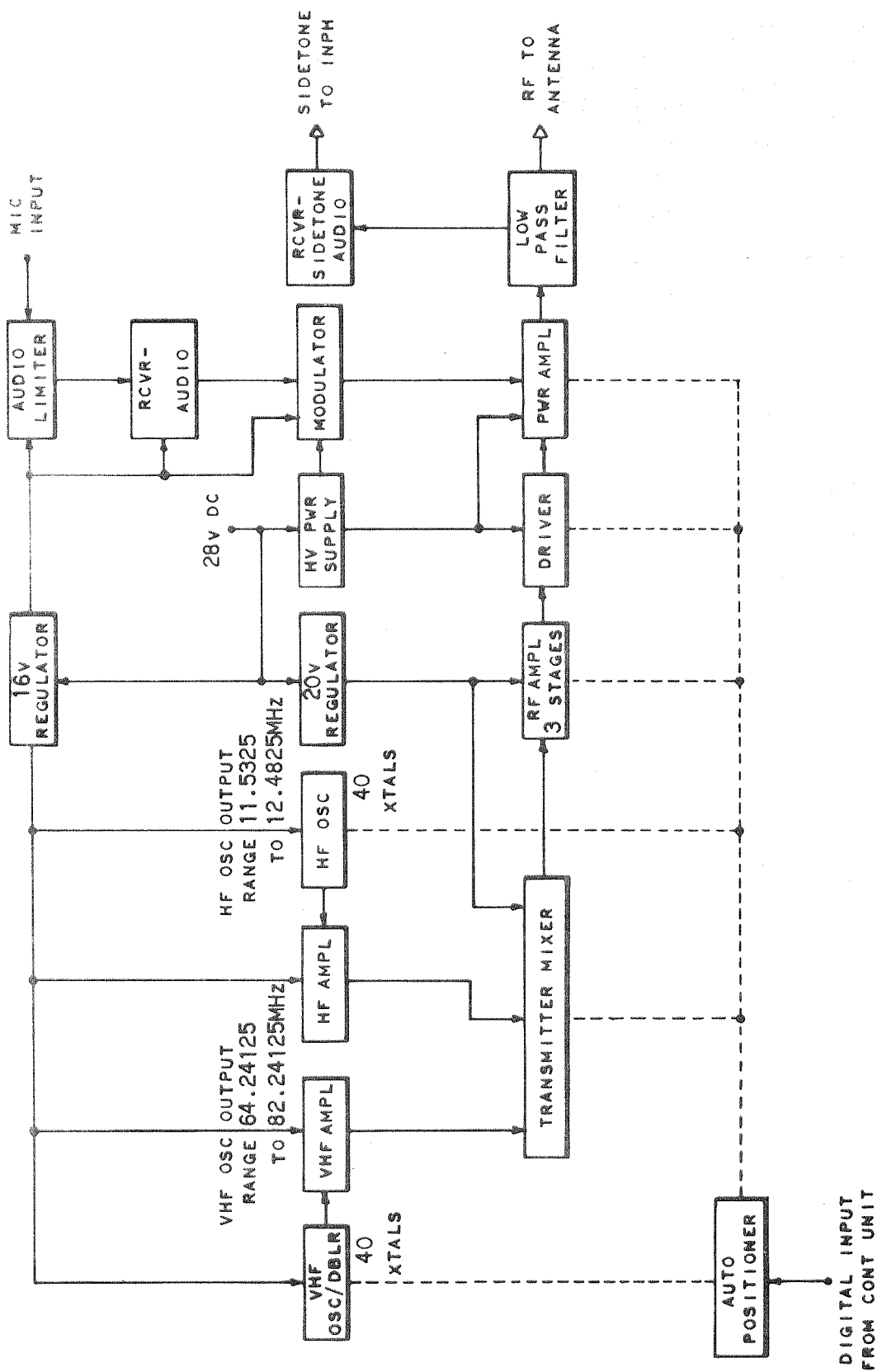




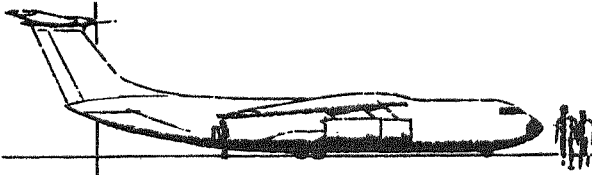
DASHED BLOCKS ARE COMMON  
TO BOTH RCVR AND XMTR

# RECEIVER BLOCK DIAGRAM





COLLINS 618M-1  
VHF TRANSMITTER BLOCK DIAGRAM



## UHF COMMUNICATION SYSTEM

### GENERAL

Two complete and independent systems are installed providing the air crew with UHF radio communications with other aircraft or ground facilities.

These systems, because of their operating frequencies, will be subject to line-of-sight characteristics and the maximum range will depend on the altitude of the aircraft.

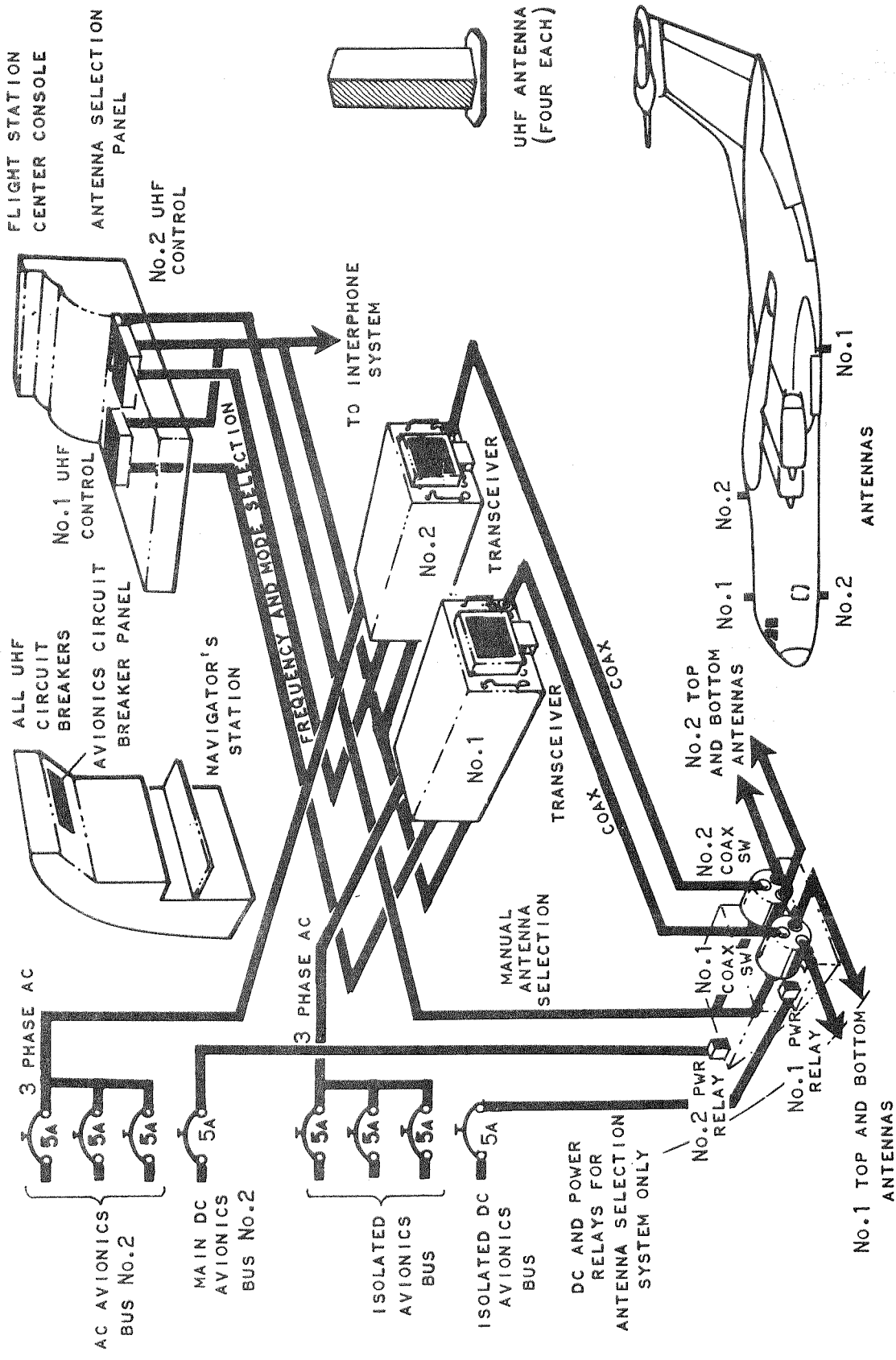
### AIRCRAFT INSTALLATION

The aircraft installation diagram will show locations and general cabling of the systems components. Those components are as follows:

- Transceiver RT-641/ARC-90
- Control Panel C-3894A/ARC-90
- Antenna Coaxial Switch SA-521/A
- Antenna AT-256A/ARC
- Antenna Selection Panel

### SYSTEM OPERATION

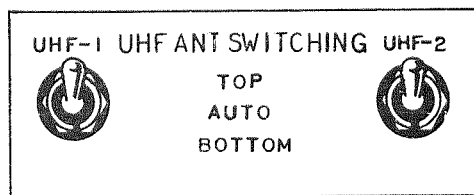
Since each system is independent of the other, operation of only one system will be discussed.



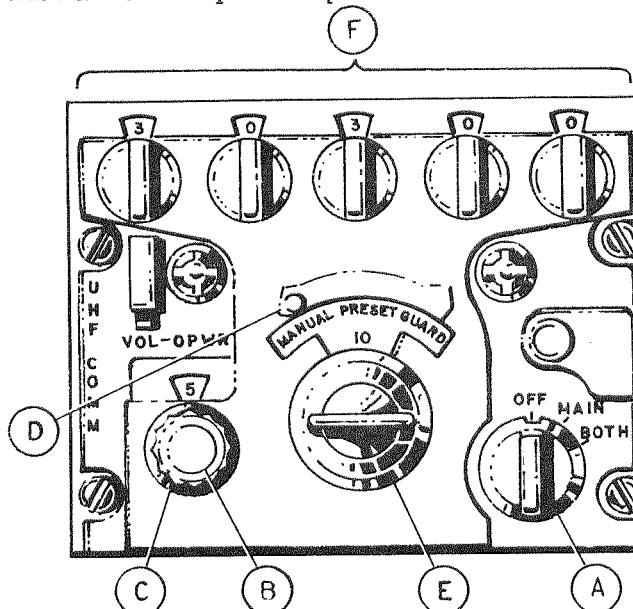
AIRCRAFT INSTALLATION



The three position toggle switches on the antenna selector panel will determine the antenna used for transmission and reception. (Automatic antenna selection has been disabled.)



The control panel provides the transceiver with all the required operational data.



The (A) knob on the control panel, when set to "MAIN", activates the main receiver. Knob (B) adjusts the volume of the receiver audio to the interphone system. To receive and transmit the interphone rotary switch must be set to the UHF system being operated.

The main receiver and transmitter sections of the transceiver are always tuned to the selected frequency. Three modes of frequency selection are possible with knob (D) .

With knob (D) in "MANUAL" position the (F) knobs are activated permitting manual frequency selection. Do not select below 225.00 with the five manual knobs.

The operating frequency appears in the (F) windows. With the (D) knob in "PRESET" position the (F) knobs are inoperative and the (E) knob is in control.

The (E) knob has channel numbers, not operating frequency, appearing in the PRESET window. Twenty channels are available. (The operating frequency of

each channel may be changed from the bottom side of the control panel.) With the (D) knob set to "GUARD" position the main receiver and transmitter are tuned to the "guard" or "emergency" frequency. No channel or frequency display occurs in this mode.

The "BOTH" position of knob (A) activates an additional guard receiver which is permanently tuned to the emergency frequency. Knob (B) also affects the guard receiver volume. The operation of this receiver does not affect or is not affected by any other operation of the control panel. However both receivers are disabled during transmission. Both receivers and the transmitter are disabled during tuning. When the operator changes frequency or channels by any mode the transceiver tuning is started. Transceiver tuning is indicated to the operator by a 400 Hz audio tone in the headsets. When the tuning cycle is completed the tone ceases. Transmission is provided by pressing the inter-phone mic button and speaking into the microphone. Releasing the button provides reception.

NOTE: Knob (C) must be set to position 10 for full transmission power. This knob's function will be discussed in detail in Specifications and Block Diagram Operation sections of this chapter.

With the tone button cover removed, tone transmission is accomplished by pressing the button.

## SPECIFICATIONS

### ARC-90 UHF RADIO COMMUNICATIONS SYSTEM

CHARACTERISTIC	SPECIFICATION
Number of Channels	3500
Number of preset channels	20 on preset drum 1 on guard channel
Frequency accuracy and stability:	
Main receiving system	$\pm 5.6$ KHz
Transmitting system	$\pm 3.6$ KHz
( With external modem)	$\pm 600$ Hz
Guard receiver	$\pm 5.0$ KHz
Channel tuning time	6 seconds (maximum)
Frequency range	225.00 to 399.95 MHz
Channel separation	50 KHz
Carrier output power	30 watts (minimum) internal modem 75 watts (minimum) external modem
Power output control	0 - to 86-db atten- uation in 10 steps
Receiving system bandwidth	44 KHz (minimum)
(Internal modem)	at $\pm 6$ db
(External modem)	10 MHz at $\pm 3$ db
Transmitting system bandwidth	8 KHz (minimum)
(Internal modem)	at $\pm 3$ db
(External modem)	10 MHz at $\pm 3$ db
Main receiver RF gain	25 db (minimum)

SPECIFICATIONS (continued)

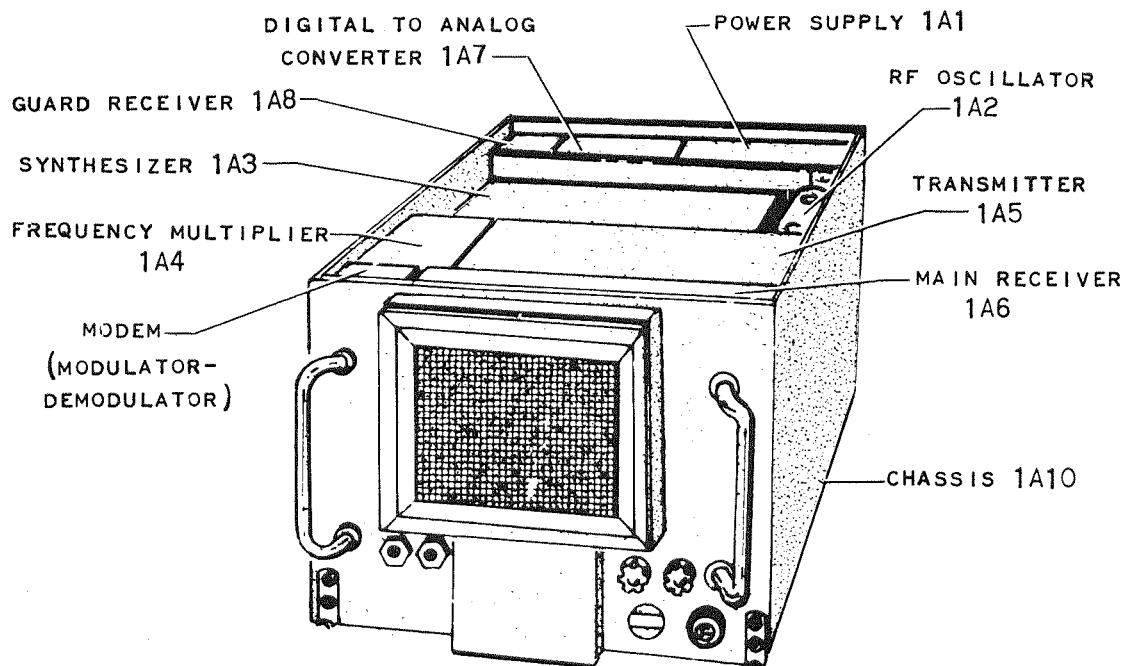
ARC-90 UHF RADIO COMMUNICATIONS SYSTEM

CHARACTERISTIC	SPECIFICATION
Noise figure	6 db
Main receiver sensitivity (for 10-db S+N/N ratio)	3 UV
Guard receiver sensitivity (for 10-db S+N/N ratio)	3 UV
Receiver Audio Output Power	100 MW to a 150 ohm load
Ambient temperature range	-55 degrees C to +71 degrees C
Maximum altitude	70,000 feet
Equipment classification	MIL-E-5400, Class II
Power requirements	3-phase, 115 volts, AC, 400-Hz, 3A per phase
Warm-up time	2 minutes (operational); 15 minutes (full perfor- mance)

## BLOCK DIAGRAM THEORY OF OPERATION

### Modules

The transceiver has ten modules. Below are shown the module numbers and locations in the transceiver.



T R A N S C E I V E R

### MODULE PURPOSES

The chassis is considered a module. The remaining nine modules plug into the chassis for electrical interconnection and mechanical support. The nine plug-in modules are mechanically independent of each other.

The chassis serves also as an air channel allowing forced air cooling of the modules.

The power supply module provides the regulated and unregulated A-C and D-C voltages required by the transceiver and operates on a 3-phase, 400 Hz, 115-volt, 3-amperes-per-phase input supply.

POWER SUPPLY OUTPUT POWER TABLE

VOLTAGE (nominal)	CURRENT (maximum)
450 volts, DC	600 milliamperes (MA)
250 volts, DC	150 MA
130 volts, DC	150 MA
28 volts, DC (regulated)	500 MA
28 volts, DC (unregulated)	3 A (steady) 14 A (surge)
-95 volts, DC	60 MA
26 volts, AC, 400 Hz	0.9 amperes
6.3 volts, AC, 400 Hz (two outputs)	3 amperes (each output)
6.3 volts, AC, 400 Hz	3.75 amperes

The digital-to-analog converter module changes digital data to tuning information for the transmitter, main receiver, and frequency multiplier modules. The digital data is provided by the control panel and is a function of the selected frequency.

The RF oscillator module produces two highly accurate output frequencies of 1.999999 Mhz and 4.136363 MHz. This is accomplished by two temperature compensated crystal oscillators. These two signals are used as standard or reference frequencies for the synthesizer module.

The synthesizer module uses the two RF oscillator reference frequencies and digital frequency selection data from the control panel to provide 3500 usable output frequencies. Each frequency is dependent on control panel frequency selection. These output frequencies are used as input to the frequency multiplier module.

The frequency multiplier module multiplies the output of the synthesizer by a factor of nine and increases the power level for injection to the transmitter or main receiver. The frequency multiplier contains a servomechanism that automatically tunes the module. The servo receives tuning voltage from the digital to analog converter. The tuned frequency of this module is a function

of the frequency selected at the control panel. The frequency multiplier output is approximately one watt and is 60 MHz higher than the selected frequency.

The modem module modulates the transmitter with the interphone mic signal during transmission. This is provided by the modulator section. The demodulator section serves as the main receiver, 60 MHz IF amplifier, and detector. During reception the main receiver signal is amplified, detected and supplied to the interphone system. The transmit output signal, from the modem, is actually a 60 MHz, amplitude modulated subcarrier. The level of this signal is 30 milliwatts modulated 95 percent.

The transmitter module translates or converts the 60 MHz, AM signal from the modem to the selected operating frequency and provides necessary amplification to raise the power to a carrier level of 30 watts minimum. A servomechanism automatically positions the tuned circuits within a maximum time of four seconds. The servomechanism requires tuning information from the digital to analog converter.

The 60 MHz, AM signal from the modem is amplified and mixed with the UHF injection signal from the frequency multiplier. The difference frequency is the operating frequency selected at the control panel.

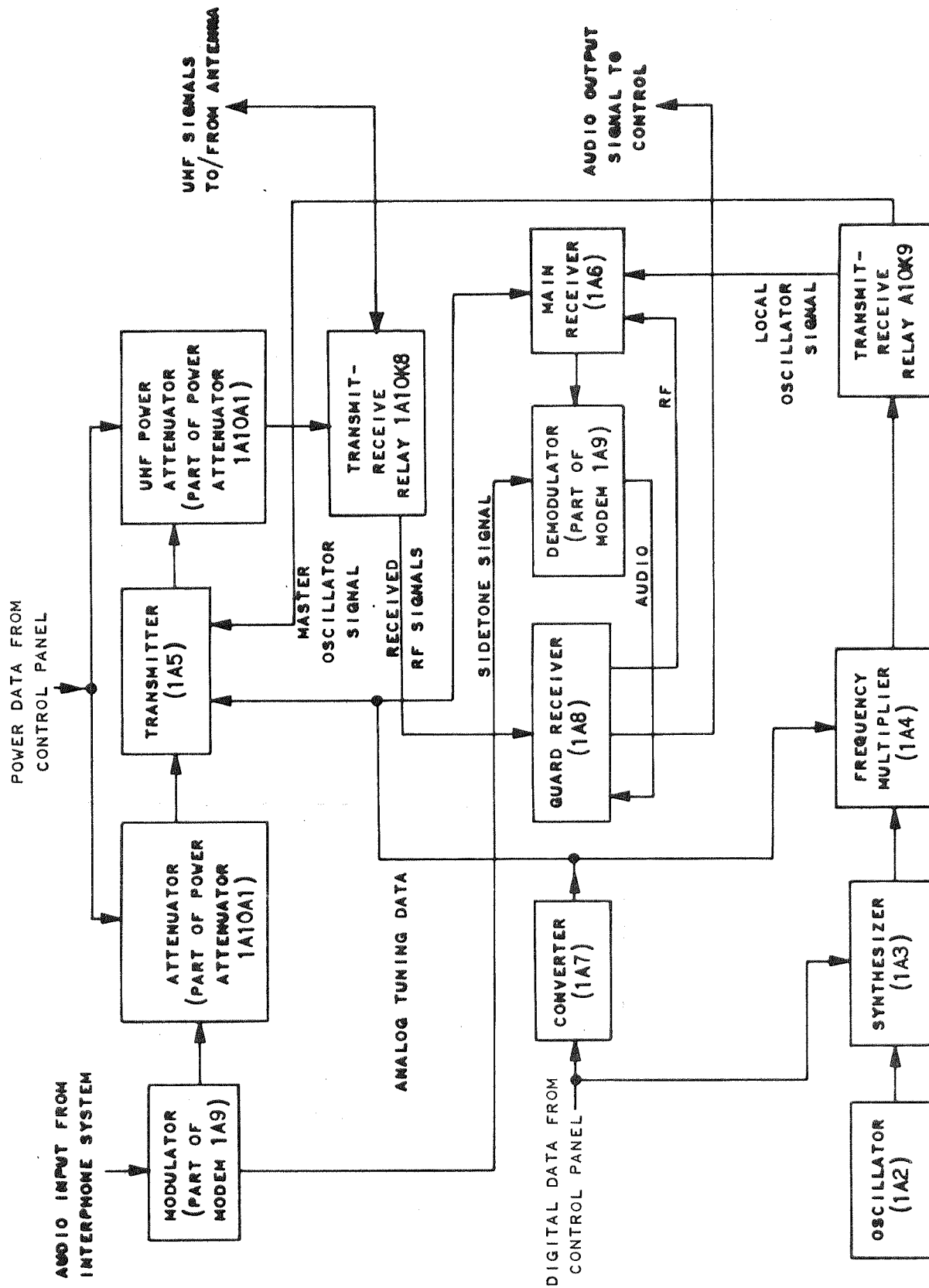
The main receiver module amplifies the received operating frequency and converts it to the 60 MHz IF required by the modem. The IF output to the demodulator portion of the modem is the difference of the received frequency and the output of the frequency multiplier.

A servomechanism automatically tunes the main receiver module to the selected frequency by using tuning information from the digital to analog converter.

The guard receiver module is a complete single-channel receiver for independent reception of emergency communications on one frequency within the 238.00- to 248.00- MHz range. 243 MHz has been chosen as the emergency frequency.

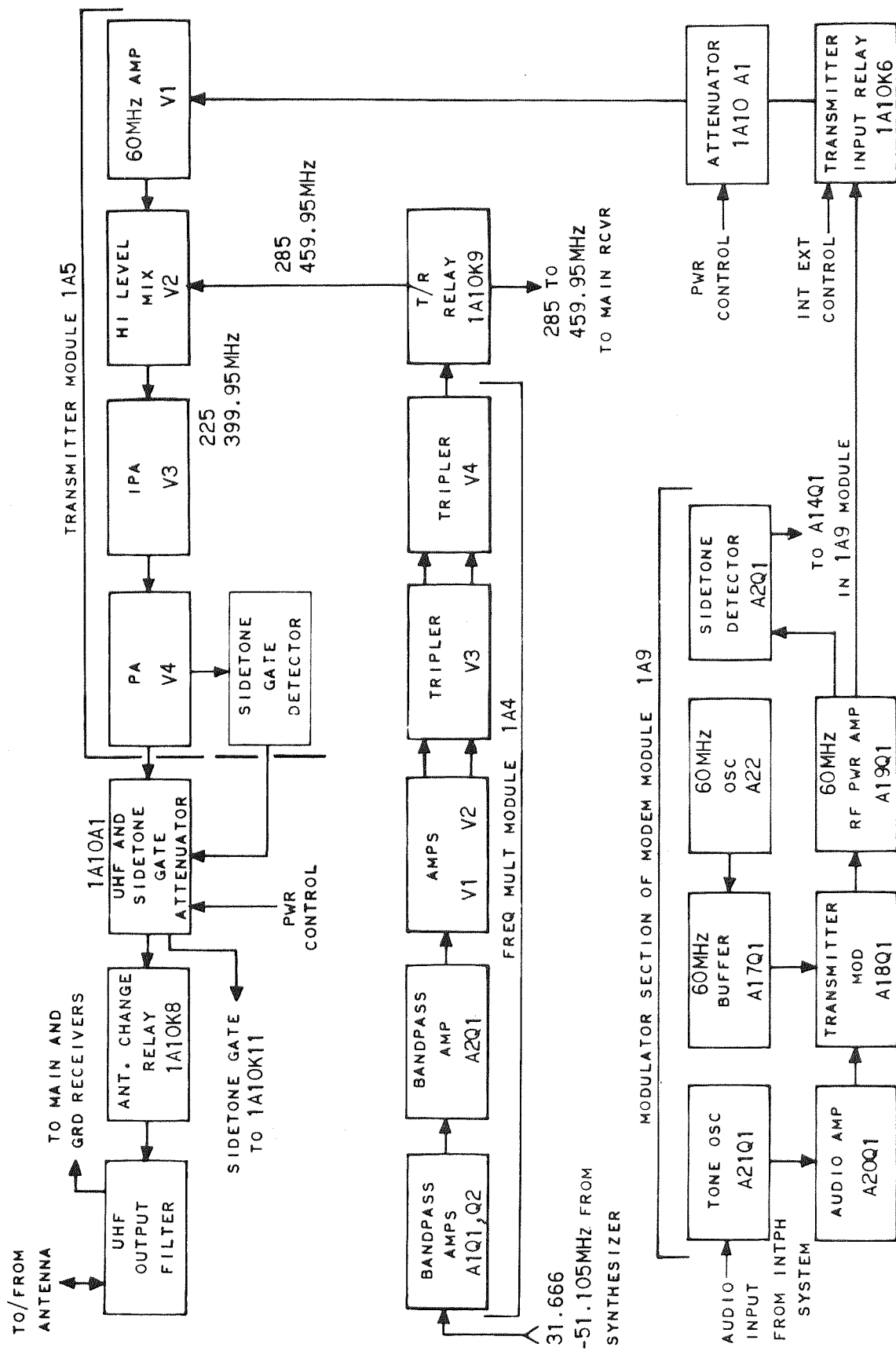
#### TRANSMIT BLOCK DIAGRAM

The interphone mic signal passes through the tone oscillator circuit to the audio amplifier A20Q1. The amplifier audio then modulates a 60 MHz signal from an oscillator providing a 60 MHz, AM signal. This signal is amplified by A19Q1. The modulated signal is detected by A2Q1 providing sidetone audio to receiver audio circuits, which will be heard by the operator. The modulating signal from A19Q1 passes through the deenergized contacts of K6 in the chassis to the transmitter module. However the level of this signal is varied by the control panel "PWR" knob. This knob (switch) has ten power positions which affects the attenuator 1A10A1. However, only positions 8, 9, and 10 affect the attenuator

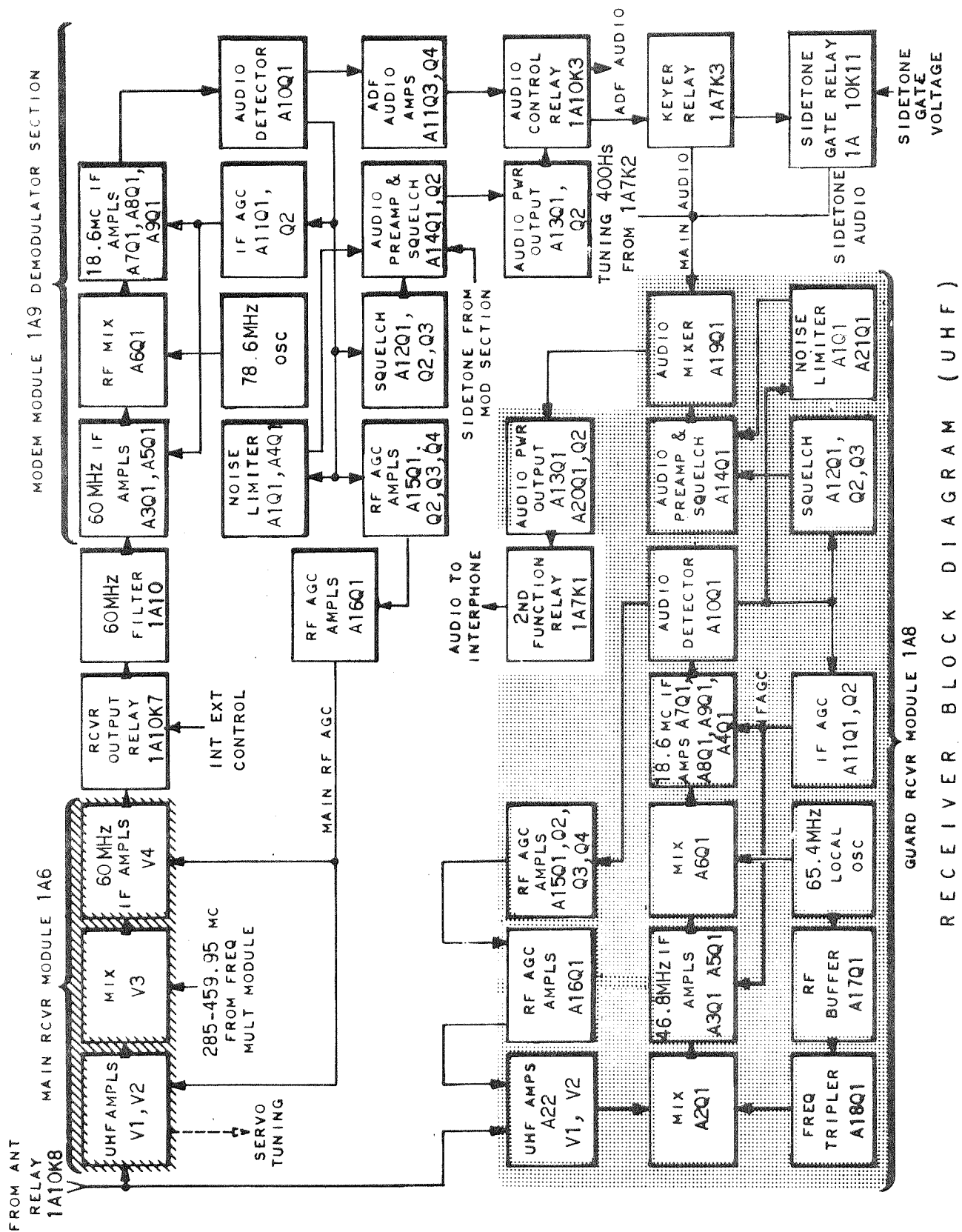


OVERALL BLOCK DIAGRAM





TRANSMIT BLOCK DIAGRAM



at this point. This provides three power levels to the transmitter. The signal is applied to V1 in the transmitter module and is mixed by V2 with the output of the frequency multiplier module 1A4. The frequency multiplier module will be further discussed in the Frequency Generation Block Diagrams section. The output frequency of the 1A4 is always 60 MHz above the selected frequency, thus  $XXX.XX \text{ MHz} + 60.0 \text{ MHz} = 1A4 \text{ output}$ . Example:  $225.00 + 60.0 = 285.00 \text{ MHz}$ .

The output frequency of V2 is the selected frequency and is amplified by the Intermediate Power Amplifier (IPA). The V4 (PA) output is detected by the sidetone gate detector. The output voltage of the detector passes through the attenuator to be adjusted by the "PWR" setting from the control panel. Since the PA signal level is changed to three levels by the "PWR" control the sidetone gate voltage will also have three levels. This is undesirable for the sidetone gate relay 1A10 K11 which must have a relatively constant voltage regardless of "PWR" setting. This is corrected by the attenuator adjustment. The sidetone gate relay (K11) in the chassis (1A10) provides coupling of the sidetone audio signal to the interphone system only if the transmitter power output is sufficient for a given "PWR" setting.

The UHF output of the PA passes through the attenuator for the seven remaining steps of the "PWR" setting, thus there are ten power output levels. The UHF signal then passes through the energized (transmit) contacts of 1A10 K8 antenna relay to the output (low pass) filter. This is the final output to the antenna.

## GUARD RECEIVER

The 243 MHz signal passes from the antenna through the deenergized (receive) 1A10K8 to the guard receiver module. With the function knob on "BOTH" (guard receiver on) the signal is amplified by A22 V1 and V2 and mixed with 196.2 MHz from the tripler A18Q1. The output of A2Q1 (1st IF) is 46.8 MHz from the local oscillator. The output of A6Q1 (2nd IF) is 18.6 MHz and is amplified by four stages. The audio detector A10Q1 demodulates the IF signal. The detected audio from A10Q1 has four signal paths. The audio output level controls the RF AGC circuits which in turn regulate the gain of the RF amplifiers A22 V1 and V2. The audio output level also controls the IF/AGC circuits which in turn regulate the gain of the 1st and 2nd IF amplifier circuits. The audio output signal passes through the noise limiting circuits A1Q1 and A2Q1 to the audio preamplifier A14Q1. This preamplifier is only turned on when the audio output level from A10Q1 is sufficient to operate the squelch circuits A12Q1, Q2, and Q3. With sufficient level the squelch circuits turn on A14Q1 permitting the audio signal to pass. The audio level required to operate the squelch circuits is determined by the GUARD squelch adjustment on the front panel of the transceiver. The guard audio signal passes from A14Q1 to A19Q1. The main audio also passes through A19Q1. A19Q1 is operative also in the "MAIN" position of the control panel function knob. The guard audio signal

is amplified by the audio power output stages, muted during tuning by 1A7K1, and is coupled to the control panel. The volume control varies the audio level to the interphone system.

### MAIN RECEIVER BLOCK DIAGRAM

The operating frequency selected at the control panel passes from the antenna through deenergized (receive) 1A10K8 to the main receiver module. The signal is amplified by V1 and V2 and mixed with the Frequency Multiplier signal. The V3 output (1st IF) is 60 MHz and is amplified by V4. The 1st IF signal is coupled to relay 1A10K7 in the chassis. The 1st IF signal passes through the deenergized contacts of the relay to a 60 MHz filter in the chassis. The output of the filter is connected to the modem module. The 60 MHz IF is amplified by 1A9A3Q1 and mixed with 78.6 MHz. The output of A4Q1 (2nd IF) is 18.6 MHz and is amplified by three stages.

The audio detector A10Q1 demodulates the IF signal. The detected audio from A10Q1 has four signal paths. The audio output level controls the RF/AGC circuits which in turn regulate the gain of the RF amplifiers 1AG V1 and V2. The audio output level also controls the IF AGC circuits which in turn regulate the gain of the 1st and 2nd IF amplifier circuits. The audio output signal passes through the noise limiting circuits A1Q1 and A4Q1. This preamplifier is only turned on when the audio output level from A10Q1 is sufficient to operate the squelch circuits A1ZQ1, Q2, and Q3. With sufficient level the squelch circuits turn on A14Q1 permitting the audio signal to pass. The audio level required to operate the squelch circuits is determined by the MAIN squelch adjustment on the front panel of the transceiver. The main audio signal passes from A14Q1 to A14Q2. The main audio signal is amplified by the audio power output stages A13Q1 and Q2. The main audio signal leaves the modem and is coupled to 1A10K3. The deenergized contacts of K3 couples the main audio through the deenergized (receive) 1A7K3 to the guard receiver audio mixer A19Q1. This line also receives a 400 Hz tone from 1A7K2 during tuning. The tune tone or main audio signal now passes through the same circuits as discussed in the Guard Receiver Block Diagram.

### SIDETONE REVIEW

During transmit the detected sidetone signal passes through the modem audio circuits. The modem output to 1A7K3 is routed to the sidetone gate relay 1A10K11. If the transmitter power output is sufficient for any given "PWR" setting K11 will energize coupling the sidetone audio to the guard receiver audio mixer 1A8A19Q1.

### FREQUENCY GENERATING BLOCK DIAGRAMS

The entire discussion of the main receiver and transmitter was based on

assuming the correct output frequency of the frequency multiplier module. The following discussion will show the frequency multiplier output.

Three modules are required for frequency generation; the RF oscillator module, synthesizer module, and frequency multiplier module.

To simplify this discussion "MANUAL" frequency selection at the control panel will be used.

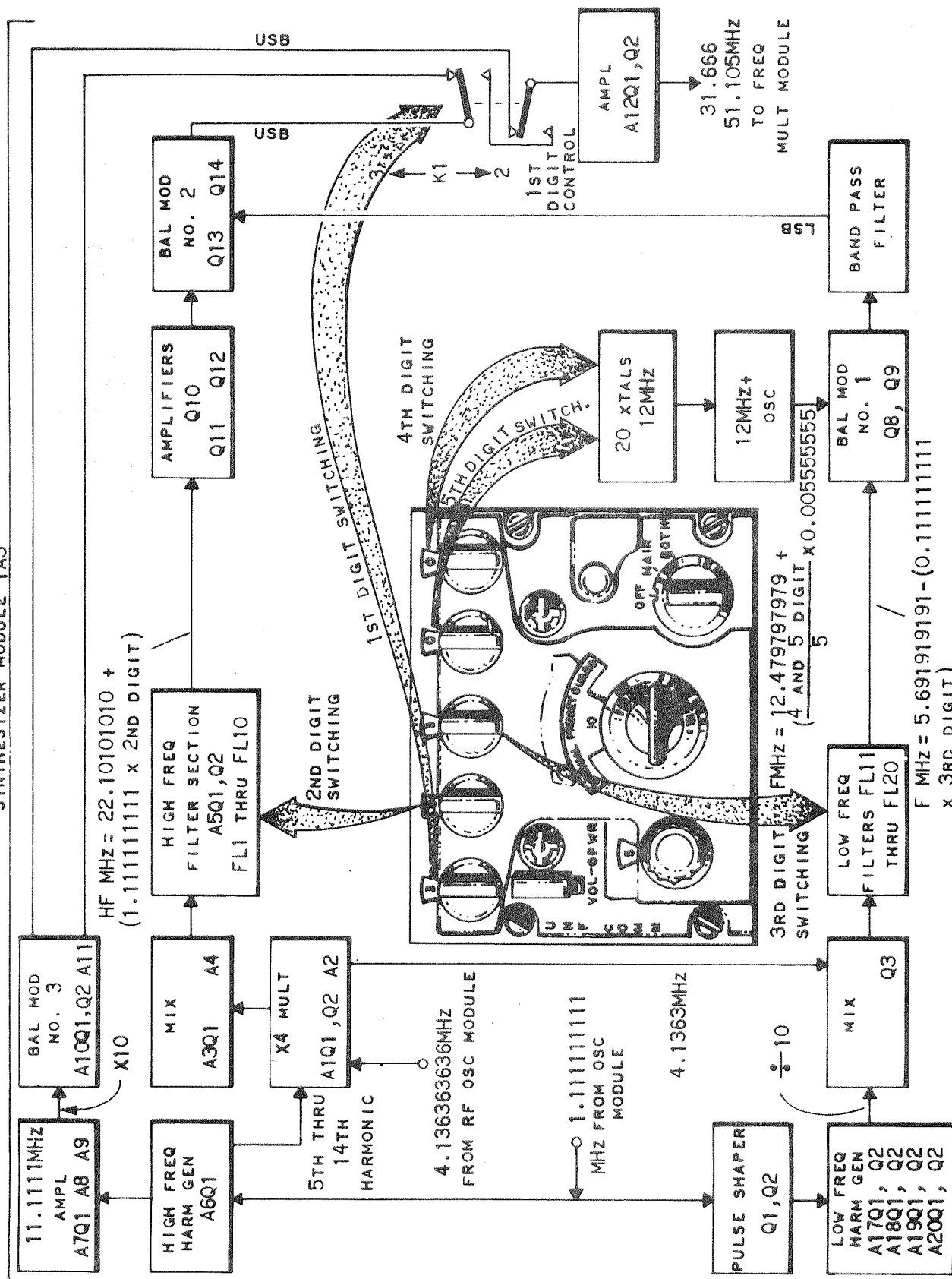
The Frequency Selection Block Diagram shows each knob (digit) controlling switching functions in the high frequency filter section, low frequency filter section, 12 MHz oscillator, and relay 1A3K1.

The 1.11111111 MHz signal from the RF oscillator module provides a 1.11111111 MHz spectrum in the outputs of A4Q1. The 4.136363636 MHz signal from the RF oscillator Module is multiplied by 4 (16.545454544 MHz) and mixed by A3Q1 with the spectrum. This shifts the spectrum up to a usable range. The usable spectrum range is ten simultaneous frequencies in 1.11111111 MHz steps from 22.101010101 MHz to 32.101010101 MHz. The high frequency filter selected by the 2nd digit will pass only one frequency. HF MHz =  $22.101010101 + (1.11111111 \times \text{2nd digit})$ . The 1.11111111 MHz signal is also divided by the low frequency harmonic generator.

This generator is a series of multivibrators producing 0.11111111 MHz square wave to mixer Q3. Since this signal is a square wave its harmonic content will be rich thus a 0.11111111 MHz spectrum. This spectrum mixes with 4.136363636 MHz shifting the spectrum to a usable range. The usable spectrum range from Q3 will be ten simultaneous frequencies in 0.11111111 MHz steps from 4.691919191 MHz to 5.691919191 MHz. The low frequency filter selected by the 3rd digit will pass only one frequency. LF MHz =  $5.691919191 - 6.11111111 \times \text{3rd digit}$ . The selected low frequency modulates the 12 MHz oscillator signal in balanced modulator No. 1. The difference (LSB) frequency is passed by the band pass filter. The 4th and 5th digits together chooses the crystal frequency for the oscillator. FM Hz =  $12.479797979 + \frac{\text{4th and 5th digit} \times 0.005555555}{5}$ .

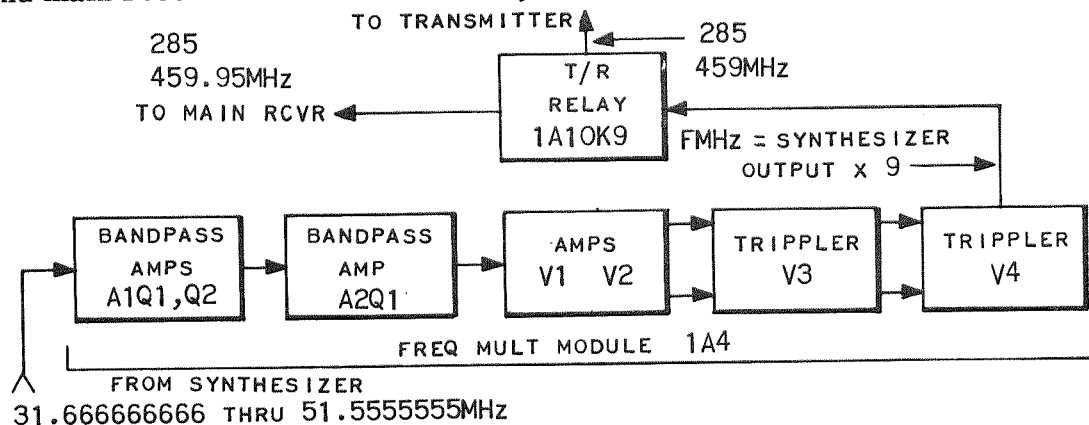
The low frequency signal modulates the amplified high frequency signal in balanced modulator No. 2 and sum frequency (USB) is used. This signal will be amplified by A1ZQ1 and Q2 when the control 1st digit is 2. This signal is coupled to the frequency multiplier module. When the 1st digit is 3 the balanced modulator No. 2 output is coupled to balanced modulator No. 3 where 11.11111111 MHz is added. This signal is then amplified and sent to the frequency multiplier module.

"PRESET" or "GUARD" frequency selection provides the same type digital data for the synthesizer module. The frequency multiplier module amplifies and multiplies the synthesizer output signal by 9 providing the transmitter module



FREQUENCY SELECTION

and main receiver module with the injection frequency they require.



## TUNING SYSTEM

The transmitter, frequency multiplier and main receiver modules must be tuned to the proper frequencies according to the control panel frequency selection. These modules tune in 100 KHz steps. (50 KHz tuning is not necessary.) The digital-to-analog converter module changes the control panel digital data to 400 Hz output voltages. Four output circuits of the converter couple these voltages to the three tunable modules.

The control panel 1st digit (3) operates the converter 1st digit relay providing 28.75 volts, AC to the first digit inputs of the three tunable modules. When the 1st digit is 2, no voltage is provided. The control box 2nd digit (0 - 9) operates a mechanical digit seeker in the converter. The seeker positions a voltage selector switch (10 positions) providing ten possible voltages (OV thru 51.75 VAC) to the 2nd digit inputs of the three tunable modules. The 3rd and 4th digit seekers and selectors provide the same ten voltages to the 3rd and 4th digit inputs to the tunable modules.

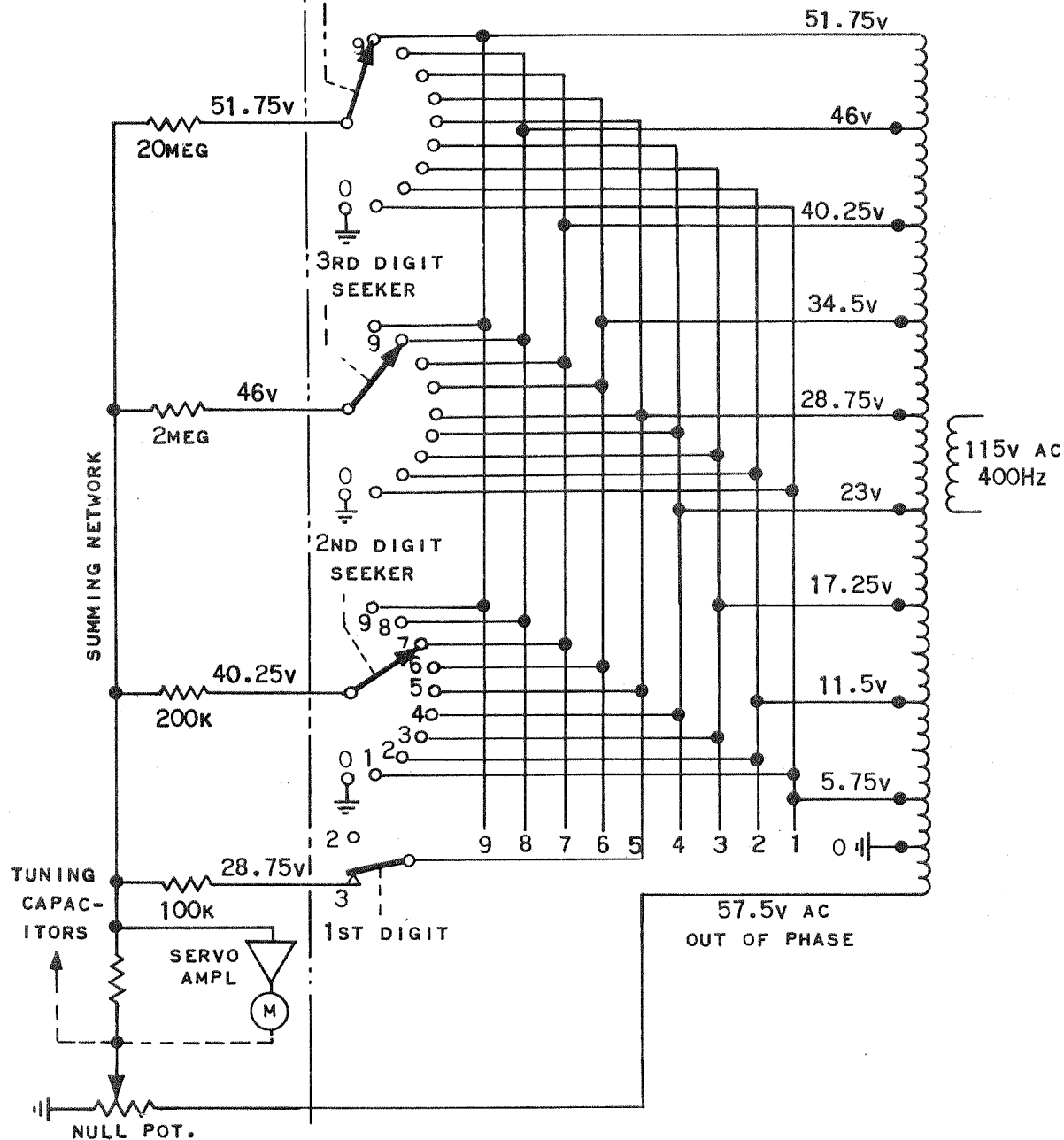
The four voltage inputs (for a given control box selection) are summed in summing resistor networks in each tunable module. The summed voltage to the servo amplifier has 2000 possible voltages. However, the mechanical tuning limits of the tuned modules permit only 1750 tuning points corresponding to 225 to 399.9 MHz. The servo will drive in the proper direction until the null "pot" is positioned to the proper point providing an out-of-phase voltage amplitude cancelling the summing network voltage. The servo motor also positions the tuning components in the module.

# DIGITAL TO ANALOG CONVERTER MODULE 378.9(EXAMPLE)

ONE OF THREE

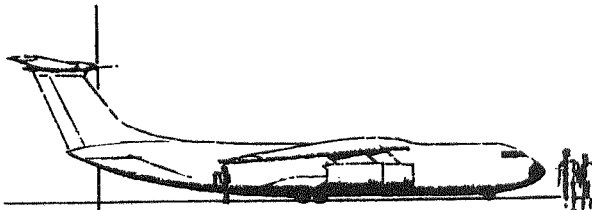
TUNABLE  
MODULES

4TH DIGIT  
SEEKER



TUNING SYSTEM

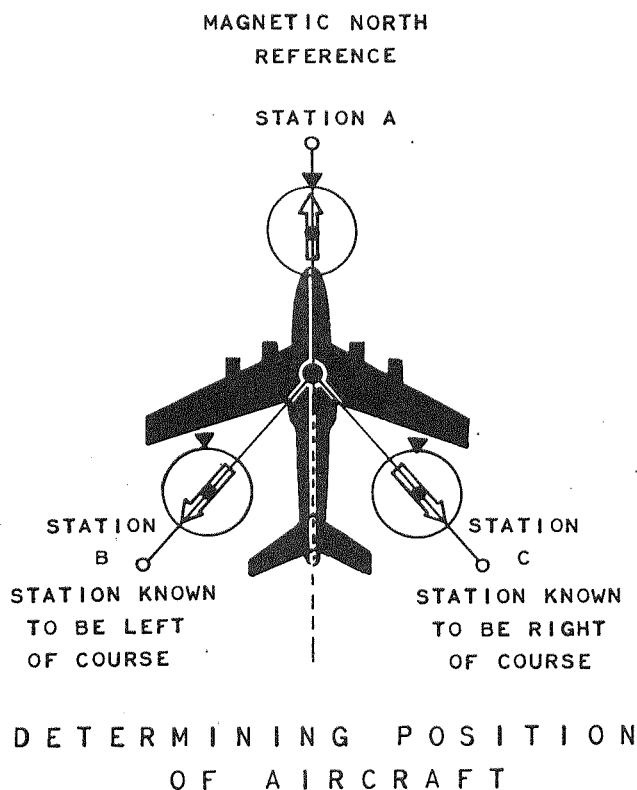


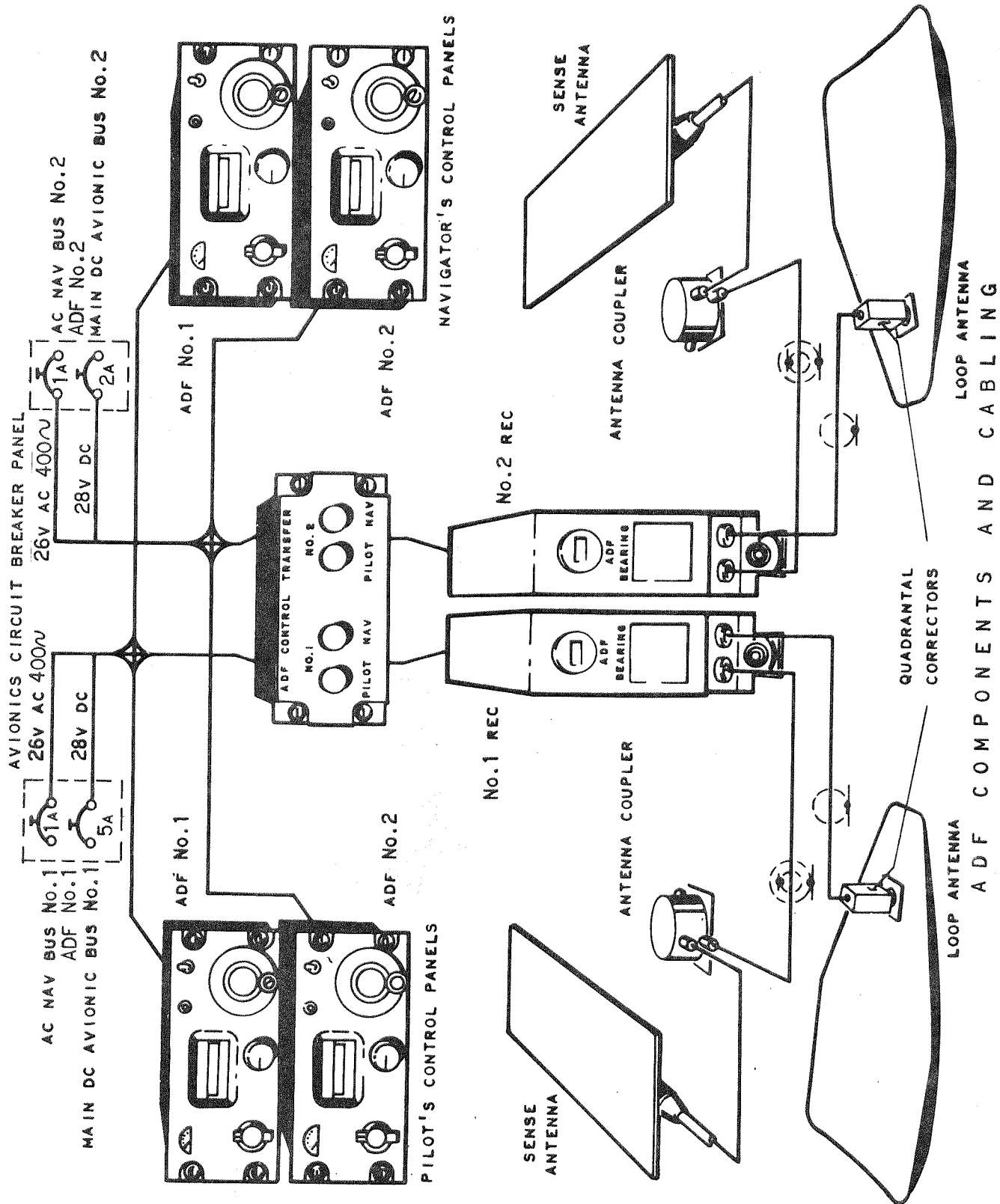


## RADIO COMPASS SYSTEM

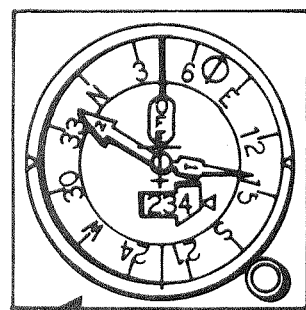
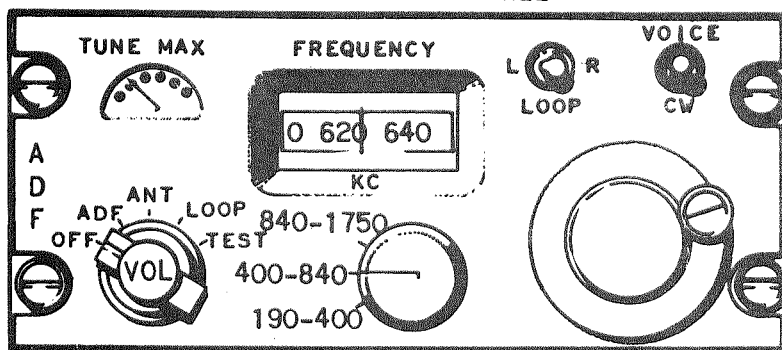
### GENERAL

Two complete and independent Automatic Direction Finder (ADF) systems are installed on the StarLifter. Each system provides automatic or manual radio direction finding as an aid to navigation. During radio compass homing the system supplies continuous visual relative-bearing to a selected ground radio station with respect to the aircraft heading. The position of the aircraft can also be determined by triangulation. Each system may also be used as a standard broadcast receiver.





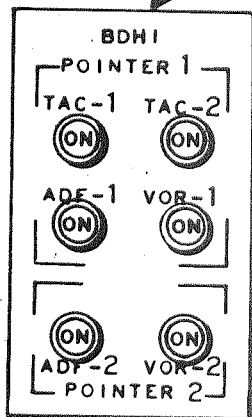
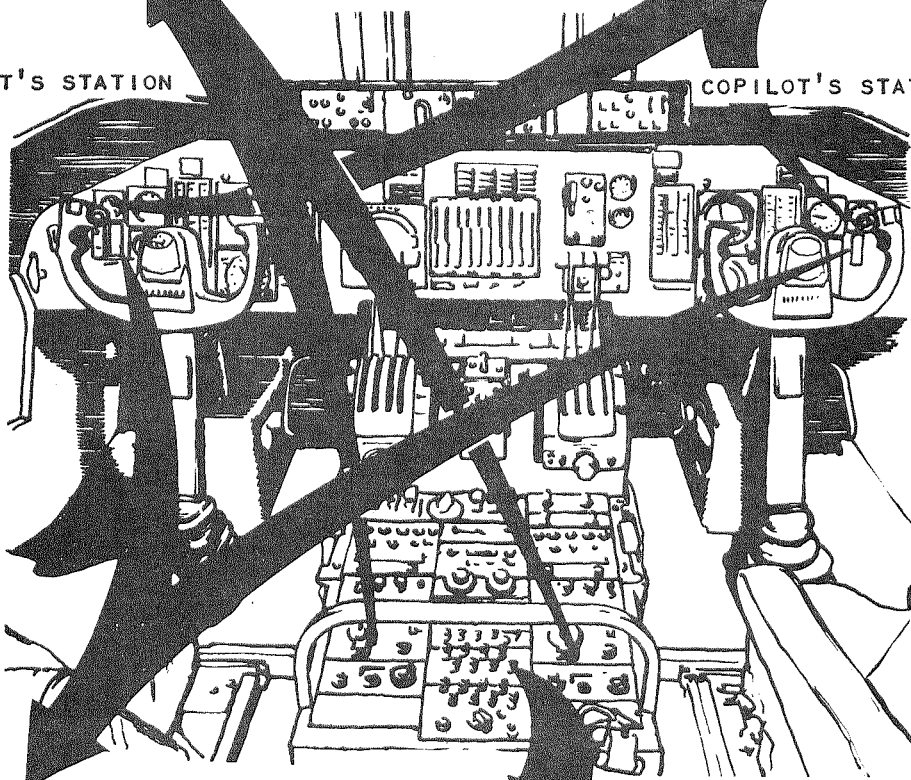
# ADF CONTROL PANEL



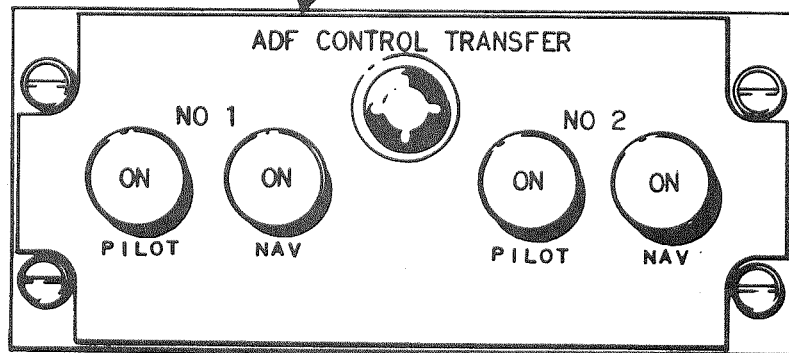
BDHI

PILOT'S STATION

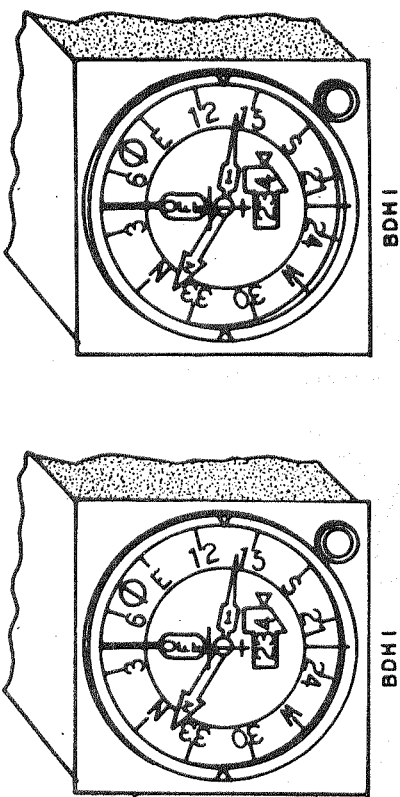
COPILOT'S STATION



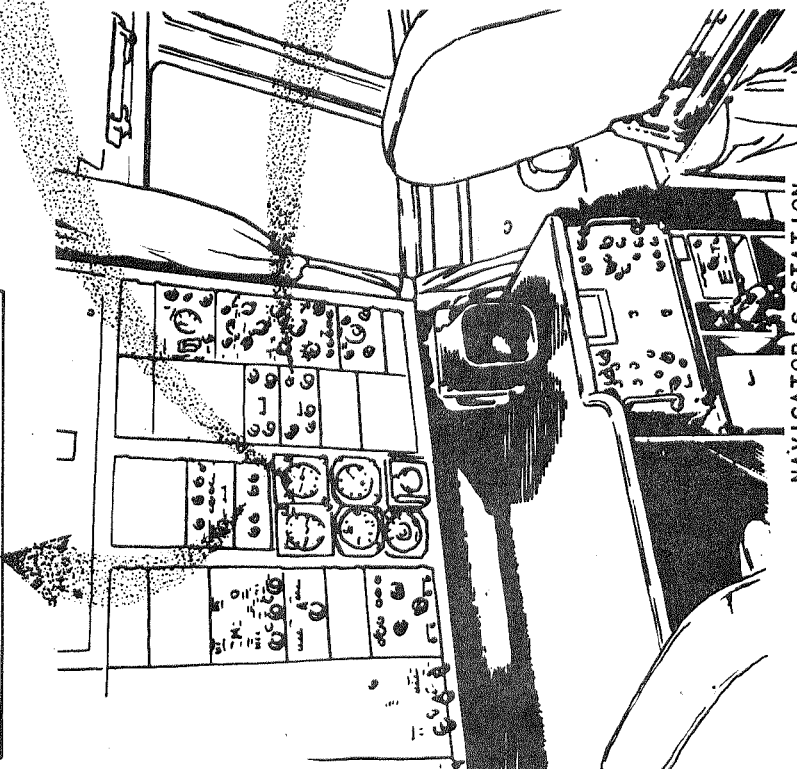
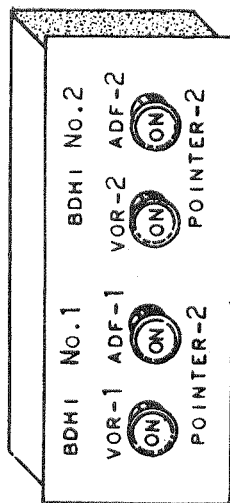
BDHI SELECTOR PANEL



PILOT'S AND COPILOT'S  
CONTROLS AND INDICATORS

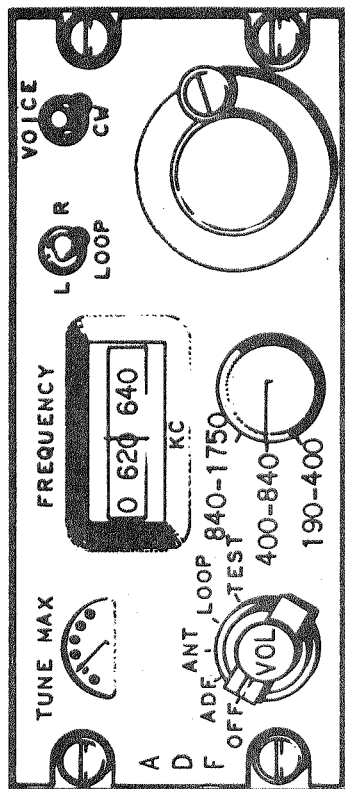


BDHI SELECTOR PANEL

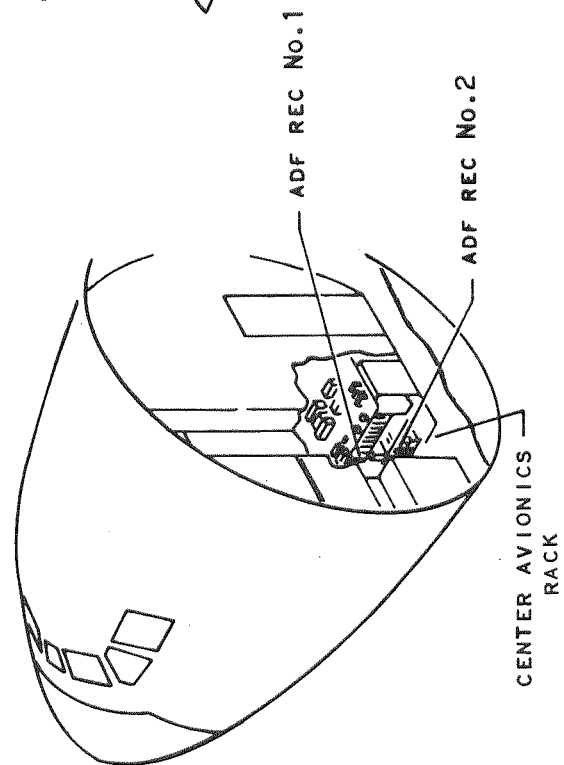
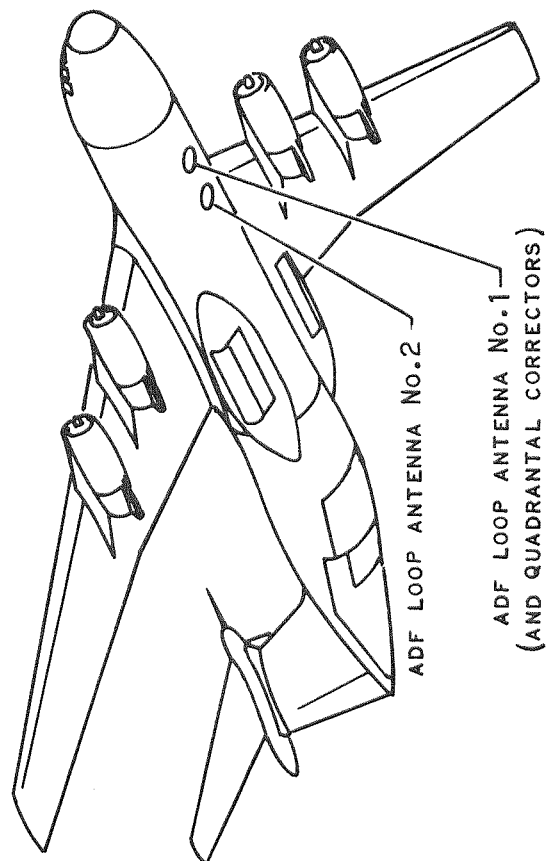
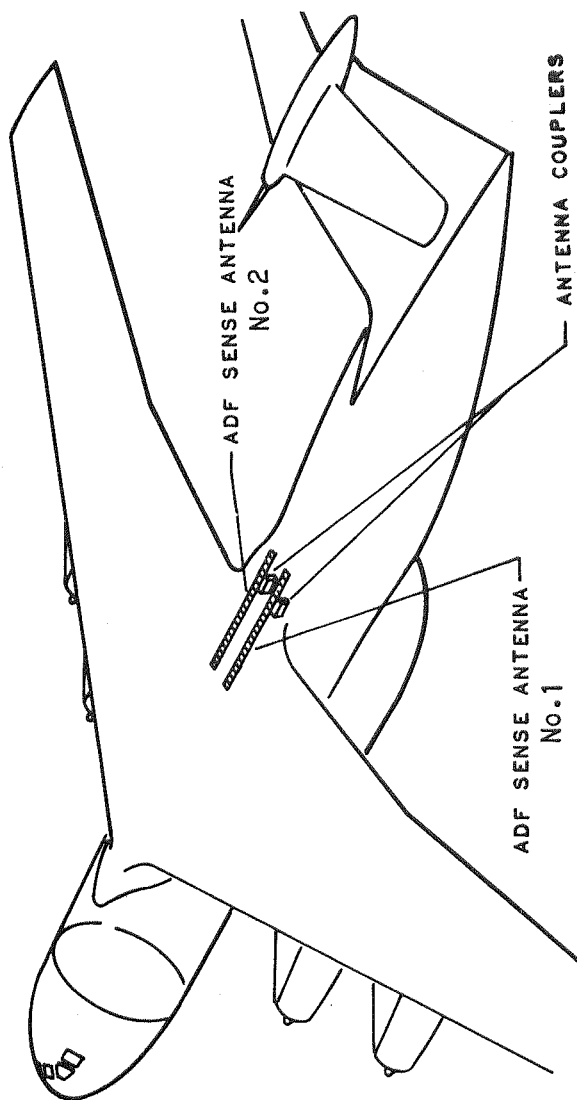


NAVIGATOR'S STATION

# NAVIGATOR'S CONTROLS AND INDICATORS



ADF CONTROL PANEL



# ADF RECEIVER AND ANTENNA LOCATIONS

## AFT INSTALLATION

Components of one system are as follows:

● Receiver	DFA-73A
● Loop Antenna	LPA-73A
● Sense Antenna	3K1707D
● Control Panel	CNA-73B
● Antenna Coupler	CUA-73A-300
● ADF Control Transfer Panel	3K90009
● Quadrantal Error Corrector	QCA 73E

All circuit breakers are at the navigator's station on the avionics circuit breaker panel.

System components, cabling, power requirements, and locations are shown in the following diagrams.

### SYSTEM OPERATION (Only one system is discussed)

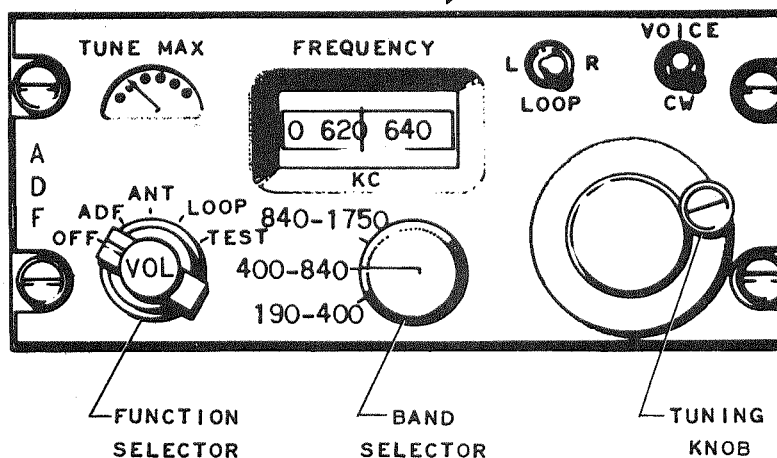
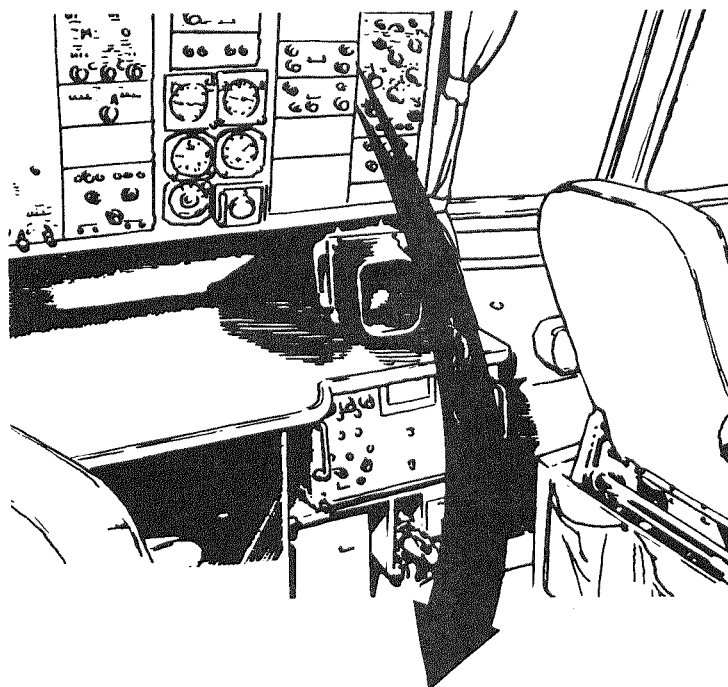
#### Control Panel

A band selector switch allows selection of the desired frequency band. The frequencies are displayed in the frequency window. The tuning knob varies the receiver frequency within each band. Exact tuning on a station is indicated by maximum pointer deflection of TUNE-MAX. meter. A VOICE-CW switch allows selection for the type of received signal. A volume control concentric with the function selector switch, varies the audio output level of the receiver to the interphone system. A five position function selector switch is used to energize the system and selects the mode of operation.

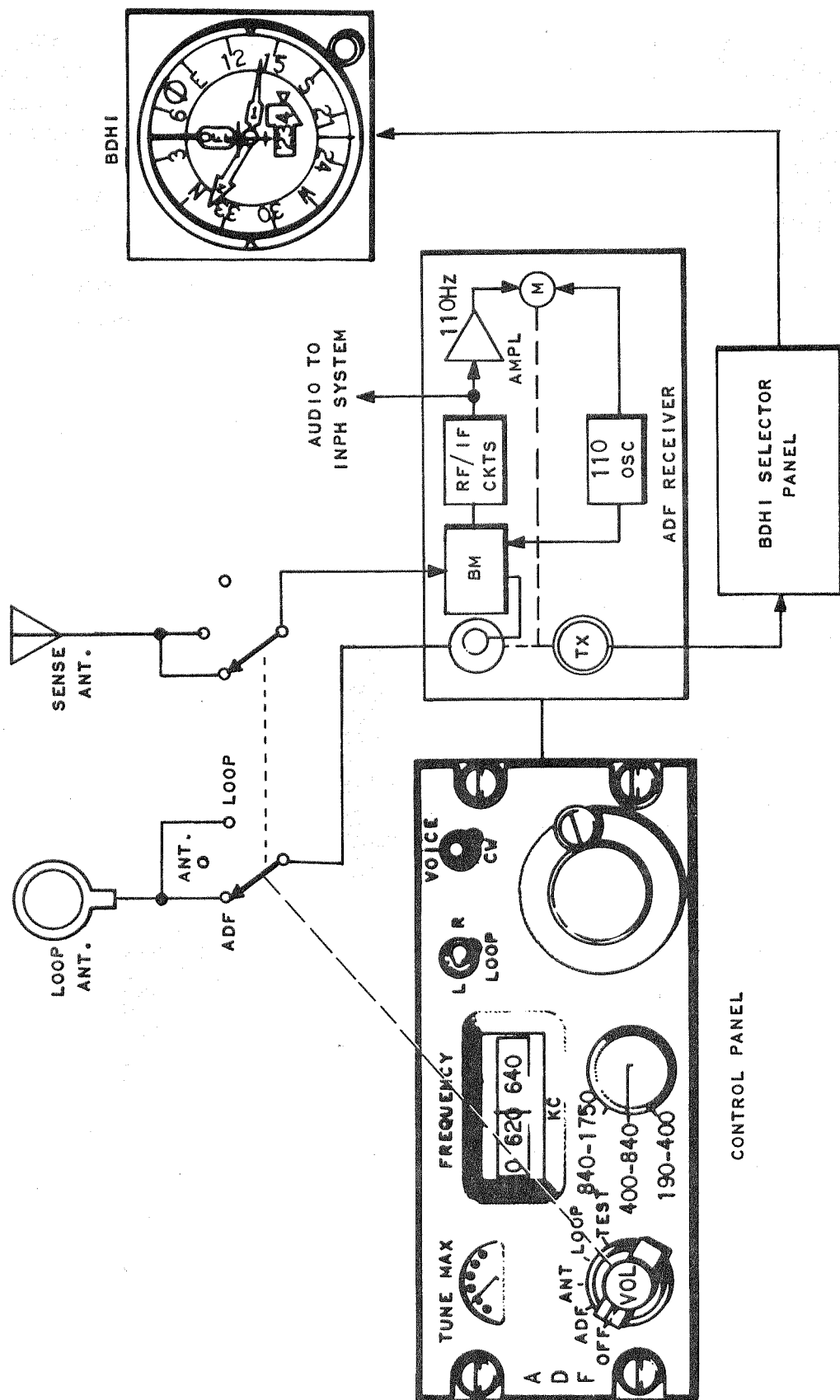
In the "ADF" position the system uses the sense and loop antenna signals to produce automatic bearing information. In "ANT" position only the sense antenna is used and the system provides standard radio reception. Normally "ANT" mode is used for exact tuning to a station before selecting "ADF" or "LOOP" modes. In "LOOP" position only the loop antenna is used and the system provides manual direction finding. The left-right (L-R) LOOP switch is used to effectively rotate the directional characteristics of the loop antenna. Relative bearing to the selected ground station will be indicated on the BDHI. A dip on the TUNE-MAX meter will indicate loop antenna null at either of two bearings. This mode is not recommended for direction finding. The "TEST" position provides a method of self-test for the system. When the switch is held in this position, simulated ADF signals cause a reading of 0 degrees on the receiver front panel and 180 degrees on the BDHIs (Bearing Distance Heading Indicator). An audible beat note is also

developed in the receiver. This note is used for calibration. Each frequency band on the control panel dial has a marked position for calibration check. As tuning is varied to select the marked position the audio beat note decreases in frequency to a zero beat at the calibration mark. Beat notes also occur at multiples of 142.5 KHz throughout the tuning range of the receiver. Push button BDHI selector panels at pilot's, copilot's and navigator's stations permit the selected BDHI pointer to operate with the ADF system labeled on the button.

An ADF control transfer panel permits selection of the desired ADF control panel. This is provided so that either of two control panels may operate the ADF. Both ADF systems have two control panels.



ADF CONTROL



SIMPLIFIED DATA FLOW



## SPECIFICATIONS

### ADF-73 AUTOMATIC DIRECTION FINDER

CHARACTERISTIC	SPECIFICATION
Type of system	Fixed loop-goniometer
Frequency range	190 - 1750 kilocycles in three bands.  Band 1: 190 - 400 KHz Band 2: 400 - 840 KHz Band 3: 840 - 1750 KHz
Tuning	Slug Tuned; servo operated from CNA-73 ADF control by two 10-turn potentiometers in an A-C comparison bridge.
Selectivity	4 KHz maximum at 6 db; Less than 12 KHz at 65 db
Stability	Resonant frequency and dial frequency agree within 0.75 percent during normal operational conditions; within 1 percent during operation at environmental extremes.
Sensitivity:	
ANT mode	32 uv/m, 190 - 1750 KHz
LOOP mode	90 uv/m, 190 - 400 KHz 70 uv/m, 400 - 840 KHz 60 uv/m, 840 - 1750 KHz
ADF mode	90 uv/m, 190 - 400 KHz 70 uv/m, 400 - 840 KHz 60 uv/m, 840 - 1750 KHz
Outputs:	
Bearing information	400~ , 3-wire synchro signal

# SPECIFICATIONS (continued)

## ADF-73 AUTOMATIC DIRECTION FINDER

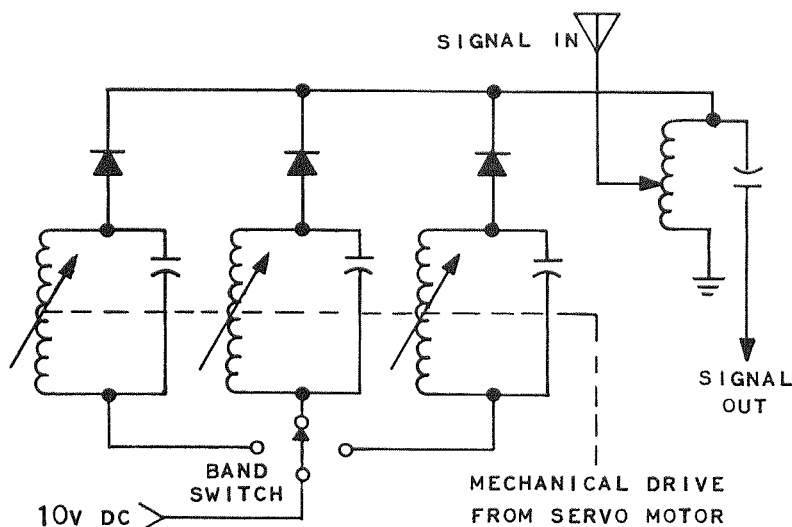
CHARACTERISTIC	SPECIFICATION
Audio	
Response	Within 9 db, 300-2000
Level	Adjustable up to 100 mw
Impedance	500 ohms
Distortion	Less than 10 percent at 100 mw (measured at 1000~ , 30 percent modulation)
Tuning Indications:	Tuning meter
Function switching	Solid state
Intermediate frequency	142.5 KHz
BFO	1020~ beat at channel center for CW reception
Tuning BFO	142.5 KHz zero-beats with incoming IF signal
Altitude	Up to 60,000 feet
AVC	Audio output does not vary more than 3 db for RF input signals from 10 uv to 0.05 volts or more than 6 db for RF input signals from 10 uv to 0.5 volts.
Isolation cross-coupling between sense and loop-circuits	60 db minimum
Overload protection	Permanent short on regulated B+ supply will not harm receiver.

## BLOCK DIAGRAM THEORY OF OPERATION

The main component of the ADF system is the receiver. It is a transistorized, light weight unit consisting of a single conversion superheterodyne receiver, a servo-driven goniometer, and circuits for combining and comparing the loop and sense antenna signals. The receiver has solid state bandswitching, function switching, and servo driven slug tuning.

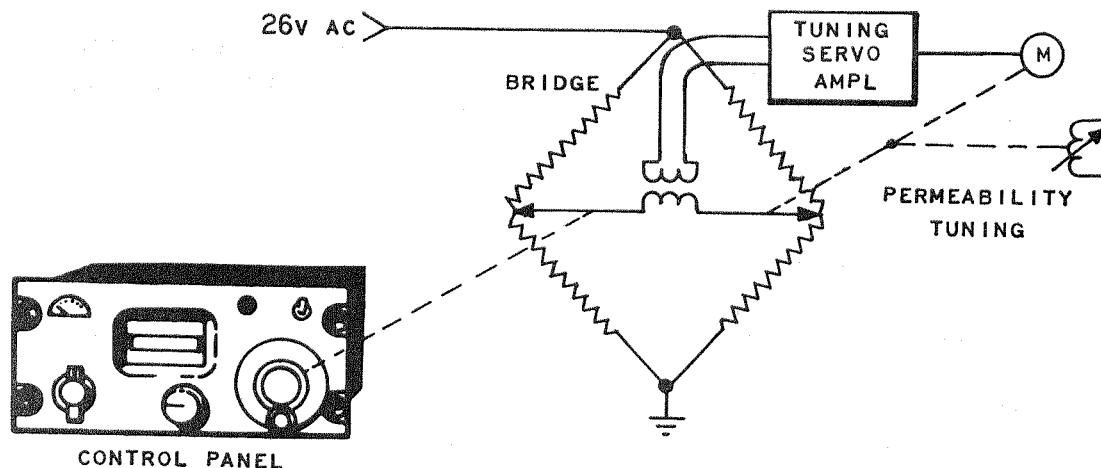
### BAND SWITCHING - TUNING

Each stage of the receiver RF section has three sets of tuned circuits, one for each frequency band. A diode rectifier in series with each tuned circuit is used to place the circuit in operation. The control panel band selector switch applies a positive D-C voltage to forward bias the switching diode, thus placing the selected tuned circuit into operation.



S I M P L I F I E D   B A N D S W I T C H I N G  
F O R   T Y P I C A L   S T A G E

All band circuits are tuned to accept the desired frequency by a balanced bridge servo loop. One leg of the bridge is a precision potentiometer in the control panel which is varied by the tuning knob. The second leg of the bridge is another potentiometer in the receiver. Selecting a frequency on the control panel unbalances the bridge, thus creating an error signal. The error signal is amplified to drive a servo motor which positions the receiver potentiometer to rebalance the bridge. The motor also mechanically adjusts the slug tuning of all tank circuits thereby tuning the receiver to the selected frequency. Function selection is accomplished by solid state circuits similar to band switching.



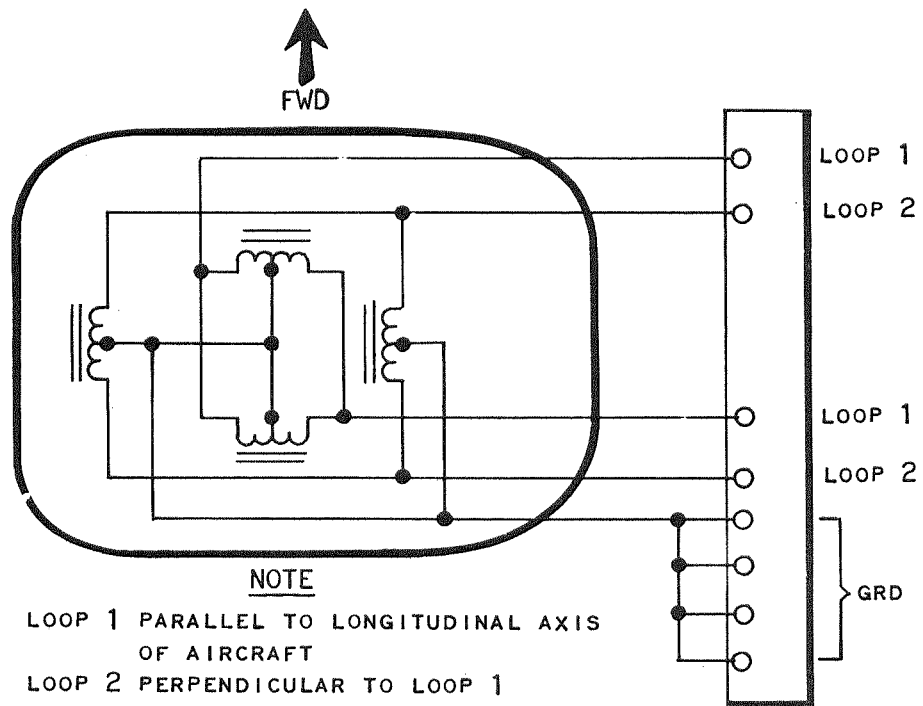
S I M P L I F I E D   T U N I N G   C I R C U I T S

## ADF OPERATION

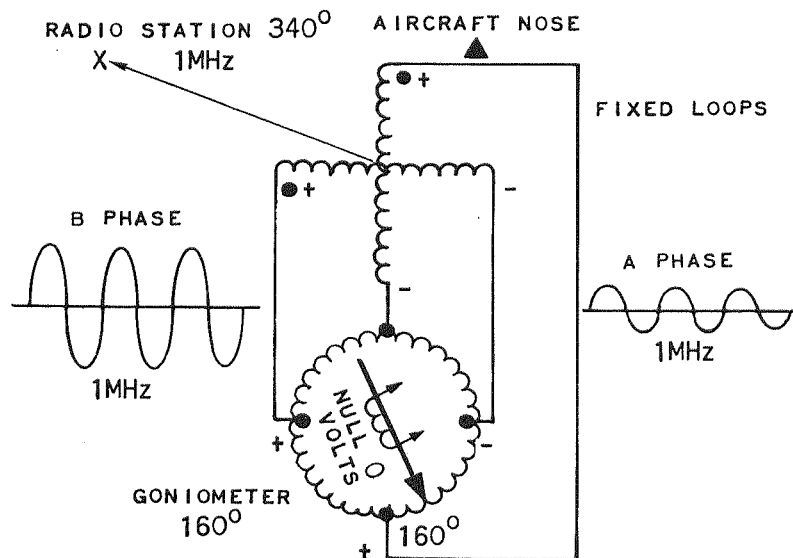
Radio direction finding is based on the directional characteristics of loop antennas. A fixed loop (now rotating) antenna having two windings on ferrite cores perpendicular to each other provides the directional characteristics. The amplitude of the voltage induced in each winding depends on the angular position of the antenna with respect to the ground transmitter. The induced voltages are a measure of the relative bearing to the transmitting station.

The omni-directional sense antenna provides a constant reference phase signal which does not vary with transmitter bearing. Due to its characteristics, the loop antenna produces a signal that either leads or lags the sense antenna signal by 90 degrees.

The two voltages developed in the loop antenna are combined in the receiver goniometer (RF servo resolver). If the position of the goniometer rotor does not correspond to the resultant null of the loop, an output is produced in the rotor. The loop signals from the goniometer are applied to the loop amplifier. The signal is amplified and phase shifted by 90 degrees. The resultant signal is either in phase or 180 degrees out of phase with the sense antenna signal. The loop signal is chopped (phase reversed) by a balanced modulator at 110 Hz. If the goniometer is left of null the loop signal from the modulator will reverse phase 110 times per second, from 0 degrees loop phase to 180 degrees loop phase. At right of null the modulator output will be 180 degrees loop phase, then 0 degrees loop phase.



In the 90 degree phase shifter the balanced modulator loop signal will be in phase (adding) or out of phase (subtracting) if the goniometer is not at null.

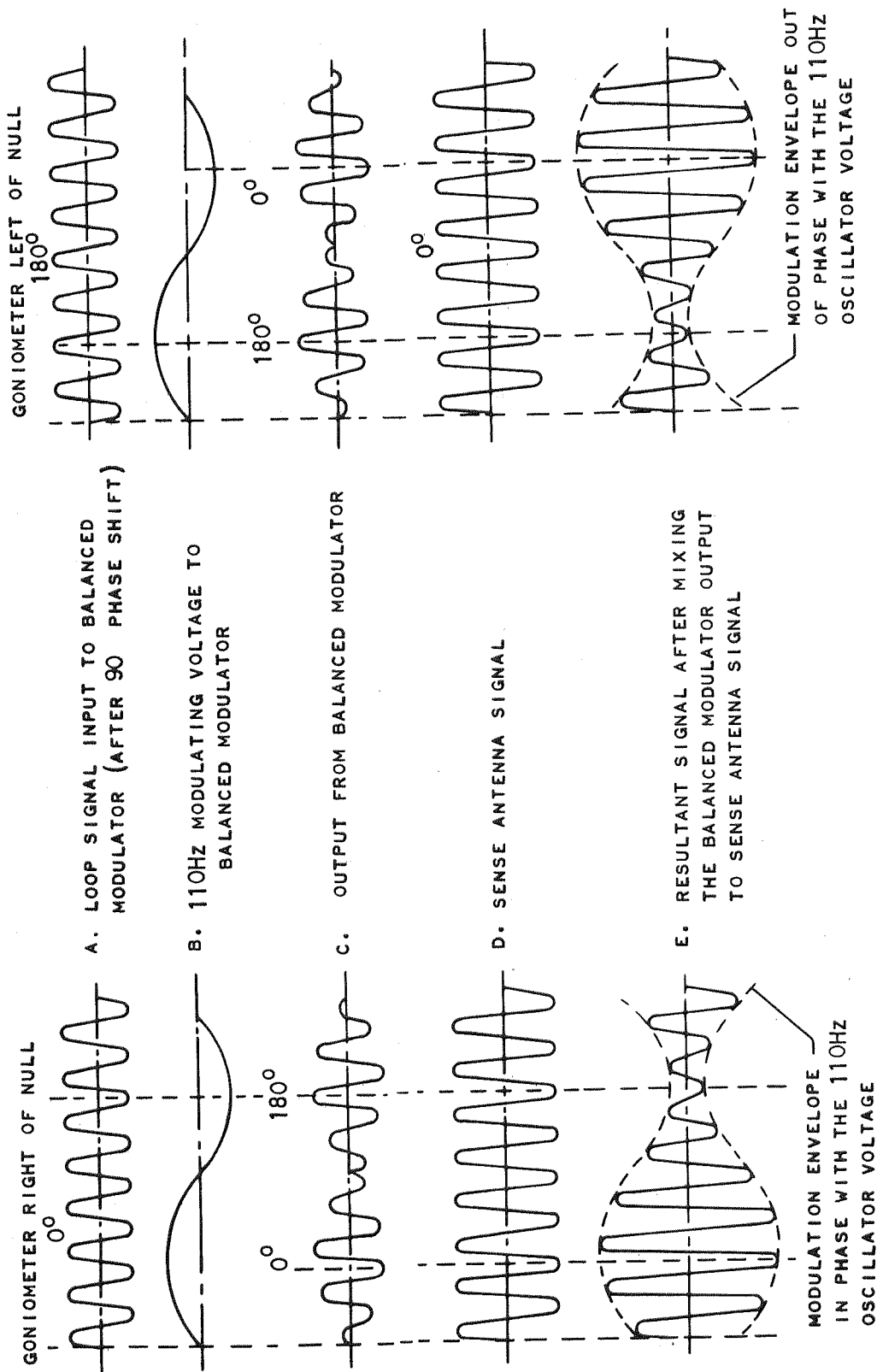


On one side of the goniometer null an adding condition will exist and on the other side a subtracting condition. The addition and subtraction of the loop and sense signals results in a 110 Hz amplitude modulation. The phase of the modulation will depend on whether the goniometer is left or right of null position. At null position the balanced modulator output is absent, resulting in no 110-Hz, AM modulation in the receiver signal.

The composite antenna signal is amplified by the RF amplifier and combined with a local oscillator signal in the mixer. The difference frequency of 142.5 Hz is selected by the tuned circuits in the mixer output. Band switching and tuning circuits maintain a 142.5 Hz difference between the local oscillator frequency and the selected receiver frequency to develop a fixed IF frequency. The IF signal is amplified and applied to the detector where the 110 Hz envelope and audio signals are recovered. An AVC detector develops a signal proportional to IF signal strength. The AVC signal is amplified and used to control gain in the RF amplifier and the first IF amplifier and also is sent to the control panel to drive the TUNE-MAX meter. The recovered 110 Hz envelope and the audio signals are routed to the audio amplifier. The first audio amplifier increases the amplitude of the 110 Hz envelope and audio signals to the level required to drive the control phase amplifier and the audio driver. The audio signal is amplified by the driver and applied to the audio power amplifier. The power amplifier increases the audio signal level. The audio signal is then routed through the control panel volume control to the aircraft interphone system. The 110 Hz signal output from the first audio amplifier is applied to the control phase amplifier as a control phase input signal. The signal is amplified, phase shifted by 90 degrees, and applied to the control windings of the two-phase, A-C servo motor. The reference phase generator (110 Hz oscillator) voltage is applied to the servo motor. The control voltage will either lead or lag the reference voltage by 90 degrees. This determines the direction of motor rotation. The motor drives the goniometer to a null position. At this point the output of the balanced modulator has no output with which to drive the servo motor. The angular position of the rotor of a synchro transmitter driven by the servo motor provides bearing information to the BDHIs.

## LOOP OPERATION

In the "LOOP" function the sense antenna and the reference phase generator signals are removed from the balanced modulator input. The system functions as a receiver connected only to the loop antenna. Manual control of goniometer rotation is provided by the LOOP L-R switch on the control panel. The switch applies signals to the servo amplifier to position the goniometer. This function provides manual direction finding. As the goniometer rotor is positioned by the L-R switch two nulls and two maximum signals will appear during 360 degrees rotation. Tuning to the correct null will provide relative bearing to the selected transmitting station. The second null will point away from the station. Loop navigation should only be used by triangulating on two ground stations in case of ADF mode failure.



BALANCED MODULATOR, INPUT AND OUTPUT



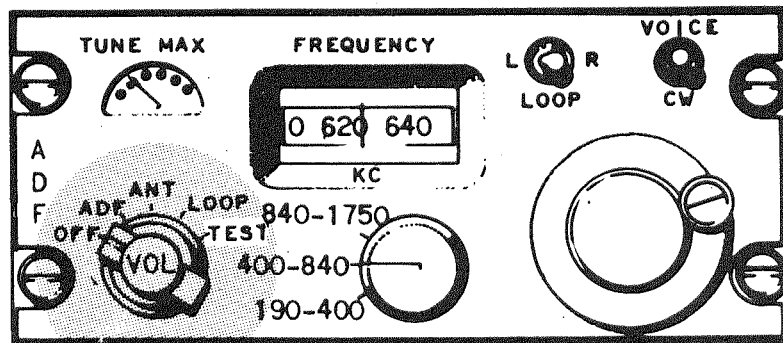


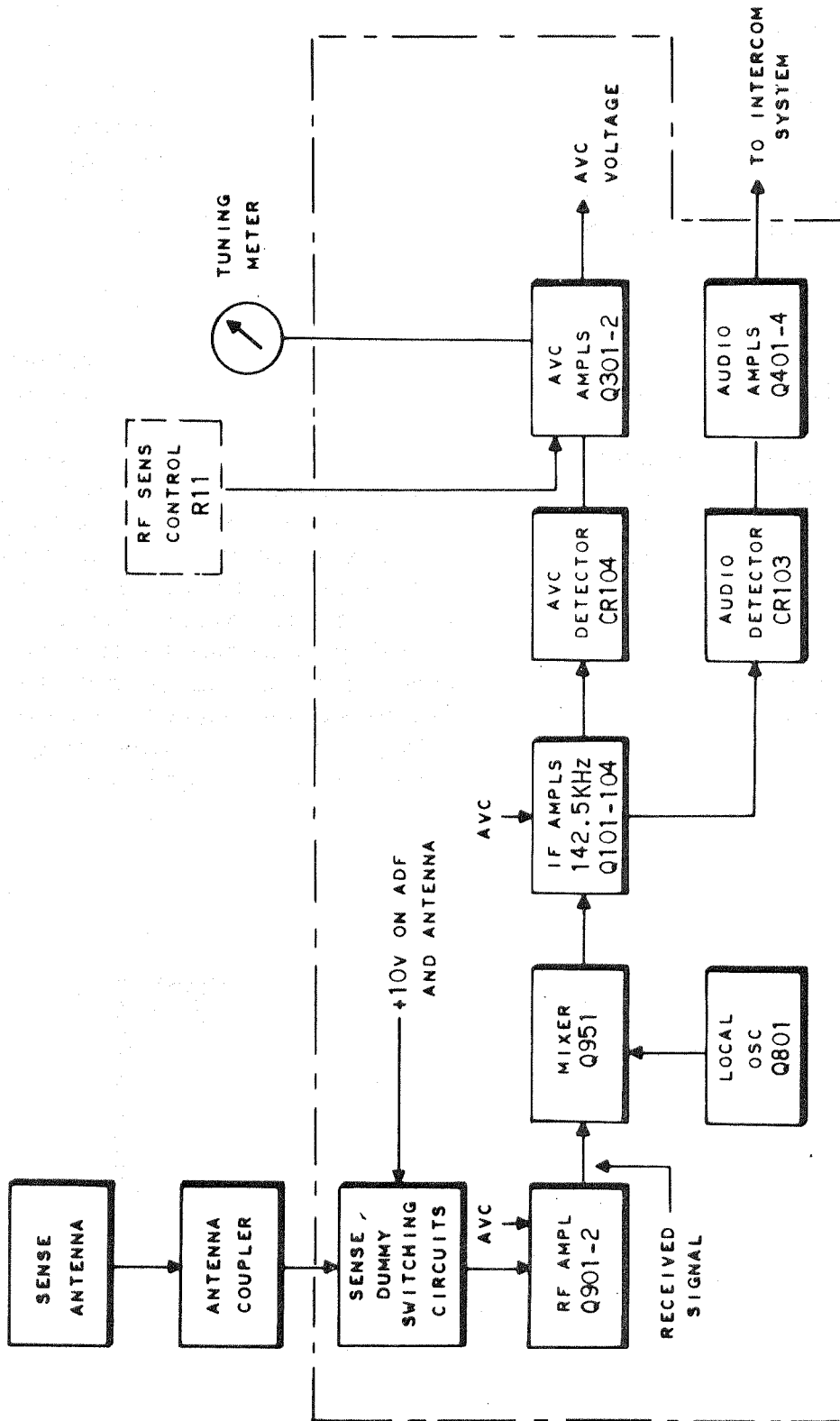
## ANTENNA OPERATION

In the "ANT" function the outputs of the goniometer and reference phase generator are removed from the balanced modulator and the goniometer servo amplifier input is disconnected. The system functions as a conventional super-heterodyne receiver connected only to the sense antenna. The antenna coupler provides impedance matching between the antenna and the receiver.

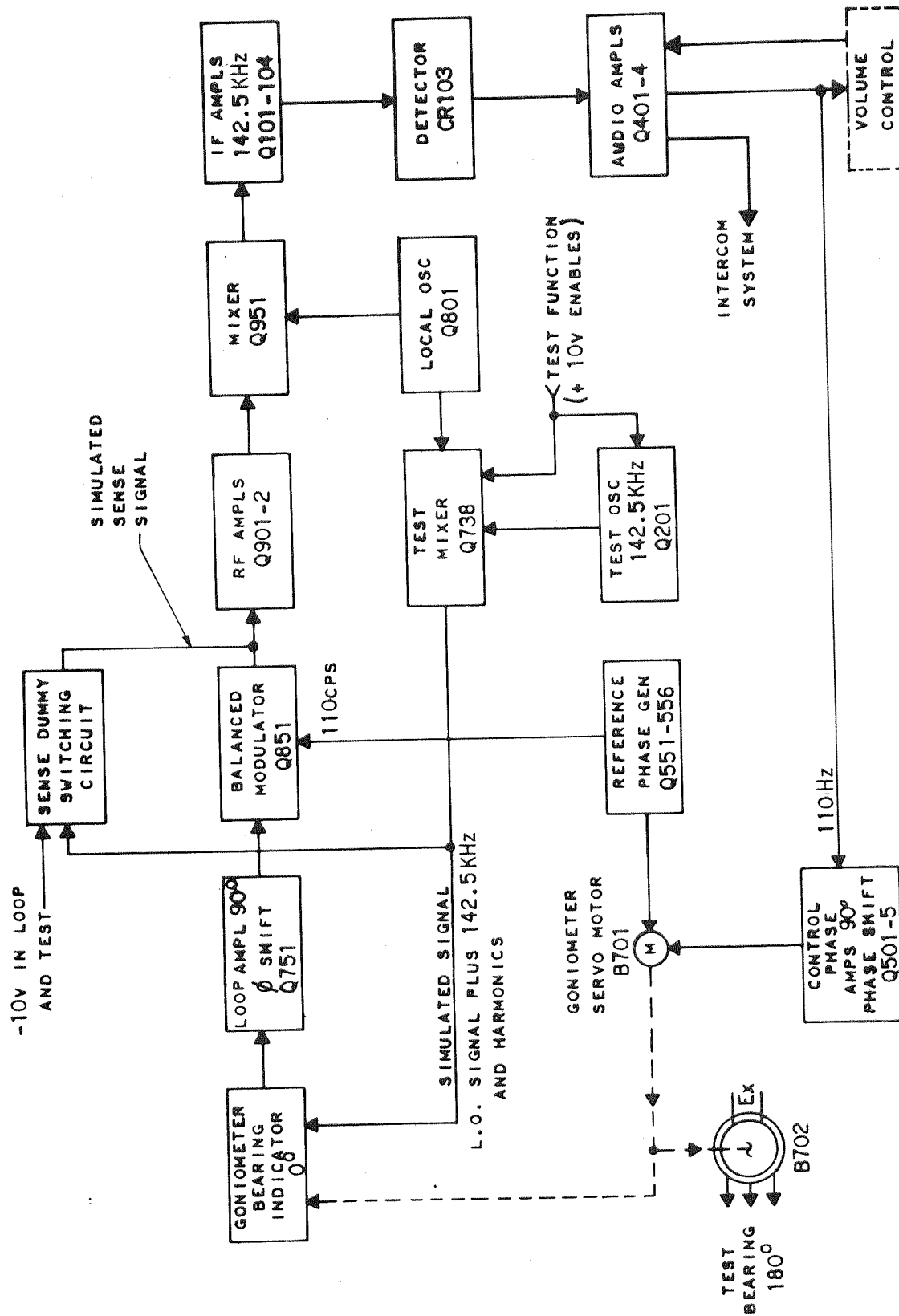
## TEST OPERATION

A self-test feature is provided by a momentary "TEST" position of the function selection switch. In "TEST" the system is connected for "ADF" operation, except the sense antenna is replaced by a dummy sense antenna within the receiver. The local oscillator frequency and a 142.5 KHz signal from the beat frequency oscillator (BFO) are applied to the test mixer. The sum frequency is selected in the mixer output to simulate a station transmitting on the frequency to which the receiver is tuned. This signal is applied to the balanced modulator to simulate a sense antenna signal. This signal is also applied to the goniometer to simulate a loop antenna signal. The phase relationship of the signals produce a system null at 0 degrees reading on the receiver front panel. The flight instruments always indicate 180 degrees out of phase from the receiver indication. An audio beat note is also produced in output of the receiver by combining the local oscillator and BFO frequency. This provides frequency calibration checks at 142.5 intervals throughout the tuning range of the receiver.





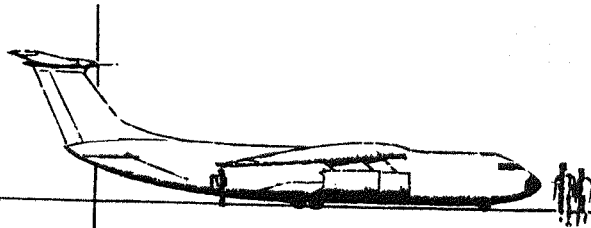
RECEIVER, ANTENNA FUNCTION BLOCK DIAGRAM



BLOCK DIAGRAM, ADF RECEIVER, TEST FUNCTION



# ADF-73 AUTOMATIC DIRECTION FINDER SYSTEM BLOCK DIAGRAM



## VHF NAVIGATION SYSTEM

### GENERAL

The VHF navigation system provides reception of the VHF omni-range (VOR) or localizer (LOC) ground station signals. The VOR data is supplied to flight director indicators to indicate bearing to the selected ground station and deviation from a selected course to that station during cross country flights. Localizer information is presented on the flight direction indicators to provide lateral guidance on Instrument Landing System approaches (ILS). The VOR/ILS signals are also used as inputs to the autopilot and all weather landing system (AWLS).

### AIRCRAFT INSTALLATION

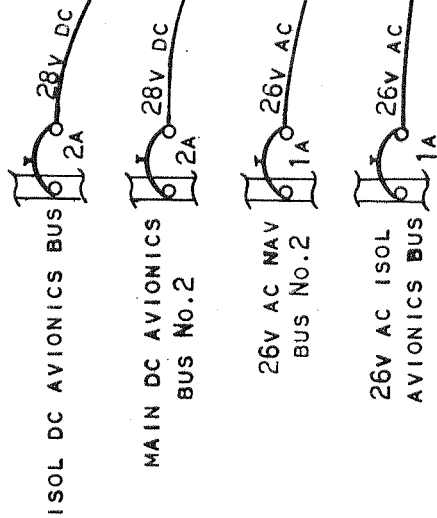
System components, cabling, power requirements and equipment locations are shown on the "Aircraft Installation" drawing.

The components of one system are as follows:

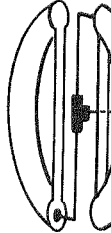
- Control Panel
- Receiver
- VHF Nav Antenna (tail)
- Localizer Antenna Switch
- Localizer Antenna (nose)

The Collins 51R-6 receivers are directly interchangeable with no modification to aircraft wiring or operating procedure. The WILCOX 9765-100 radio set control and the COLLINS 313N-2 are also directly interchangeable and may be used with either receiver.

ALL CIRCUIT BREAKERS  
ON AVIONICS CIRCUIT  
BREAKER PANEL



LEFT HAND ANTENNA



RIGHT HAND ANTENNA

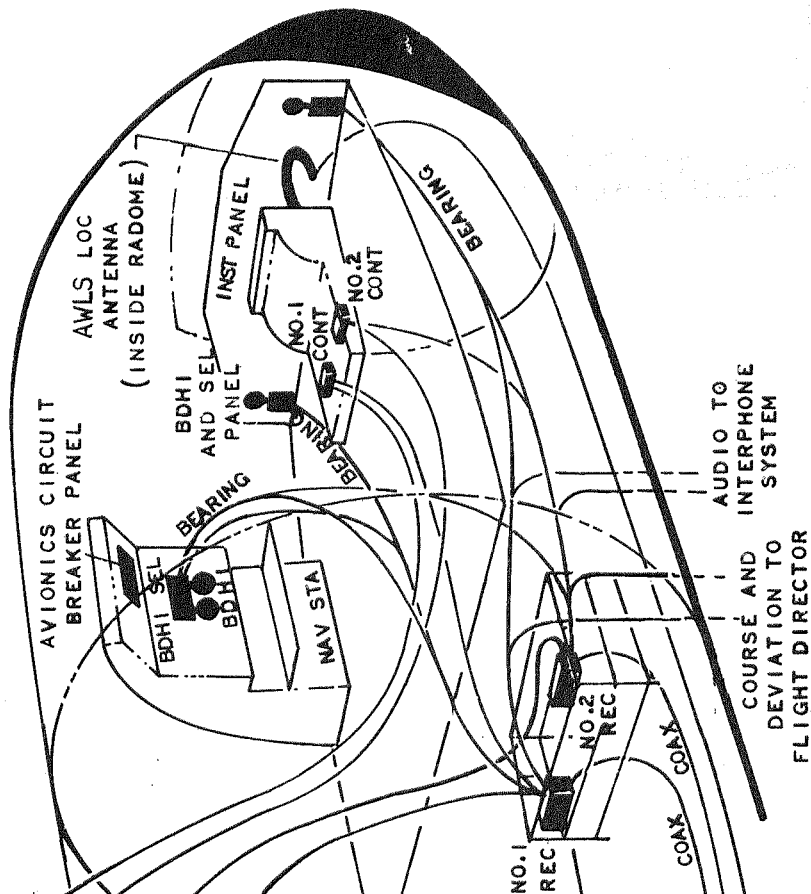
LOCALIZER  
ANTENNA SW  
(AWLS)

IN  
LEFT HAND  
AVIONICS EQUIPMENT  
RACK (UNDER NAVIGATOR'S STATION)

"T" CONNECTOR

COAX

NO.1 REC  
NO.2 REC  
AUDIO TO  
INTERPHONE  
SYSTEM  
COURSE AND  
DEVIATION TO  
FLIGHT DIRECTOR

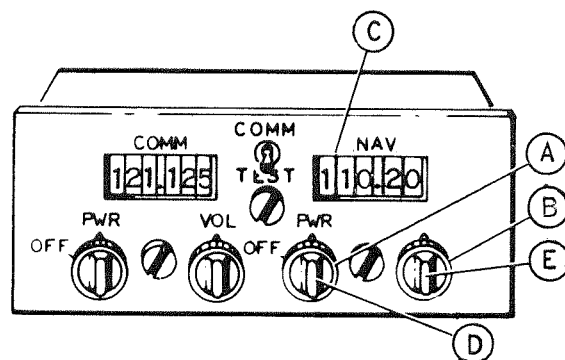


AIRCRAFT INSTALLATION

## SYSTEM OPERATION

System operation is controlled from the VHF/NAV portion of the control panel. The power "ON-OFF" switch (A) energizes the system. A volume control (B) adjusts the level of the audio output to the interphone system. Frequency selection is accomplished by setting the desired frequency into the frequency selection window (C). The whole megahertz (MHz) selection is controlled by the left knob (D) and the fractional MHz selection is controlled by the right knob (E).

The frequency range of the system is 108.00 to 117.95 MHz in 50 KHz steps. However, due to aircraft wiring, channel spacing of the 100 KHz is used. When a 50 KHz channel is selected on the control panel (108.05, 108.25 etc.) the receiver tunes to the next lowest channel. A frequency selection of 108.60 MHz or 108.65 MHz provides an operating frequency of 108.60 MHz.



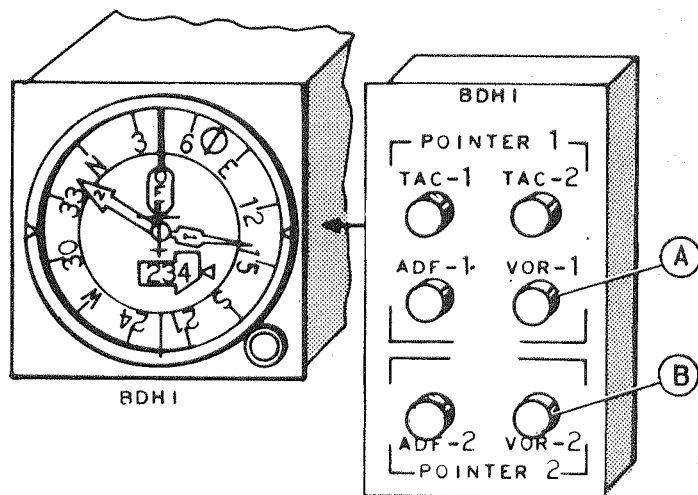
P I L O T ' S   A N D   C O P I L O T ' S  
R E C E I V E R   C O N T R O L S   ( T W O )

Mode of receiver operation, VOR or LOC, is determined by the selected frequency. VOR operation is provided when frequencies from 108.0 MHz to 112.0 MHz are selected in even tenths (108.0, 108.2, 108.4 etc.) or 112.0 MHz to 117.9 MHz all tenths. Localizer operation is provided when frequencies from 108.1 MHz to 111.9 MHz are selected in odd tenths (108.1, 108.3, etc.).

## VOR OPERATION

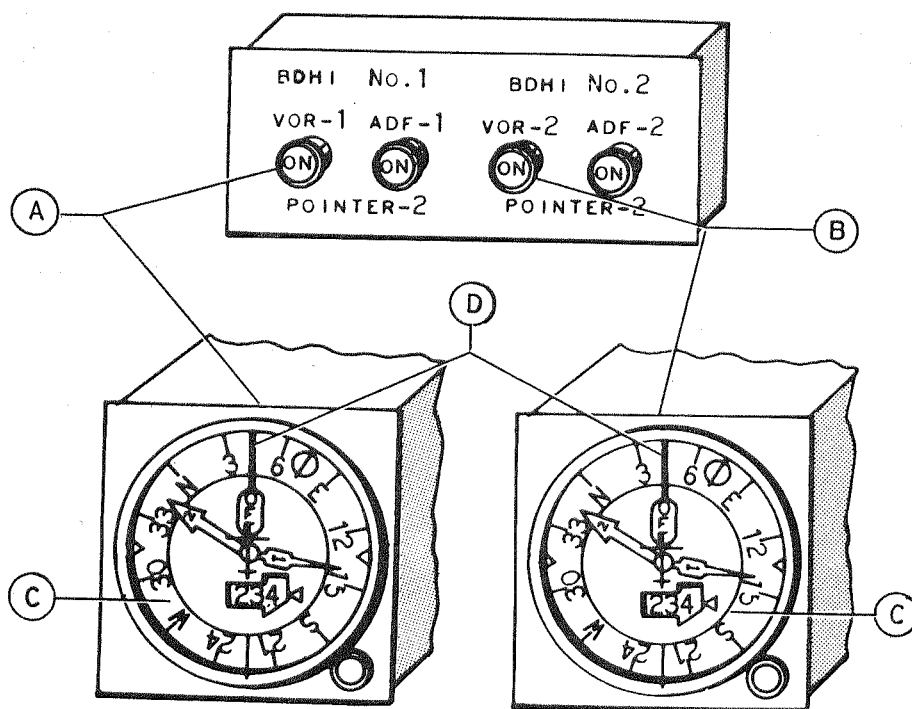
In VOR operation the bearing signal can be selected to drive pointers on Bearing Distance Heading Indicators (BDHI) and Horizontal Situation Indicators (HSI). Switch panels on the pilot's and copilot's instrument panels are used to select information displayed on their BDHI. System No. 1 information can be selected for the No. 1 pointers (A) and system No. 2 can be selected for the No. 2 pointers (B).

A BDHI pushbutton selector panel at the navigator's station is used to select information displayed on the BDHI's at his station. The No. 2 pointers are used to display VOR information. Bearing information from system No. 1 is displayed on BDHI No. 1 (A) and bearing from system No. 2 system is displayed on BDHI No. 2 (B).



### PILOT'S OR COPILOT'S STATION

The bearing to the VOR station, relative to magnetic north, is indicated when the pointer position is read directly from BDHI compass card (C). When the pointer is read with respect to the indicator top index (D), the indication is the bearing of the VOR station relative to aircraft heading.



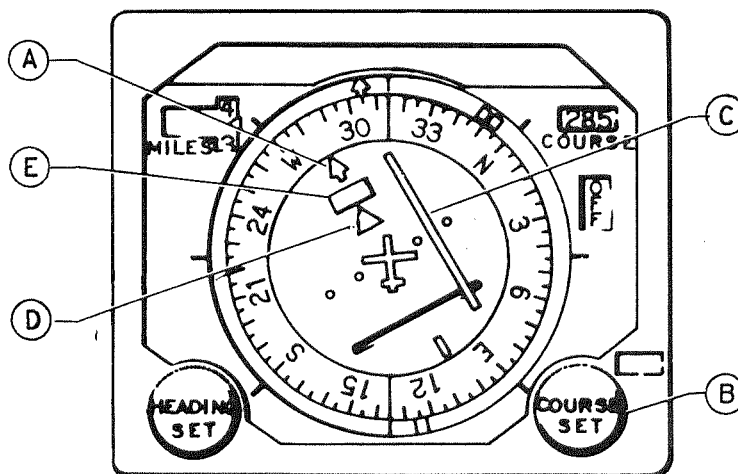
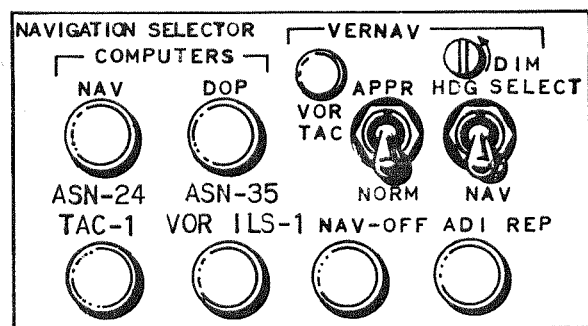
### NAVIGATOR'S BDHI'S & SELECTOR PANEL



The VOR signals can also be selected for use by the flight director systems. Two navigation selector panels on the glare shield enable the pilot and copilot to select VOR-ILS (A) signals for their flight director systems. The pilot can select signals from the No. 1 system and the copilot from the No. 2 system.

To fly a VOR radial, the desired radio course is selected on the HSI. The course arrow (A) of this indicator is positioned to the desired VOR course by the COURSE SET knob (B). This information is supplied to the VHF navigation receiver.

The receiver compares "selected course" from the HSI with signals from the VOR ground station to develop deviation information. This information is displayed on the HSI deviation bar (C). The deviation bar indicates that the aircraft is off course (bar left fly left, bar right fly right). The "to-from" indicator (D) shows that the aircraft is on a radial toward or away from the selected station. The alarm flag (E) is used to monitor the VOR signal for reliability. When the flag is in view the information being displayed is unreliable and should not be used for navigation.



HSI

## SPECIFICATIONS

### WILCOX 806 A

CHARACTERISTIC	SPECIFICATION
Audio output	100 milliwatts into an external 200- or 500-ohm resistive load for a 3-microvolt input signal, 30 percent modulated at 1,000 Hz.
Audio response	Less than 6 db total variation from 350 to 2,500 Hz.
Audio distortion	Less than 7.5 percent at normal rated output.
All undesired responses	At least 60 db down.
AGC	Receiver output will not vary more than 2 db over the range of signal input levels from 3 to 100,000 microvolts.
Power input	27.5 volts, DC + 10 - 20 percent, 1.0 - ampere maximum.  26 volts ( $\pm$ 5percent) AC, 380-420 Hz, 0.2-ampere maximum.
Frequency range	108.00 to 117.95 MHz.
Channels	200 channels with 50-KHz spacing are provided. Limited to 100 channel 100 KHz spacing.
Frequency selection	Accomplished by Mark 2 standardized navigation frequency selector designed in accordance with ARINC Specification No. 410.
Frequency stability	Better than $\pm$ 0.0035 percent under all operating conditions.

## SPECIFICATIONS (continued)

### WILCOX 806 A

CHARACTERISTIC	SPECIFICATION
Input impedance	52-ohm coaxial.
Sensitivity	A maximum signal of 3.0 microvolts, modulated 30 percent at 1,000 Hz is required to achieve 6 db signal plus noise to noise ratio.
Selectivity	$\pm 20.4$ KHz wide (MIN) at 6 db down; $\pm 35$ KHz wide at 60 db down.
Altitude	To 55,000 ft.
Bearing accuracy	Manual 0.50 degree; automatic 0.50 degree.

## SPECIFICATIONS

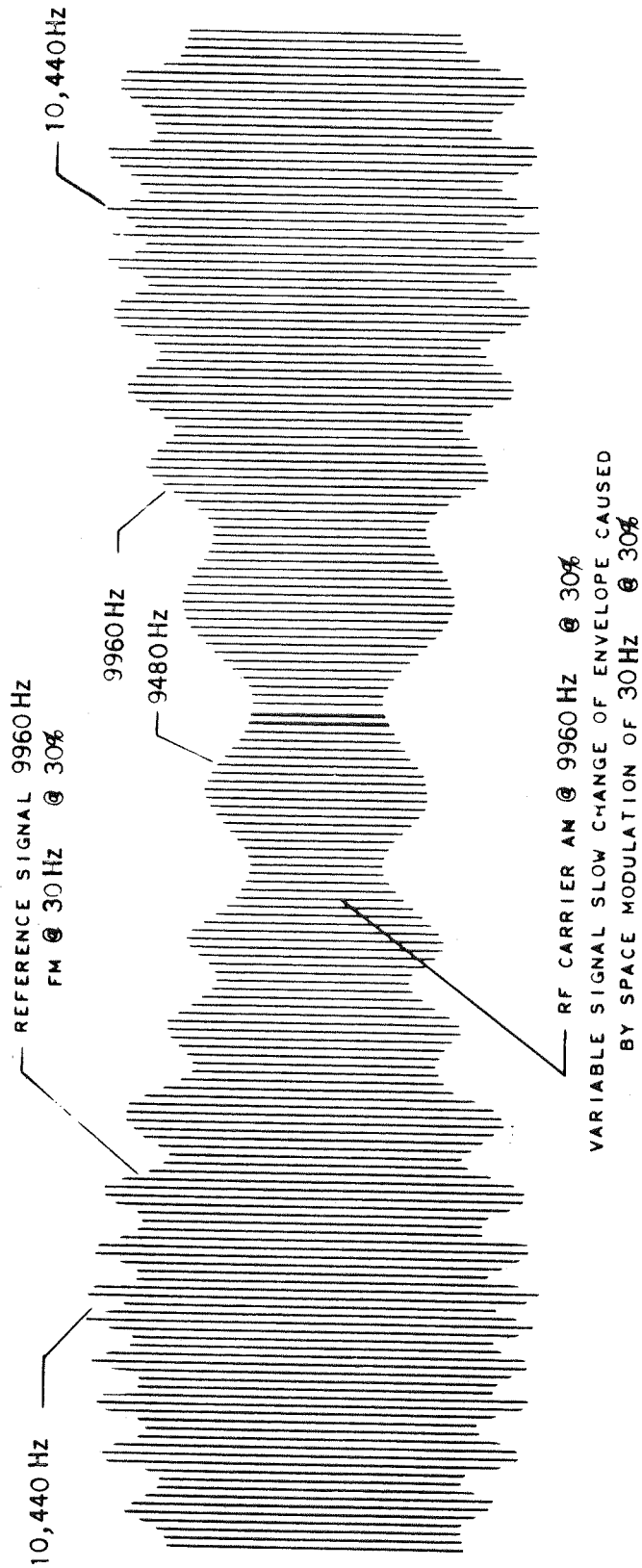
### COLLINS 51R-6

CHARACTERISTIC	SPECIFICATION
Power requirements	
VOR operation	27.5 volts, D-C, 1.45 amperes. 26 volts, 400 Hz, 0.23 ampere.
ILS operation	27.5 volts, D-C, 1.82 amperes. 26 volts, 400 Hz, 0.23 ampere.
VOR/LOC performance:	
Frequency range	108.00 to 117.90 MHz in 100 KHz increments.

# SPECIFICATIONS (continued)

## COLLINS 51R-6

CHARACTERISTIC	SPECIFICATION
Sensitivity	
Aural channel	3-microvolt input for 6-db S+N/N ratio.
VOR channel	3-microvolt input for satisfactory navigation performance.
Selectivity	40 KHz at 6-db points and 68 KHz at 60-db points with 3-db or less ripple.
Altitude	Up to 45,000 feet.
Spurious response	At least 70 db down.
Gain	100 milliwatts output into a 600-ohm load with a 5-microvolt input signal modulated 30 percent with 1000 Hz.
AGC	3-db variation from 5-microvolts to 50,000 microvolts.
Frequency stability	0.004 percent from +10 to +55°C (+50 to +131°F).  0.005 percent from -55 to +71°C (-67 to +160°F).
Navigation outputs	Five deviation indicator loads, four flag indicator loads, two TO-FROM loads, and two RMI pointer loads.

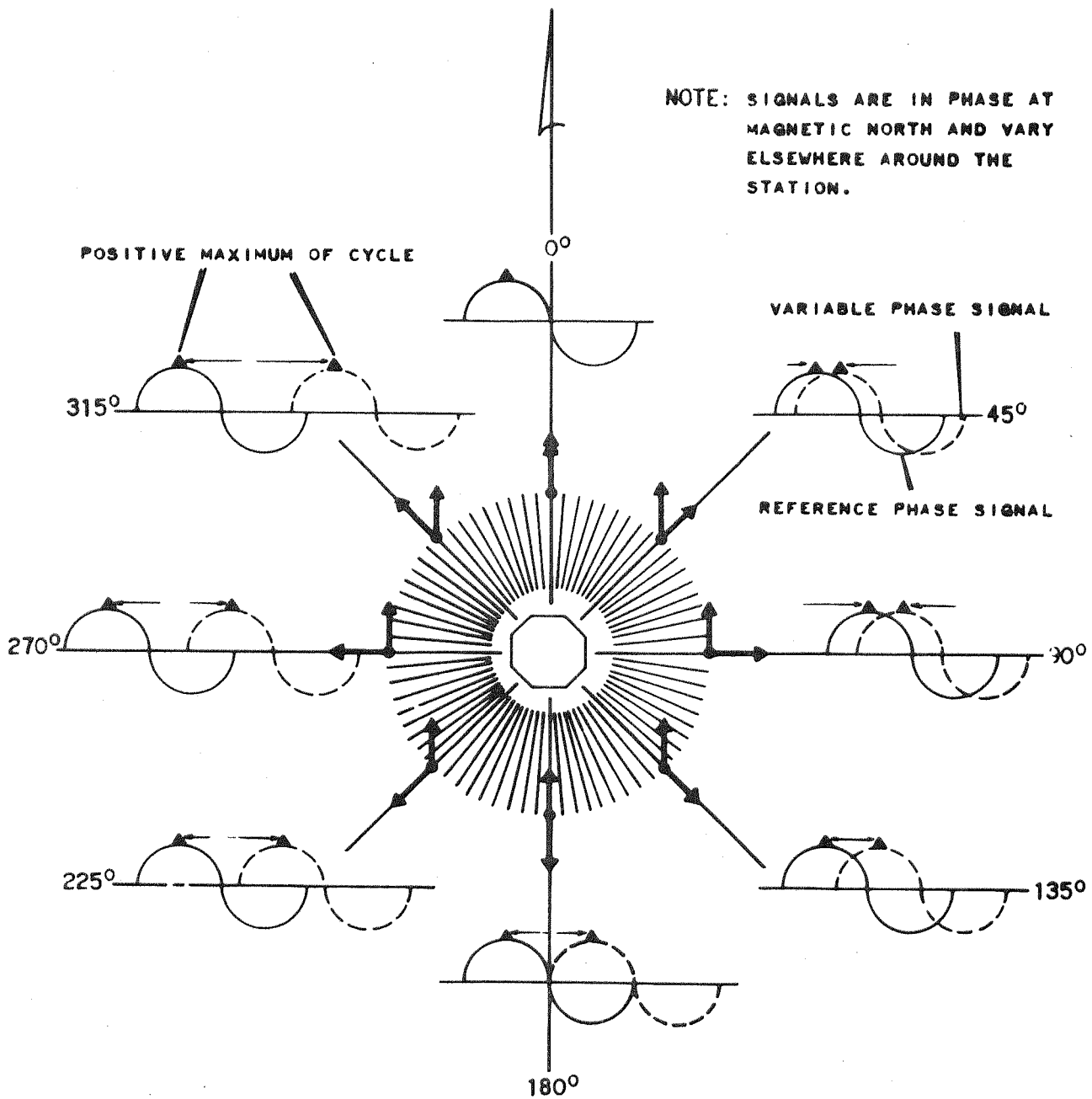


VOICE = 30% AM (NOT SHOWN)  
ID = 8% AM (NOT SHOWN)

RECEIVED VOR SIGNAL

MAGNETIC NORTH

NOTE: SIGNALS ARE IN PHASE AT  
MAGNETIC NORTH AND VARY  
ELSEWHERE AROUND THE  
STATION.



SIGNAL PHASE ANGLE RELATIONSHIP

## BLOCK DIAGRAM THEORY OF OPERATION

### VOR Ground Station

A basic understanding of the VOR ground station signal is necessary in order to comprehend VOR system operation.

The ground station antenna system consists of an element that radiates an omnidirectional pattern, and an element or group of elements that radiate a directional pattern rotated at 1800 RPM (30 Hz).

The 30 Hz reference signal consists of a 9960 Hz subcarrier frequency modulated by a 30 Hz signal. The frequency modulated 9960 Hz subcarrier and then amplitude modulates the VHF carrier. This signal is radiated by the omnidirectional antenna. The 30 Hz variable signal is produced by the rotating directional pattern varying the signal field strength (space modulation) at the receiver antenna.

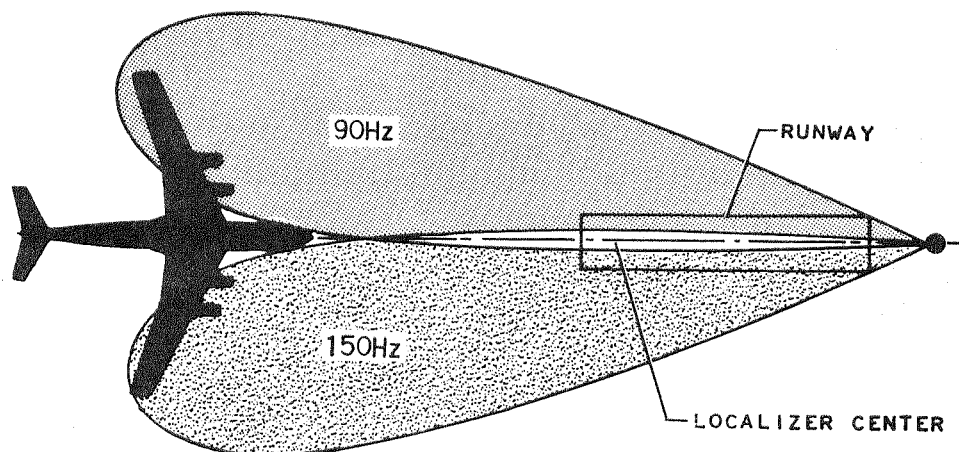
### RECEIVED SIGNAL

The received signal from the VOR ground station consists of a station identification signal and two 30 Hz modulated components. The reference phase 30 Hz signal has the same phase, regardless of the bearing from the aircraft to the VOR station. The variable phase 30 Hz signal varies degree-for-degree with the magnetic bearing of the aircraft with respect to the VOR station.

The two signals are in phase when detected by an aircraft receiver which is due north of the station (see the Signal Phase Angle Relationship illustration). East of the station the variable phase lags the referenced by 90 degrees. South of the station the two signals are 180 degrees out of phase. The variable phase lags the reference by 270 degrees at a point west of the station. As an aircraft north of the station flies a circle clockwise around the station, the phase relationship of the two signals varies from 0 degrees 360 degrees.

The localizer ground station radiates two directional beams, one on each side of the airfield runway. One beam is modulated by a 90 Hz signal; the other is modulated by a 150-Hz signal. The 90-Hz pattern is directed along the right side of the runway and the 150-Hz pattern on the left side. The relative amplitude of the 90-Hz to the 150-Hz signal varies with the horizontal position of the aircraft in respect to the instrument approach path. In the center of the approach path the beams overlap and form an area where the two signals are of equal strength.

The amplitude of the two signals are compared in the receiver, and an off-course deviation signal is produced when an amplitude difference exists. The deviation signal is selected for use by the flight director system when "VOR-ILS" is selected on the navigation selector panel.



LOCALIZER ANTENNA PATTERN

## RF SECTION 806A WILCOX

The RF section of this receiver uses a double conversion system consisting of oscillators and mixers to develop a 10.7 MHz fixed frequency IF. The RF circuits have a 10 MHz bandwidth which eliminates the need for tuning. Only the crystals of the oscillators need be changed to effect a channel change. Channel selection is accomplished by switching crystals in the oscillators used to develop mixer injection voltages. An all electronic crystal switching arrangement which requires no mechanical switching is used. When the desired operating frequency is selected at the control panel, the proper crystal is selected by diodes operating as switches.

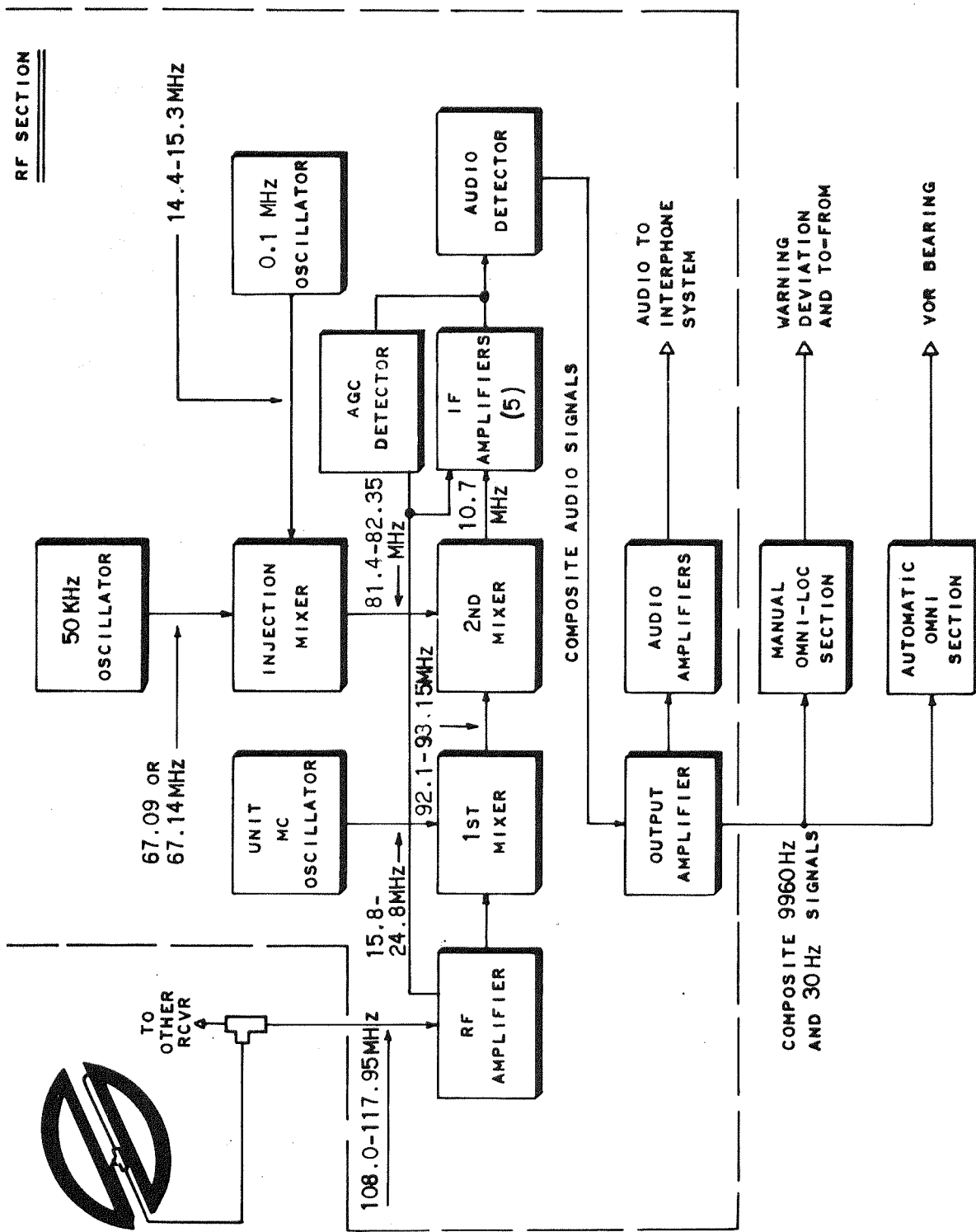
Following the conversion circuits are five 10.7 MHz IF amplifiers. The AGC circuits provide Automatic Gain Control (AGC) up to a predetermined level to the second and fourth IF stages. Above a predetermined level AGC is removed from the IF stages and applied to the "front end" stages. The IF amplifier output is detected by a diode detector which reproduces the reference and variable phase signals when VOR signals are being received. In localizer operation the detector output is the 90 Hz and 150 Hz localizer signals. Station identification audio is sent to audio amplifiers in the receiver before application to the aircraft interphone system. The VOR or localizer signals are applied to the manual omni-localizer and automatic omni sections of the receiver.

## MANUAL SELECTION

The manual omni-localizer section contains a variable phase channel, reference



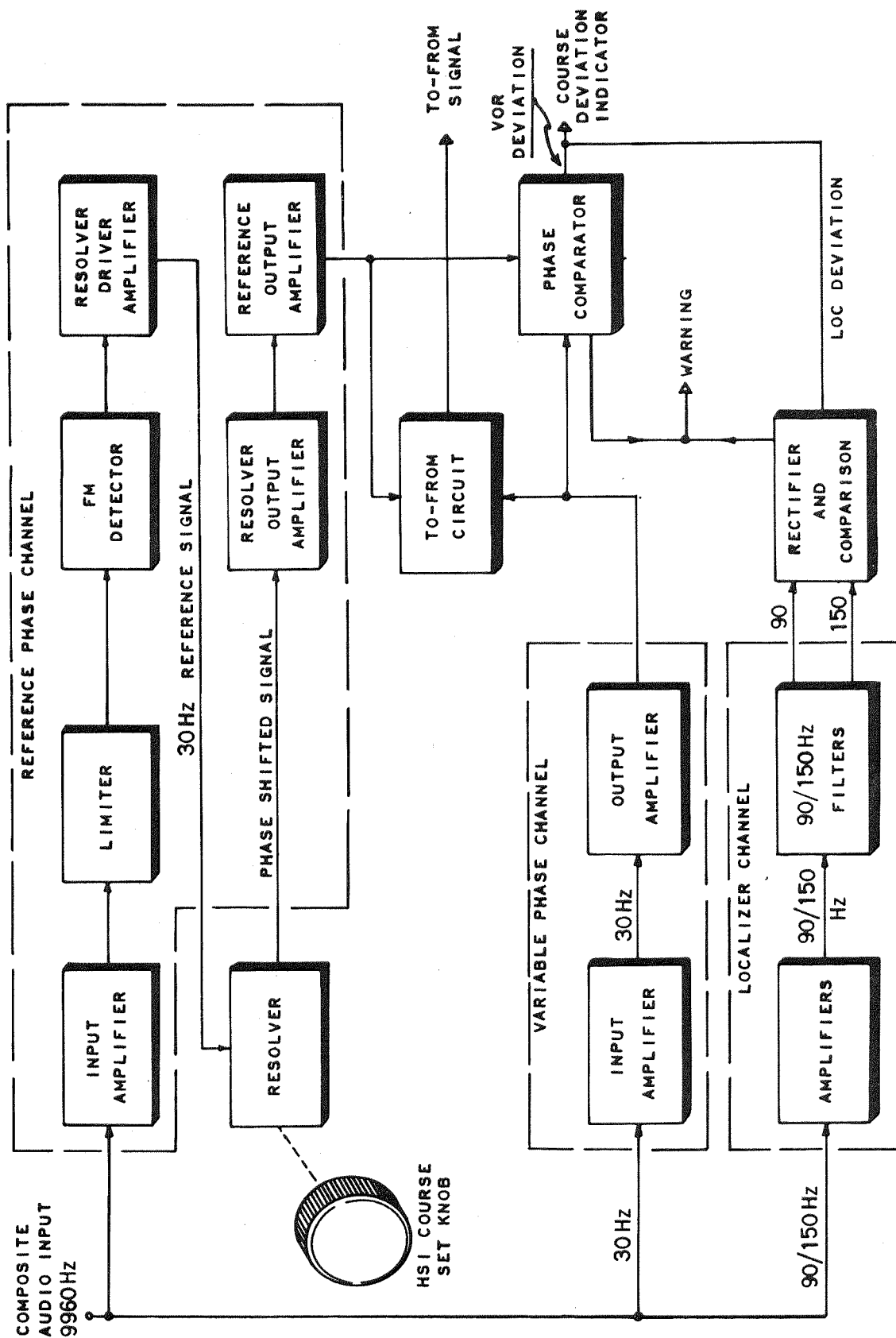
RF SECTION

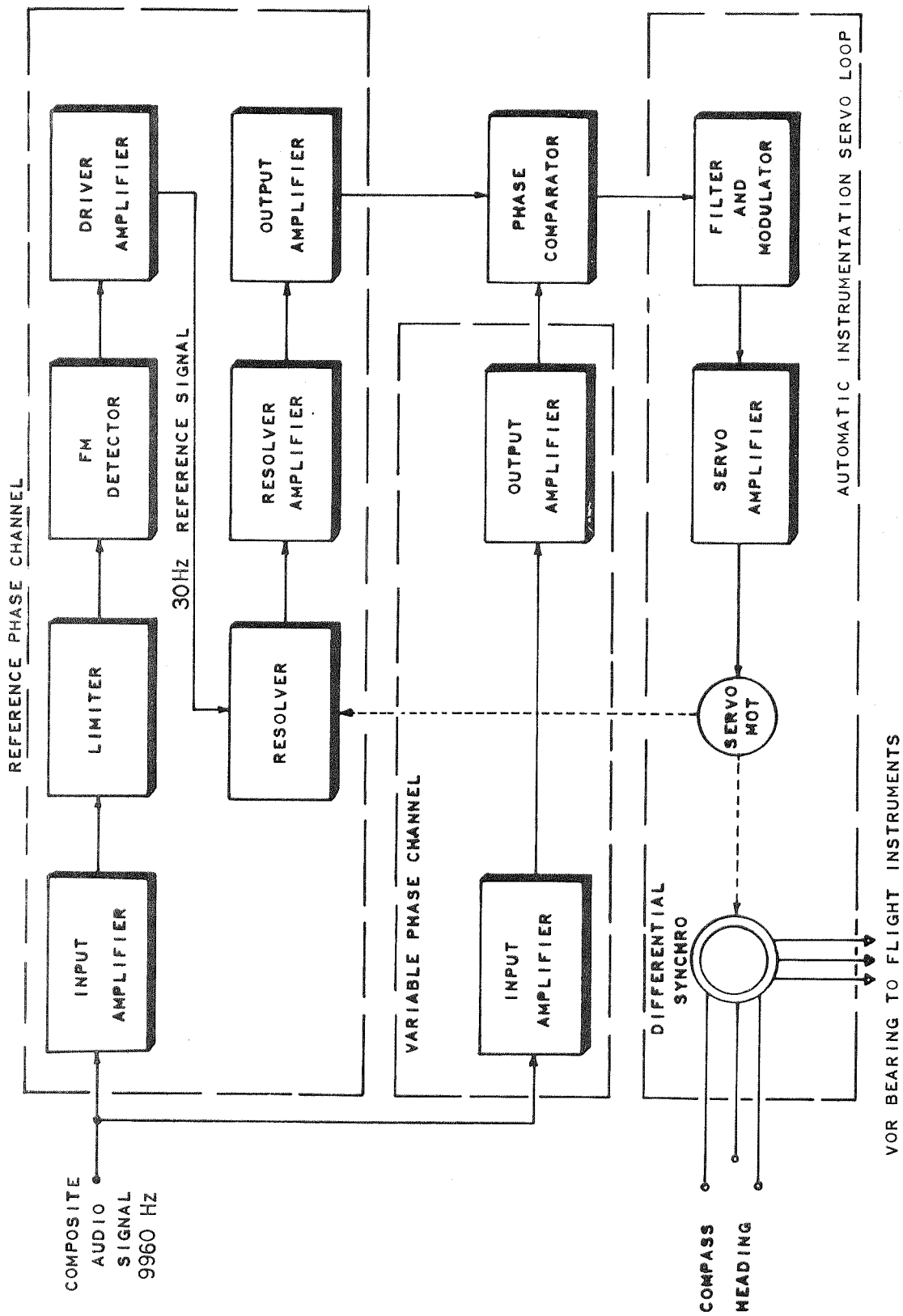


phase channel, and localizer channel. In VOR operation the reference phase and variable phase signals are applied to their respective channels. The reference phase signal is a Frequency-Modulated (FM) sub-carrier which is amplified in the reference phase channel. After amplification and limiting, the 30 Hz modulation is reproduced in an FM detector. The 30 Hz reference signal is then applied to a resolver in the HSI. The position of the resolver rotor is determined by the selected VOR course (COURSE SET knob position). The selected course of the resolver phase shifts the 30 Hz reference phase signal. The resultant signal is amplified and applied to a phase comparator. The variable phase 30 Hz signal is amplified and also applied to the phase comparator. The comparator circuit develops a polarized D-C output when the two signals are not in phase. This polarized signal provides deviation information to the HSI and flight director system. The reference phase signal, with selected course information added, is also compared with the variable phase signal in the to-from circuit. The phase relationship of the two signals produces a polarized D-C output. The polarity of this DC determines the to-from display position. In localizer operation the signal is processed by the localizer channel. The receiver section supplies an audio signal containing a 90 Hz component and a 150 Hz component. After amplification, the composite audio signal is separated into 90 Hz and 150 Hz components by fixed tuned filters. The two audio components are rectified and when the resultant voltages are equal in amplitude, the output voltage will be zero. This indicates an aircraft on-course condition. When the two signals are unequal in amplitude, a polarized deviation (error) signal will result. The deviation output is applied to the HSI deviation bar.

#### AUTOMATIC SECTION

The automatic omni section of the receiver also has a reference phase channel, variable phase channel, and phase comparator. The operation of these channels is similar to the manual omni-localizer section. However, an automatic instrumentation servo loop has been added. The comparator automatically and continuously compares the reference phase and variable phase signals. The comparison is used to position a differential synchro which transmits bearing information to the BDHI's and HSI. When the variable phase and reference phase are not in phase, the comparator develops a polarized D-C output. The D-C voltage is converted to an A-C signal whose phase is determined by the polarity of the comparator output. The A-C voltage is amplified and used to drive an A-C motor. The direction of motor rotation is dependent upon the phase of the applied voltage. This gives sense of direction to the loops. The motor positions the resolver in the reference phase channel until the reference phase and variable phase signals are in phase. As the two signals approach an in-phase condition, the comparator output decreases to zero and the motor stops. A differential synchro is positioned by the motor and transmits bearing information to the BDHI's and HSI. Assuming that a bearing of 90 degrees exists





BLOCK DIAGRAM VHF NAV RECEIVER, AUTOMATIC SECTION

between the aircraft and VOR station, the variable phase signal then leads the reference phase by 90 degrees. Therefore, the comparator circuits develop an output. This results in the motor driving the reference phase resolver 90 degrees to bring the two signals in phase. The 90 degree shaft rotation is transmitted to the bearing pointers of the indicators by a differential synchro. This synchro is supplied excitation from the compass system; therefore, the synchro output is bearing relative to the indicator compass card.

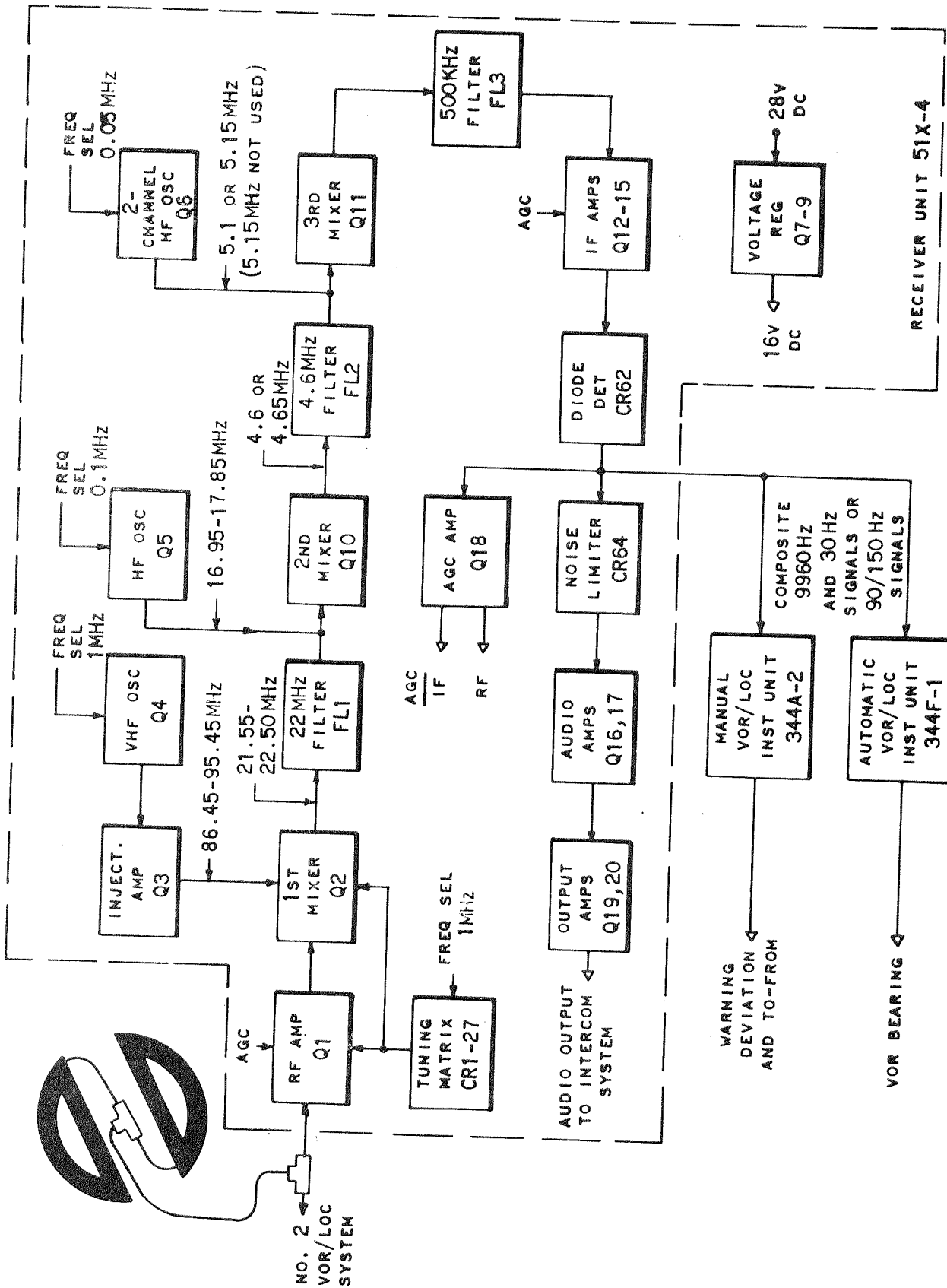
#### RECEIVER SECTION 51R-6 COLLINS

The RF section uses a triple conversion system consisting of oscillators and mixers to develop a 500 KHz IF. Solid stage switching of oscillator crystals is used for frequency selection requiring no mechanical switching. The IF signals are transformer-coupled through four stages of amplification to the detector. The detector output is applied to the AGC amplifier, noise limiter and VOR/LOC output terminals. AGC voltage controls the RF amplifier and the first two IF stages. The noise limiter output is coupled through four audio amplifiers before going to the aircraft interphone system. The VOR/LOC signals are sent to the manual and automatic instrumentation units.

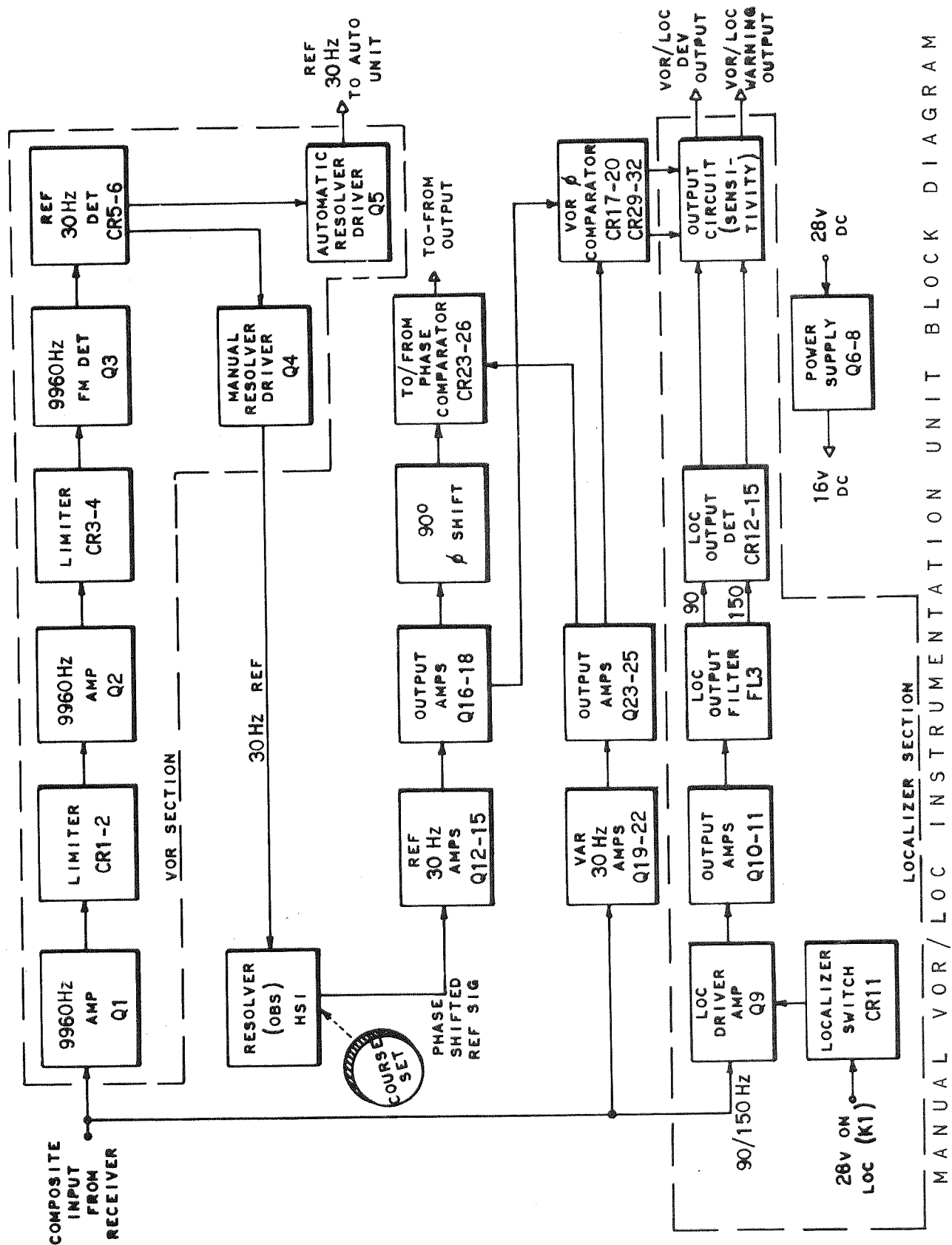
#### MANUAL INSTRUMENTATION UNIT

The manual instrumentation unit has two channels, reference and variable. The composite VOR signal consists of the 9960 Hz FM subcarrier containing the 30 Hz reference signal and the amplitude modulated 30 Hz variable signal. The composite signal is routed to the inputs of both the reference and variable channels. The variable 30 Hz signal is separated by a low pass filter in the variable channel. The variable signal is amplified, filtered to remove any 30 Hz harmonics and further amplified to the power level required by the variable channel input circuitry of the deviation and to-from phase detectors.

In the reference channel the composite VOR signal goes through stages of amplification and limiting. The limiters eliminate all effects of amplitude modulation (variable signal) from the composite VOR signal. After the amplification and limiting stages, the 9960 Hz sub-carrier is detected to recover the reference 30 Hz signal from the reference 30 Hz detector and one output is routed to the autoresolver driver for use in the automatic instrumentation unit and the self-test circuits. A second output is routed through the manual resolver through the manual resolver driver to the OBS resolver in the HSI. The rotor of the OBS resolver is manually positioned by setting in the selected VOR course (radial) with the course set knob. Rotating the course knob (resolver rotor) phase shifts the reference 30 Hz signal degree per degree with selected course (Inherent phase shift of the resolver and associated circuitry is 90 degrees with no deviation from selected course). The phase shifted reference signal is amplified and filtered to remove any 30 Hz resolver generated harmonics, and applied to



VOR/LOC RECEIVER BLOCK DIAGRAM



the deviation and to-from phase comparators.

The deviation phase comparator produces a D-C error voltage proportional to the phase difference between the reference and variable signals. The error voltage output of the phase comparator is routed to the HSI deviation bar, driving it left or right depending on the error signal polarity. The reference and variable signals are also summed in the phase comparator and used as flag warning. Loss of either or both of the 30 Hz signals will reduce the flag signal level enough to allow the VOR/LOC flag to appear. The 90 degree phase shifted reference signal from the OBS resolver is shifted an additional 90 degrees before application to the to-from phase comparator. The reference and variable signals are in phase or 180 degrees out of phase. When the signals are in phase, the to-from phase comparator will drive the indicator to a "TO" indication. A 180 degree phase relationship will provide a "FROM " indication.

### LOCALIZER

When a localizer frequency is selected, a diode switch allows the localizer signals to be amplified and applied to the 90 Hz and 150 Hz filters. The two signals are AM and are compared in the localizer output circuits to produce a deviation signal. The amplitudes are summed to produce a localizer reliability flag signal. During localizer operation diode switches turn off the output amplifiers of the manual and automatic instrumentation units.

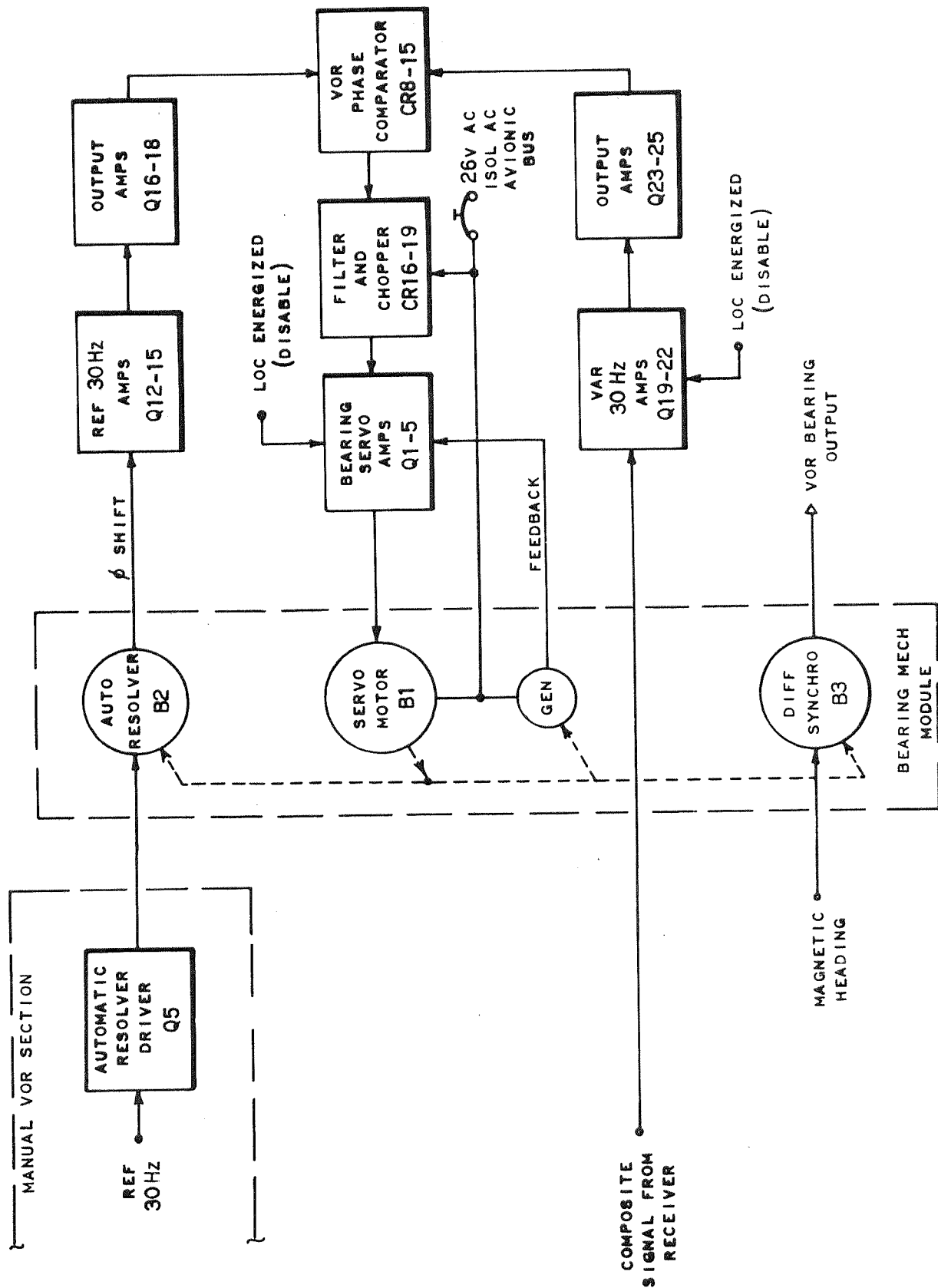
### AUTOMATIC INSTRUMENTATION UNIT

The reference signal is applied to the autoresolver, amplified and sent to the VOR phase comparator in the auto-instrumentation unit. The variable signal is amplified and compared with the reference signal in the phase comparator. The D-C output of the comparator is sent through a filter and chopper (D-C to A-C inverter) amplified and drives the servo motor. The servo motor repositions the autoresolver rotor until the reference and variable phase signals are in quadrature (90 degree phase difference). A differential synchro is also positioned mechanically by the motor. The differential synchro compares magnetic heading with rotor shaft position and sends a synchro output to the BDHI and HSI bearing pointers.

### SYSTEM PECULIARITIES

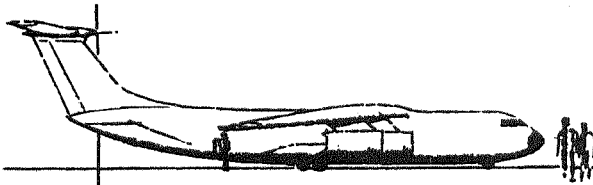
The Localizer deviation signals are sent to the AWLS system during an AWLS approach. The deviation signals are desensitized before being applied to the flight director instruments. The localizer antenna switch is also activated by the AWLS system. At localizer beam center the rear VHF antenna is disconnected from the system and the nose VHF antenna inserted.





AUTOMATIC VOR INSTRUMENTATION UNIT BLOCK DIAGRAM



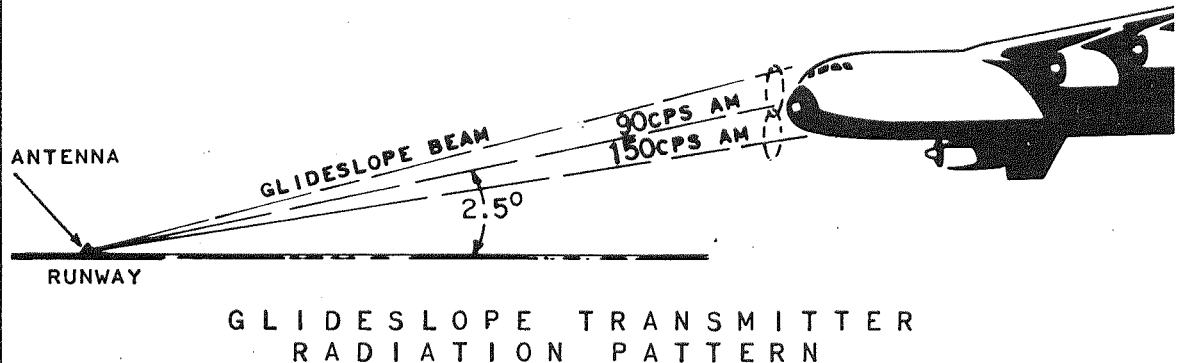


## GLIDESLOPE SYSTEM

### GENERAL

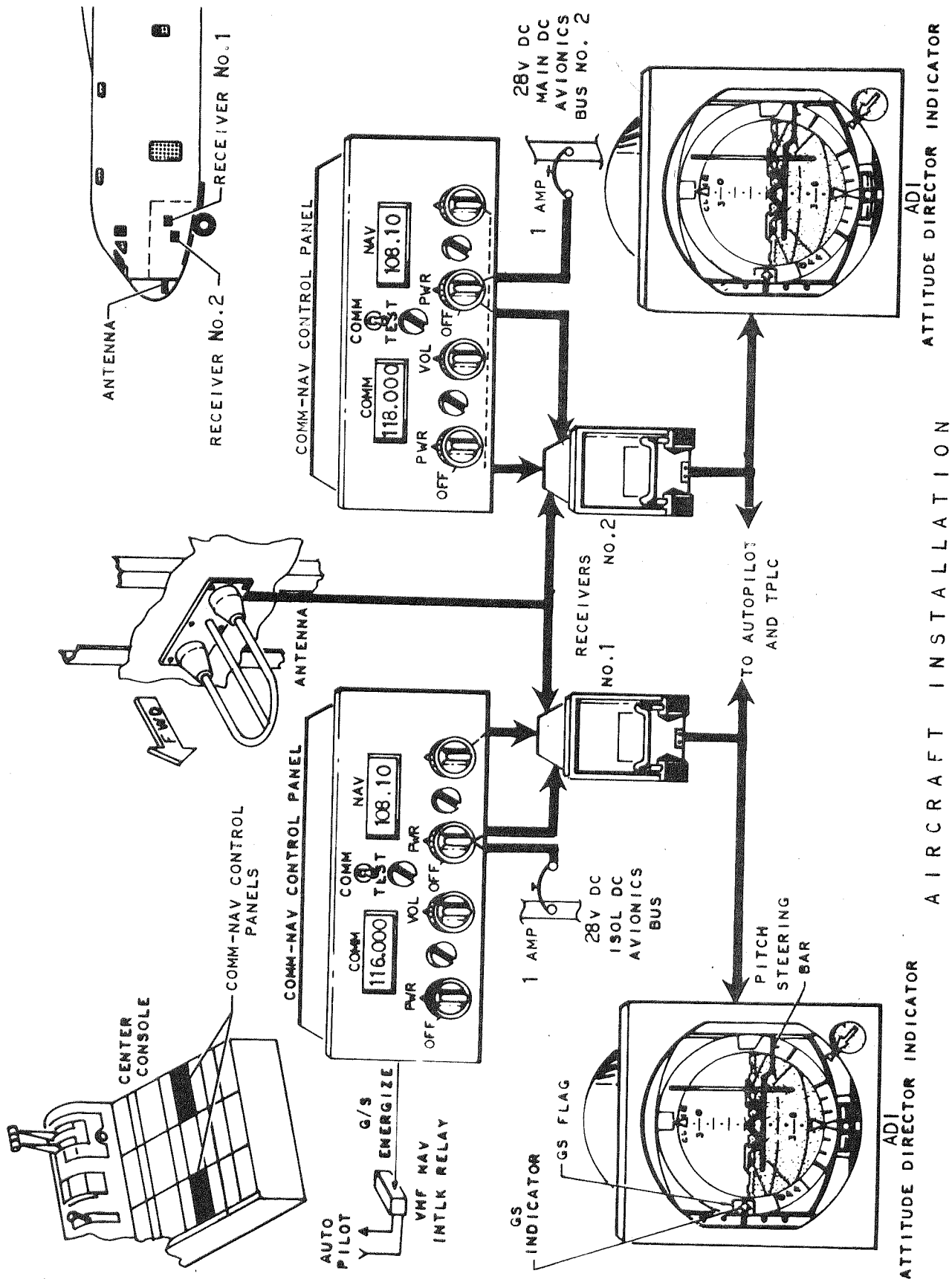
The glideslope system is used with the VHF navigation system during an instrument approach to the runway. The glideslope system provides vertical guidance information and the VHF navigation system provides the lateral guidance information. A glideslope system will also provide a warning indication if the vertical guidance information is unreliable.

A glideslope ground station transmitter with its antenna located adjacent to and about a 1000 feet from the approach end of a runway transmits a specific frequency which is amplitude modulated with a 90 Hz and a 150 Hz audio tone. This signal is transmitted as dual radiation patterns which are called "beams". The 90 Hz and the 150 Hz beams overlap each other to give an imaginary glide path line in the center of the overlap.



### AIRCRAFT INSTALLATION

The dual glideslopes are turned "on" and "off" by the VHF nav control panel power switch. Both systems use the same antenna which is located below the radar antenna in the radome. Operating power is supplied by the appropriate D-C bus. Glideslope frequencies are selected by selecting an ILS frequency on the VHF nav control panel.



## SYSTEM OPERATION

The transistorized glideslope receiver provides 20 crystal controlled channels spaced 300 KHz apart. The frequency range is 329.3 to 335.0 MHz and each glideslope frequency is paired "one-for-one" with a localizer frequency.

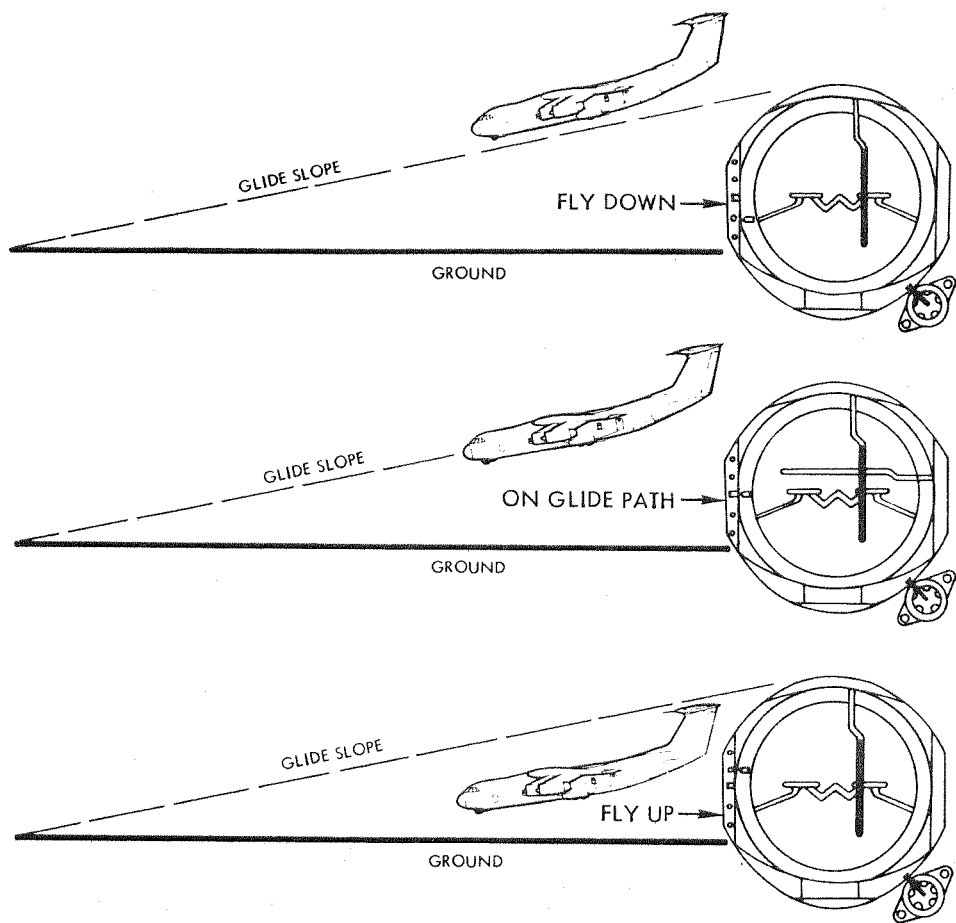
By selecting a given localizer frequency, a matched glideslope channel is selected. When the VHF nav system has VOR frequencies selected, the glideslope is switched to standby by the VHF nav control panel.

When the VHF nav control panel has a localizer frequency selected, the glideslope receiver is "on" and its output is applied to the Attitude Director Indicator (ADI) on the instrument panel.

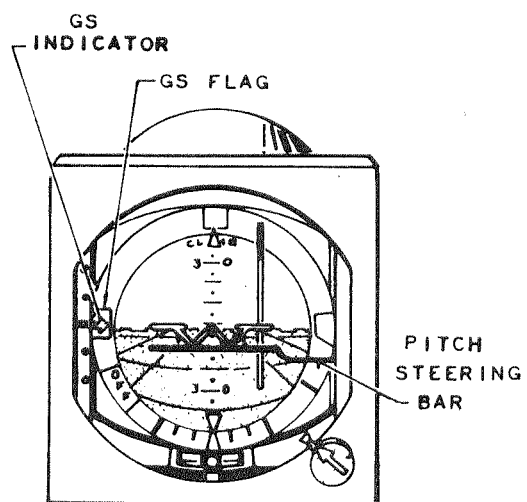
Displacement from the glidepath is displayed as ADI vertical pointer deflection. Deflection of the pointer represents the relative position of the aircraft from beam center. An upward deflection indicates that the aircraft is below beam center and requires "fly up" to the glidepath. A downward deflection indicates that "fly down" is required. Should the glideslope deviation signals become unreliable, a warning flag appears covering the ADI glideslope pointer.

LOC FREQ MHz	GS FREQ MHz
108.1	334.7
108.3	334.1
108.5	329.9
108.7	330.5
108.9	329.3
109.1	331.4
109.3	332.0
109.5	332.6
109.7	333.2
109.9	333.8
110.1	334.4
110.3	335.0
110.5	329.6
110.7	330.2
110.9	330.8
111.1	331.7
111.3	332.3
111.5	332.9
111.7	333.5
111.9	331.1

LOCALIZER GLIDESLOPE  
FREQUENCY PAIRING CHART



## GLIDESLOPE INDICATOR DISPLAY

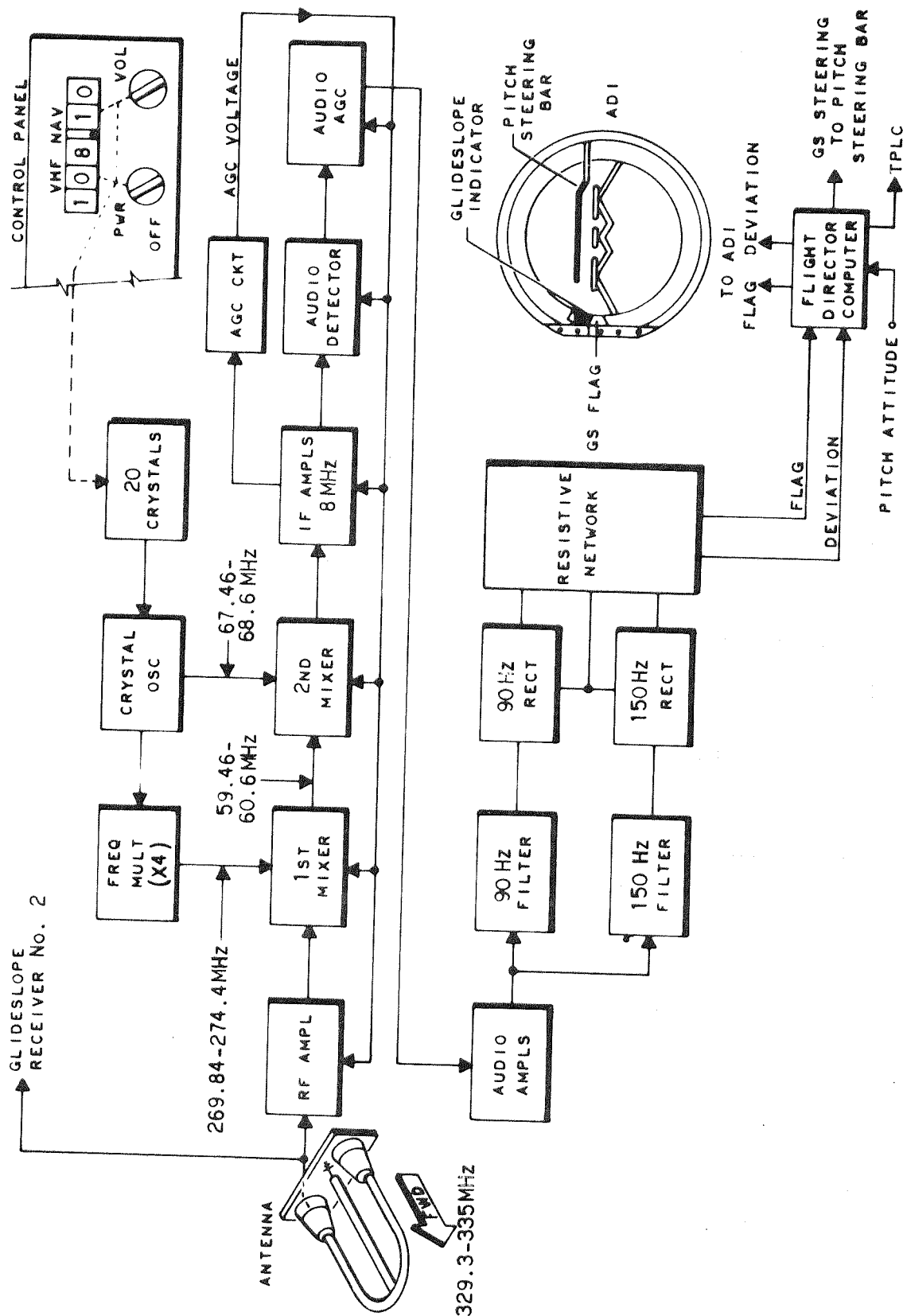


## ATTITUDE DIRECTOR INDICATOR (ADI)

## SPECIFICATIONS

### WILCOX 800 B

CHARACTERISTIC	SPECIFICATION
Power requirements	27.5 volts, DC
Frequency range	329.3 to 335.0 MHz
Number and spacing of channels	20 channels, spaced 300 KHz
Frequency selection	ARINC (2 out of 5 wires)
Input impedance	52 ohms
Type receiver	Dual conversion super-heterodyne crystal controlled.
Indicator circuit	Supply sufficient output for five 1000-ohm indicator loads in parallel.
Alarm signal	Supply sufficient output for four 1000-ohm flag alarm loads in parallel.



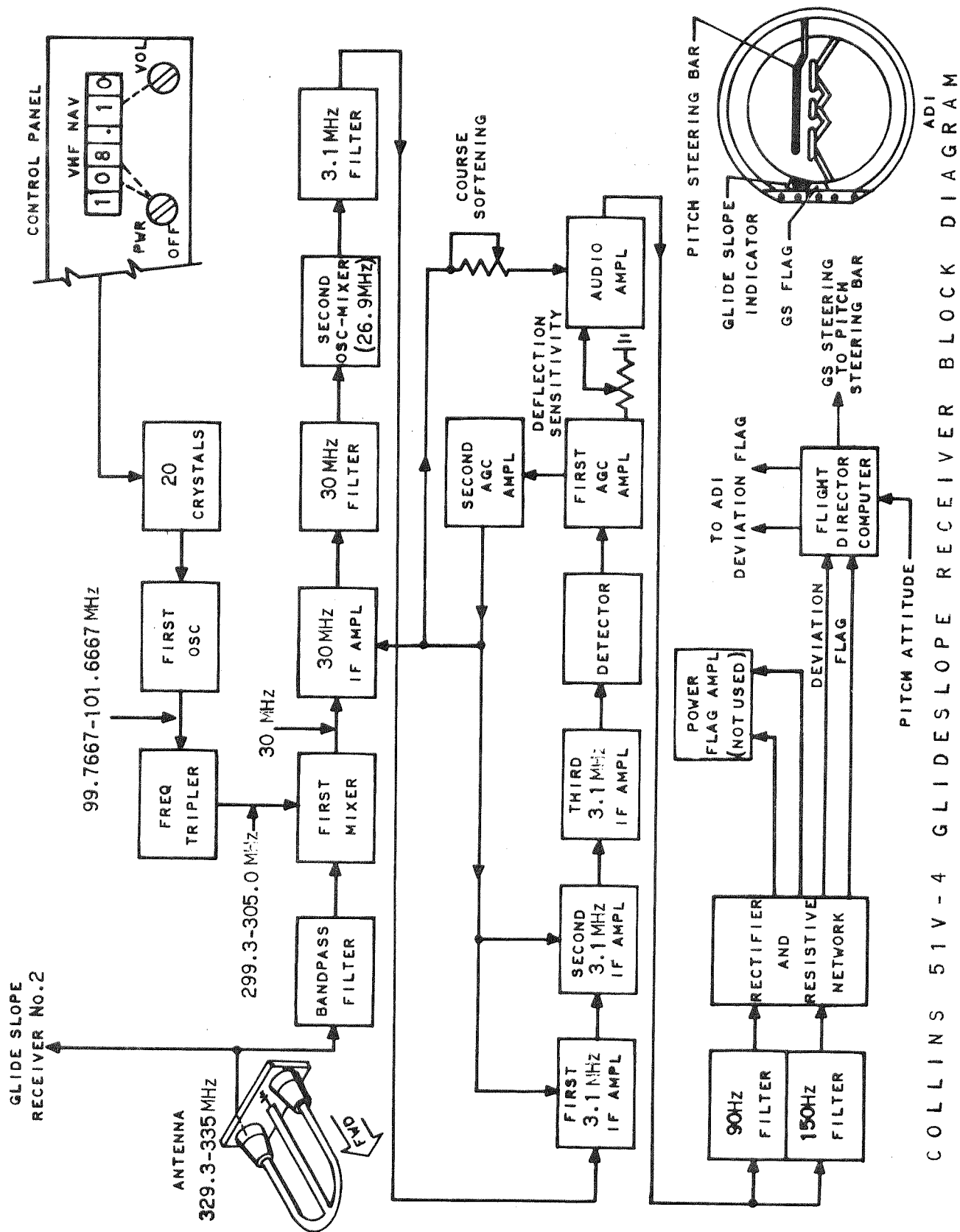
WILCOX 800  
GLIDESLOPE RECEIVER BLOCK DIAGRAM



## SPECIFICATIONS

### COLLINS 51V-4

CHARACTERISTIC	SPECIFICATION
Power requirements	27.5 volts, DC
Frequency range	329.3 to 335.0 MHz
Number and spacing of channels	20 channels, spaced 300 KHz apart
Frequency selection	ARINC (2 out of 5 wires)
Input impedance	52 ohms
Type receiver	Dual conversion, superheterodyne
Indicator circuit	Supply sufficient output for three 1000-ohm deviation indicator loads in parallel
Alarm signal	Supply sufficient output for two 1000-ohm flag alarm loads in parallel



## BLOCK DIAGRAM THEORY OF OPERATION

The glideslope receiver is a dual conversion, superheterodyne with crystal-controlled local oscillator.

A signal is received by the antenna. This signal, amplitude modulated at 90 and 150 Hz, is passed to a strip line filter which is designed for a bandpass of 329 to 335 MHz. This output is fed to the RF amplifier. The carrier is amplified by the RF amplifier and applied to the first mixer. The gain of the RF amplifier is controlled by the AGC voltage.

The input to the first mixer is heterodyned with the first injection signal in the range of 269.84 to 274.40 MHz. The first injection signal is the frequency-quadrupled output of the local oscillator. The first mixer output is the first high intermediate frequency (IF) and is in the range of 59.46 to 68.60 MHz.

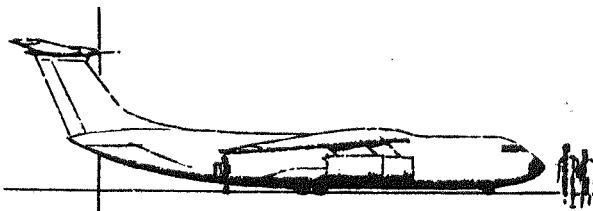
The local oscillator is crystal controlled, ranging from 67.46 to 68.60 MHz. The output of this oscillator is applied to the second mixer stage and through the frequency quadrupler to the first mixer.

The second mixer heterodynes the first mixer output with the oscillator output to produce an 8 MHz IF. The 8 MHz IF is amplified by the IF amplifiers, then detected by an audio detector. This output is amplified and applied to the 90/150 Hz filter. The 90 Hz and 150 Hz are separated and applied to separate bridge rectifiers. The rectified output from both rectifiers is compared and, if the aircraft is on course, the voltage will be equal in magnitude and opposite in polarity. This will produce a zero output to the deviation indicator which will remain centered. If the 150 Hz signal is greater in magnitude than the 90 Hz, the deviation indicator will deflect upward; and downward if the reverse is true.

## SYSTEM PECULIARITIES

The glideslope has a flag warning and deviation indication input to the Test Program Logic Computer (TPLC) for use during (AWLS) operation.

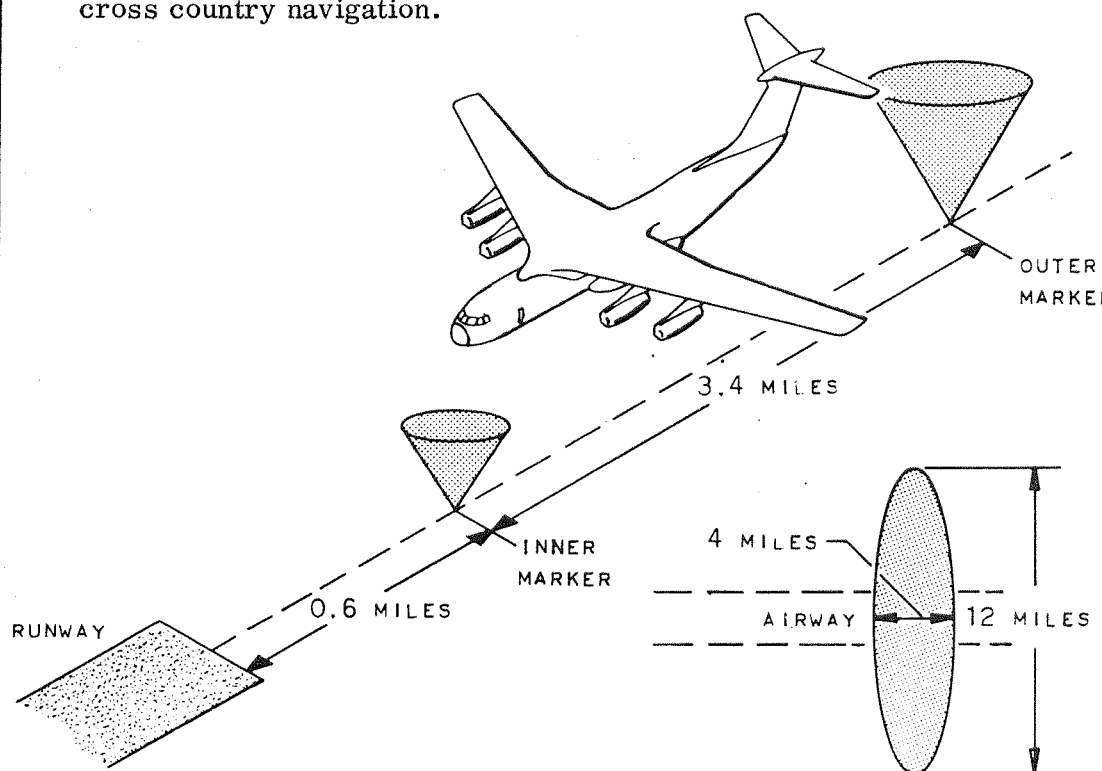




## MARKER BEACON SYSTEM

### GENERAL

The Marker Beacon system is used to provide an aural and visual indication to the pilot and copilot when the aircraft passes over a marker beacon ground station. Inner and outer marker beacons are located at the end of runways to indicate passage during instrument landings. Airways marker beacon stations are located along air routes, aiding the pilots in cross country navigation.



TYPICAL MARKER  
BEACON GROUND STATIONS

All marker beacon stations transmit a 75 MHz carrier modulated at different audio tones which identify the type station. An airways station

A modulates the 75 MHz carrier with a 3,000 Hz tone, which is interrupted by Morse code providing the pilots aural station identification through the interphone system. The outer marker O carrier is modulated with a 400 Hz tone and the inner marker I carrier with a 1300 Hz tone.

### AIRCRAFT INSTALLATION

The marker beacon system, having no power switch, is on whenever power is applied to the main D-C avionics bus No. 1. The system outputs are audio to the interphone system and illumination voltage to lamps on the instrument panel.

### SYSTEM COMPONENTS

The components of the marker beacon system are as follows:

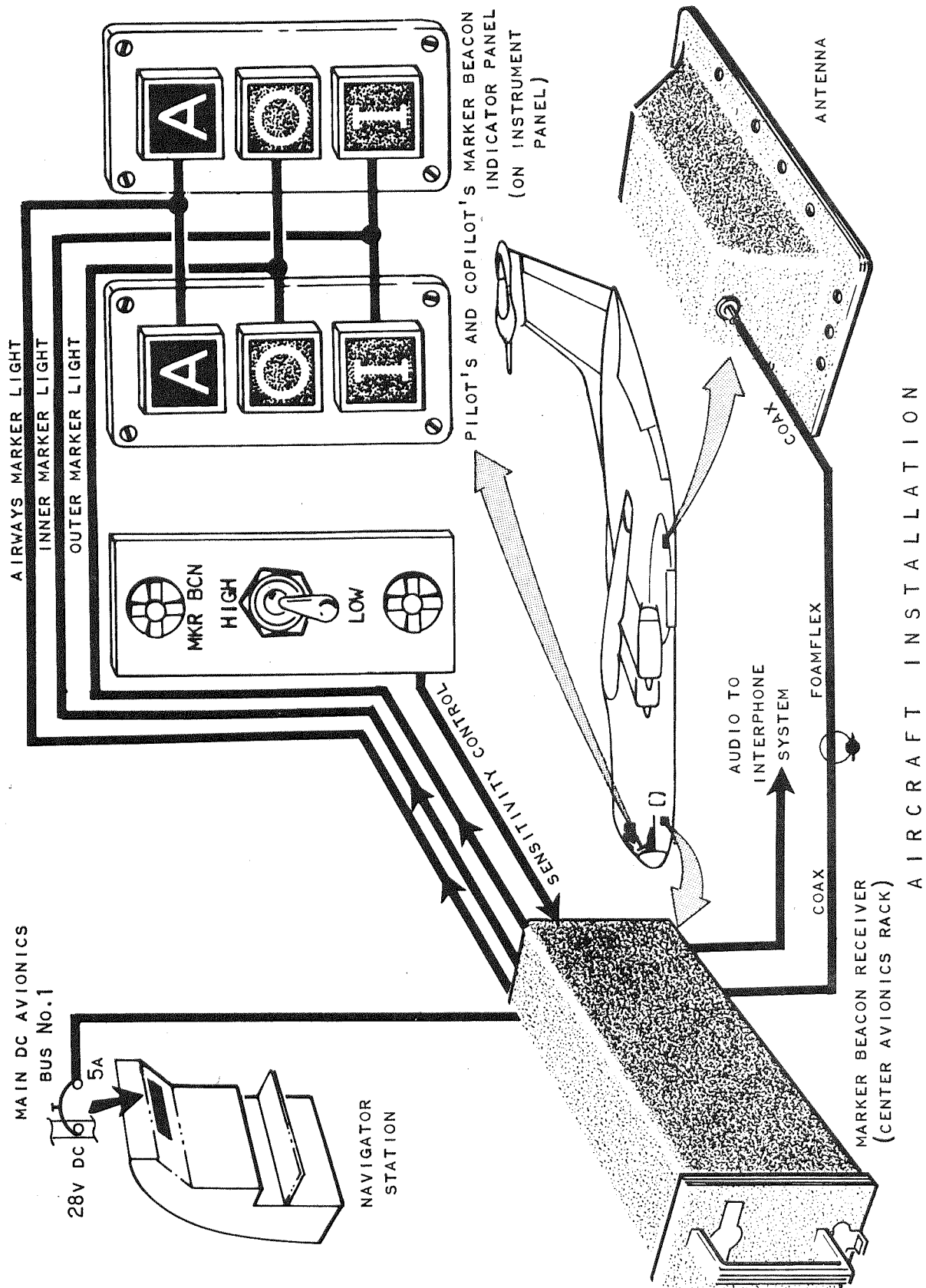
- Marker Beacon Receiver                      51Z-3
- Antenna    AT-536/ARN
- Light Assembly (2 ea)
- Marker Beacon Sensitivity switch

### SYSTEM OPERATION

With the marker beacon system operating, an aircraft flying over an airways station will receive a signal which will cause the white airways A lamp to illuminate. A 3000 Hz identification tone will be heard through the interphone when the interphone "BCN" monitor switch is on.

During ILS operation when the aircraft passes over the outer marker, the blue outer marker O lamp will illuminate and a 400 Hz audio tone will be heard through the interphone. When the inner marker is passed over the amber inner marker I lamp will illuminate and a 1300 Hz audio tone will be heard through the interphone.

A Marker Beacon HIGH-LOW switch is used to control the receiver sensitivity when receiving weak or strong signals. "HIGH" for weak signal reception and "LOW" for strong signal reception. With "HIGH" selected, the lamp will illuminate in the fringes of the signal during passage. Selecting "LOW" at this time will extinguish the lamp permitting it to relight when the aircraft is more directly over the beacon.



## SPECIFICATIONS

### 51Z-3 MARKER BEACON

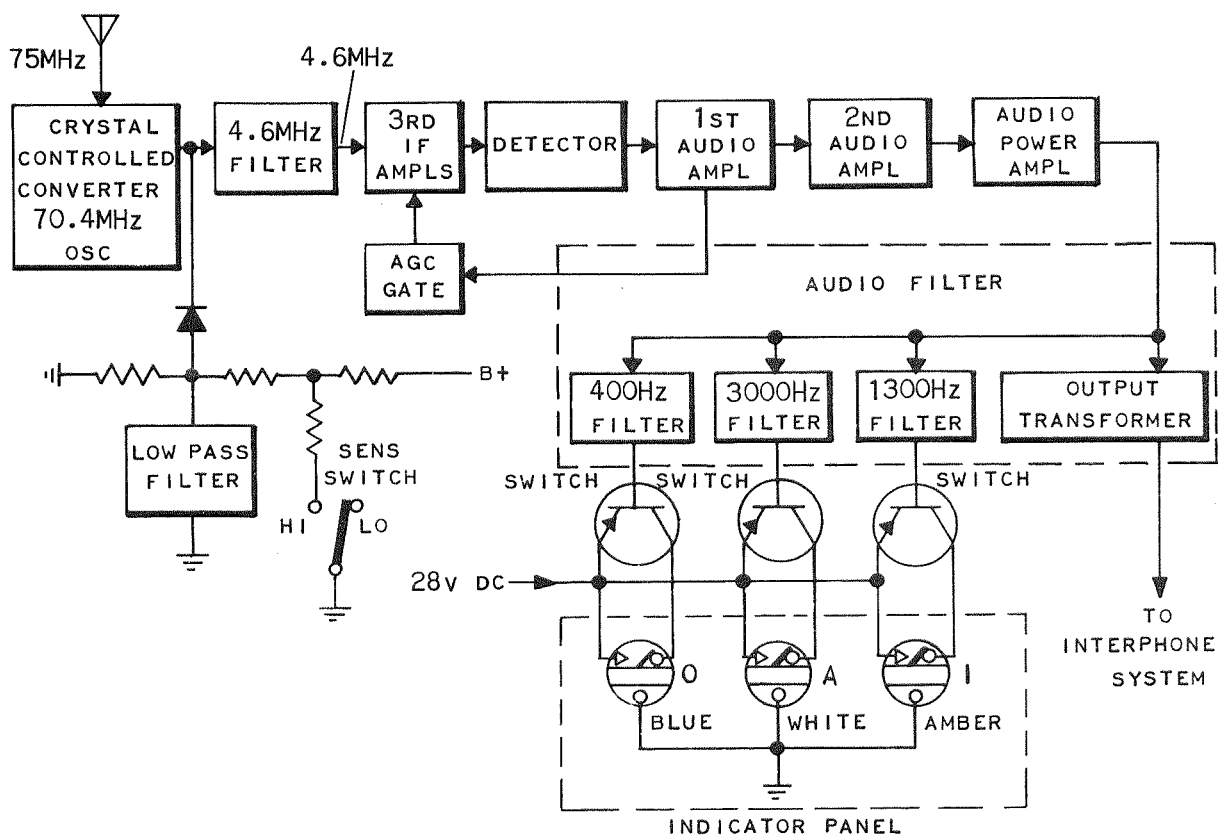
CHARACTERISTIC	SPECIFICATION
Power reg.	28 volts, DC 4.4 watts normal, 11 watts passing over marker beacon
Type reception	AM at 400 Hz, 1300 Hz or 3000 Hz
Operating frequency	75 MHz
Indications	Audio by tone Visual by indicator lights
Sensitivity	200 UV, 75 MHz signal modulated at 95 percent will light two No. 47 lamps in parallel
Selectivity	40 KHz min. at 6 db down, 250 MHz max at 60 db down
Antenna input impedance	50 ohms unbalanced
Audio output and impedance	100 MW, 600 ohms balanced



## BLOCK DIAGRAM THEORY OF OPERATION

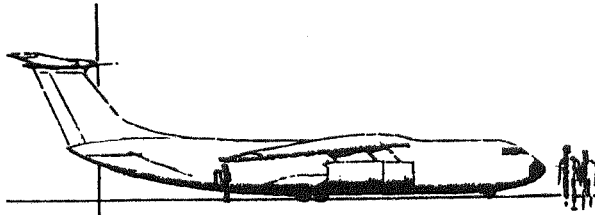
The 51Z-3 is a transistorized, single conversion, crystal controlled receiver operating on a fixed frequency of 75 MHz. Signals appearing on the antenna are fed to the converter. The 75 MHz signal is mixed with the 70.4 MHz signal generated by a crystal-controlled oscillator. A 4.6 MHz filter selects the difference frequency and passes it to the three IF amplifiers which increase the signal level. The detector separates the audio component (400 Hz, 1300 Hz or 3000 Hz) from the IF signal. The 1st audio amplifier is also the Automatic Gain Control (AGC) amplifier. AGC voltage is applied through the AGC gate to the three IF amplifier stages. The 1st audio amplifier is an emitter follower and supplies audio drive for the 2nd audio amplifier. The output of the 2nd audio amplifier is transformer-coupled to the audio power amplifier. The audio power amplifier supplies audio power to the output transformer and to the three audio filters. The output transformer supplies audio to the interphone system.

The output of the three filters, 400 Hz, 1300 Hz, and 300 Hz, are used to drive lamp switch transistors. A lamp switch transistor, when turned on by one of the three filters, will provide a low-impedance path for lamp current which will cause the proper lamp to illuminate indicating passage over a marker beacon station.



MARKER BEACON RECEIVER BLOCK DIAGRAM

Shown on the block diagram is a simplified sensitivity circuit. In the "LOW" sensitivity switch position the diode anode voltage is positive enough to cause diode conduction. Diode conduction allows the low pass filter to shunt the IF signal reducing the receiver sensitivity. In the "HIGH" switch position the anode voltage is less reducing conduction. Less IF signal is shunted to ground through the filter allowing receiver sensitivity to increase.



## TACAN SYSTEM

### GENERAL

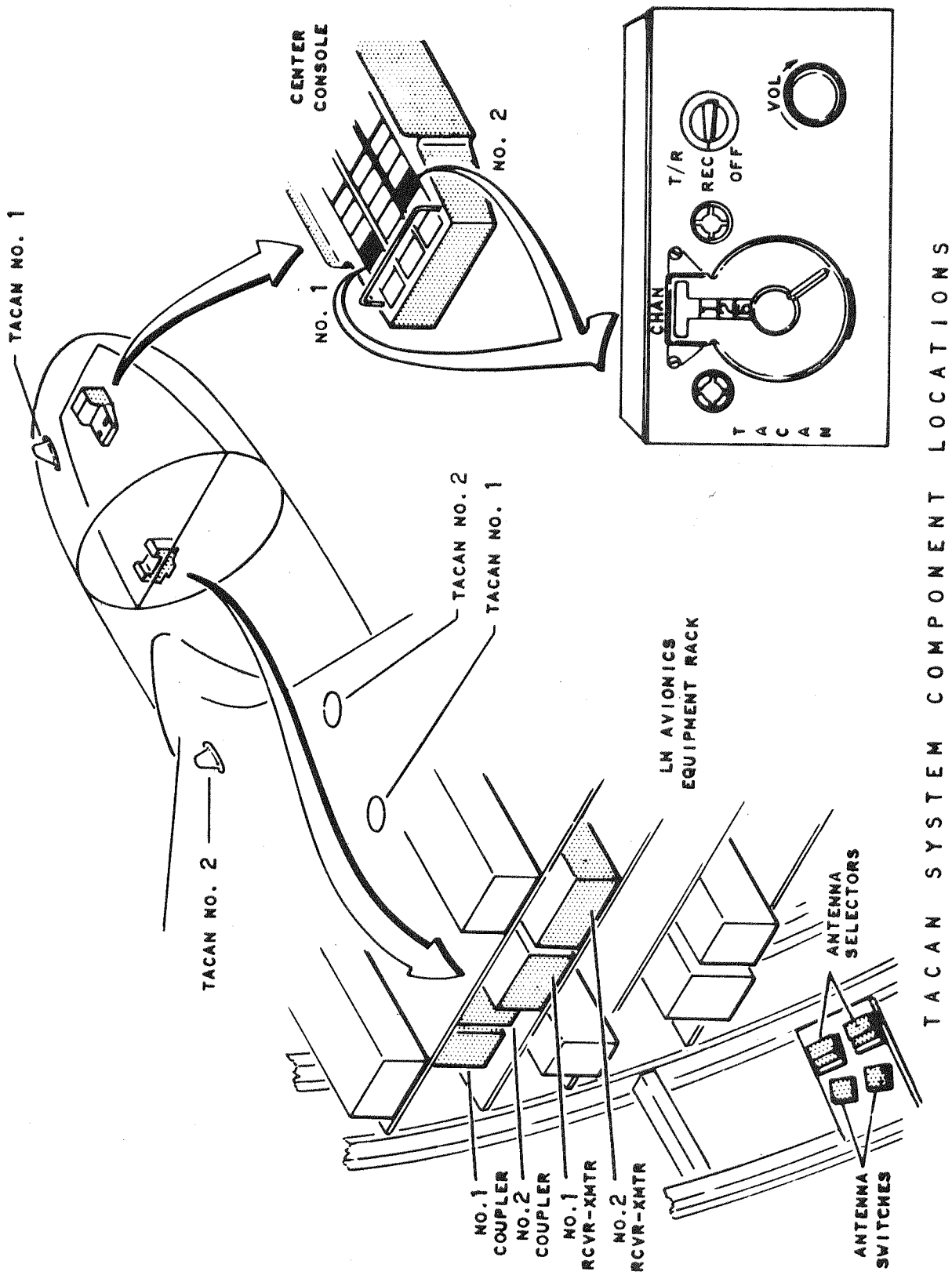
The Tactical Air Navigation (TACAN) systems are used to determine the bearing and distance of a selected surface beacon station from the aircraft. Continuous bearing and distance information is displayed on indicators as a navigational aid, during cross-country flights.

### AIRCRAFT INSTALLATION

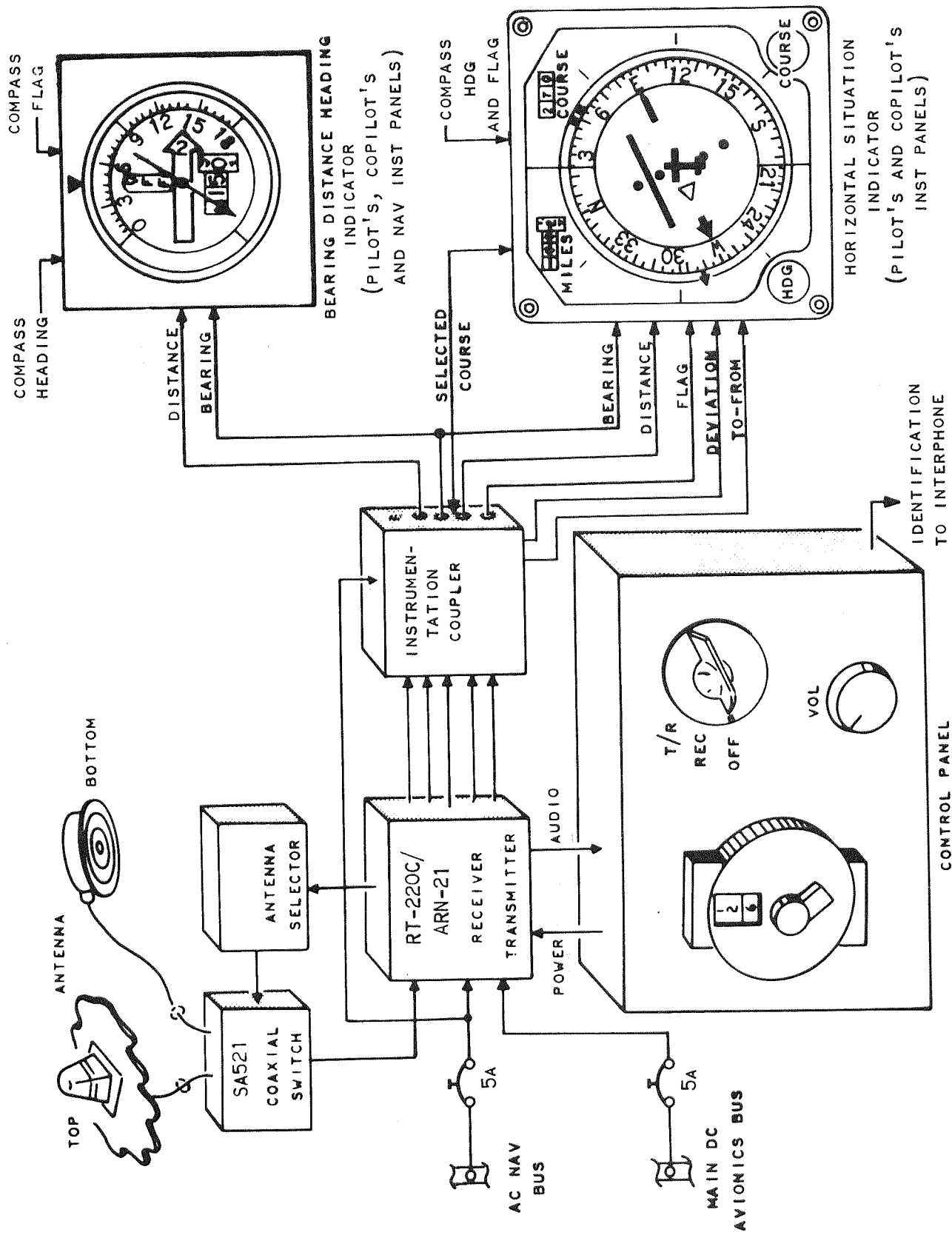
Two complete and independent ARN-21C TACAN systems are installed in the aircraft. Each system includes the following components:

- Receiver-Transmitter
- Control Panel
- Instrumentation Coupler
- Antenna Selector
- Antenna Switch
- Top Antenna
- Bottom Antenna

The Receiver-Transmitter (RT) units and instrumentation couplers are installed in the left-hand avionics equipment rack (underdeck). The antenna selectors and antenna switches are located to the left and slightly aft of the left-hand avionics equipment rack. The control panels are installed in the center console; one is on the pilot's side of the center console and the other is on the copilot's side. A stub-type antenna for each system is mounted on the top centerline of the fuselage. The bottom antenna for each system is flush-mounted on the bottom centerline of the fuselage. 115-volt, A-C power is applied through circuit breakers on the avionics circuit breaker panel. No. 1 TACAN receives A-C power from navigation bus No. 1 and D-C power from the main D-C avionics bus No. 1. The No. 2 TACAN is supplied in an identical manner from the No. 2 buses.



TACAN SYSTEM COMPONENT LOCATIONS



UNIT BLOCK DIAGRAM ARN-21C

## SYSTEM OPERATION

The two systems are designated as the No. 1 (pilot's) TACAN and the No. 2 (copilot's) TACAN. The No. 1 TACAN obtains compass reference from the No. 1 C-12 Compass system while the No. 2 TACAN is referenced to the No. 2 C-12 compass. Cross-connection between the two compass systems, through the pilot's and copilot's instrument panels, provide increased reliability in the event of failure in one of the compass systems. The TACAN systems may be selected for use by the flight director systems to provide lateral guidance information. TACAN beam deviation signals may be supplied by the No. 2 TACAN system to the All-Weather Landing System (AWLS) autopilot. Bearing and distance signals may be furnished by the No. 1 TACAN system to provide a source from which the AN/ASN-24 navigational computer may develop ground track information. For each TACAN system there is one top and one bottom antenna. Since aircraft attitude during maneuvers may blank out one of the antennas, an antenna selector monitors the TACAN receiver output and automatically selects the antenna which is receiving adequate signal.

NOTE: For the remainder of this chapter, unless otherwise indicated, only one TACAN system will be discussed, since both systems are identical in composition and operation.

All controls necessary for operation of the system are on the Control Panel. Two rotary switches allow selection of any channel from 1 through 126. Two modes of operation are available: "REC" (receive) and "T/R" (transmit/receive). When "REC" operation is selected, the receiver circuits of the TR unit are energized, and the system provides bearing information. When the "T/R" mode is selected, both receiver and transmitter circuits are energized, and the system provides bearing and distance information. The "VOL" (volume) control varies the audio output to the AN/AIC-18A interphone system.

When the receiver circuits are energized, signals from the beacon station are processed to provide bearing and station identification signals. The bearing signals, transmitted by the beacon station, consist of four modulated components: two 15 Hz (hertz) signals and two 135 Hz signals. One 15 Hz signal has a "fixed" (reference) phase regardless of the bearing of the aircraft to the beacon station. It varies degree-for-degree with the magnetic bearing of the aircraft, with respect to the beacon station. The 15 Hz variable phase is a result of the rotation of the cardioid pattern of the ground station antenna. The 135 Hz signals also consist of a reference phase and a variable phase. The 15 Hz signals provide coarse bearing information, and the 135 Hz signals provide fine bearing information. These bearing signals are applied to reference and variable bearing detectors in the receiver. The reference signals and the variable bearing signals are separated by the detectors and compared in phase comparison circuits.

The phase difference (determined by the position of the aircraft, relative to the beacon station) between the signals is converted into bearing information.

The bearing information is displayed on Bearing-Distance-Heading Indicators (BDHI). There is one BDHI on the pilot's instrument panel, one on the copilot's instrument panel, and two at the navigator's station. BDHI selector panels, on the pilot's and copilot's instrument panels, are used to select the information displayed on their respective BDHI's. Two navigation selector panels enable the pilot and copilot to select TACAN signals for their flight director systems. When TACAN signals are selected for use by the flight director, distance to the beacon station is displayed on Horizontal Situation Indicator (HSI). Two HSI's are provided; one on the pilot's instrument panel, one on the copilot's instrument panel. To fly a TACAN radial, the course arrow of the HSI is manually positioned to the desired TACAN course. The selected course information is compared with the TACAN bearing signals to develop course deviation information. This comparison takes place in the TACAN instrumentation coupler. The course deviation information is displayed by the course deviation indicator of the HSI. Deviation of the indicator in either direction (left or right) shows that the aircraft is not on the selected course, and it must be flown in the direction of the indicator deviation to get on course. The "to-from" indicator of the HSI shows whether the aircraft is flying on a radial toward or away from the beacon station. The deviation indicator alarm flag is used to monitor the reliability of the TACAN signal. When the flag is in view, the information being displayed is unreliable. TACAN bearing is displayed by the HSI bearing pointer when TACAN is selected at the NAVIGATION SELECTOR panel.

The radar principle is used to measure distance. It is based on the constant speed of RF energy as it travels through space.

NOTE: RF energy travels one nautical mile in approximately 6.18 microseconds.

When the "T/R" mode of operation is selected, the RT unit transmits a signal to the ground station. Narrow, widely-spaced interrogation pulses are repeatedly transmitted. These pulses are picked up by the surface beacon and applied to the beacon receiver. The receiver develops a signal which causes the beacon transmitter to send out reply pulses. The reply pulses are picked up by the airborne receiver. Timing circuits in the receiver measure the interval between the original transmission and the reply from the surface beacon. This time interval is converted into distance information.

Distance information is displayed on the navigator's two BDHI's. The No. 1 BDHI displays distance information from the No. 1 TACAN system and the No. 2 BDHI is used with the No. 2 TACAN. The pilot's BDHI displays No. 1 TACAN distance and the copilot's BDHI displays No. 2 TACAN distance. When TACAN signals are selected for use by the flight director systems, distance information is also displayed on the HSI's.

The antenna selection is determined on the basis of a minimum usable signal. When the system is not receiving a usable signal, the antenna selector operates, causing the antenna switch to alternately connect the top and bottom antennas to the receiver. When an antenna which is receiving an adequate signal is connected to the receiver, the receiver applies a signal to the antenna selector unit. This stops the switching action and keeps the selected antenna connected.

# SPECIFICATIONS

## ARN-21C TACAN

CHARACTERISTIC	SPECIFICATION
Frequency range	962 MHz to 1213 MHz
Low band (channels 1-63)	Transmitter: 1025 MHz to 1087 MHz Receiver: 962 MHz to 1024 MHz (63 MHz below transmitter frequency)
High band (channels 64-126)	Transmitter: 1088 MHz to 1150 MHz Receiver: 1151 MHz to 1213 MHz (63 MHz above transmitter frequency)
Intermediate frequency (IF)	63 MHz $\pm$ 70 KHz (transmitter frequency used for receiver injection)
Receiver sensitivity	-90 db triggering level
Transmitter pulse power output	1 KW minimum, 2.5 KW maximum
Pulse pair transmission rate (PRF)	Search: 120 to 150 ppps (varying) Track: 22 to 30 ppps (varying)
Channel selection time	12 seconds maximum



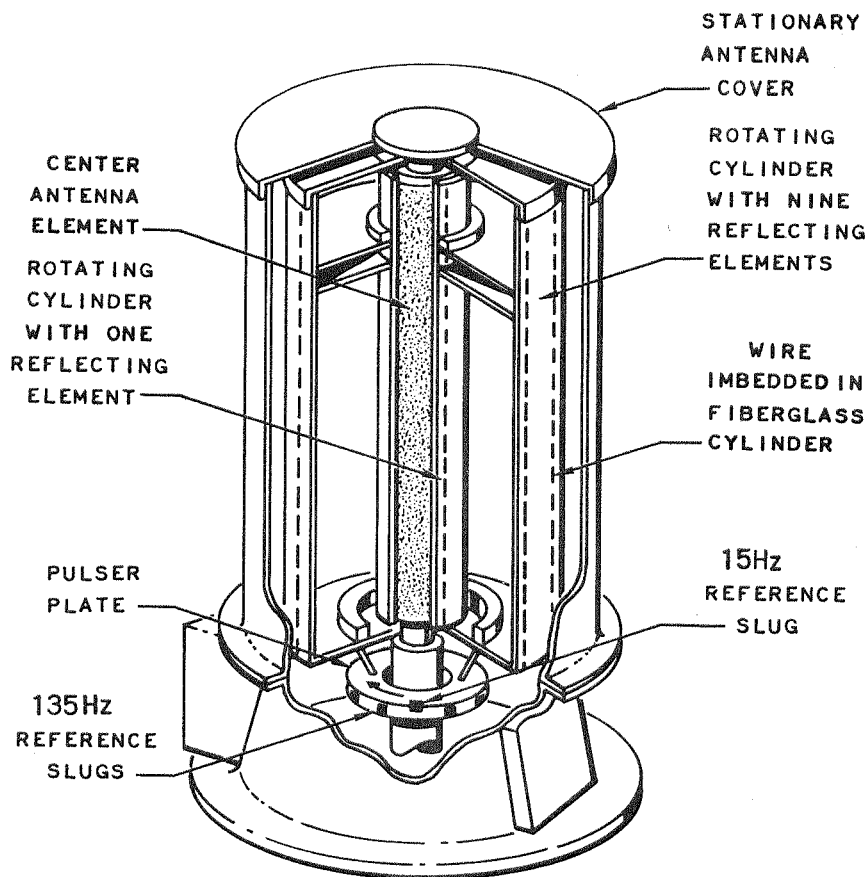
SPECIFICATIONS (continued)  
ARN-21C TACAN

CHARACTERISTIC	SPECIFICATION
System accuracy	Azimuth: $\pm 0.5$ degree Range: $\pm 0.1$ nautical mile plus 0.2 percent of distance
Beacon identity tone	Morse coded audio tone at 1350 Hz
Operating range	195 nautical miles at 40,000 feet
Power requirements	115 volts, AC, 380-1000 Hz, single phase 115 volts, AC, 380-420 Hz, single phase 28 volts, DC

BLOCK DIAGRAM THEORY OF OPERATION

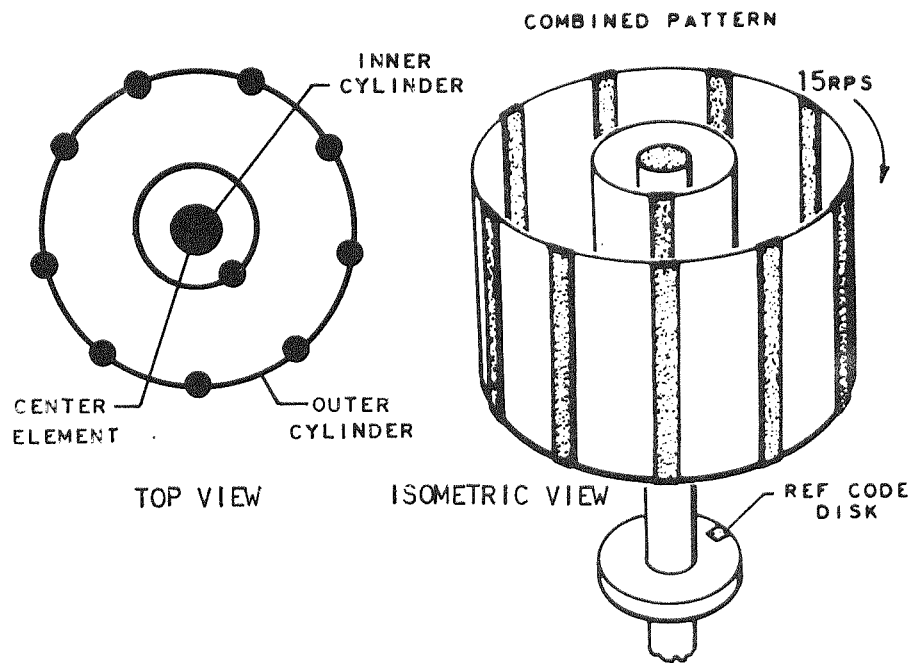
BEACON OPERATION

The surface beacon station is a pulsed transmitter-receiver system. Approximately 3,600 paired pulses per second are transmitted. Approximately 25 per cent of these pulse-pairs are used as reference bearing signals. The remaining pulses are randomly-spaced filler pulses and distance reply pulses in a ratio determined by the number of aircraft interrogating the beacon. The surface beacon also transmits an identification signal at 37.5 second intervals. This signal is keyed with three international Morse code characters, configured to provide a three-letter identification of the surface beacon. The transmitter is capable of responding to interrogations from as many as 120 airborne systems simultaneously. When distance information is desired, interrogation pulses are sent out by the airborne transmitter. This interrogation is detected by the surface beacon and used to trigger the beacon transmitter. Some of the random pulse-pairs are now synchronized with the interrogation pulses. These synchronized pulses are called reply pulses. The airborne receiver measures the time between the interrogation and the reply. This interval is converted into distance information.



T Y P I C A L   G R O U N D   B E A C O N   A N T E N N A

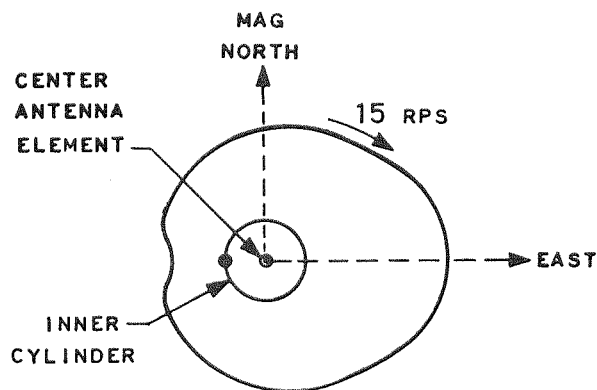
The surface beacon station antenna has four major parts; a center element, surrounded by an inner and an outer fiberglass cylinder, and a pulser plate. These components develop a directional radiation pattern. The center element is excited by the RF energy from the transmitter. This element is stationary and is omni-directional in the horizontal plane. Around the element is the inner fiberglass cylinder which has a vertical conductive wire embedded in the fiberglass. This wire acts as a reflector to distort the normal radiation pattern into a cardioid. The cylinder is rotated at 15 revolutions per second to cause the entire cardioid pattern to rotate. As a result of the pattern rotation, the signal received in any direction from the beacon will have sinusoidal variations in strength as a function of time. The signal received by the airborne system will vary in amplitude at a 15 Hz rate. This equals one cycle for each antenna revolution. For each degree of geographic bearing change, there is a one degree change in the electrical phase of the 15 Hz variable phase signal. The phase of the signal is used to develop coarse bearing information. It is necessary to have a fixed reference of the same frequency for phase measurement.



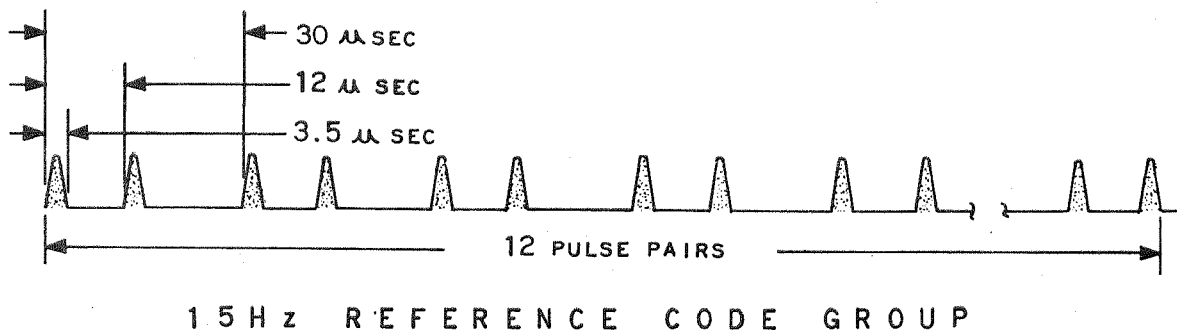
### GROUND BEACON ANTENNA

The fixed reference must be received in all directions around the beacon with identical phase. Therefore, each time the maximum point of the cardioid pattern passes through "east" (referenced to a magnetic compass), a series of pulses is transmitted. This is the reference phase 15 Hz signal. This signal is commonly referred to as the Main Reference Burst (MRB).

The variable phase 15 Hz signal and the MRB are compared in the airborne receiver to form the coarse bearing signal of the TACAN system.



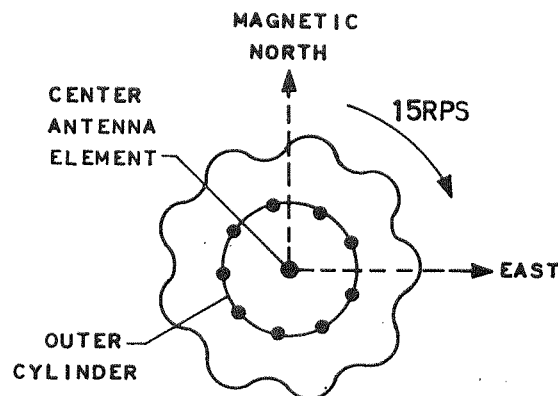
### 15 H z P A T T E R N



## FINE BEARING INFORMATION

A fine bearing feature is used to produce greater accuracy than is possible with the cardioid antenna pattern system. The outer cylinder of the surface beacon antenna is used to produce the fine bearing signal. The cylinder has nine vertical conductive wires embedded in the fiberglass. These wires are spaced uniformly at 40 degree intervals. The wires distort the cardioid pattern. The resulting composite pattern maintains the overall cardioid variation pattern resulting in sinusoidal variation in amplitude of the received signal

in any direction from the beacon transmitter. The received signal has the basic 15 Hz amplitude variation as before. The nine minor lobes produce nine cycles of amplitude variation with each antenna revolution. Since the pattern rotates at 15 revolutions per second, the nine lobes produce a 135 Hz signal ( $15 \times 9 =$

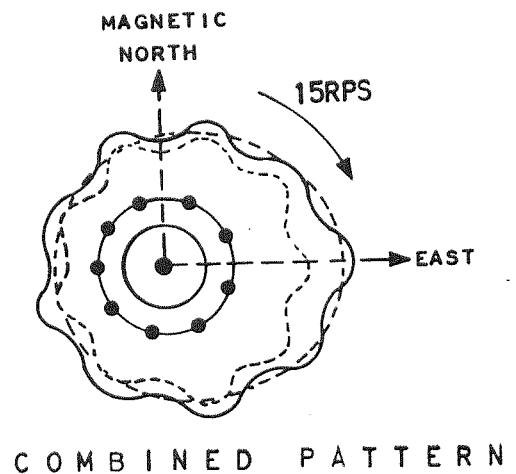


135 Hz PATTERN  
FINE BEARING  
INFORMATION

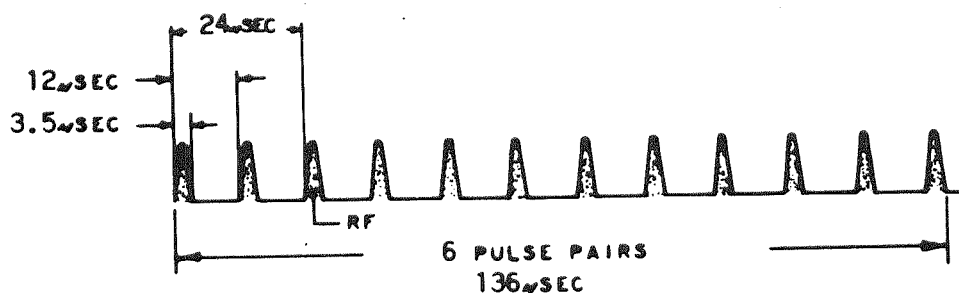
135). To furnish a reference phase for the 135 Hz component, another series of coded pulses - the Auxiliary Reference Burst (ARB) - is transmitted. The ARB's are spaced 40 degrees apart. The first ARB appears 40 degrees after the maximum point of the antenna radiation pattern rotates past east. Comparing the ARB's and the 135 Hz variable bearing signals provides fine bearing information. In a 40 degree arc of bearing, which is the width of a minor lobe, the phase of the received 135 Hz signal will vary through a complete cycle of 360 degrees.

Thus each degree of bearing change results in a nine degree change in the phase of the 135 Hz signal. The ratio of nine electrical degrees to one rotational degree gives a pronounced magnifying effect in the process of detecting changes in bearing.

The MRB's and ARB's are controlled by the pulser plate (reference code disc) on the surface beacon antenna assembly. The plate consists of a rotary aluminum disc with soft iron slugs embedded in the outer edge. The disc rotates at 15 revolutions per second. The slugs pass through a



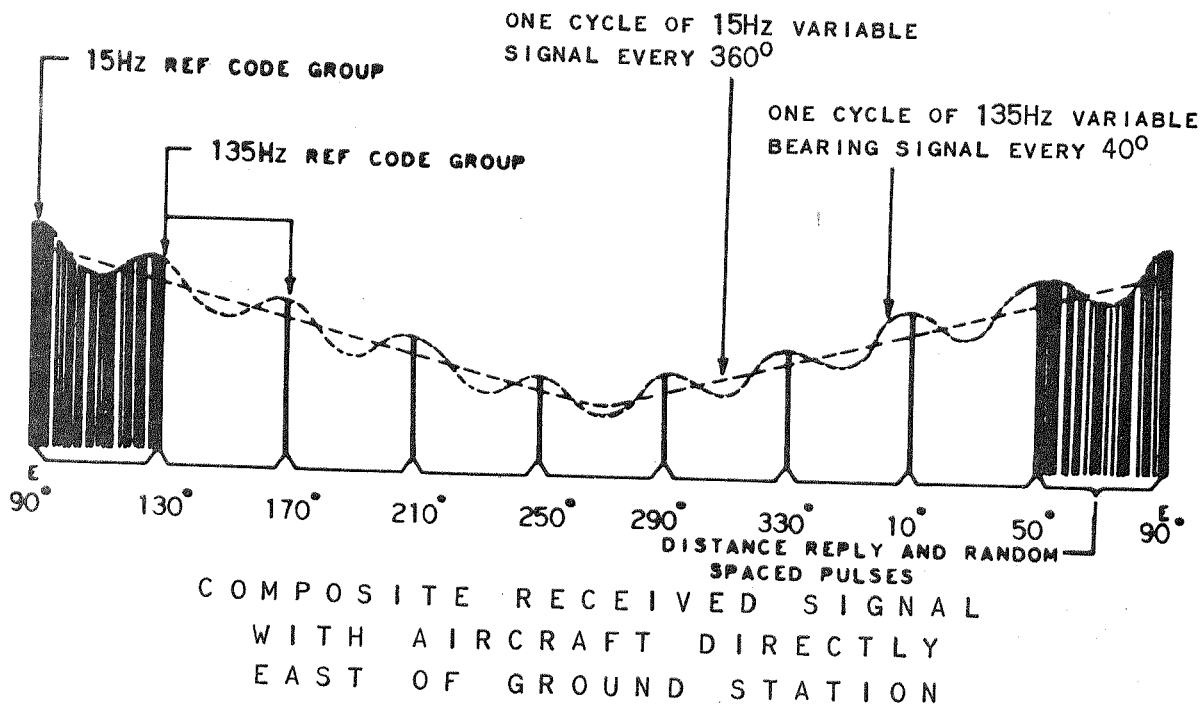
pickup coil, producing two sets of voltage (trigger) pulses. One pulse occurs once for each 360 degrees of disc rotation; the other occurs at 40 degree intervals thereafter. These pulses are synchronized with the 15 Hz and 135 Hz modulation components, and are used to trigger the transmitter which generates the



135 Hz REFERENCE CODE GROUP

MRB's and ARB's. The MRB's and ARB's have priority over distance reply, identification, and randomly-spaced filler pulses.

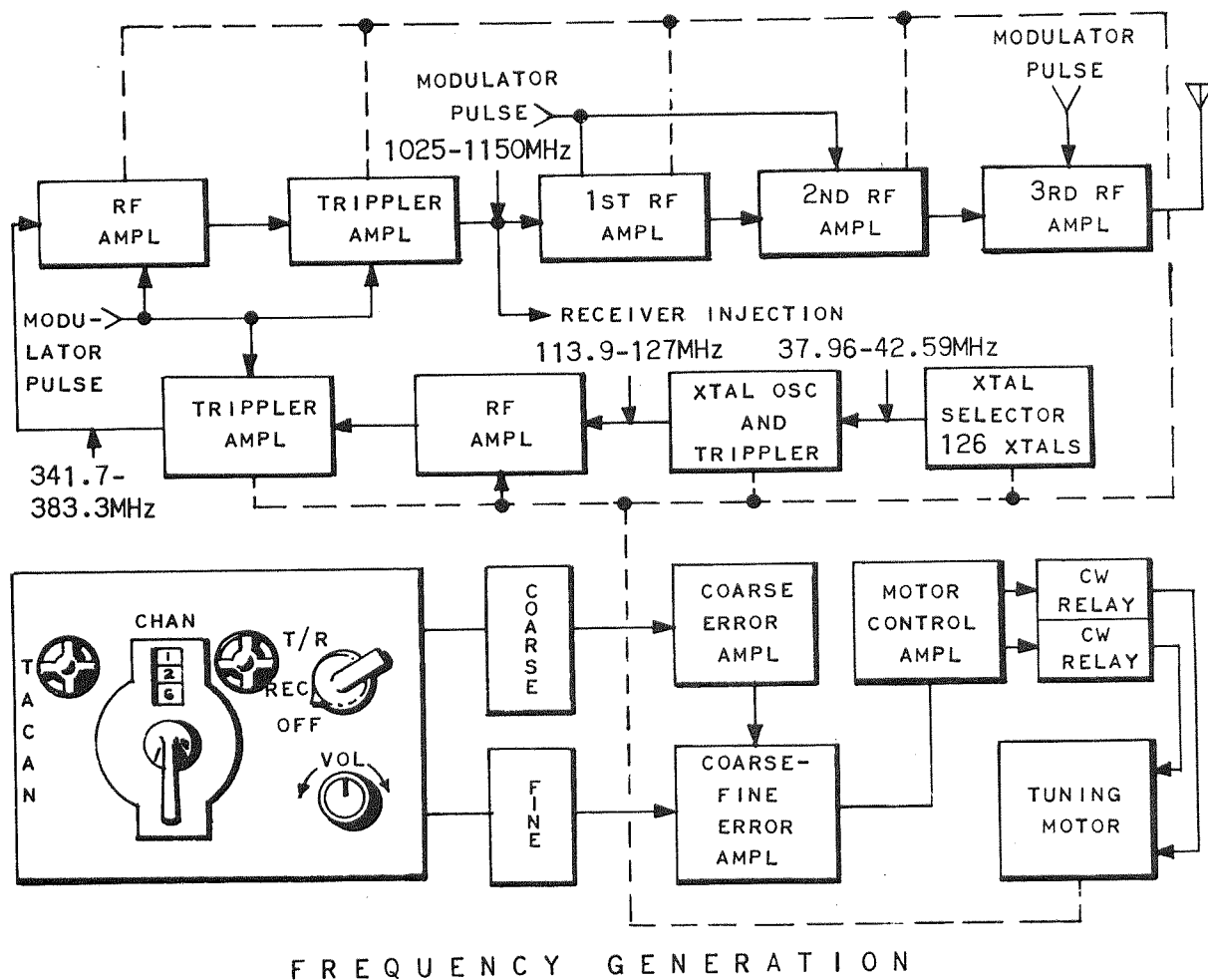
The Receiver and Transmitter have the same frequency selection system, tunable to any of the 126 channel frequencies. These channels are spaced one Megahertz (MHz) apart. The transmitter operates in the frequency range of 1,025 through 1,150 MHz with a peak pulse power output between 1.0 and 2.5 kilowatts. The receiver operates from 962 through 1,024 MHz in low band and from 1,151 through 1,213 MHz in high band. The receiver frequency is 63 MHz below the transmitter frequency for low band (channels 1-63) operation and 63 MHz above the transmitter frequency for high band (channels 64-126) operation. This



enables the transmitter frequency to be used as the local oscillator frequency for the receiver. Operating frequencies are developed from a crystal-controlled oscillator. The oscillator output is multiplied in frequency by a factor of 27 to develop a signal for transmitter excitation and receiver oscillator voltage.

#### CHANNEL SELECTION

Channel selection is accomplished by selecting the proper oscillator crystal and tuning all of the RF circuits to accept the operating frequency. Channel selection is controlled by two balanced-bridge servo loops. One bridge is composed of a precision-resistive-network, connected across a coarse frequency selector switch in the control panel, and a potentiometer located in the RT unit. The fine frequency selector switch is part of a similar bridge circuit. Selecting a new frequency on the control panel unbalances one or both of the bridge circuits. A voltage appears across the bridge, providing an input signal to the servo amplifier which causes the tuning servo motor to drive. The motor adjusts the potentiometers in the RT unit to balance the bridge. The motor also positions the tuning mechanism to select the necessary oscillator crystal and tune the RF circuits to accept the selected frequency. The coarse bridge error causes the tuning mechanism to drive to within 10 channels of the desired frequency; then the fine bridge error drives the tuning mechanism to the selected channel.

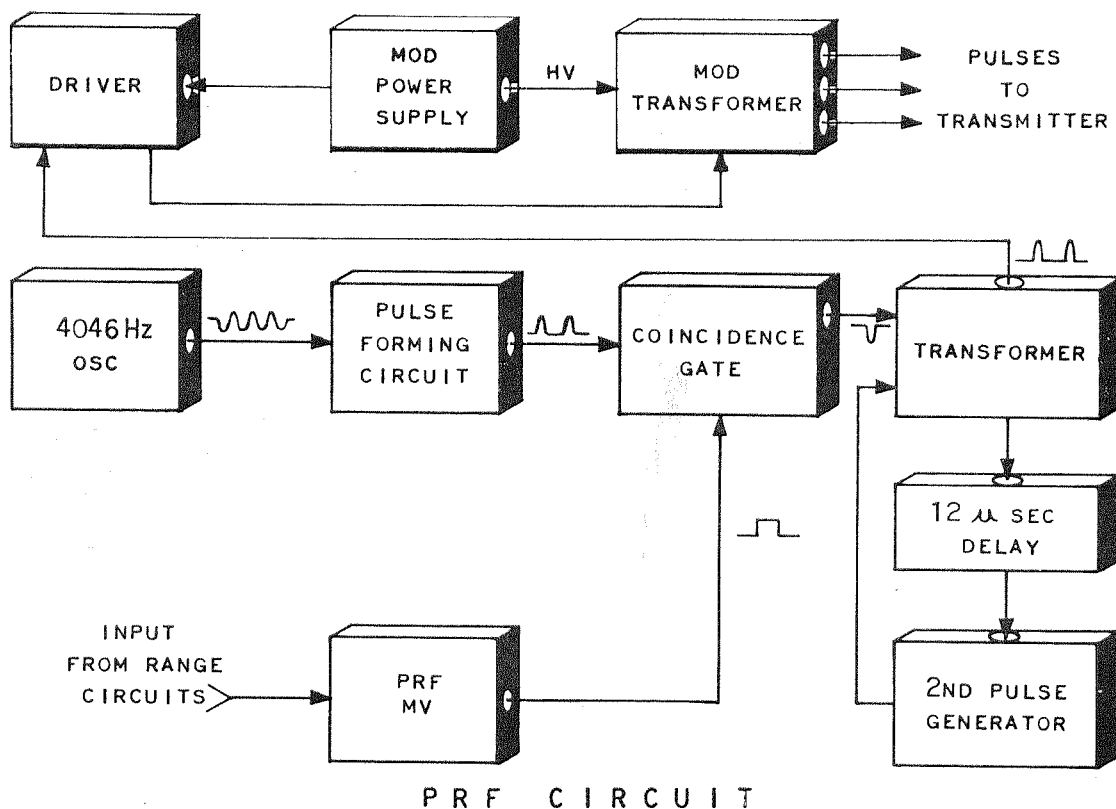


When the control panel frequency is changed by as much as 10 channels, a coarse error results. The signal is amplified by the coarse error amplifier and applied to the coarse-fine error amplifier. Any fine bridge error signal is also applied to the coarse-fine error amplifier. The output of this stage is applied to a motor control amplifier. The amplifier operates either a Clockwise (CW) or a Counter-Clockwise (CCW) relay. The relays determine in which direction the tuning motor will drive. As the motor drives, both tuning bridges will balance. As balance occurs, the error signal decreases to zero and the motor stops. Tuning is now complete.

#### RANGE CIRCUITS-TRANSMITTER

The frequency multiplier and transmitter-preselector subassemblies contain the circuits which generate and amplify the desired RF output. The frequency multiplier contains the crystal oscillator and two frequency tripler circuits. The oscillator operates at the frequency of the crystal selected by the tuning system.

There are 126 crystals which operate in the range of 37.96 - 42.59 MHz. The oscillator output frequency is multiplied in the two tripler circuits, providing



a signal to the transmitter ranging from 341.7 - 383.3 MHz. Within the pre-selector, a tripler-amplifier develops the transmitter output in the frequency range of 1,025 - 1,150 MHz. A portion of this signal is applied for receiver injection. In "T/R" operation, high voltage pulse pairs are applied to the RF circuits. These pulses are developed by the modulator circuits to enable the transmitter to develop sufficient RF power output. The short bursts of RF energy, provided by the transmitter, are the interrogation pulses for the surface beacon station.

The time reference for the interrogation is a crystal-controlled oscillator which generates a 4,046 Hz sine wave. The time of one complete sine wave is equivalent to 20 radar miles. A sharp pulse is generated from each cycle of the 4,046 Hz sine wave by a pulse generator circuit. These pulses are applied to a coincidence gate where a lower frequency pulse is generated. The Pulse Repetition Frequency (PRF) is permitted to vary (within limits) in an irregular or random manner. This is achieved by employing a non-stable multivibrator to control the output of the coincidence gate. When the 4,046 Hz pulse and the multivibrator gating pulse are coincident, the coincidence gate provides an output pulse. These pulses, which are time-coincident with one of the 4,046 Hz

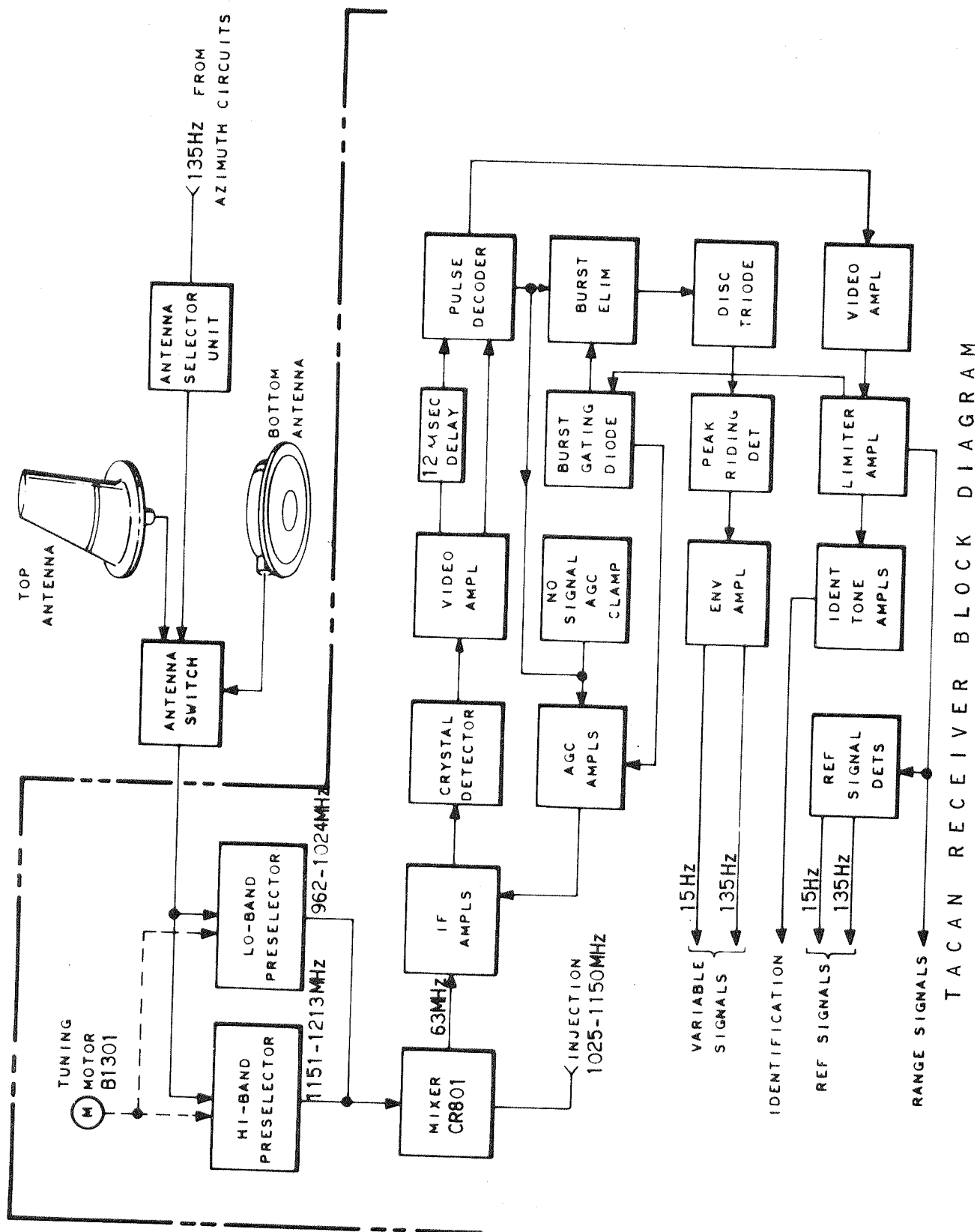


timing pulses, establish the repetition rate of the modulator trigger and the interrogation pulses. The modulator trigger pulse is coded by a 12 microsecond delay line and a second pulse generator to supply a second pulse for each input from the coincidence gate. The modulator, therefore, receives two pulses which are 12 microseconds apart. These pulses trigger the modulator circuits to supply the high voltage required for transmitter operation. The transmitter radiates pulses of RF energy, 3.5 microseconds wide. These pulses are transmitted in pairs, spaced 12 microseconds apart. After the transmission of each pulse pair, time is allotted for the surface beacon station reply.

#### RANGE CIRCUITS-RECEIVER

The received replies from the surface beacon station are applied to the receiver preselector, which consists of four tuned RF cavities arranged in pairs. One pair is used for low band reception and the other pair is for high band. The channel selection circuits tune the cavities and select which pair is to be used. The output of the preselector is applied to a mixer, where the RF signal is combined with an injection signal (1,025 - 1,150 MHz) from the transmitter circuits. The difference frequency of 63 MHz is applied to a six IF amplifier stage. The output of this stage is applied to a crystal diode detector circuit which removes the IF component of the signal. The detected pulse output is applied directly to a pulse decoder and through a 12 microsecond delay line to the pulse decoder. When properly spaced pulses are applied, the pulse decoder develops a video pulse for each pulse pair. The video pulse coincides with the second pulse in the pulse pair. The decoder output is amplified and applied to identification, bearing, and range circuits.

The range circuits must search for, find, and track the beacon distance reply pulses which correspond to an interrogation. These reply pulses arrive at a certain fixed time after each interrogation, corresponding to the distance between the aircraft and the surface beacon. The tracking circuits are inoperative at all times except during a time interval centering around the arrival of the correct reply pulses. In this way, the tracking circuits can ignore the reply pulses of other aircraft interrogating the surface beacon. This is accomplished by generating gates to coincide with the reply pulse arrival. When the system is first turned on and a surface beacon station selected, the system has no way of predicting when reply pulses will arrive. Therefore, it must search for the correct reply pulses. The pulse which triggers the modulator and causes the transmitter to interrogate the surface beacon is also used to start a variable-width gate. The width of the gate is made to progressively increase (search) with each interrogation. The trailing edge of the gate is used to start a selector pulse. As the system searches, the selector pulse is progressively delayed to effectively lengthen the search distance. This process continues until a delay corresponding to the surface beacon distance is produced. At this time, the reply pulses and the selector gate will coincide, and the circuits will assume the "track" mode of operation. The position of the selector gate will then be

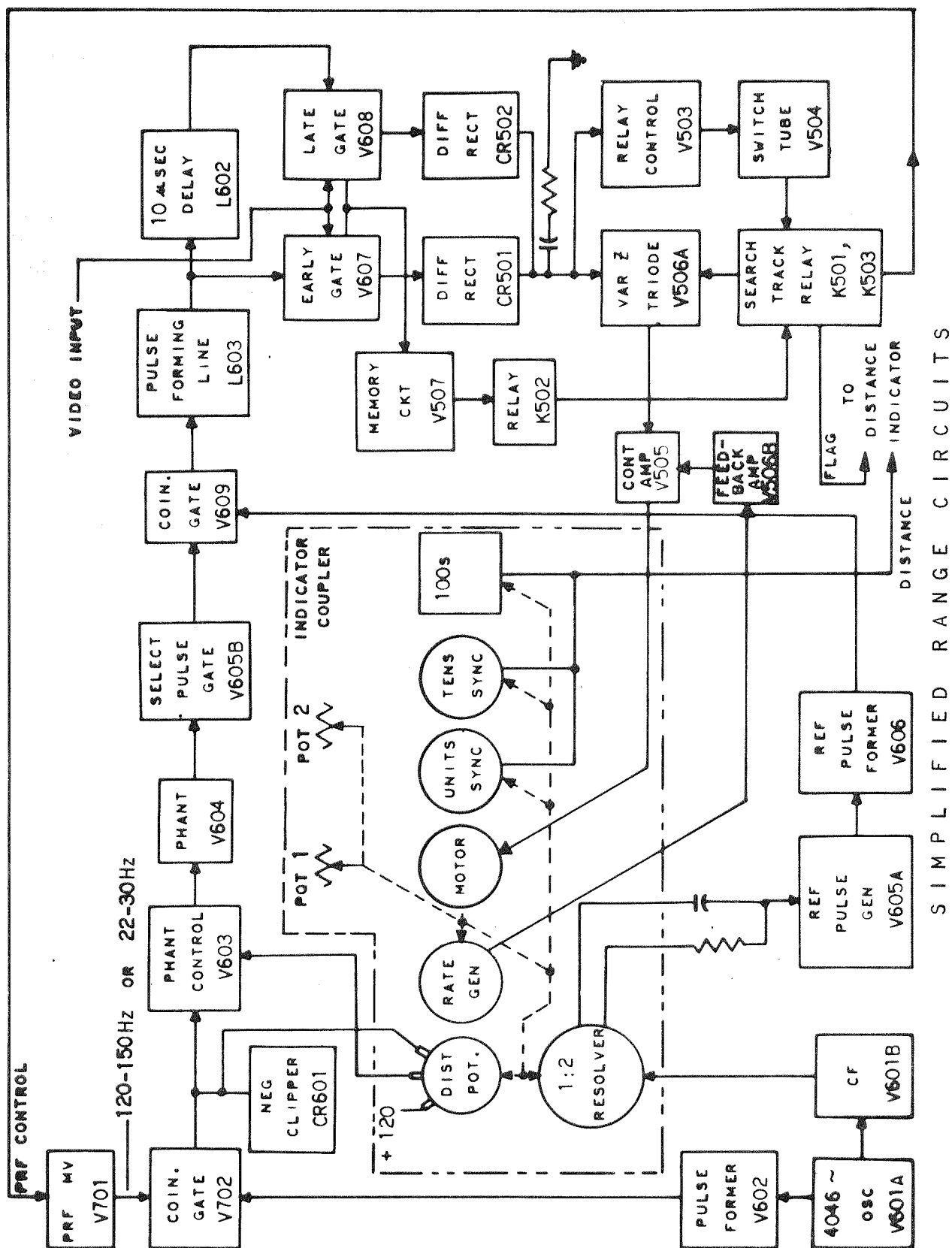


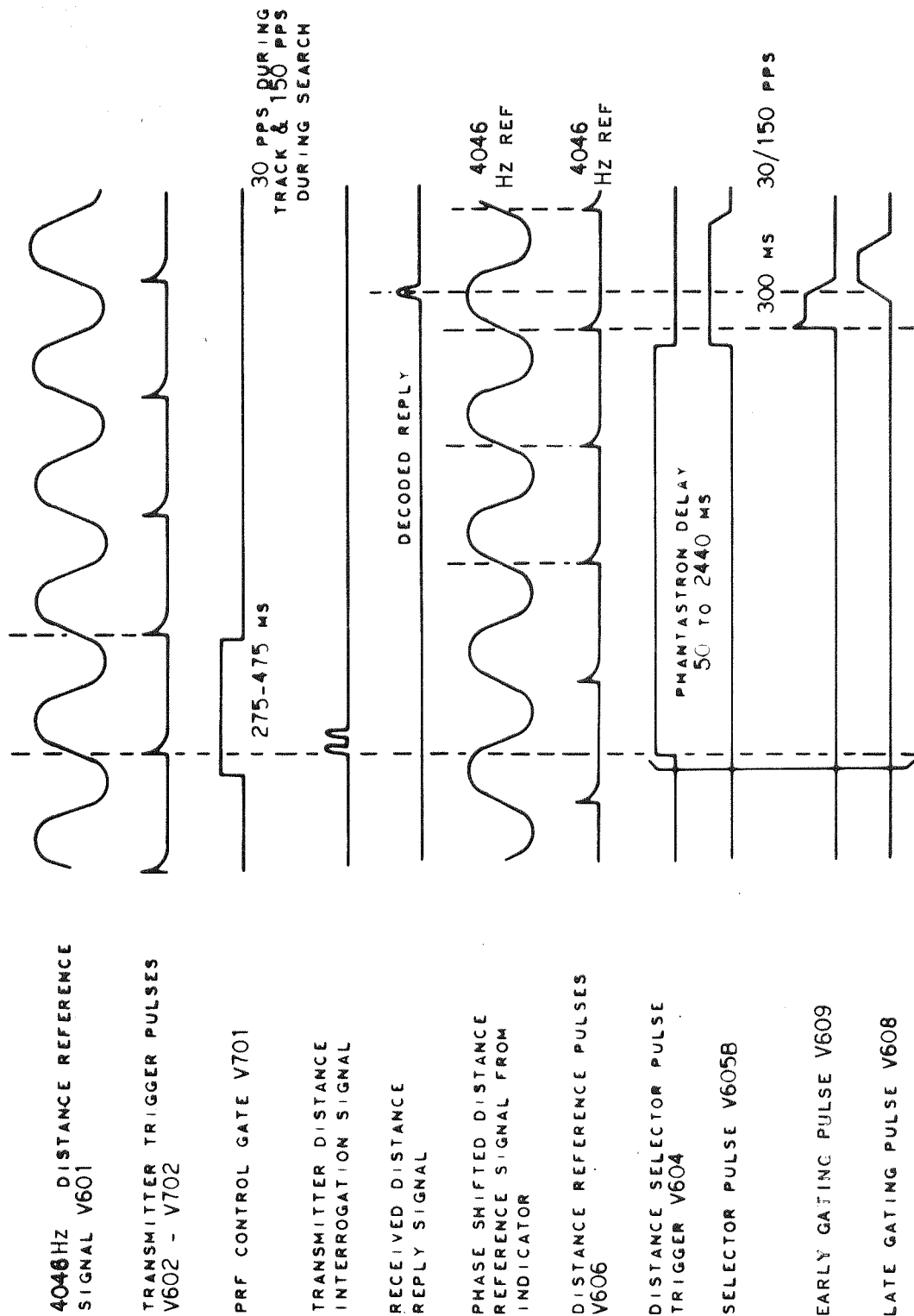
TACAN RECEIVER BLOCK DIAGRAM

controlled by circuits which compare coincidence of the reply pulse and the gates. The gate will thereby be made to coincide with the reply pulse for the duration of the track mode.

In the range circuits, a signal from the 4,046 Hz reference oscillator is applied to the rotor of the range resolver in the instrumentation coupler. The phase-shifted output from the resolver is used to develop a reference pulse for each sine wave cycle. These pulses appear 20 nautical miles apart. One revolution of the resolver produces a change in range of 20 miles. These reference pulses are applied to a coincidence gate to be compared in time with the selector gate signal. To develop the selector gate, a timing pulse from the modulator is applied to a phantastron. The modulator pulse causes the phantastron to generate a range gate. A distance potentiometer, located in the instrumentation coupler, applies bias to the phantastron to determine the width of the gate. One revolution of the potentiometer produces a 200 mile change in range. When the range resolver and the distance potentiometer are set to zero, the duration of the range gate is 50 microseconds. When the indicated range is 195 miles, the range gate duration is 2,400 microseconds. A 50 microsecond gate is required at zero range because an intentional 50 microsecond delay is introduced at the surface beacon station between distance interrogation pulses and distance reply pulses. The range gate is applied to the selector gate generator. A selector gate is produced by the trailing edge of the range gate. The selector gate and the 4,046 Hz reference pulses are applied to the coincidence gate.

The first reference pulse occurring within the selector gate will produce a 12 microsecond pulse in the output of the coincidence gate. This pulse is applied directly to the early gate stage and, through a 10 microsecond delay line, to the late gate stage. These stages are gated on for approximately 12 microseconds each. Video pulses (distance reply pulses) from the receiver are also applied to these stages. Since the combined "on" time of the two gates is 24 microseconds, the tracking circuits function to accept reply pulses from an area approximately 2 miles wide. In "search" operation, the range resolver and the distance potentiometer are being driven to cause the gate signals to be progressively delayed after each interrogation. This action causes the tracking circuits to





RANGE CIRCUITS, WAVEFORMS

continuously "step out" in range until distance reply pulses fall within the gating time interval. When the video pulses occur midway between the early and late gate pulses, both stages conduct simultaneously. Their outputs are rectified and connected to produce an output of zero. When the video pulses are coincident with either the early or late gate, a polarized D-C output will be developed. The polarized output is amplified and used to control the servo motor. As the motor drives, the range resolver and distance potentiometer are rotated to change the gating circuits and center the early and late gate stages to keep the system in track operation when reply pulses are momentarily lost. When the gating circuits lose their output for a period greater than 10 seconds, the memory circuit causes a relay to switch the circuits back to search operation. It also causes the distance indicator warning flag to cover the distance indicators when the system is searching.

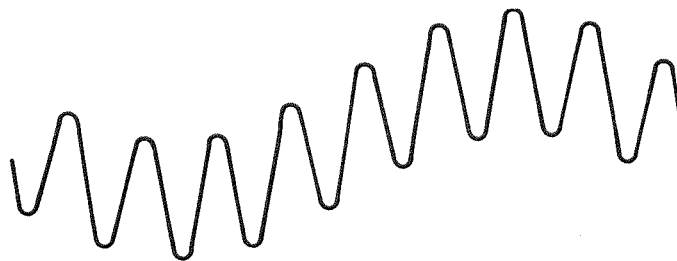
## AZIMUTH CIRCUITS

Two types of bearing signals are applied to the bearing circuits. The coarse and fine reference bearing signals (15 Hz and 135 Hz) are applied to a limiter stage to remove amplitude variations. Removing amplitude variations removes any variable bearing signal. The composite coarse and fine variable bearing signals are also supplied a burst eliminator which removes any reference bearing signal components. The output of the burst eliminator is applied to a peak riding detector circuit where amplitude variations are detected to provide an output containing 15 Hz and 135 Hz amplitude variations. This composite signal is applied to two filters where the 15 Hz and 135 Hz components are separated. The 15 Hz (coarse) signal is shifted in phase by a bearing potentiometer in the instrumentation coupler. The 135 Hz (fine) signal is shifted in phase by a bearing resolver in the instrumentation coupler. The two signals are then compared with the reference bearing signals. The coarse signals are compared in the reference signal gate and the fine signals are compared in the phase discriminator. The phase shifted 15 Hz variable bearing signal is used to produce a 40 degree gate. In search operation, the bearing circuits are continuously being driven and the 40 degree gate is continuously being shifted until the gate and the 15 Hz reference bearing signal coincide. At coincidence, the indicated bearing is within 20 degrees of the actual aircraft bearing.

When the 15 Hz reference signal is coincident with the 40 degree gate, the reference signal gate stage provides a signal to actuate the search-track relay. The relay transfers control of the indicator bearing servo loop to the phase discriminator which is controlled by the fine bearing signals. Square waves are produced from the 135 Hz variable bearing signal and applied to the phase discriminator. When the two signals are not properly in phase, the discriminator develops a polarized error signal. The error signal is amplified and used to drive the bearing servo motor. As the motor drives, the 135 Hz variable bearing signal is shifted in phase by the bearing resolver to bring the variable bearing signal and the reference bearing signal into the proper phase relationship.



COMPLEX 15 AND 135 Hz  
VARIABLE BEARING SIGNAL  
FROM PULSE ENVELOPE  
DETECTOR



15 Hz VARIABLE BEARING  
SIGNAL FROM 15 Hz  
FILTER



135 Hz VARIABLE  
BEARING SIGNAL FROM  
135 Hz FILTER



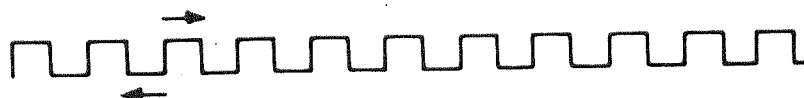
40 DEGREE 15 Hz  
VARIABLE BEARING SIGNAL  
GATE FROM GATE GENERATOR



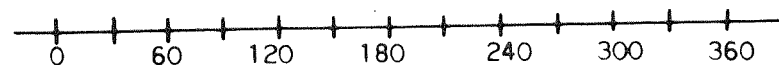
15 Hz REFERENCE  
BEARING SIGNAL FROM  
15 Hz REFERENCE  
PULSE RINGING CIRCUIT



135 Hz VARIABLE  
BEARING SIGNAL FROM  
SQUARE WAVE GENERATOR



135 Hz REFERENCE  
BEARING SIGNAL FROM  
135 Hz REFERENCE  
PULSE RINGING CIRCUIT



DEGREES SCALE

# A Z I M U T H   C I R C U I T S ,   W A V E F O R M S



As this occurs, the discriminator output decreases to zero and the bearing servo motor stops. The phase shift necessary to maintain this coincidence is measured by a synchro transmitter to provide an accurate indication of the ground beacon station bearing.

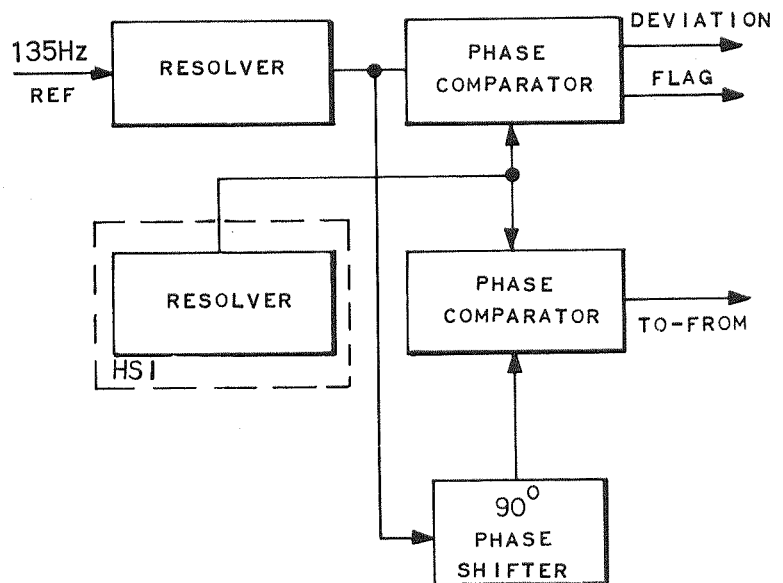
## INSTRUMENTATION COUPLER

The instrumentation coupler receives all range and bearing information signals from the TACAN RT unit and distributes them to the BDHI's and HSI's. Bearing, distance, and distance flag signals are fed directly to the appropriate BDHI's. No. 1 instrumentation coupler outputs are sent to the pilot's BDHI and the navigator's No. 1 BDHI. No. 2 instrumentation coupler outputs go to the copilot's BDHI and the navigator's No. 2 BDHI. TACAN outputs are also provided by the No. 1 instrumentation coupler for use by the AN/ASN-24 navigational computer. These outputs consist of distance and bearing information. In addition, outputs of the No. 2 instrumentation coupler are provided for use by the AWLS autopilot system.

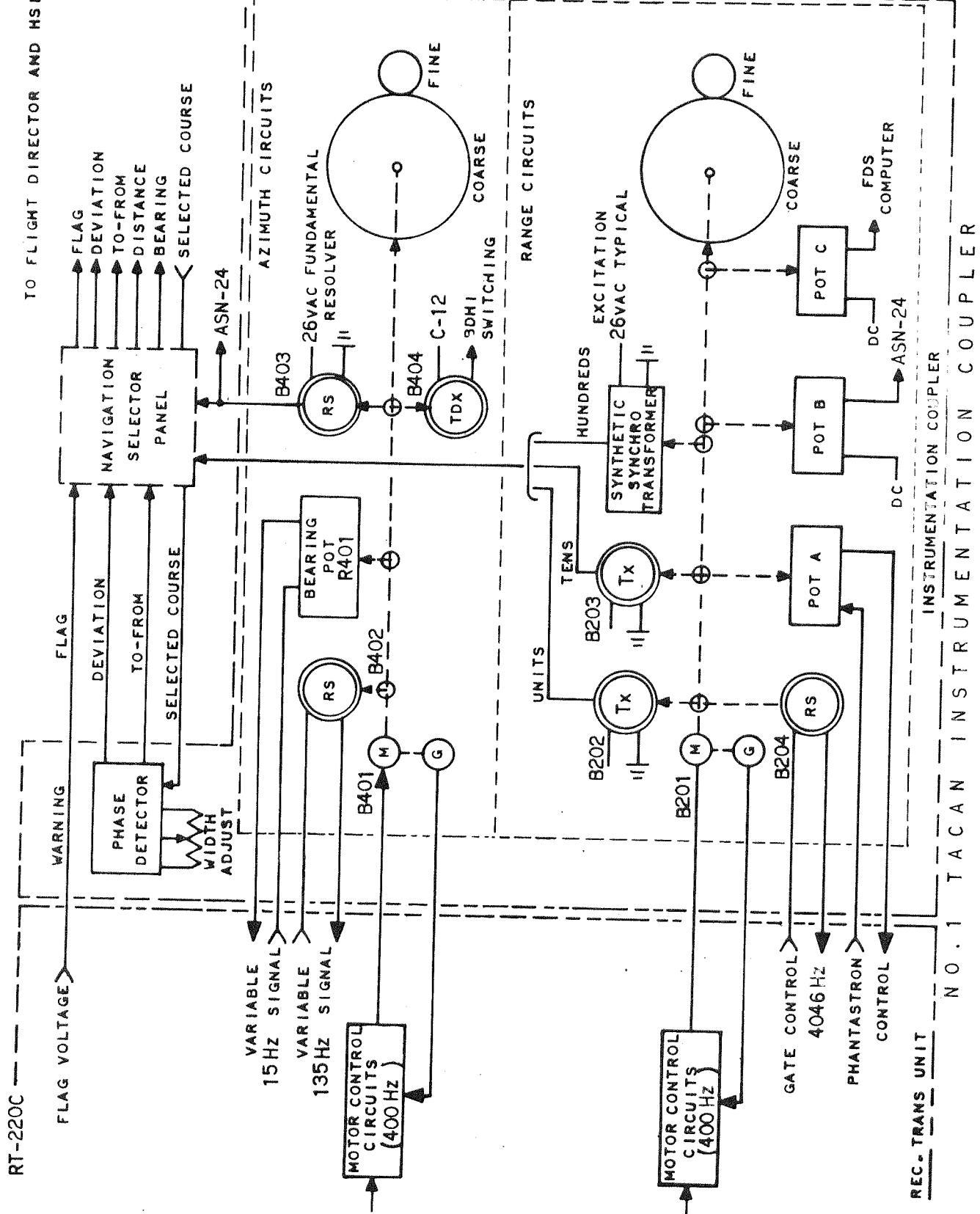
A bearing resolver within the instrumentation coupler is used in conjunction with a resolver in the HSI to provide deviation and to-from signals. The resolver in the instrumentation coupler is positioned as a function of TACAN bearing, while the HSI resolver is positioned as a function of selected course. Both resolvers are connected to deviation and to-from detector circuits in the instrumentation coupler. These circuits measure any existing difference between the selected course and the actual course.

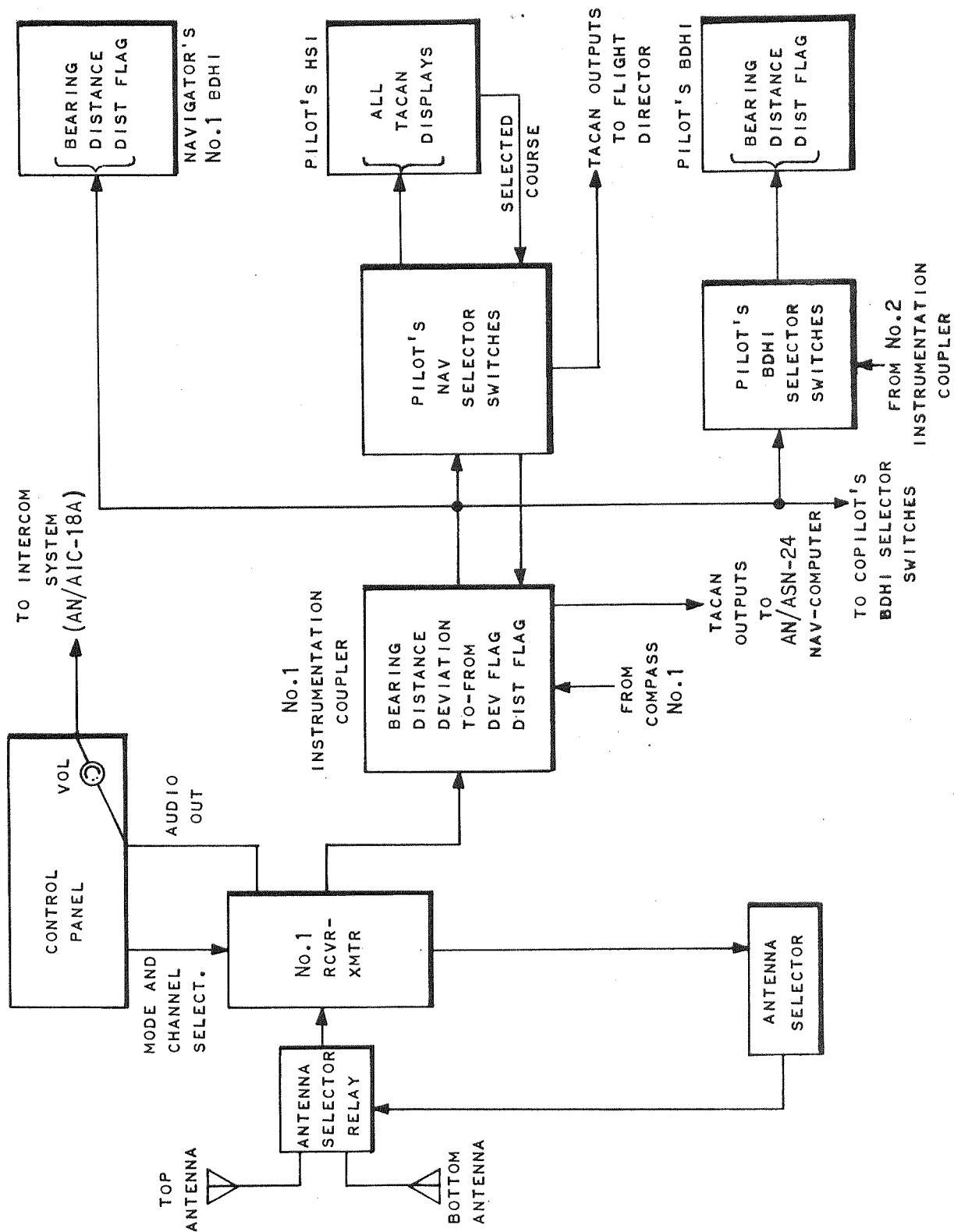
When the two signals do not agree, the deviation

circuits develop a D-C voltage which is applied to the course deviation indicator of the HSI. This indicator presents lateral deviation of the aircraft to the right or left of the desired course. It also presents the desired track; when the deviation bar is to the left of center, the aircraft is right of the selected course.



T O - F R O M   A N D   D E V I A T I O N  
B L O C K   D I A G R A M





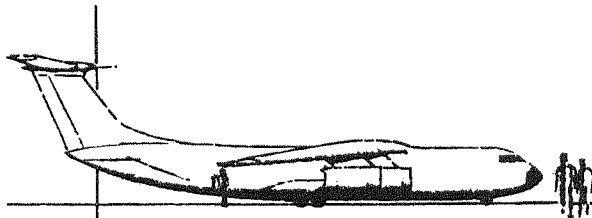
NO. 1 TACAN OUTPUT DISTRIBUTION

The instrumentation coupler also provides a signal to the to-from indicator of the HSI and reliability signals to the deviation warning flag.

## SYSTEM PECULIARITIES

Although the channel selector switches on the control panel do not give an indication of channel frequencies, it is always possible to compute both the transmitter and receiver frequencies for any selected channel. Since there are 126 selectable channels which increase from 1 - 126 in 1 MHz steps, knowing the transmitter frequency for only channel 1 will suffice for computing the frequencies of any other channel. Example: the channel 1 transmitter frequency is 1025 MHz. To compute the transmitter frequency for channel 39, merely add 38 MHz to the channel 1 frequency (1025 plus 38 = 1063 MHz). To find the channel 119 transmitter frequency, add 118 MHz to the channel 1 frequency (1025 plus 118 = 1143 MHz).

In computing the receiver frequencies, it must be remembered that the receiver operates in two bands. Channels 1 - 63 use the low band input; channels 64 - 126 use high band. In low band, the receiver frequency can be determined by subtracting 63 MHz (IF) from the transmitter frequency. Example: channel 39 transmitter frequency minus IF equals receiver frequency (1063 minus 63 = 1000 MHz). In high band, the receiver frequency is computed by adding 63 MHz (IF) to the transmitter frequency. Example: channel 122 transmitter frequency plus IF equals receiver frequency (1143 plus 63 = 1206 MHz).



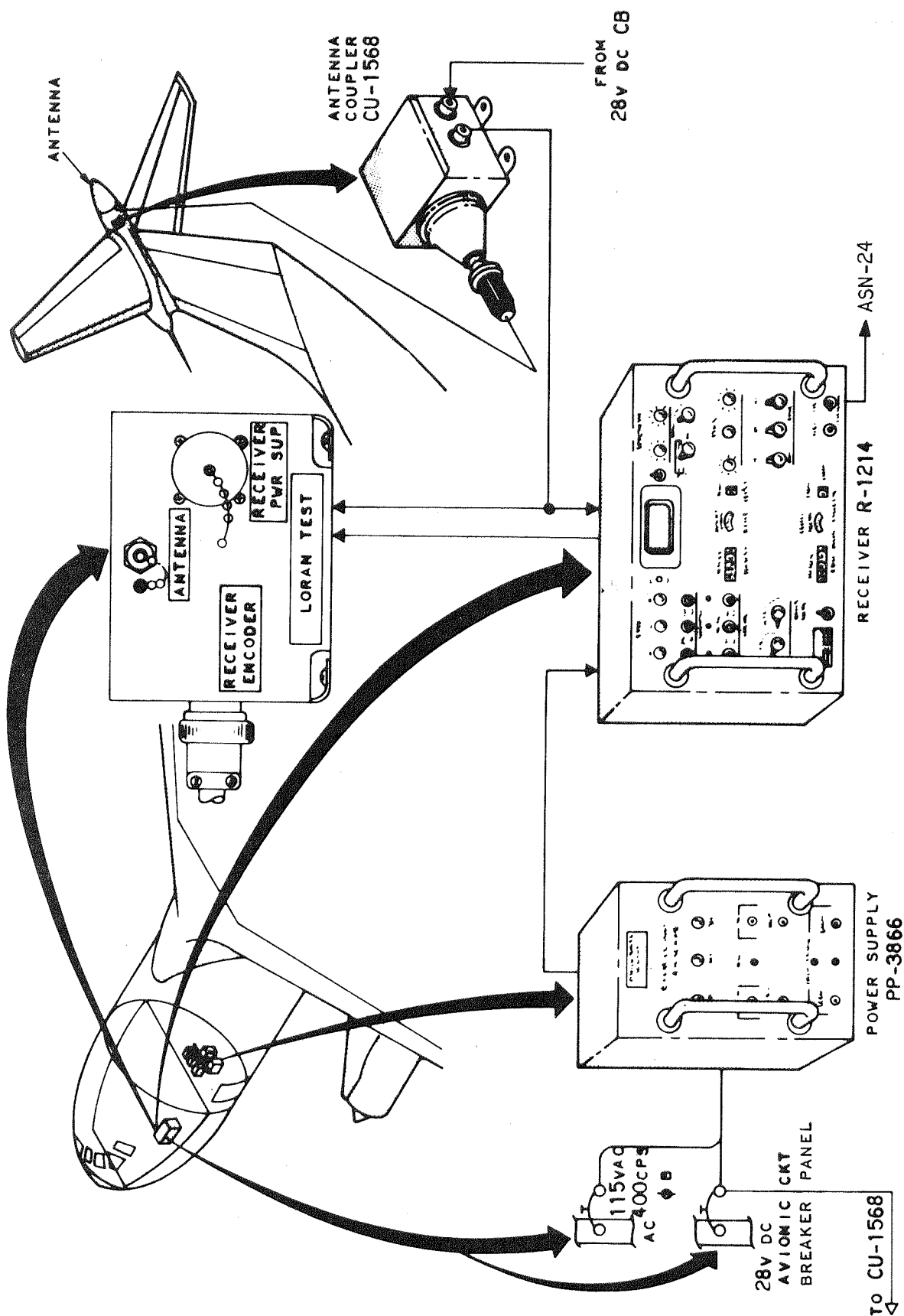
## LORAN-C SYSTEM

### 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 recurrence 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

## AIRCRAFT INSTALLATION

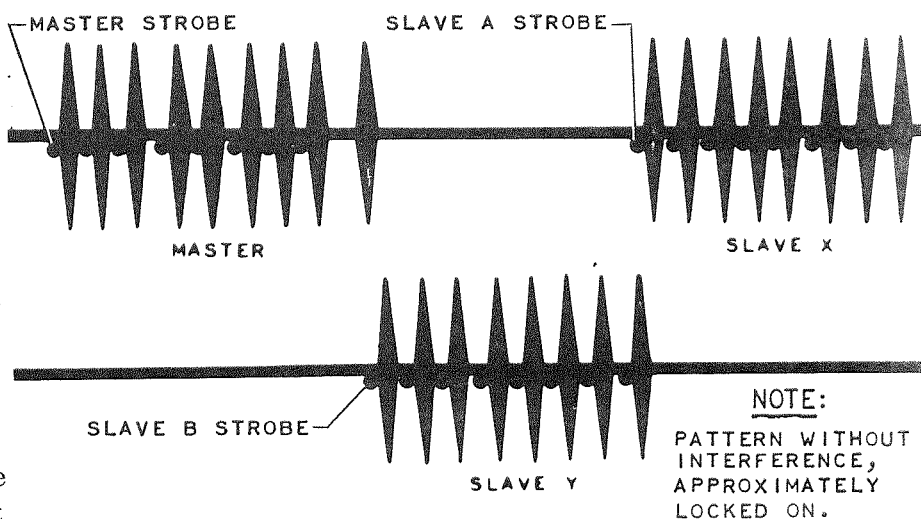
The R-1214 LORAN receiver and test receptacle are located at the navigator's station. The PP-3866 power supply is in the center underdeck avionics equipment rack. The antenna is part of the aft fairing of the horizontal stabilizer bullet, and the CU-1568 antenna coupler is inside the bullet.

Single phase A-C power is supplied from the A-C nav bus No. 1, and D-C power is supplied from the main D-C avionic bus No. 1. The system circuit breakers for the system are on the avionics circuit breaker panel. This panel is located above the navigator's instrument panel.

## SYSTEM OPERATION

To make time-difference measurements, the operator must first manually align the receiver generated track strobes with the received LORAN signals.

The Visual Display illustration shows a visual display of one complete LORAN cycle as transmitted by the ground transmitters. The master pulse train consists of eight pulses spaced 1,000 usec apart, and a ninth identification pulse that lags the eighth pulse by 500 to 1200 usec. Each slave train consists of eight pulses with 1,000 usec spacing.



V I S U A L   D I S P L A Y

The receiver generates eight master, eight slave A, and eight slave B track strobes. These track strobes are spaced 1,000 usec apart and must be manually aligned with the received pulses for time difference measurement. Once the tracking circuits are locked on, the receiver continuously gives a numerical read-out of the time differences.

The timing of the ground stations is arranged so that the master pulse train will be received first regardless of the aircraft's position. Also, the slave X pulses will be received before the slave Y pulses. This is accomplished by using the

master station as a time reference and delaying the slave transmission an amount that is a function of the distance between the transmitters.

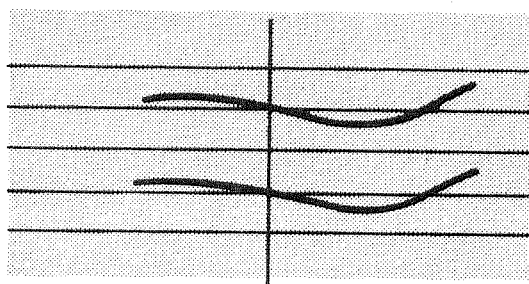
## LOCK-ON PROCEDURES

All controls and indicators for LORAN operation are located on the front panel of the R-1214 receiver as shown in the "Loran Receiver, Controls and Indicators" illustration. The ON-OFF-STBY switch (17) energizes the APN-157. The Pulse Repetition Rate (PRR) is selected by the basic rate switch (27) and the specific rate switch (26). Forty-eight pulse repetition rates are available for use. The PRR of a LORAN chain may be found on the navigation charts.

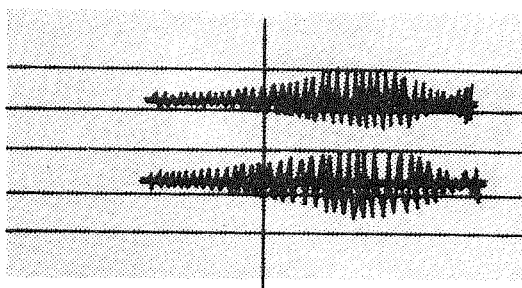
Since the time difference measurements are referenced to the master station, the operator must first align master strobes with master pulses by use of the M-DRIFT control (16). M-GAIN control (1) varies the amplitude of the received master pulses. Visual display (5) monitors Radio Frequency (RF) signals when RF/Video selector (9) is placed in the "WIDE" position or the "NARROW" (more selective) position. The "NOTCH" position of the RF/Video selector enables monitoring of CW interference. The "VIDEO ENV" (envelope) position allows viewing of pulse envelopes. Sweep speed switch (10) selects "S" (slow), "M" (medium), or "F" (fast) sweep. Video amplitude is controlled by GAIN control (12).

Once the master strobes are locked on, the slave A strobes can be aligned with the slave X pulses by operating "SA-SLEW" control (15). Slave A RF amplitude is controlled by GAIN control (2). After alignment, the video display should be set for video envelope monitor and fast sweep speed. M-SA, M-SB switch (6) must be set to the "M-SA" position.

The video envelopes should be aligned to correspond to the correct phase code shown in the "Loran Receiver Visual Display" illustration. The master envelope



CORRECT PHASE CODE

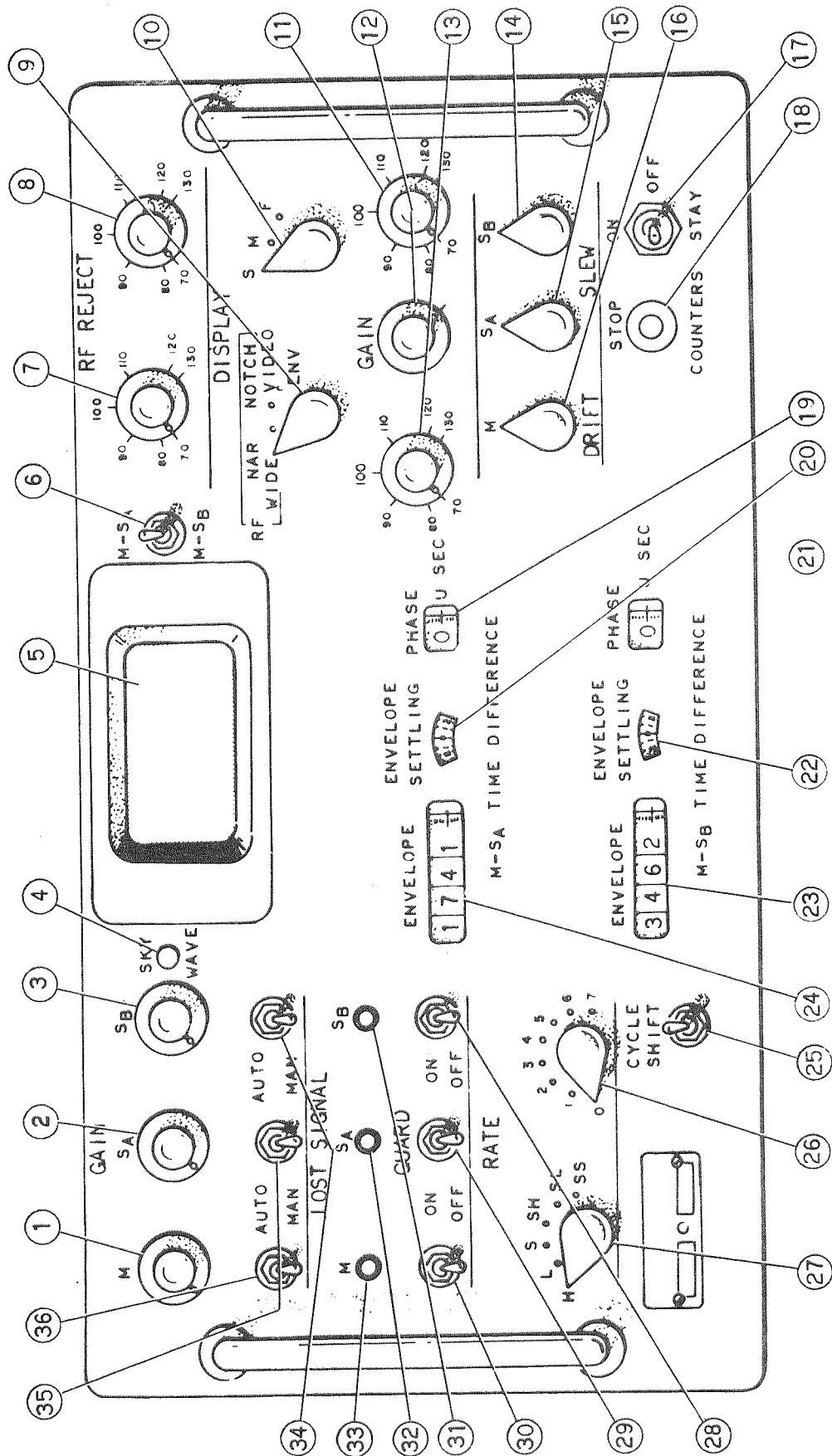


INCORRECT PHASE CODE

### RECEIVER VISUAL DISPLAY ( F SWEEP ) PHASE CODE TEST

is on the top trace and the slave X envelope is on the bottom trace. The illustration of an incorrect phase code indicates an improper phase relationship





LORAN RECEIVER OPERATING CONTROLS

between the received signal and the internally generated reference signal. CYCLE SHIFT switch (25) must be actuated to create proper phase of the two signals.

The M-SA time difference indicators (19), (20), (24) read the envelope difference (coarse) and the phase difference (fine). ENVELOPE SETTING (20) indicates any deviation between the envelope counter and the phase counter. The M-SA time difference shown in the "Visual Display" illustration reads 17,410 usec. The next step in the lock-on procedure is the alignment of slave B strobes with slave Y pulses. The strobes are moved along the time axis by slave B SLEW control (14). Slave B RF amplitude is adjusted by slave B gain control (3). M-SA, M-SB switch must be in the "M-SB" position. Proper M-SB alignment will yield the correct phase code display as illustrated in the "Visual Display" illustration. In this case the slave Y envelope is on the bottom trace. M-SB time difference indicators (21), (22), (23) read distance information in microseconds.

The STOP COUNTERS pushbutton switch (18) stops both M-SA and M-SB time difference indicators for 5 seconds so that the operator may note the readings. The distance information in microseconds will identify a pair of hyperbolic lines on the LORAN navigation chart. The intersection of the two lines gives the aircraft's position.

The lost signal lamps (31), (32), (33) should extinguish when valid LORAN signals are locked on. Once the lamps are extinguished switches (34), (35), and (36) may be placed in "AUTO". This maintains the RF gain at a preset level. The manual gain controls are bypassed when automatic gain is selected.

#### SKY WAVE GUARD

To insure that the APN-157 is not tracking sky-waves, the receiver generates guard strobes 40 usec ahead of the track strobes. Since the sky-waves lag the ground waves by 30 to 50 usec, coincidence of guard strobes and ground wave pulses indicates that the LORAN receiver is locked on a sky wave. The master, slave A, and slave B guard circuits are actuated by switches (28), (29) and (30) respectively. If either master, slave A, or slave B is tracking a sky wave, the SKY WAVE lamp (4) will illuminate. If this occurs the receiver must be realigned to track the desired ground wave.

#### INTERFERENCE REJECTION

RF REJECT controls (7) and (8) and video reject controls (11) and (13) are provided to reduce CW interference. Each control rejects an individual frequency from 70 to 130 KHz. To set these controls the RF/Video switch should be placed in the "NOTCH" position. The right video reject control (11) should be adjusted for maximum interference as presented on the CRT. Next, the left RF REJECT control (7) should be adjusted for minimum interference amplitude on the CRT.

Following this, readjust the right video reject control until another interference frequency is maximized. Then adjust the right RF REJECT control (8) for minimum interference.

Again adjust right video reject to another interference frequency and adjust left video reject control (13) for minimum interference. The last step is to set right video reject to a fourth interference frequency. This completes the interference rejection set-up. Each reject control is now set to filter an individual frequency. If only one interference frequency is present, each reject control may be set to that frequency.

### SPECIFICATIONS

The operating characteristics of the R-1214/APN-157 receiver are as follows:

CHARACTERISTIC	SPECIFICATION
Power requirements	115 $\pm$ 10 volts $\pm$ 20 Hz single phase, 1.6 amperes. 28 $\pm$ 4.0 volts, DC, 2.0 amperes maximum. 6.3 volts, 400 Hz, single phase, 3.5 amperes maximum.
Weight (pounds)	54.70
Size (inches)	7.75 height 15.5 width 22.8 depth
Frequency range	100 KHz with a bandwidth of 90 to 110 KHz
Repetition rates	Six basic rates modified by eight specific rates making a total of 48 different rates.
Type of reception	Amplitude-modulated (pulsed) signals conforming to LORAN-C patterns and repetition rates.
Receiver output	Two four-digit and two one-digit numerical readouts on front panel. LORAN Receiver R-1214/APN-157 pro- vides, also, remote readout of time- difference data with four encoders.

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Ambient operating temperature range	-54°C (-65°F) to +55°C (+131°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°C change within range of 0°C (+32°F) to +65°C (+149°F).
c. Crystal operating temperature	c. +70°C (+158°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 Hertz)		
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.

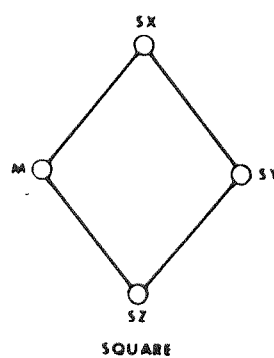
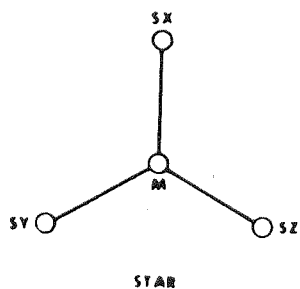
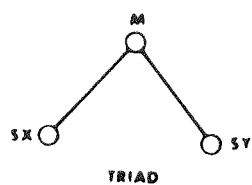
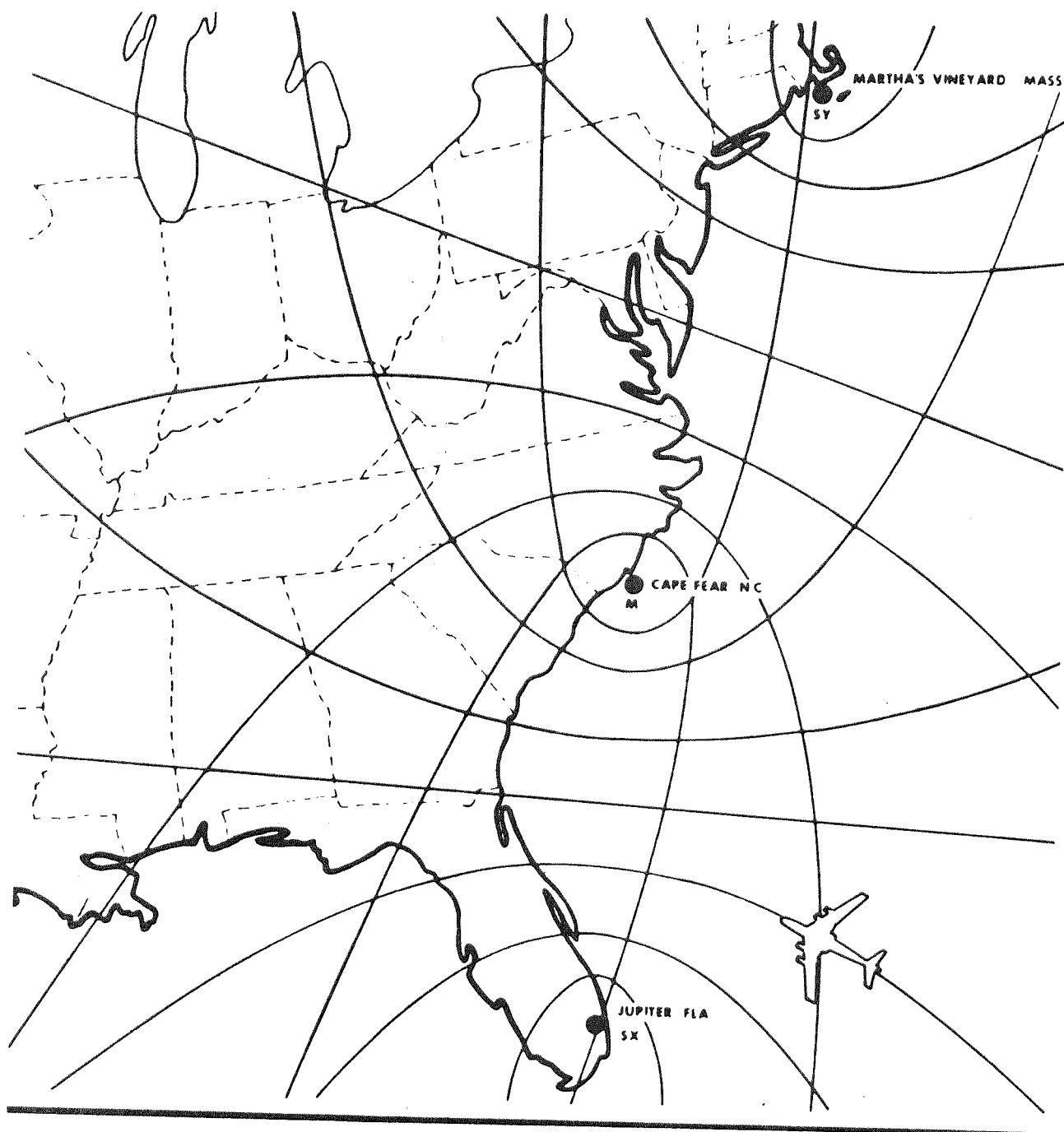
Each hyperbolic line shown in the illustration identifies the RF arrival time difference of LORAN transmitter pairs. The intersection of these hyperbolic lines accurately locates the geometric position of the aircraft up to approximately 1200 nautical miles.

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 recurrence 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.



# 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	+--+++++	+--++--

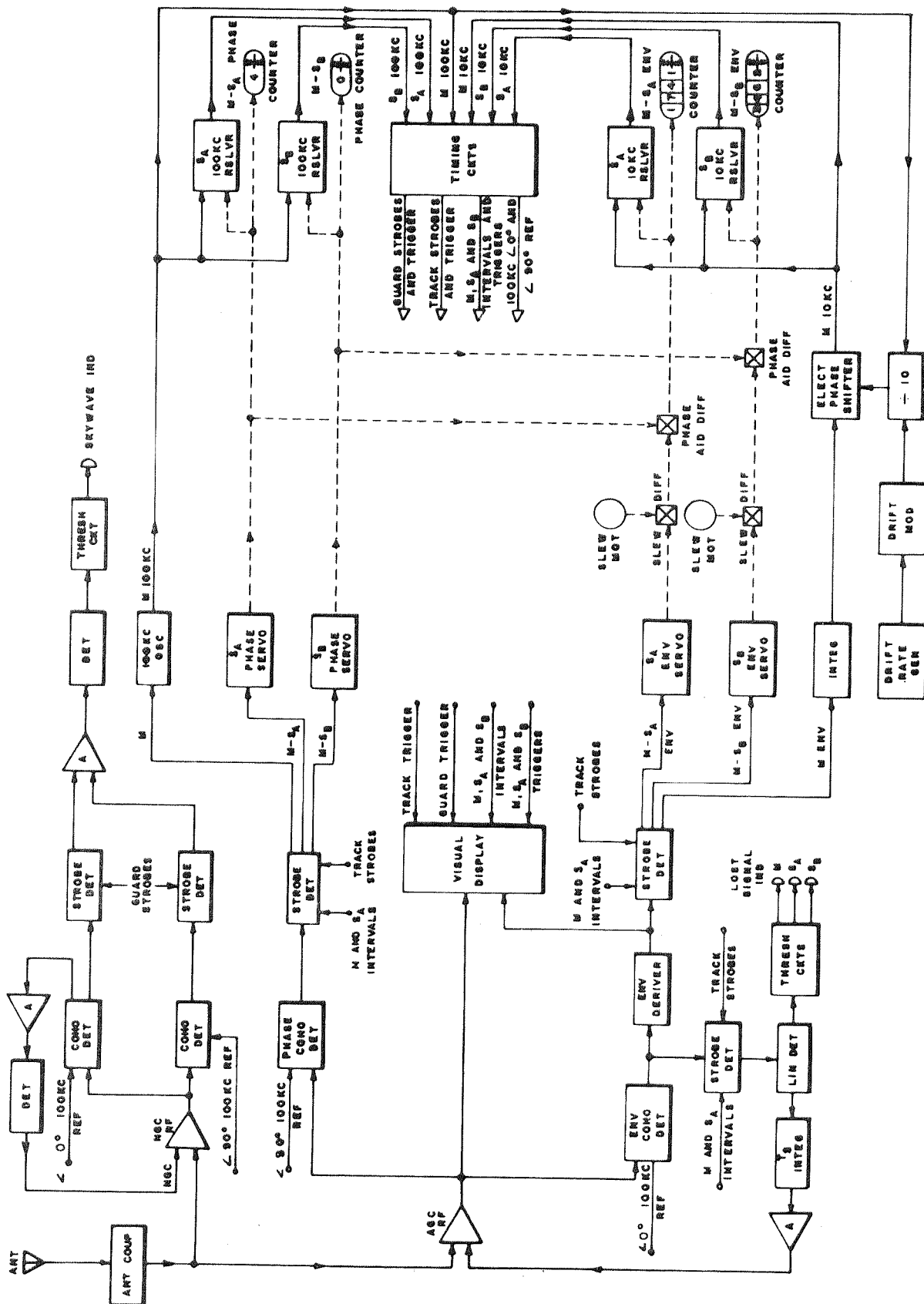
The LORAN chain has two phase coding patterns. The ground transmitters alternate between these two patterns. The phase coding for Sx, Sy, and Sz is the same for any one LORAN cycle. Phase coding is used to prevent sky-wave contamination of the LORAN signals.

#### 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.

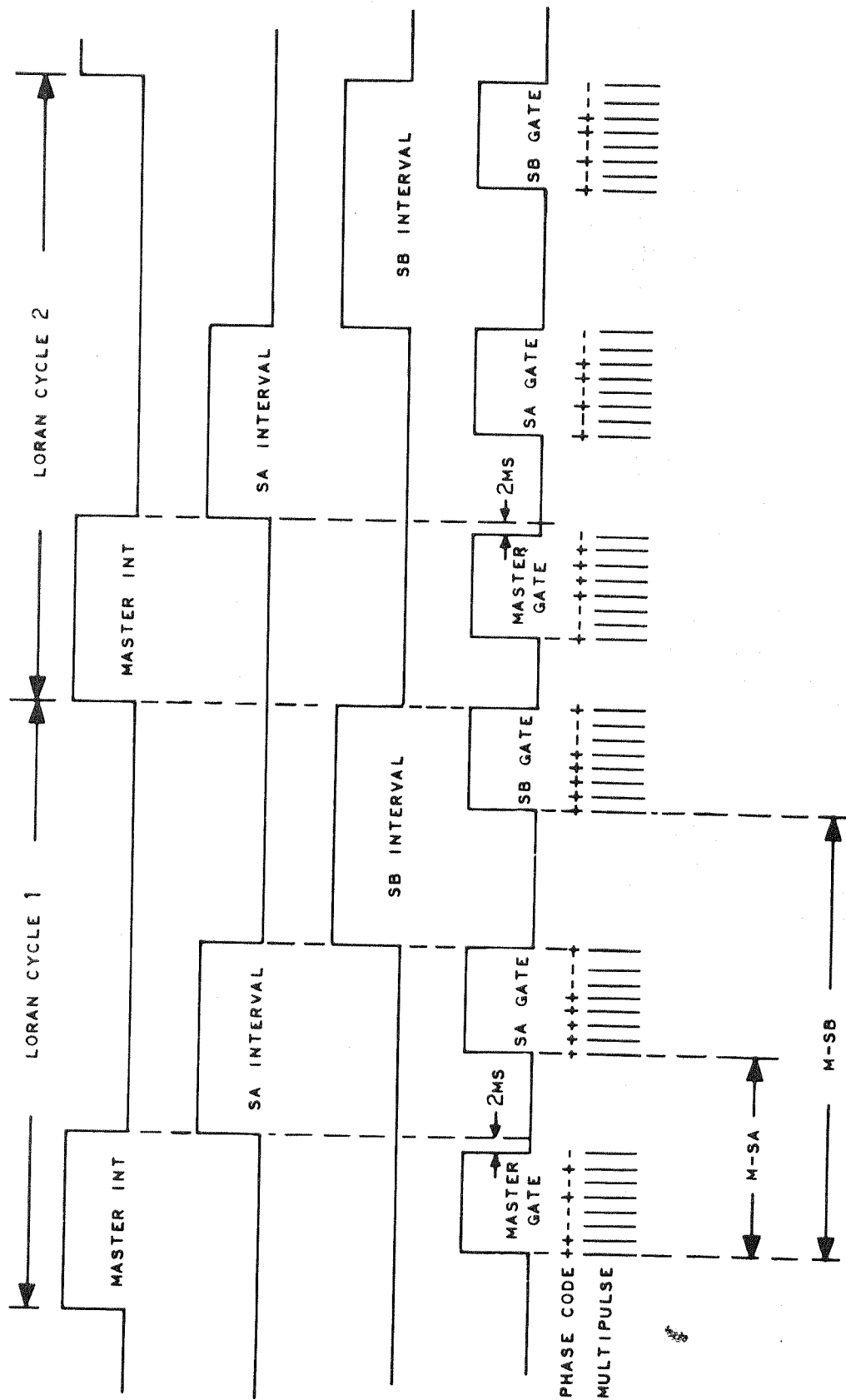
The incoming RF is applied to the sky-wave guard circuits and to the AGC RF amplifiers. The AGC RF amplifiers have outputs to the two primary servo loops and to the visual display. The AGC and lost signal circuits sample the RF energy in the envelope servo loop.

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.

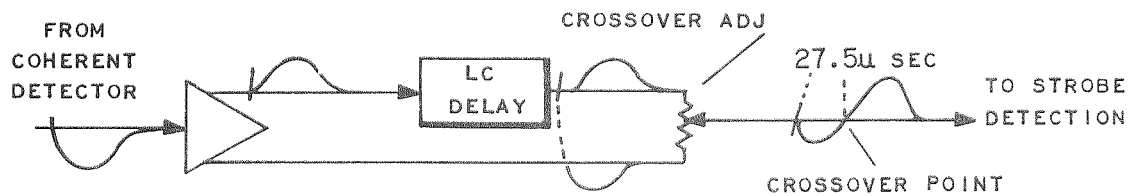
#### MASTER ENVELOPE SERVO LOOP

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 crossover, or null, 27.5 microseconds after the beginning of the envelope. The negative polarity video envelopes are coupled to a paraphase amplifier. The positive

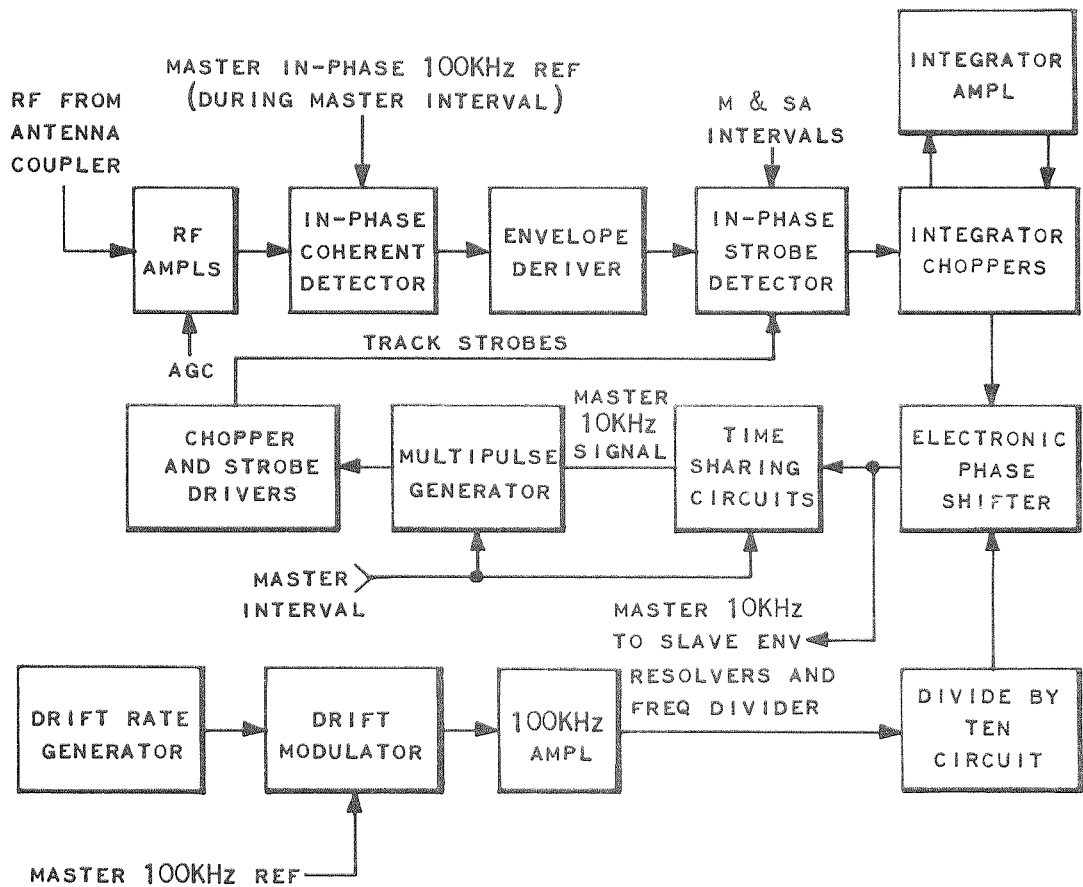


BASIC TIMING WAVEFORMS

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 occurring 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 DRIVER



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.

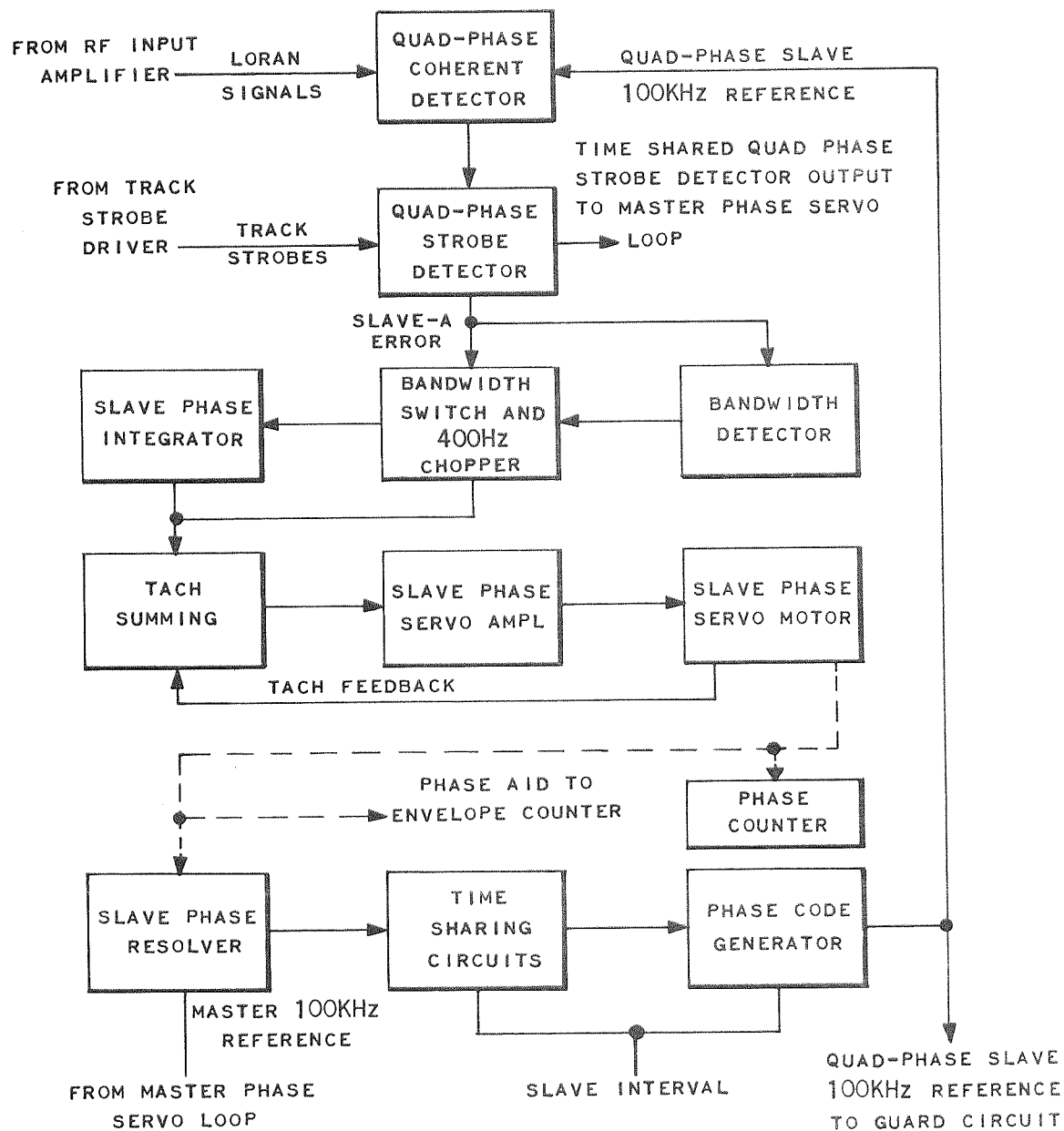
## MASTER PHASE SERVO LOOP

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



25

## SLAVE PHASE SERVO LOOP



S L A V E   P H A S E   S E R V O   L O O P

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

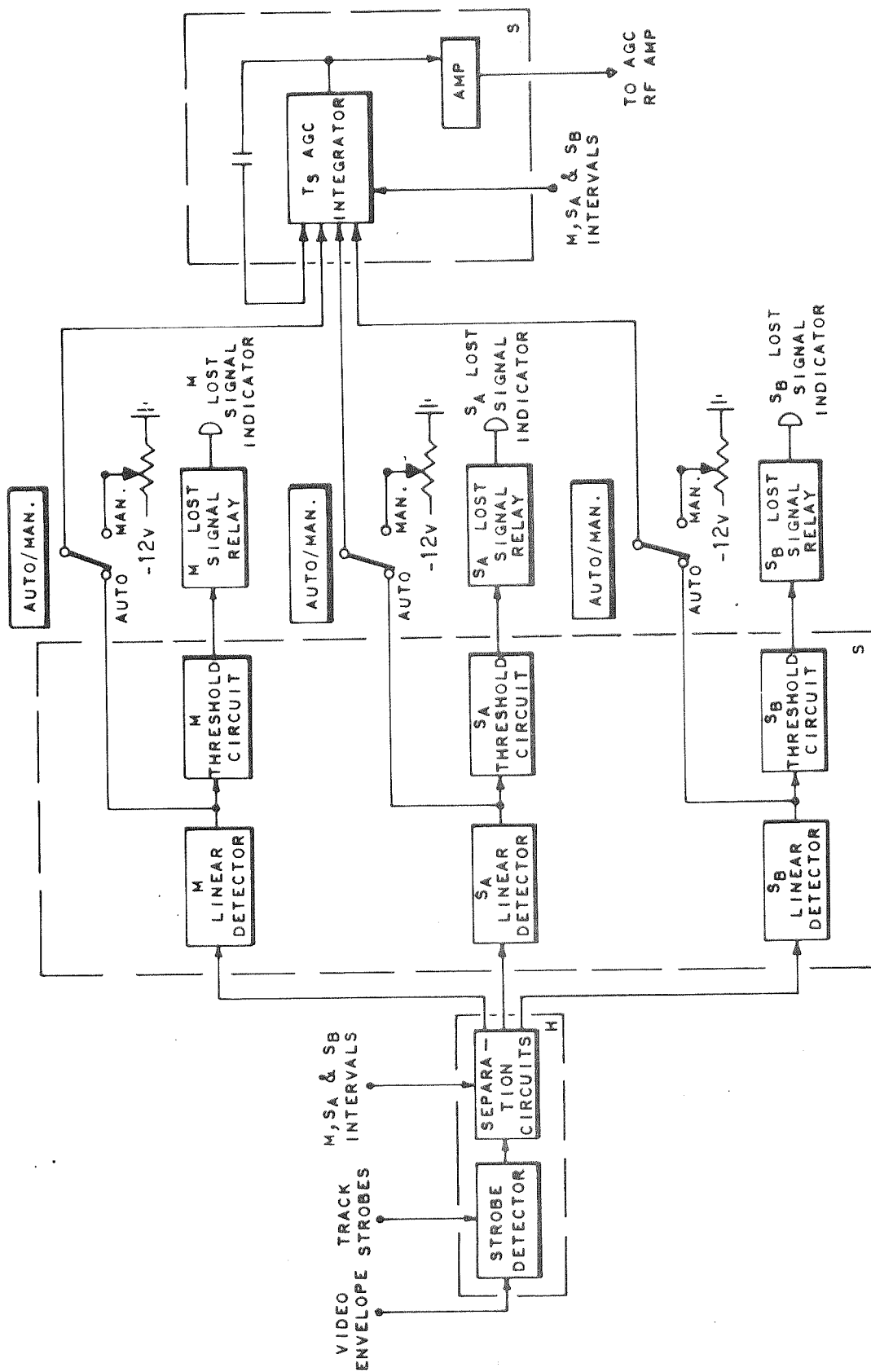
The circuits shown in the "Lost Signal Block Diagram" illustration have a dual function. First, the amplitude of the video envelopes is processed to produce an Automatic Gain Control (AGC) voltage for the master, slave A, and slave B intervals. The second function is the triggering of lost signal indications 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.

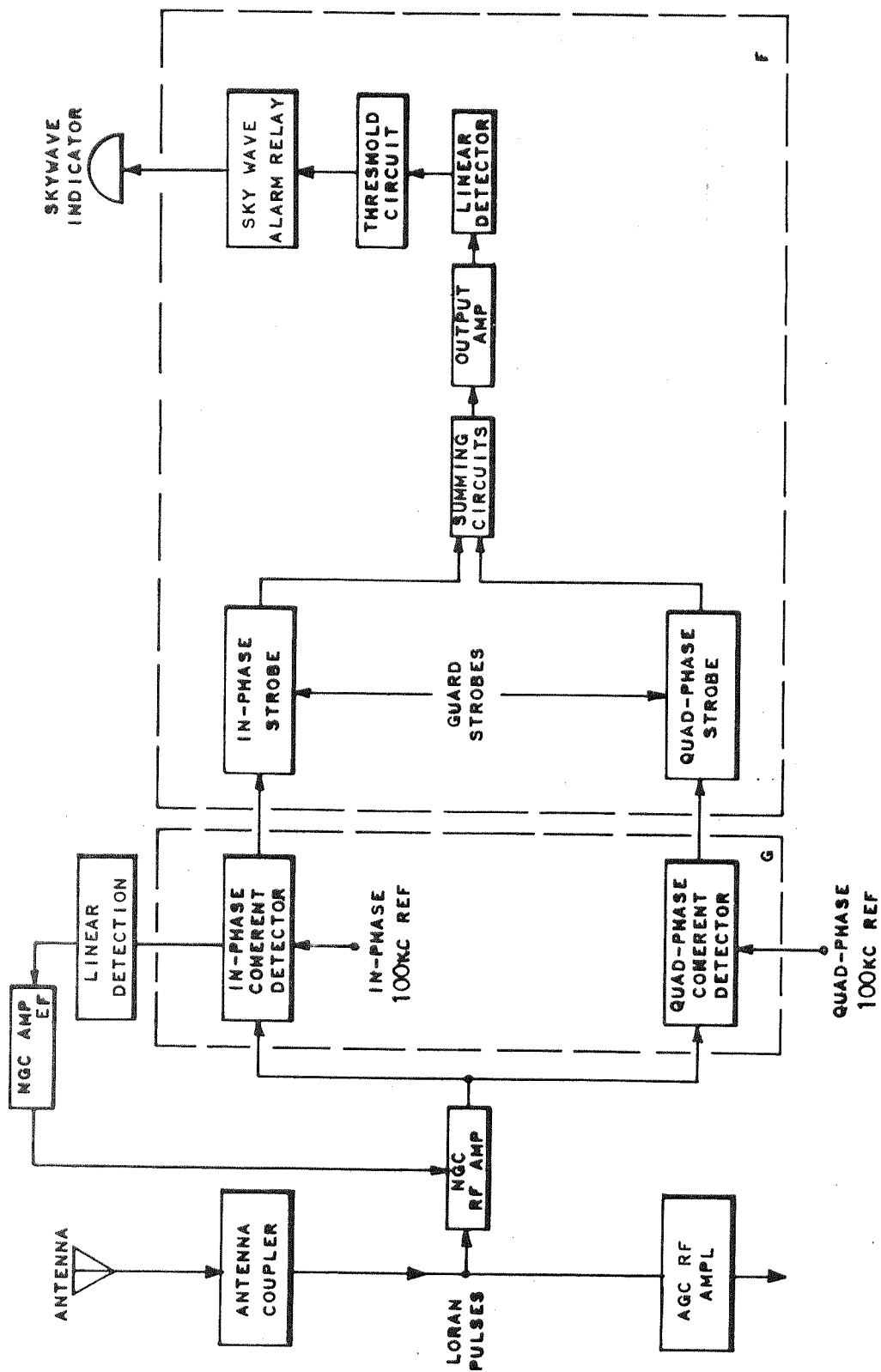
The detected AGC voltage for each interval is coupled to the time-shared integrator, and at the same time to the three threshold circuits. The integrator compares individual D-C levels with a reference voltage. The time shared difference voltage out of the integrator adjusts the RF amplifier gain so 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 ionosphere 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.

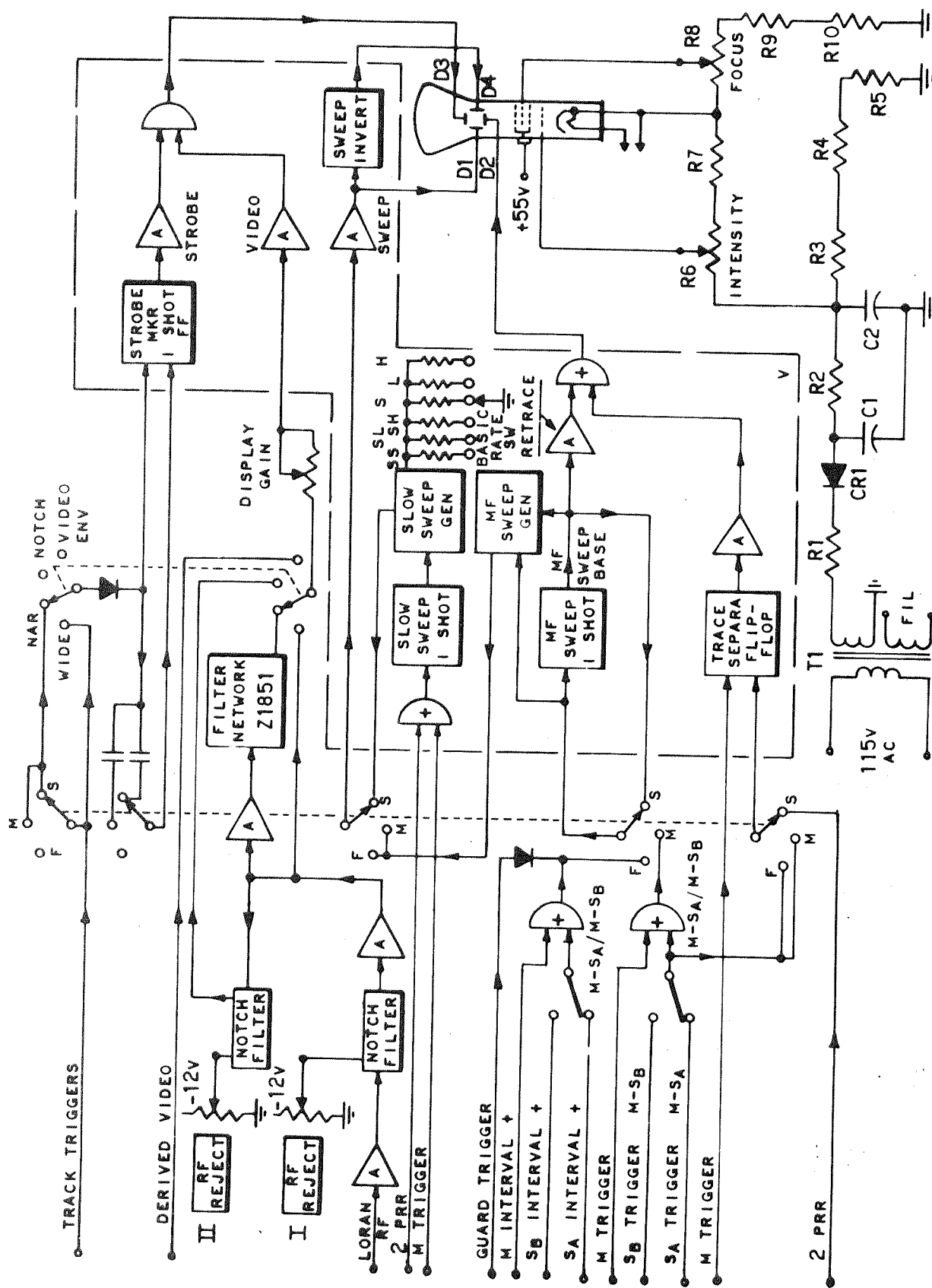
The guard circuit is gain controlled by the Noise Gain Control (NGC) circuits. Pulse envelopes are taken from the in-phase coherent detector and applied to a linear detector. The detector produces a D-C output proportional to the average amplitude of the envelopes. The gain control voltage is amplified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

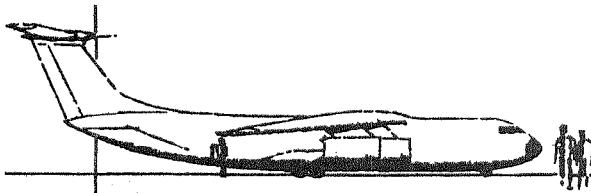
Three series regulators provide -12 volts, DC, -55 volts, DC, and +55 volts, DC. Voltage dividers are employed to produce the -11 volts, D-C and the -30 volts, D-C outputs. The unregulated +15 volts, DC is fused within the power supply and is the power source for the servo amplifiers in the receiver.

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 or 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

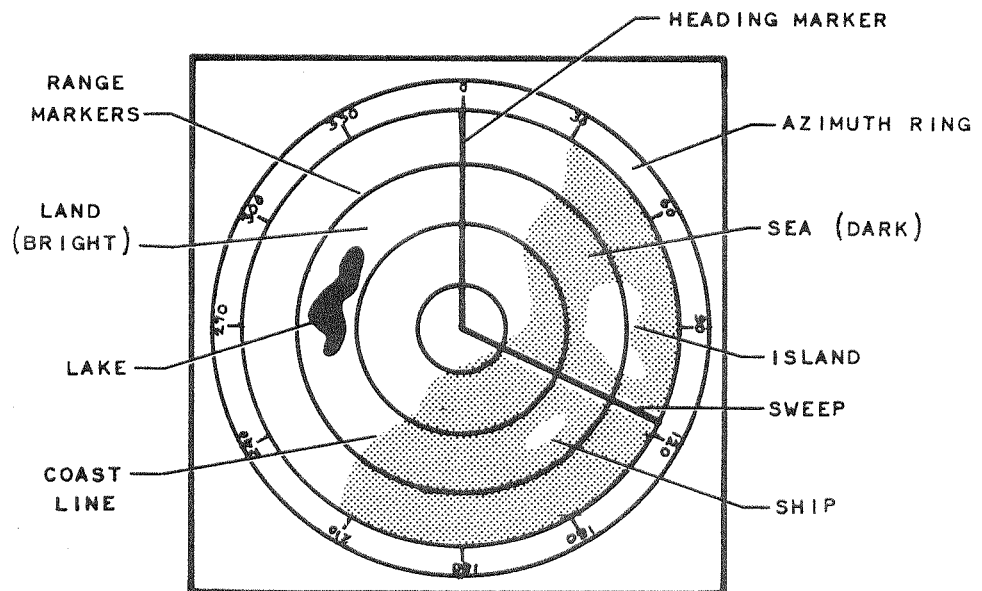
The CU-1568/APN-157 antenna coupler amplifies and filters the RF signal and matches the impedance of the 50 ohm line to the receiver. The coupler is tuned to a bandwidth of 30 KHz. The signal gain is 15-20 DB while noise is attenuated by approximately 30 DB. A lightning arrestor with a breakdown potential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



## 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.

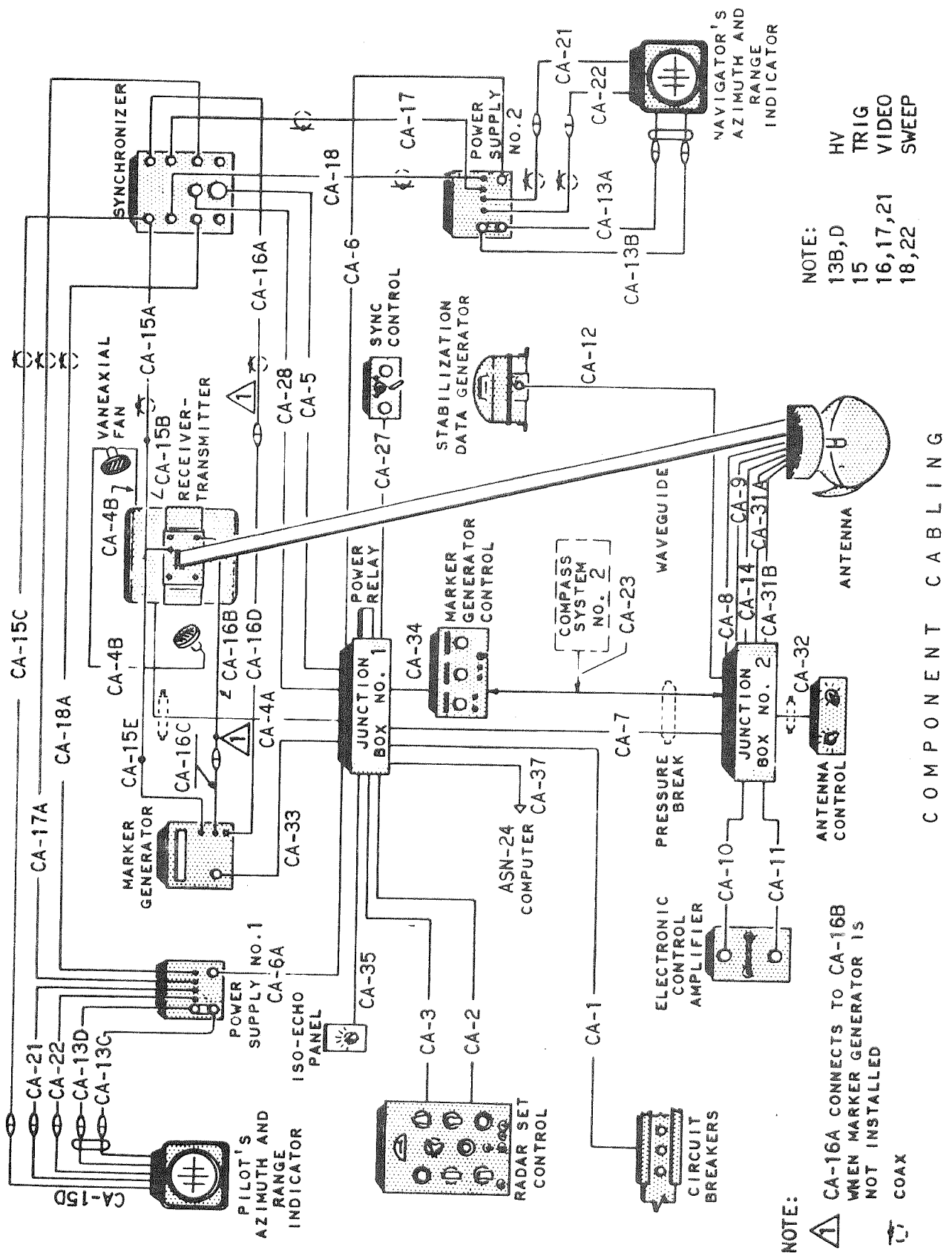
Components of the system are shown in the cabling illustration. Each component is designated by the short name normally used by maintenance personnel. The

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

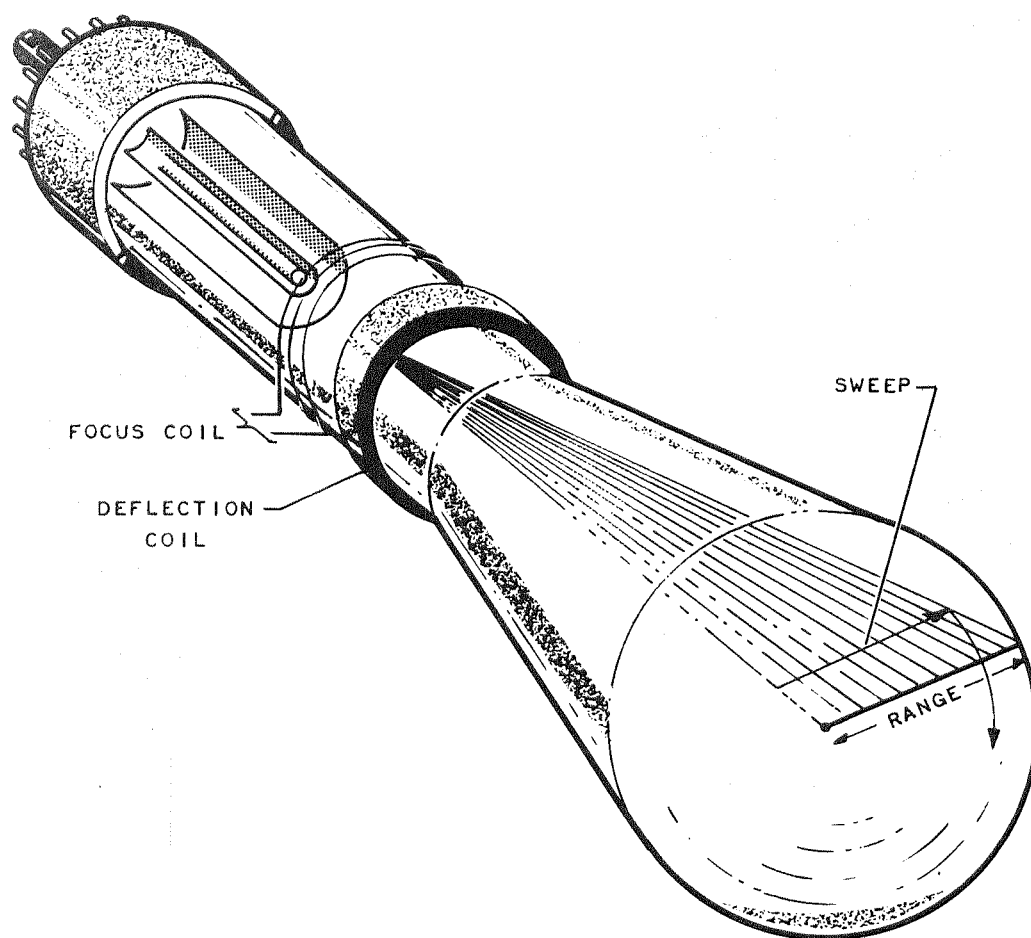
The radar system transmits and receives RF energy pulses at a nominal frequency of 9375 megahertz (MHz). The system transmits a pulse of energy and waits to receive echo signals, then transmits another pulse and again waits for echo signals. This transmit and receive cycle (pulse repetition frequency) 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.





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 ( $2 \times 6.18$  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 ( $50 \times 12.36$  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 ( $12.36 \text{ us} \times 10 = 123.6 \text{ us}$  between markers). These markers also intensity-modulate the CRT beam and appear as bright spots, or circles, when the sweep is rotated.

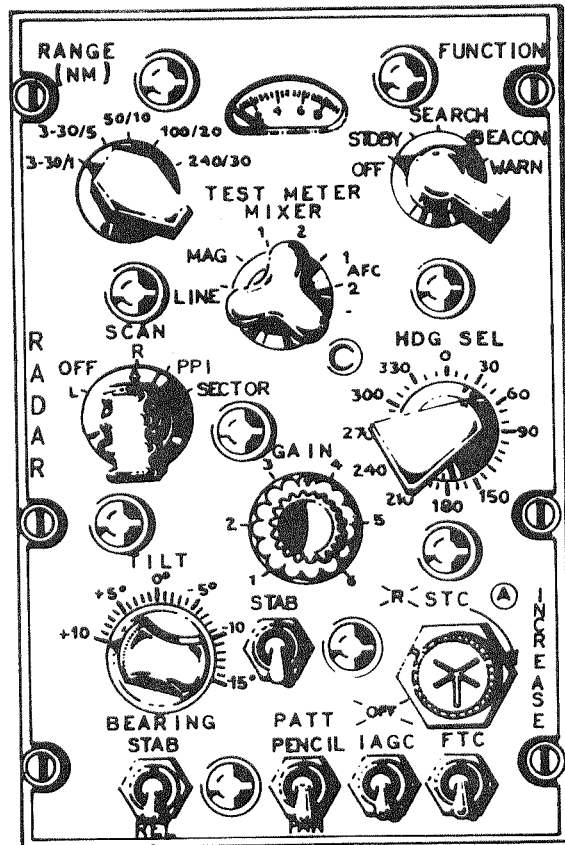
### OPERATING CONTROLS

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



R A D A R   C O N T R O L   P A N E L

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.

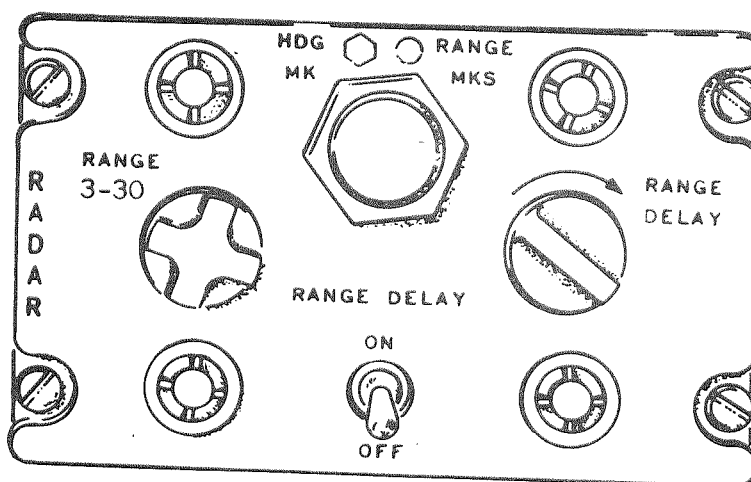
The "MIXER 1 and 2" positions allow monitoring of the receiver crystal currents. The crystals are balanced and should indicate the same current. The "AGC 1 AND 2" positions allow monitoring of the automatic frequency control crystal currents. These are also balanced and should indicate the same current.

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.

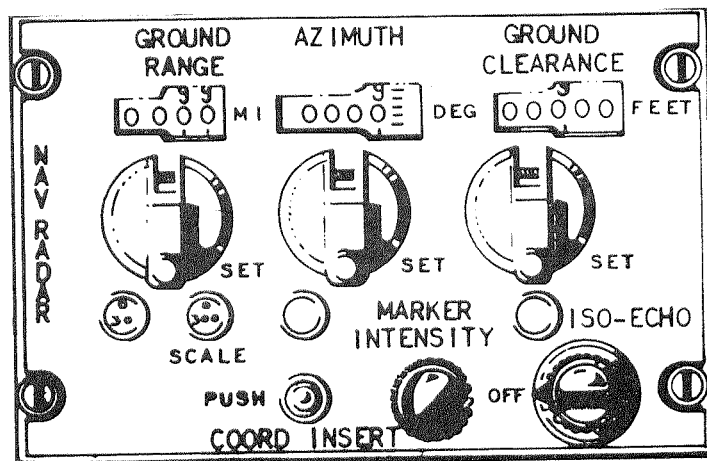
The RANGE MKS control varies the intensity of the range markers. The marks appear and brighten with clockwise rotation of the control.

### 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.

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.

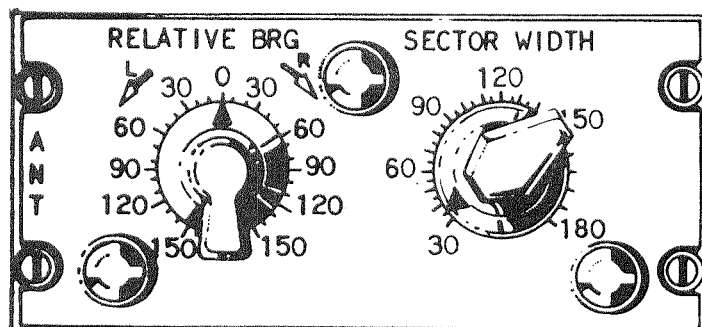
A second ISO-ECHO control is on the pilot's instrument panel. It provides the same function as the navigator's control. If the pilot's control is turned clockwise, the same results will occur. In addition, the ISO-ECHO lamp on the marker generator control goes "on" to indicate pilot control of iso-echo. 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 sectorized 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

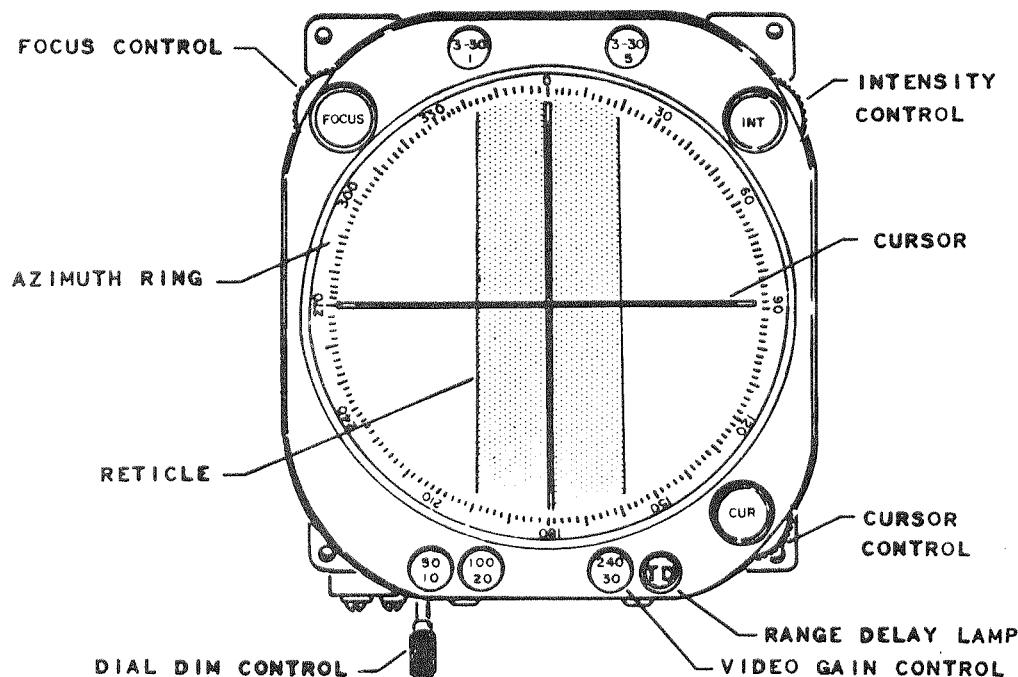
left and right of center). The center of the area to be sectored is variable 180 degrees left and right, or a total of 360 degrees.

### NAVIGATOR'S INDICATOR



ANTENNA CONTROL PANEL

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.

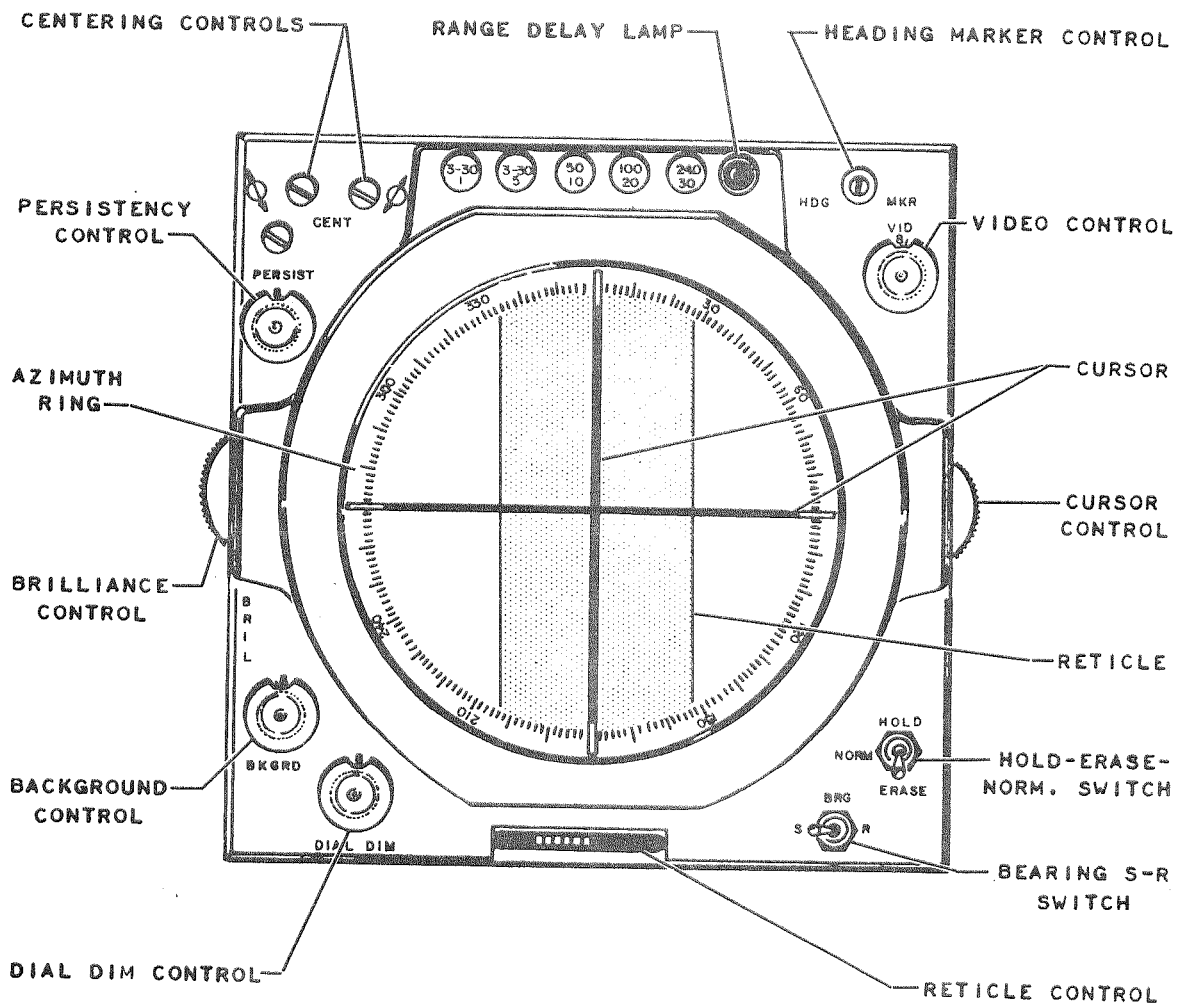


NAVIGATOR'S INDICATOR

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

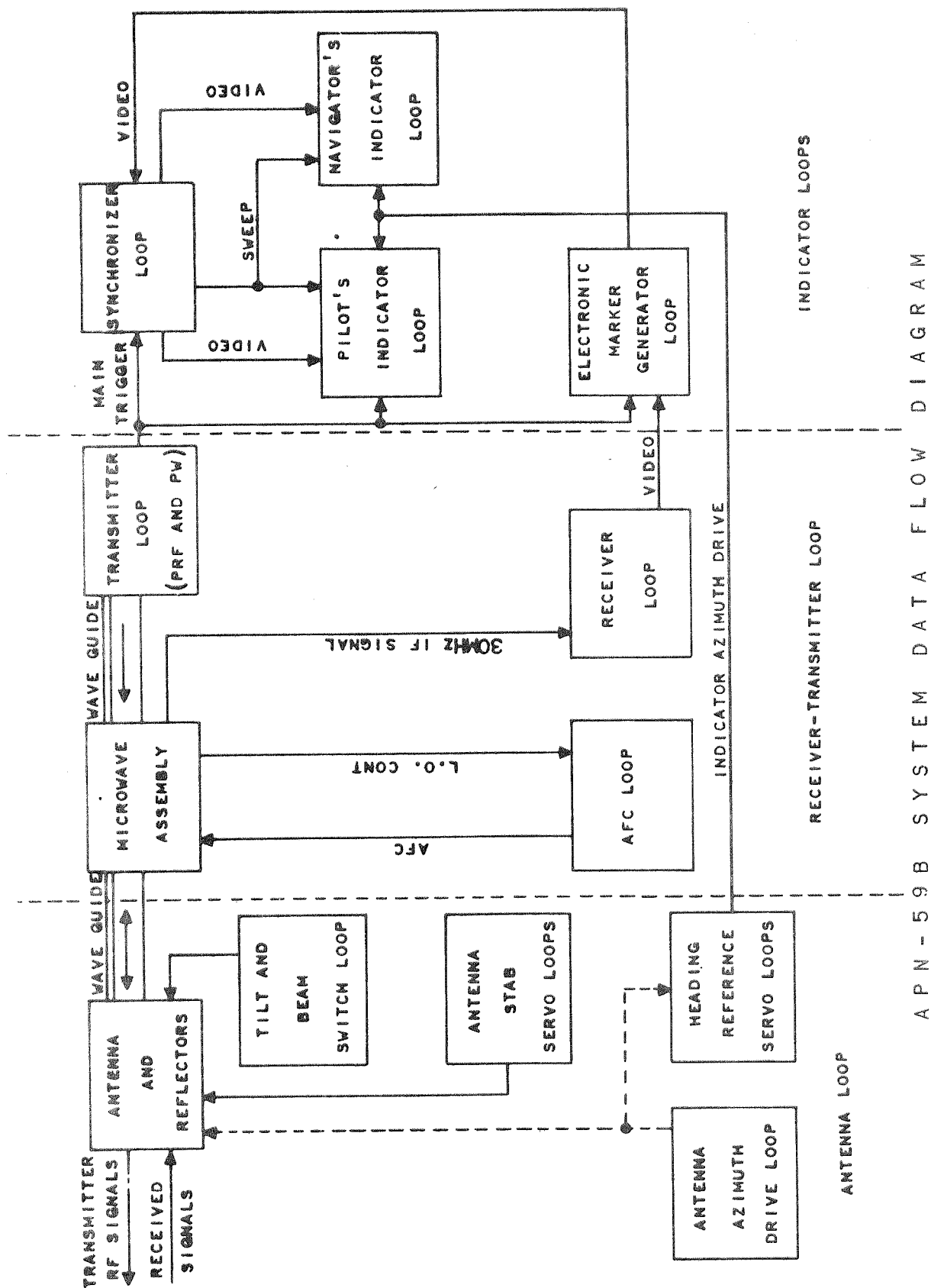
- Transmitter =  $9375 \pm 40$  MHz
- Receiver =  $9375 \pm 40$  MHz (radar) and 9310 MHz (Beacon)
- Intermediate Frequency = 30 MHz
- Power Output = 50 kilowatts of peak power (minimum)
- Pressurization = Antenna and Waveguide: 15 pounds per square inch (Minimum).

## 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



## 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.

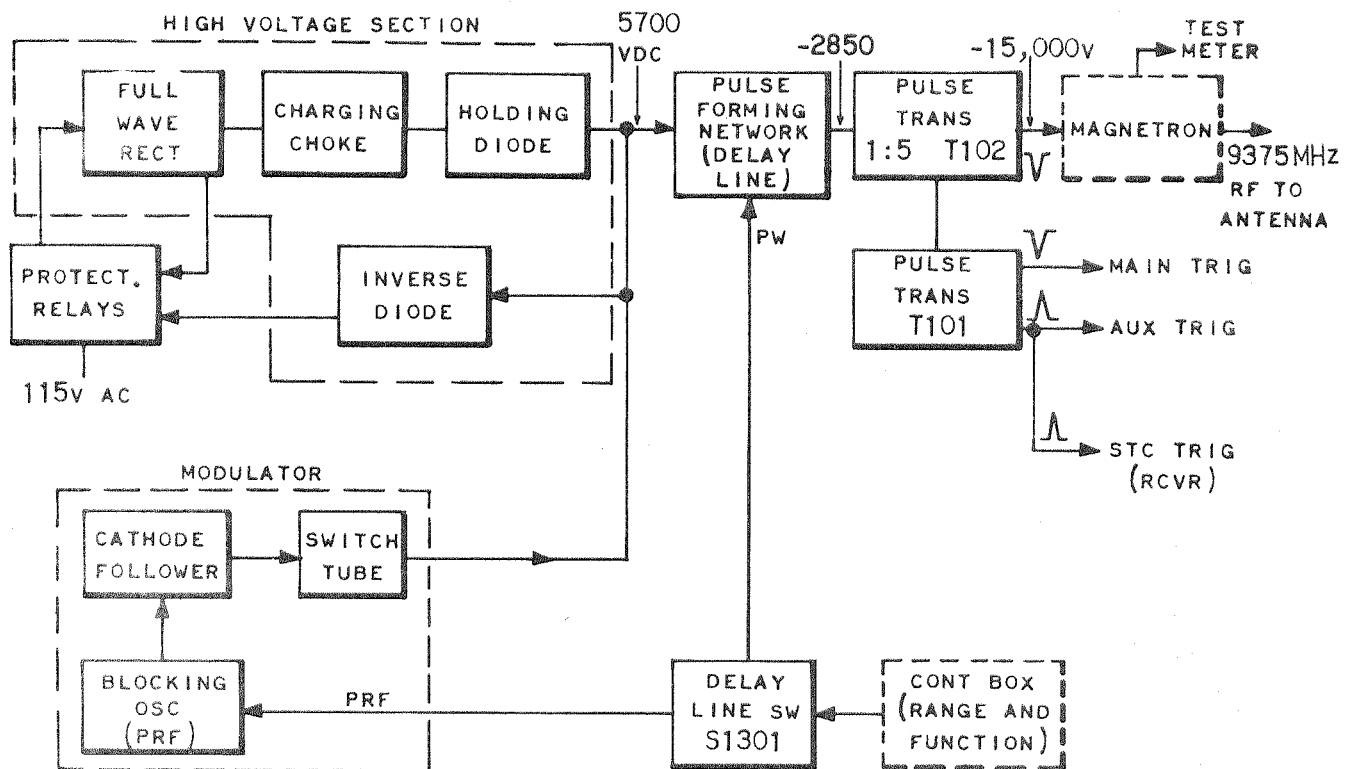
The low voltage power supply provides operating voltages for the radar system. These voltage outputs can be checked from the fuse box. The power supply also provides a 230-volt interlock voltage, which is used to interlock the high voltage section of the transmitter to power supply operation. The high 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  $\mu$ s pulse width; the first and second sections in series produce a 0.8  $\mu$ s pulse width; the first three sections produce a 2.35  $\mu$ s pulse width; and all four sections produce a 4.5  $\mu$ s 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 thyatron 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.

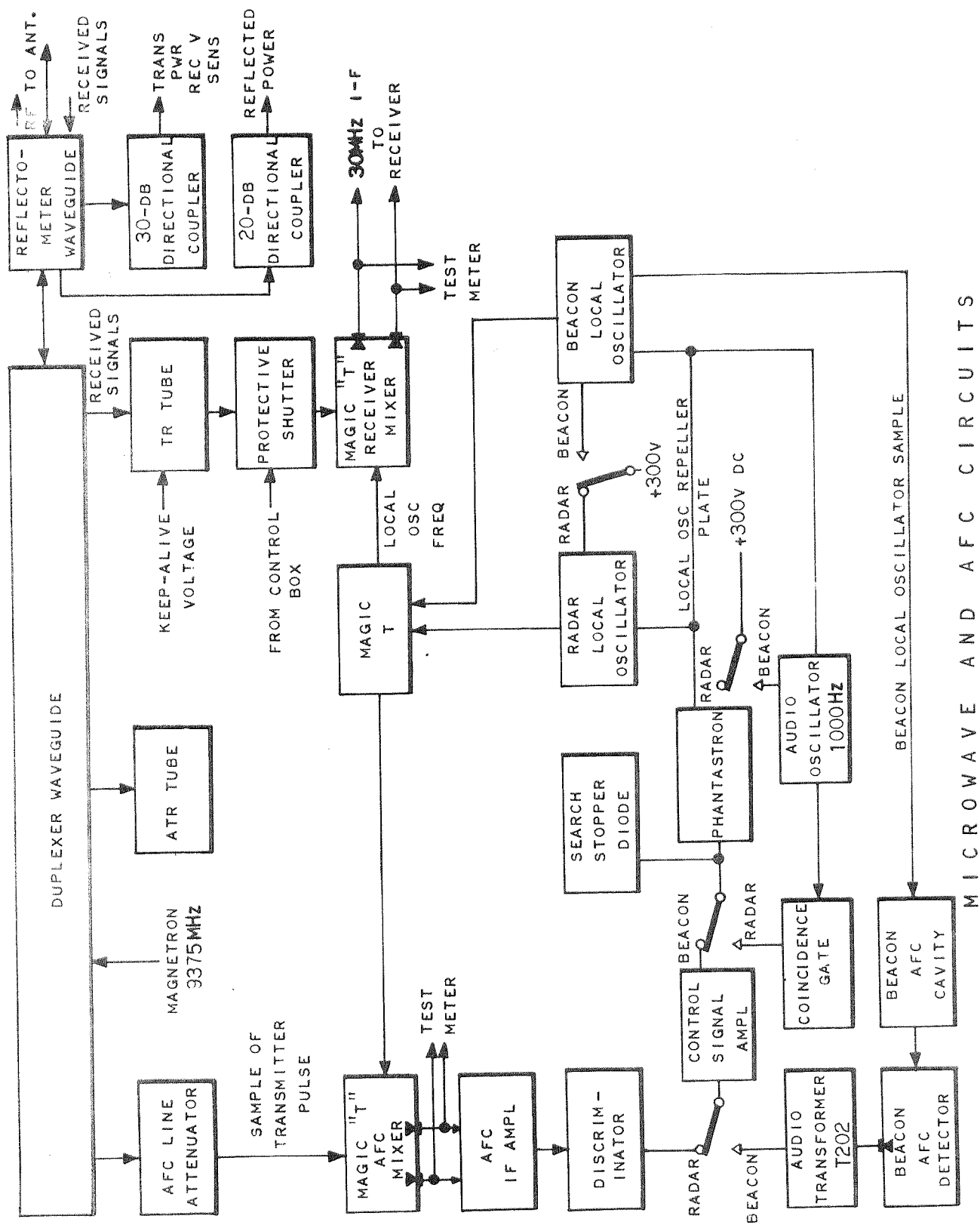
The TR tube is in the receiver waveguide and is slightly ionized by a "keep-alive" voltage. When a pulse is transmitted, the TR tubes fire immediately, blocking the pulse from entering the receiver. The ATR tube is also fired by the transmitter pulse. These tubes effectively close the wall of the duplexer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

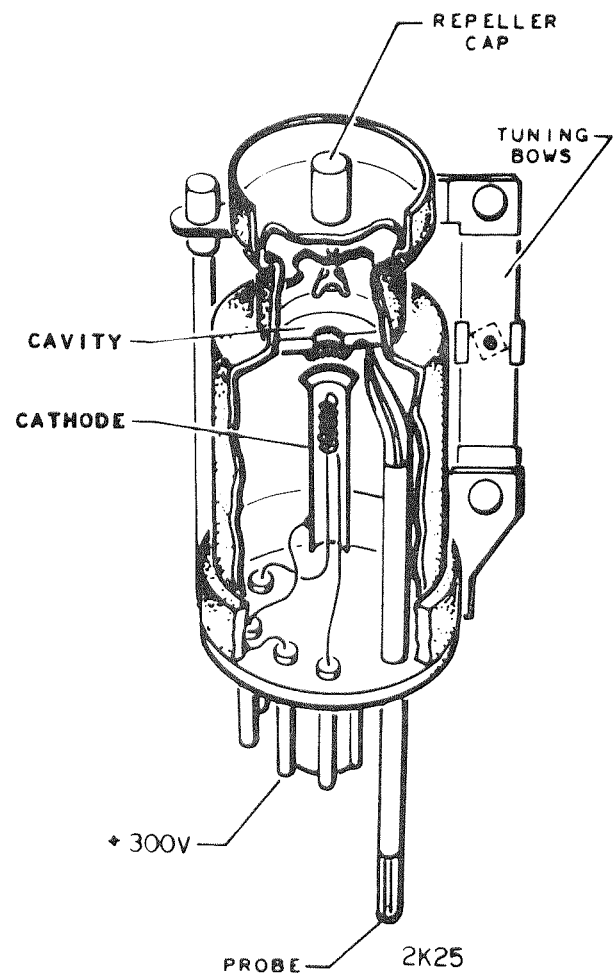


When the LO reaches a frequency that produces an IF slightly above 30 MHz, the discriminator output becomes a negative pulse. The negative pulses are amplified, inverted, and applied to the search stopper diode. The diode develops a negative bias for the phantastron which then stops oscillating. The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

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



REFLEX KLYSTRON  
LOCAL OSCILLATOR

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.

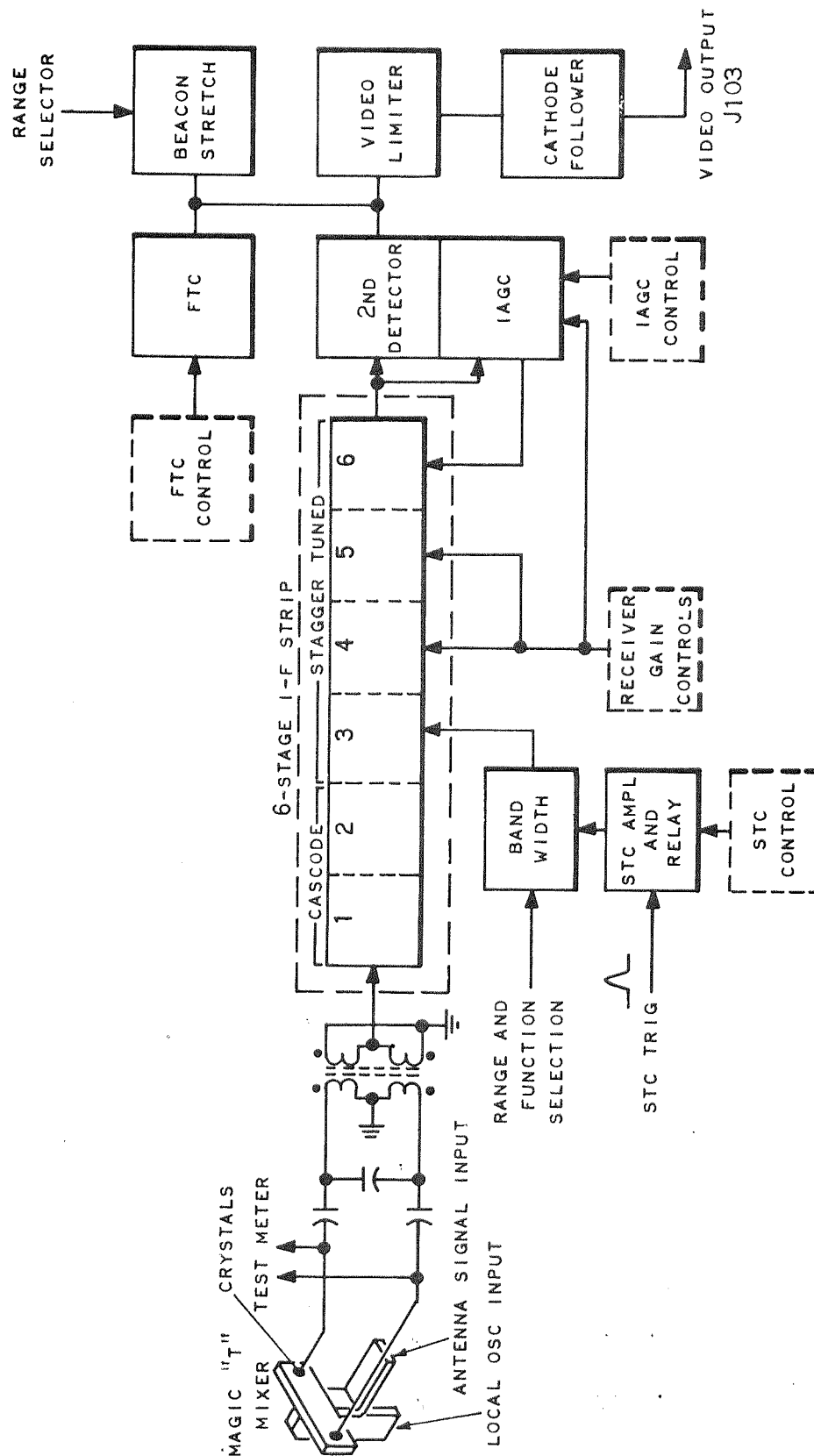
In beacon operation, the 9,280-MHz output of the beacon LO is fed to the receiver mixer with the received 9,310-MHz beacon signal to produce a 30 MHz-IF signal. In search or warning operation, the 9,405-MHz output of the radar LO is fed to the receiver mixer, with the 9,375-MHz received echo signals, 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, IAGC, 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 50-mile search operation, or in beacon operation, narrow pulses are transmitted. Under these conditions, the receiver bandwidth of 6 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.

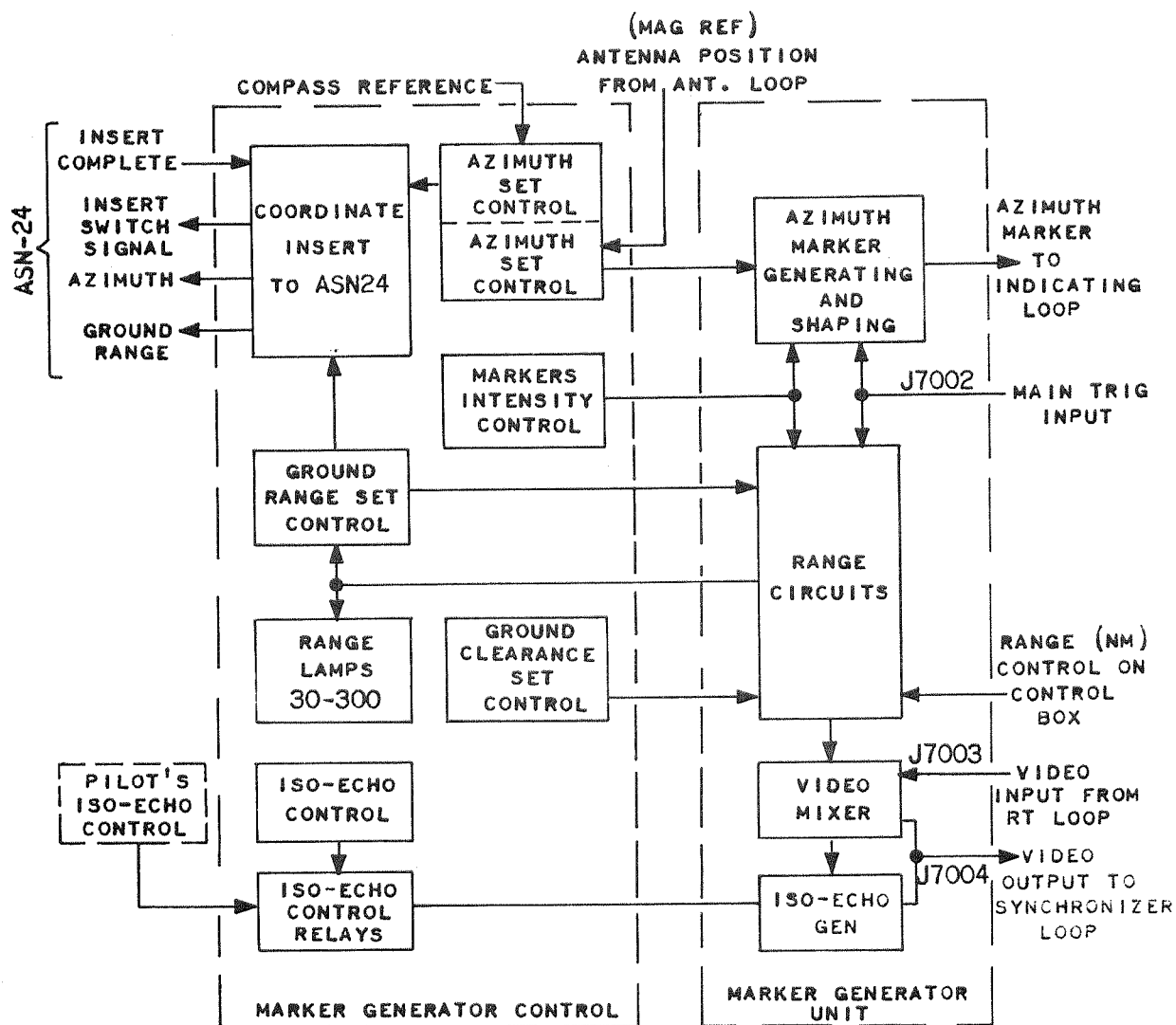
The circuit uses a rectifier, resistor, and filter. When the IAGC switch is placed in the "ON" position, a relay is energized which permits the IAGC circuit to function. The setting of the RECEIVER GAIN control determines the normal signal amplification of the sixth IF amplifier. When a signal of high 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 as 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.

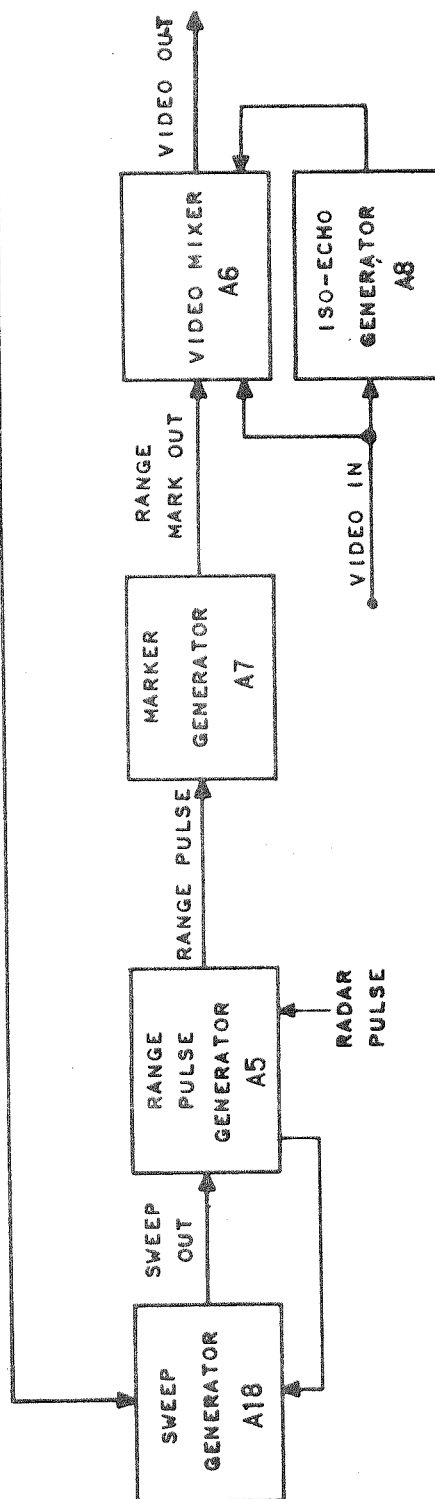
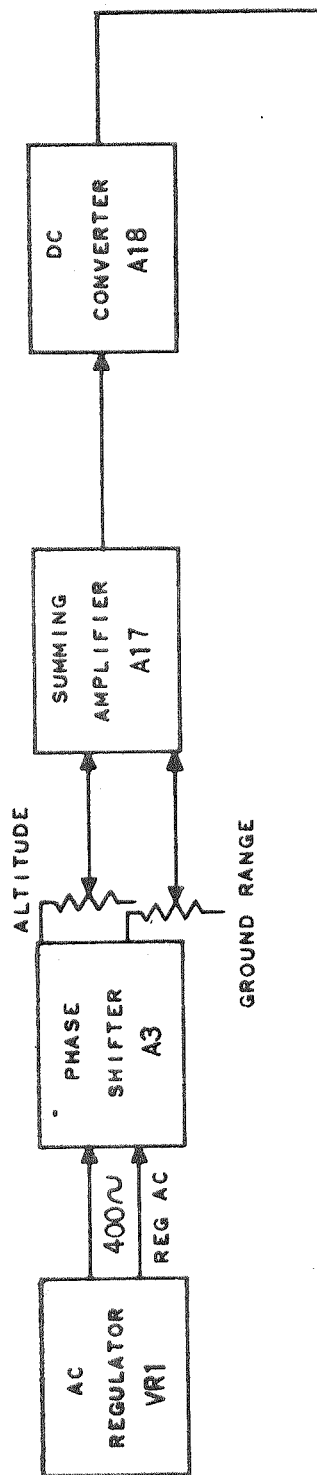
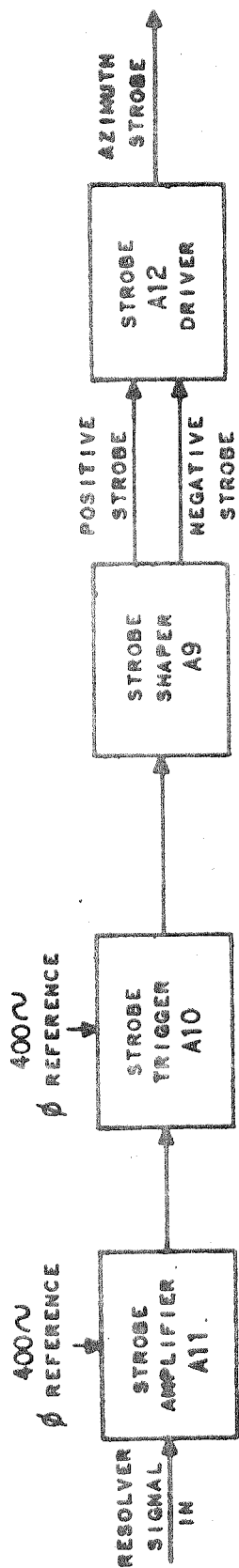
#### MARKER GENERATOR

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 clipping 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.

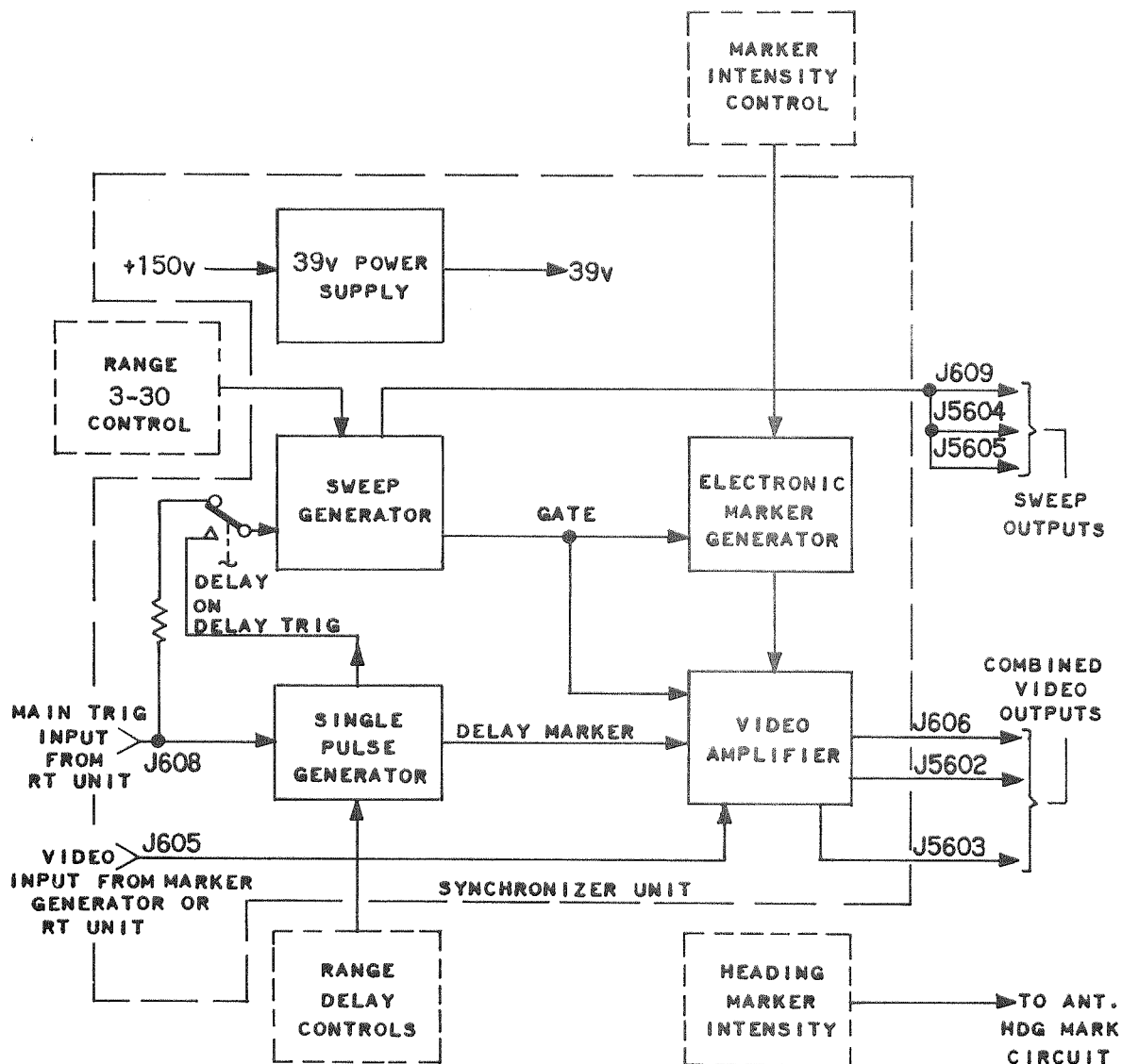
The iso-echo generator receives the video signal through an emitter follower stage. The output of the emitter follower passes through a reverse-biased diode, at a level determined by the setting of the ISO-ECHO control(s). Signals which exceed the bias voltage are amplified, inverted, and sent to the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





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.

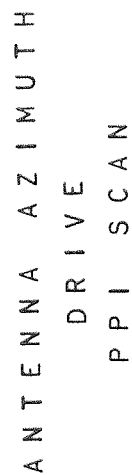
Relays accomplish the switching necessary to allow 12-rpm clockwise rotation, 12-rpm counterclockwise rotation, or 45-rpm clockwise rotation. Sector scan relays reverse the motor voltage, causing the scan to reverse after the degrees of travel, as preset by the antenna control unit settings have been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

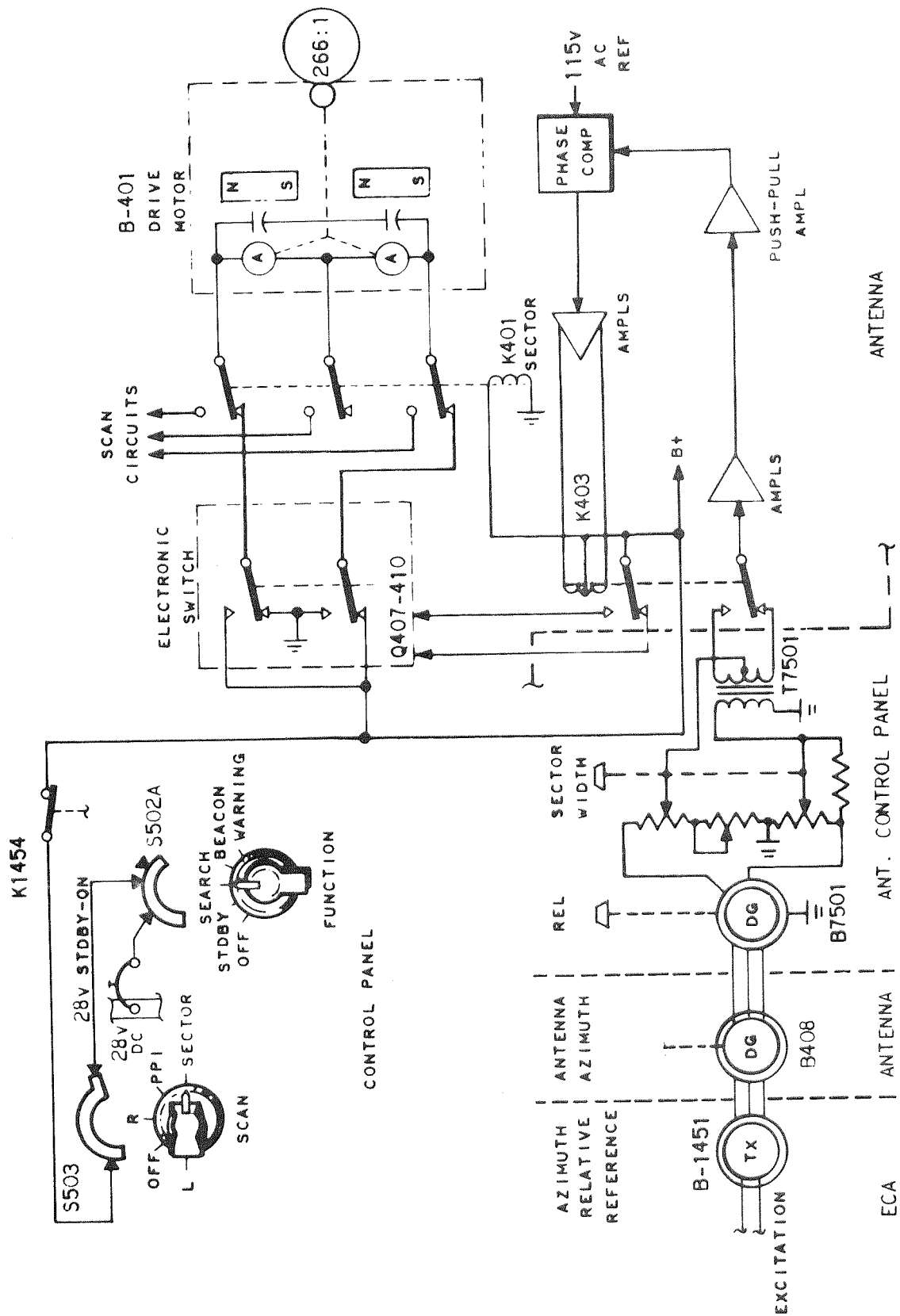
The synchro reference is supplied to the differential synchros in the antenna, then to indicator servo loops, which position CRT deflection coils to track antenna azimuth changes. The indicators contain a control transformer and servo motor. The servo amplifiers are in the indicator power supply units.

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 SECTOR SCAN 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.

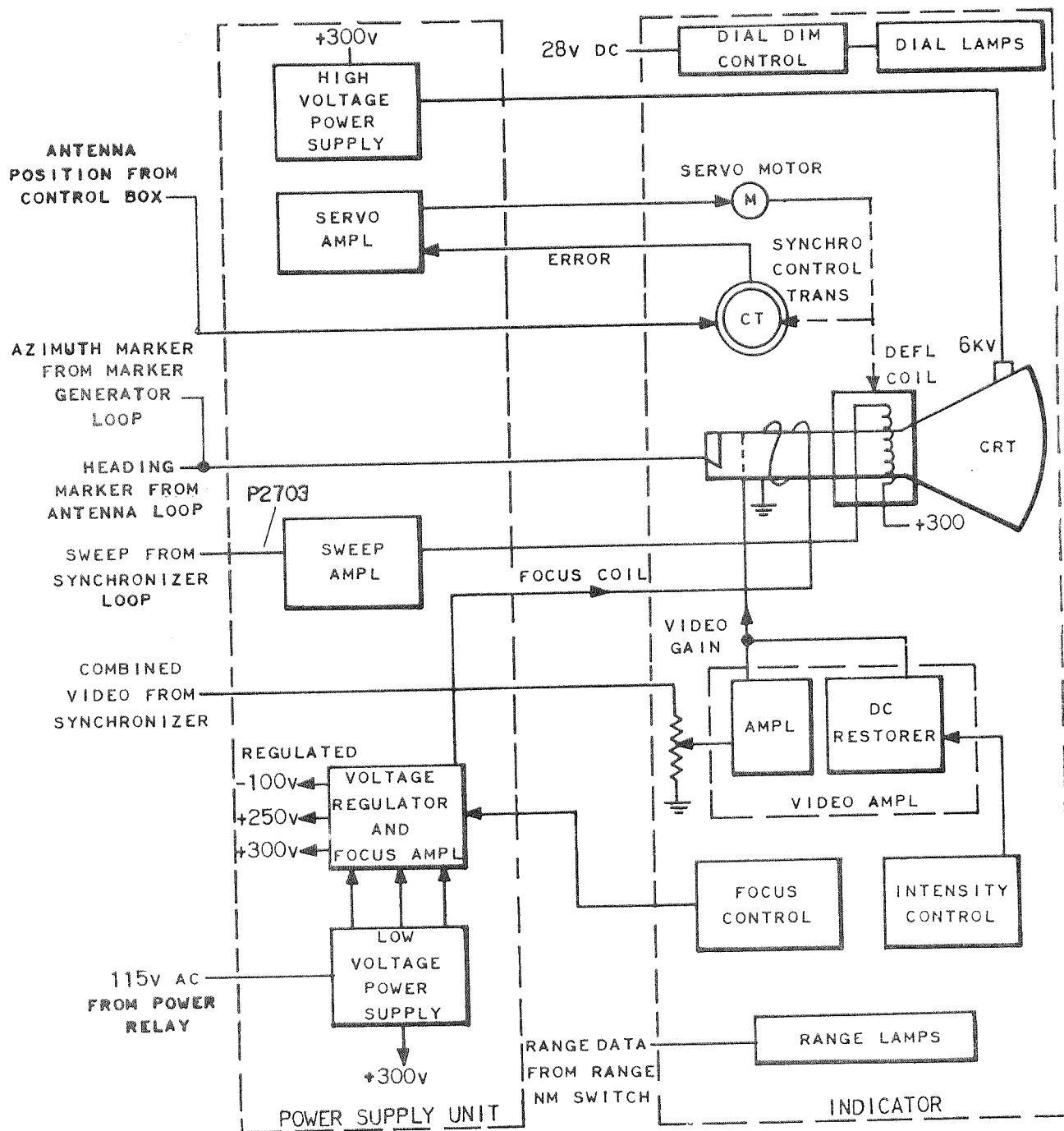
The sweep generated in the synchronizer is amplified in the power supply unit by the sweep amplifier subassembly. The amplified trapezoidal output is applied to the CRT deflection coil. The sweep output causes the electron beam to move from the center to the outside of the CRT during each sweep. The 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.

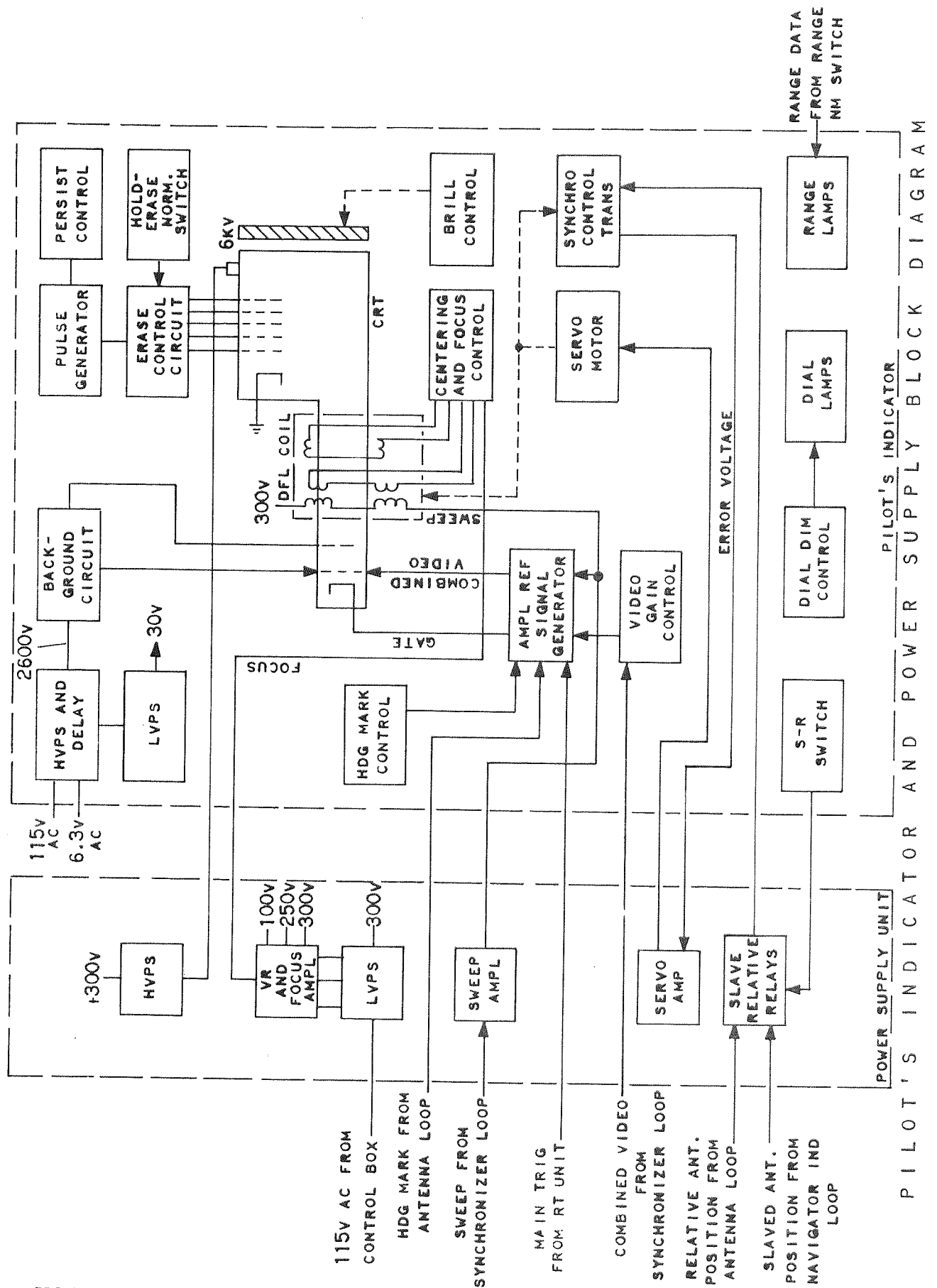
NOTE: Brightness only is varied on the pilot's indicator.

The power supply units contain a low voltage power supply, voltage regulator, sweep amplifier, servo amplifier, and high voltage power supply. These sub-assemblies 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



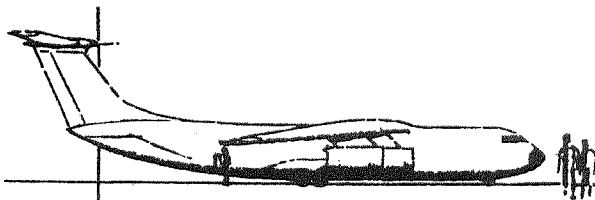
The pilot's indicator contains a direct view storage tube which has an unusually bright display. It has the ability to hold a display for an extended period of time, the length of which is determined by the setting of the PERSIST control. The direct view storage tube essentially consists of two electron 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.



## RADAR PRESSURIZATION SYSTEM

### GENERAL

The AN/ASQ-70 system maintains approximate sea level pressure within the receiver-transmitter unit and antenna waveguide assembly of the AN/APN-59B radar set.

### AIRCRAFT INSTALLATION

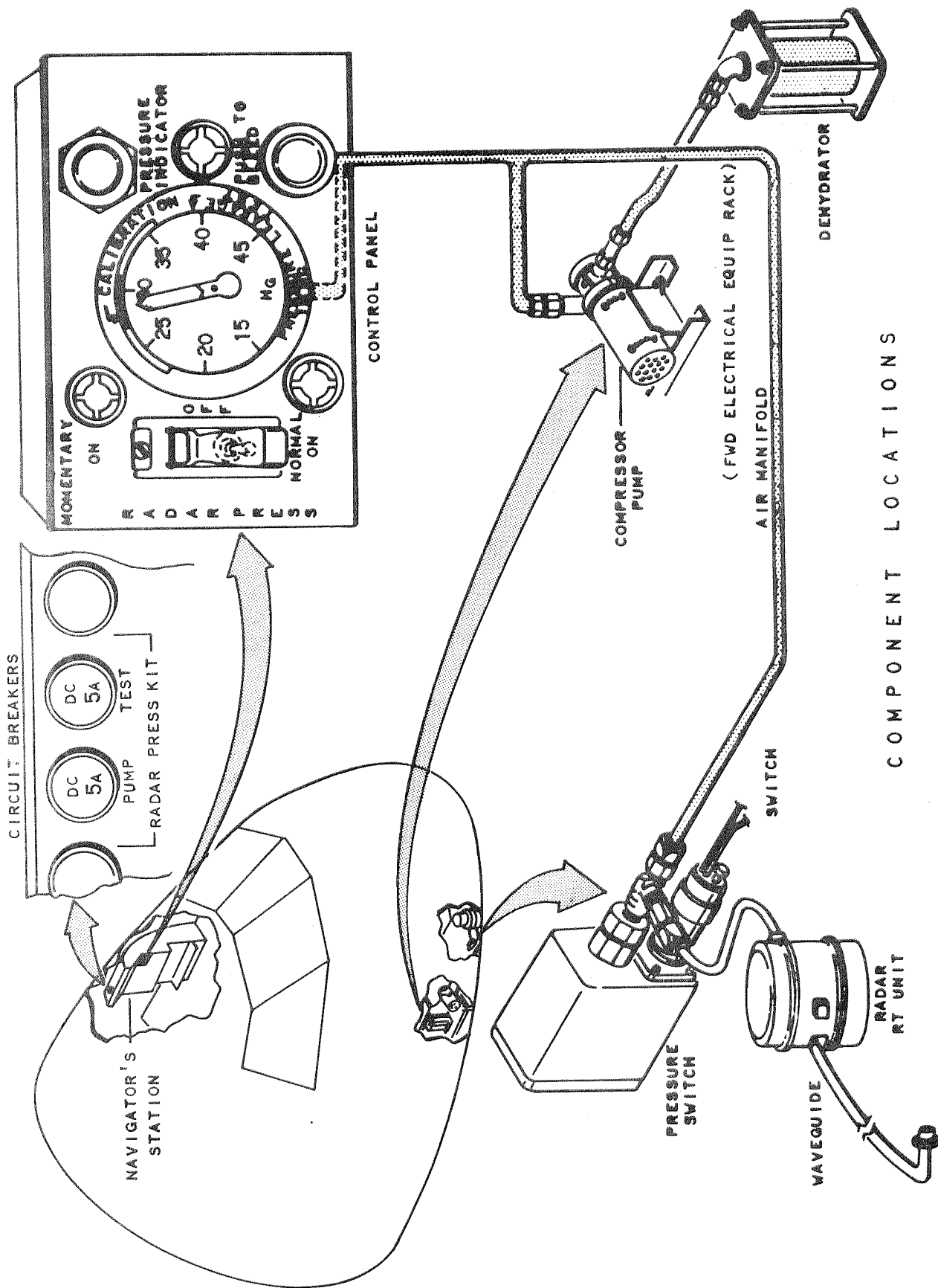
The system is independent of all other pressurization systems on the airplane. It consists of a control panel, dehydrator, air compressor, and pressure switch. The control panel is on the navigator's panel above the APN-59B radar set control; the dehydrator and compressor are mounted in the forward electrical equipment rack on the right-hand side of the underdeck area, and the pressure switch is located on the right side of the nose wheel well next to the APN-59B RT unit.

Aircraft power for system operation is supplied through circuit breakers on the avionics circuit breaker panel above the navigator's station. Power required is 28 volts, DC from the main D-C avionics bus number one.

### SYSTEM OPERATION

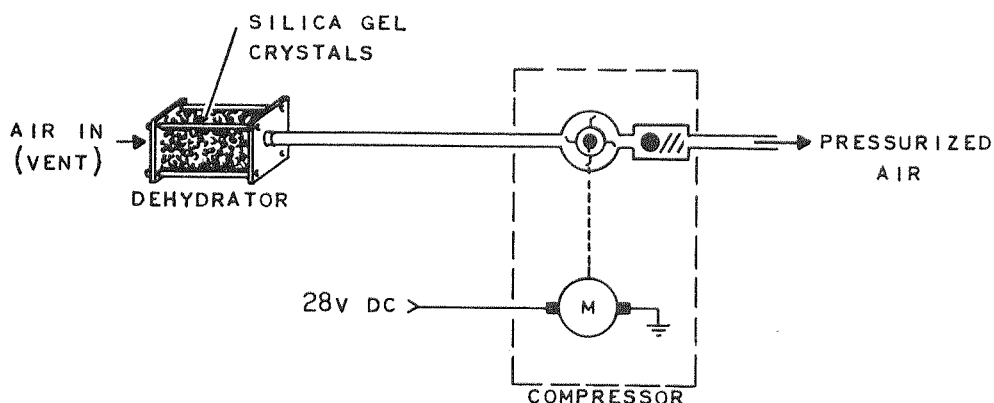
The pressurization system maintains the density of the air close to that of air at sea level within the APN-59B RT unit and waveguide assembly. High voltage circuits are located within these units. Spacing of terminals and components is designed for safe operation, based upon the insulating properties of air at sea level pressure.

At lower pressures, the insulating ability of air decreases. Between two voltage points, therefore, arcing might occur at altitudes. Sea level pressure alone would not be sufficient to prevent arcing, since excessive moisture in the air also decreases its insulating ability. For this reason, the air used for pressurization is dehydrated.



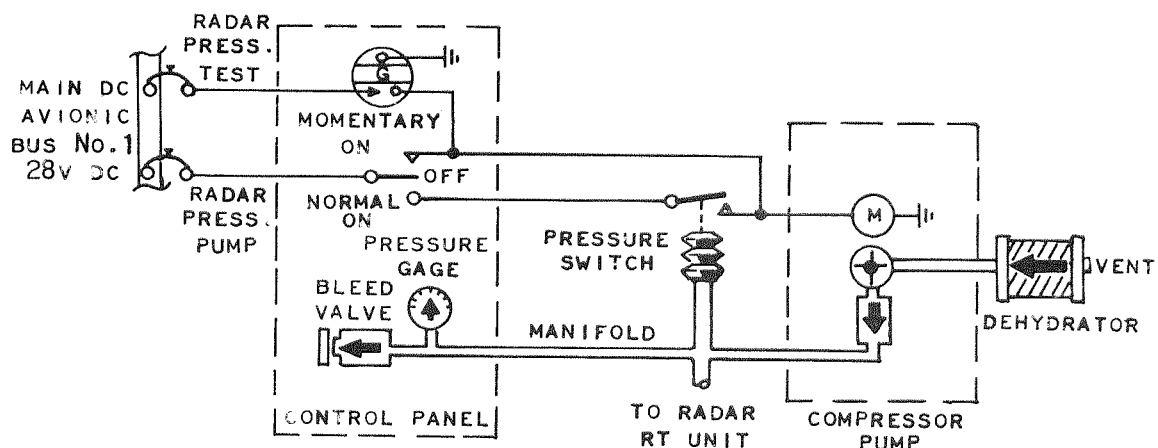
COMPONENT LOCATIONS





DEHYDRATOR AND COMPRESSOR

The compressor consists of a vane-type air pump and a D-C motor mounted on the same shaft. The air intake port is connected to the dehydrator. The dehydrator removes any moisture or foreign matter from the air before it enters the pump. The dehydrator is a clear plastic cylinder filled with silica gel dehydrator crystals. A filter pad is installed at each end of the cylinder. The dehydrator crystals are normally deep blue in color. As they absorb moisture, their color gradually turns pink. A multicolored humidity indicator label in the cylinder serves as a guide for checking the condition of the crystals. When the color of the crystals matches the UNSAFE area of the label, the crystals are saturated with moisture and should be replaced.



RADAR PRESSURIZATION SYSTEM

When the system is operating, air is drawn into the compressor from the aircraft cargo compartment. After being compressed, the air is delivered to a common manifold which connects the pressure gauge, pressure switch, and

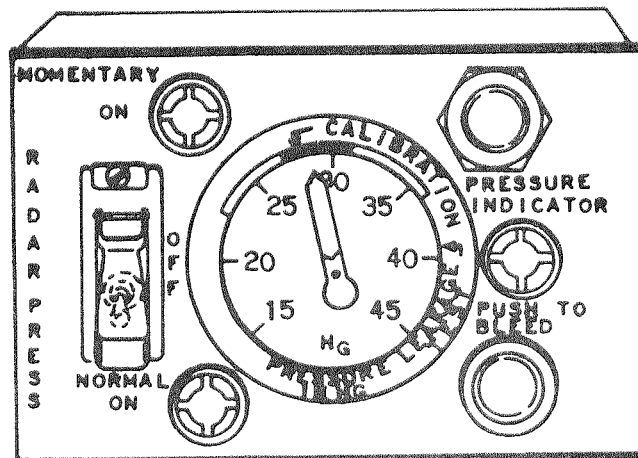
radar receiver-transmitter. A check valve, mounted on the compressor air outlet port, prevents the loss of pressure through the compressor when it is stopped.

The control panel provides a means of reading system pressure and for starting and stopping the compressor. The panel contains a power-controlling RADAR PRESS switch, an absolute pressure gauge, a PRESSURE INDICATOR light, and a PUSH TO BLEED button.

Placing the RADAR PRESS switch in the "NORMAL ON" position applies power to the pressure switch. The pressure switch determines when the compressor will run. The switch senses pressure existing in the radar receiver-transmitter unit and waveguide assembly. If pres-

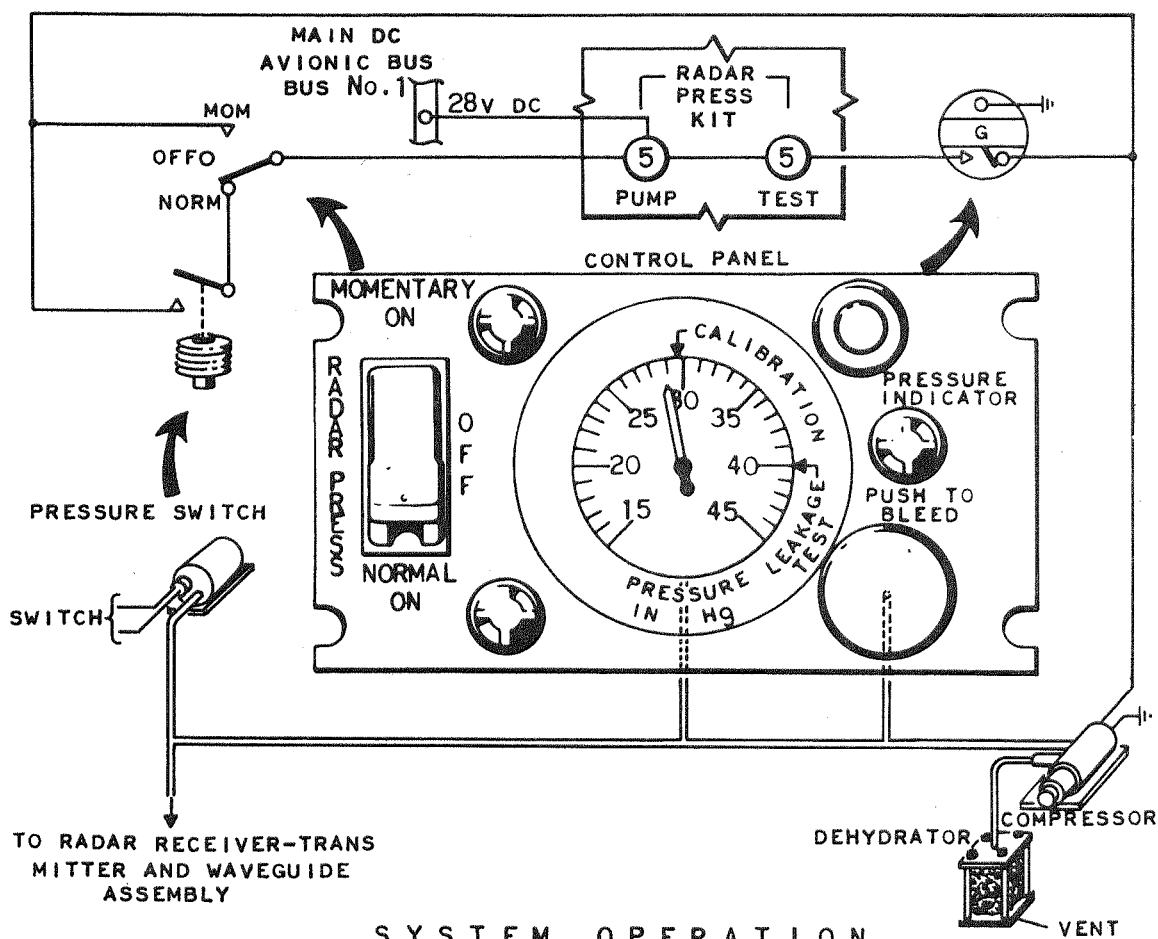
sure is less than that of sea level atmosphere (approximately 30 inches of mercury), contacts of the switch close and supply voltage to the compressor motor. The motor runs until system pressure builds up to slightly more than 30 inches of mercury. At this time the pressure switch contacts open. In this manner the required system pressure is automatically maintained. A slotted screw extending through the front of the pressure switch permits the closing point of the contacts to be varied from 24 to 32 inches of mercury. It is normally preset to 30.15 inches of mercury. The contacts open when pressure is increased approximately 3.5 inches of mercury above the preset level (differential between "on" and "off" is 3.5 inches of mercury).

The "OFF" position of the RADAR PRESS switch deenergizes the system. The "MOMENTARY ON" position applies power directly to the compressor motor. This permits compressor operation to be checked. The PRESSURE INDICATOR light glows whenever the compressor is running, regardless of the method used to turn the system on. System pressure is continuously indicated in inches of mercury (Hg) on the pressure gauge. An adjustable calibration mask on the face of the gauge is set to the desired pressure range.



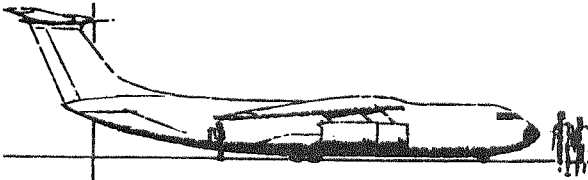
CONTROL PANEL

The PUSH TO BLEED button actuates a bleed valve to depressurize the system to the air pressure inside the flight station.



SYSTEM OPERATION





## IFF TRANSPONDER

### GENERAL

The AN/APX-64 IFF (Identification Friend or Foe) radar system consists of an airborne receiver-transmitter capable of automatically transmitting coded reply signals when challenged by a radar beacon station (Air Traffic Control Station).

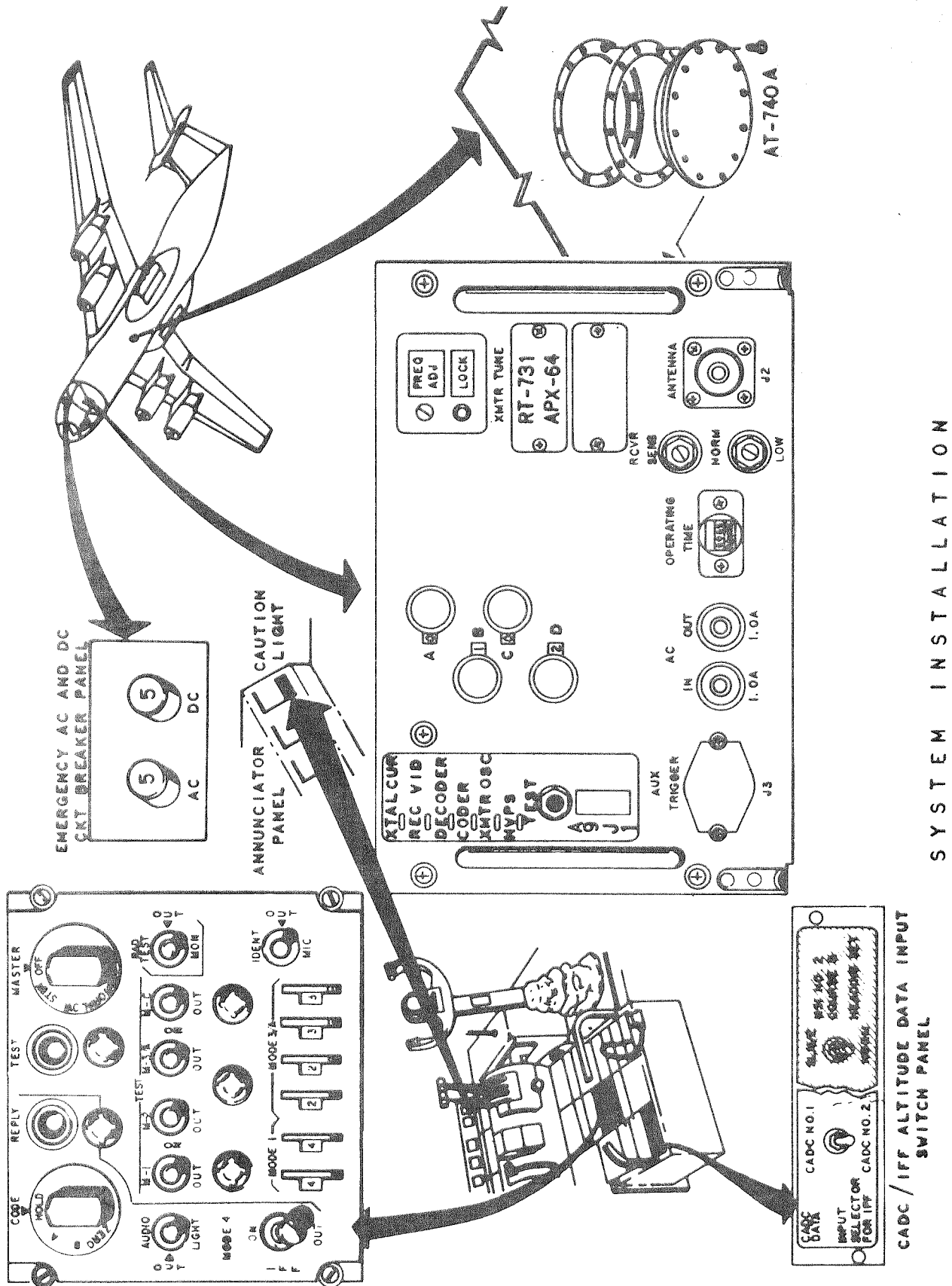
The coded reply signals are used by the beacon station to locate and identify the aircraft and to continuously track its flight path. The APX-64 is generally known as a "transponder" due to its ability to automatically transmit a reply in response to the received challenge (interrogation signal).

A radar beacon station in conjunction with the transponder equipped aircraft within its service area form a complete radar beacon system with the airborne transponders returning reply signals in much the same manner as echos are returned in a pulse-echo radar system.

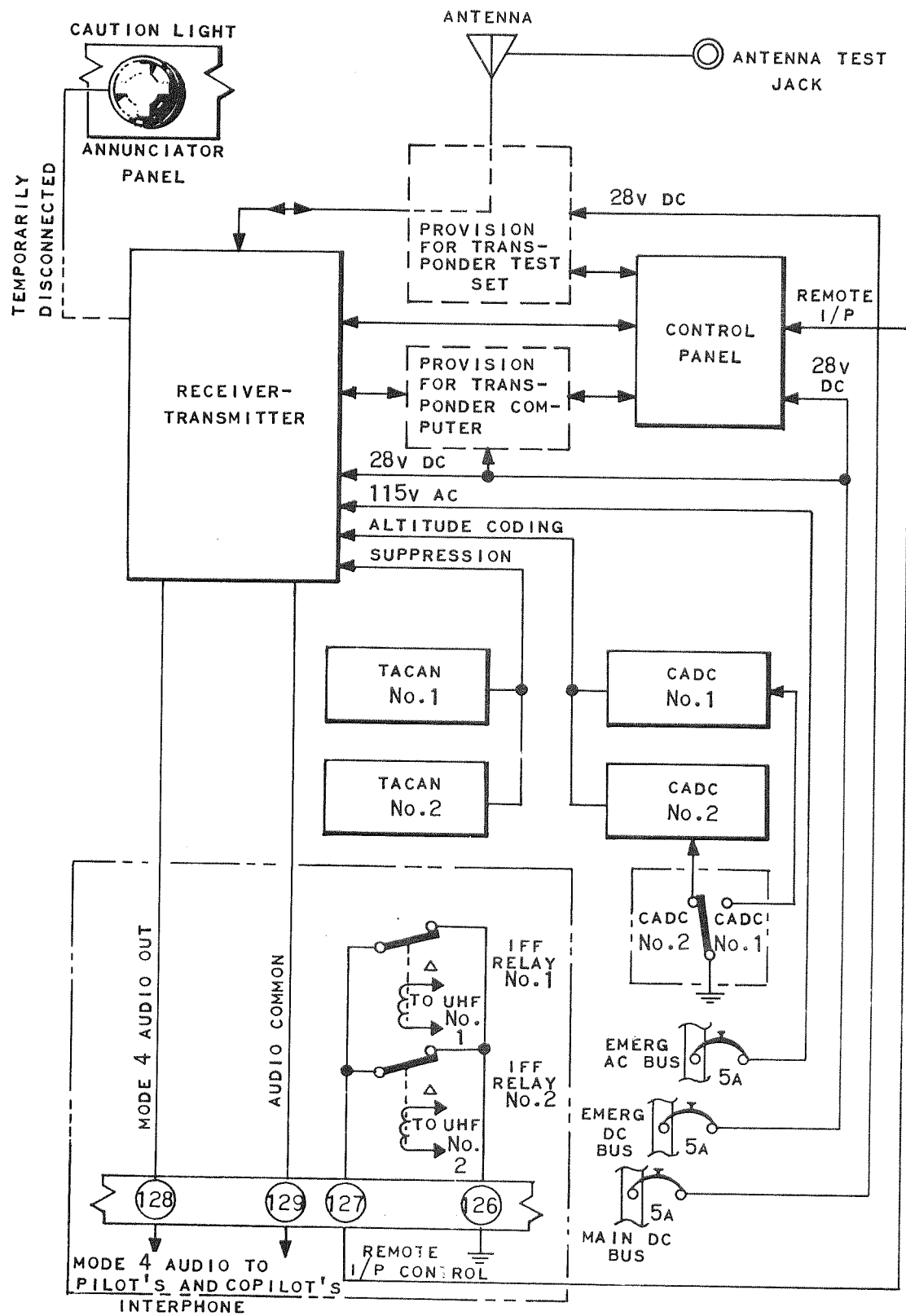
The APX-64 transponder is also capable of coding its reply signals to correspond to aircraft altitude (altitude reporting).

### AIRCRAFT INSTALLATION

The AN/APX-64 radar identification system is presently installed on aircraft AF65-244 and up and on AF61-2775 through AF64-243 if modified by T. O. 1C-141A-837. Refer to aircraft installation and tie-in drawings for components and locations. The present installation provides only wiring provisions for the transponder computer and the transponder test set. The caution light on the annunciator panel will be used in conjunction with the transponder computer and is, therefore, temporarily disconnected. The AN/APX-64 system uses input signals from the selected central air data computer for altitude coding and from both TACAN systems for signal suppression. An audio output signal is wired to the pilot's and copilot's interphone system but requires the installation of the transponder computer for operation. Input signals from either UHF transmitter may be used to automatically change the reply signal coding each time either system transmits. This automatic coding, Identification of Position (IDENT) operates when selected by the APX-64 control panel.



SYSTEM INSTALLATION



## SPECIFICATIONS

CHARACTERISTIC	SPECIFICATION
Input Power Requirements	
AC	115 volts, 320 to 480 Hz single phase; 80 watts at 0.2 percent duty cycle
DC	26.5 volts, 10 watts
High Voltage Circuit Protection	1 amp. 115-volt A-C circuit breaker
Operating Temperature Ranges	-55°C to +95°C continuous, +125°C intermittent at sea level
Operating Altitude Ranges	0 (sea level) to 100,000 feet
Receiver Characteristics	
Frequency	1030 MHz
Frequency stability	±1.5 MHz
Frequency control	Crystal
Intermediate frequency	59.5 MHz
Bandwidth	7.0 to 9.0 MHz at points 6db from maximum response
Normal sensitivity	-78dbm
Low sensitivity	-66 dbm
Spurious response	Response to signals below 1010 MHz and above 1050 MHz at least 70 db below response at desired frequency of 1030 MHz



# SPECIFICATIONS (continted)

CHARACTERISTIC	SPECIFICATION
Suppression Input	
Amplitude	15 to 70 volts
Duration	1.5 to 250 usec
Polarity	Positive
Input resistance	2200 ohms
Rise time	At least 10 volts/usec
Decay time	Peak amplitude to 1.0 volt within 10 usec
Recovery time	Sensitivity returns to within 3 db of normal in no more than 15 usec after the suppression pulse falls to 1 volt.
Transmitter Characteristics	
Frequency	1090 MHz
Frequency stability	$\pm 3$ MHz
Power output	29 dbw at a duty cycle of 0.2 percent (-6 dbw min under any service condition at 1 percent)
Output Pulses	
Width	$0.45 \pm 0.1$ usec
Rise time	0.05 to 0.1 usec
Decay time	0.05 to 0.2 usec
Interrogation Code	
Mode 1	2 pulses spaced $3 \pm 0.1$ usec
Mode 2	2 pulses spaced $5 \pm 0.1$ usec
Mode 3/A	2 pulses spaced $8 \pm 0.1$ usec

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Test mode	2 pulses spaced $6.5 \pm 0.1$ usec
Mode C	2 pulses spaced $21.0 \pm 0.1$ usec
Mode 4	4 sync pulses followed by a vacant pulse position, followed by as many as 32 pulses. The spacing from the leading edge of any pulse to the leading edge of the succeeding pulse is $2 \pm 0.1$ usec. An Anti-Interference Interrogation (AII) pulse is inserted between any consecutive vacant pulse spaces. The spacing of the AII pulses is $1 \pm 0.15$ microsecond in odd multiples from the leading edge of the fourth sync pulse. Recognition-of-interference action is accomplished by sensing the lack of pulses in the mode 4 interrogation.
Interrogation Pulse	
Characteristics of modes 1, 2, 3/A, C and Test	
Pulse width	$0.8 \pm 0.1$ usec
Rise time	Between 0.05 and 0.1 usec
Decay time	Between 0.05 and 0.2 usec
Mode 4	
Pulse width	$0.05 \pm 0.1$ usec
Rise time	Between 0.05 and 0.1 usec
Decay time	Between 0.05 and 0.2 usec

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Automatic Overload Control	
Modes 1, 2, 3/A, C, Test, I/P, emergency (Modes 1 and 3/A).	1200 replies/sec
Emergency (Mode 2)	800 replies/sec
Reply Pulses	
Mode 1	Zero to five information and two framing pulses spaced $20.3 \pm 0.05$ usec apart
Mode 2	Zero to 12 information and two framing pulses spaced $20.3 \pm 0.05$ usec apart
Mode 3/A	Zero to 12 information and two framing pulses spaced $20.3 \pm 0.05$ usec and the I/P pulse
Test Mode	Zero to 12 information and two framing pulses spaced $20.3 \pm 0.05$ usec apart
Emergency	
Modes 1 or 2	Selected code appears in the first pulse train fol- lowed by three sets of framing pulses, each framing pulse spaced $24.65 \pm 0.10$ , $44.95 \pm$ $0.15$ , $49.30 \pm 0.20$ , $69.60 \pm 0.25$ , $73.95 \pm$ $0.30$ , and $94.25 \pm 0.35$ usec from the first fram- ing pulse of the first train.

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Mode 3/A	Code 7700 appears in the first pulse train followed by three sets of framing pulses as above.
I/P	
Mode 1	Selected code appears twice, the second reply train spaced $24.65 \pm 0.1$ usec between the leading edges of the first framing pulses
Mode 2 or Mode 3/A	Selected code appears in the first pulse train followed by a single pulse spaced $24.65 \pm 0.1$ usec from the first framing pulse.
Auxiliary Trigger	
Pulse width	0.3 to 1.5 usec
Amplitude	15 to 30 volts across $90 \pm 10$ ohms
Rise time	0.1 usec or less
Decay time	0.2 usec or less
Polarity	Positive
Suppression Output	
Polarity	Positive
Amplitude	20 volts min, 50 volts max with a 300-ohm load resistor in parallel with 1850-uuf capacitor.
Start time	Pulse reaches 20 volts minimum by the time an RF output pulse has reached 10 percent of its amplitude.

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Stop time	Suppression output is less than 5 volts, 5 usec after the last RF framing pulse of the reply train has fallen to 50 percent amplitude. (The first framing pulse is always followed by a second framing pulse for the purpose of this requirement.) Suppression output is also less than 5 volts, 5 usec after each RF output pulse (resulting from the auxiliary trigger or Mode 4 input) has fallen to 50 percent amplitude.
Interrogation Side-Lobe Suppression Control	
Pulse width	$0.8 \pm 0.1$ usec for Modes 1, 2, 3/A, C, or Test; $0.5 \pm 0.1$ usec for Mode 4.
Pulse position	$2.0 \pm 0.15$ usec after the first pulse of a Mode 1, 2, 3/A, C, or Test interrogation, or $8.0 \pm 0.15$ usec after the first pulse of a Mode 4 interrogation.
Rise time	Between 0.05 and 0.1 usec
Decay time	Between 0.05 and 0.2 usec
Pulse frequency	$1030 \pm 0.2$ MHz
Mode 4 Reply Input	
Pulse width	0.3 to 0.7 usec
Amplitude	3 to 6.5 volts across $90 \pm 10$ ohms

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Rise time	0.1 usec or less
Decay time	0.25 usec or less
Polarity	Positive
Mode 4 Disparity Input	
Duration	0.3 to 1.0 usec
Amplitude	3 to 6.5 volts across $90 \pm 10$ ohms
Rise time	0.15 microsecond maximum
Decay time	0.5 microsecond maximum
Polarity	Positive
Mode 4 Trigger	
Duration	0.5 to 3 usec
Amplitude	1.5 to 25 volts across $90 \pm 10$ ohms
Rise time	0.1 usec or less
Decay time	1.0 usec or less
Polarity	Positive
Mode 4 Video	
Duration	0.4 to 0.6 usec
Amplitude	1.5 to 5 volts across $90 \pm 10$ ohms
Rise time	0.1 usec maximum
Decay time	0.2 usec maximum
Polarity	Positive
Mode 4 Computer Reset Trigger	
Duration	0.3 to 10 usec

## SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Amplitude	6 to 10 volts across 1000 ohms $\pm$ 10 percent
Rise time	0.25 usec maximum
Decay time	5.0 usec maximum
Polarity	Positive

## SYSTEM OPERATION

### BEACON SYSTEM-GENERAL

In order to better understand the purpose and functions of the circuits within the APX-64 transponder, it is necessary to become familiar with the general operation of a complete radar beacon system, of which the APX-64 is a part.

A radar beacon consists of a base station containing an interrogator and its associated display equipment. The interrogator generates a group of radio-frequency pulses called the interrogation signal and transmits these signals from a directional antenna. At the same time, the interrogator generates a trigger pulse to initiate the sweep of an electron beam across the face of a cathode ray display tube. The transmitted beam travels outward until it reaches the airborne APX-64 transponder. The transponder receives the interrogation signal and immediately transmits a group of radio frequency pulses called the reply signal. The reply signal travels back to the base station where it is received and displayed as a bright spot (or spots) on the display scope. Since radio frequency energy travels through space at a constant rate (one mile in 6.18 usec), the distance between the base station and the transponder-equipped aircraft can be determined by measuring the time between the transmitted interrogation and the received reply. The electron beam moves at a linear rate across the face of the display scope which may be calibrated in time per inch, or better still, miles per inch giving a visual indication of distance.

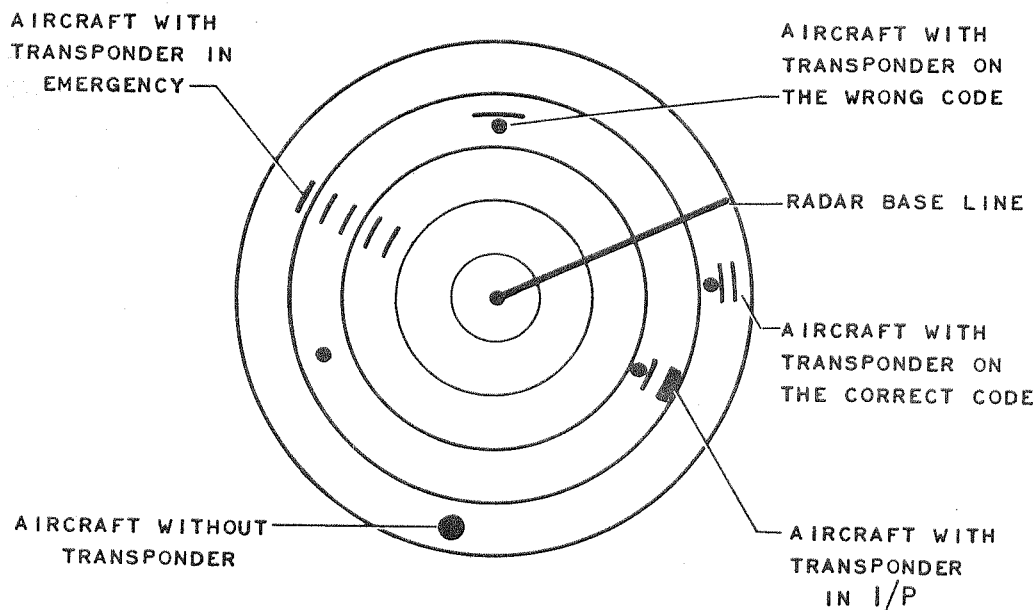
The interrogation signal is transmitted by a highly directional antenna, therefore the APX-64 will only respond when the antenna is pointed toward the aircraft. The position or bearing of the aircraft from the base station may be determined by noting the position of the antenna when replies are received. Aircraft position information is derived by synchronizing the display scope sweep position with the

position of the antenna. The sweep will then always move from the center of the screen in the same direction as the antenna is facing. The antenna may then be rotated through an arc of 360 degrees and each transponder-equipped aircraft will appear as a bright spot on the screen as the antenna beam sweeps across its path.

The operation thus far is identical with that of a pulse-echo radar system except that the returned signals are transmitted at high power from the aircraft rather than a reflection (echo) of the base station signal. The transponder method of returning signals allows the beacon system to operate at long ranges and under noise conditions that would render an equally powered pulse-echo system inoperable.

The unique feature of the radar beacon system is in its ability to selectively identify the aircraft within its range. Identification is accomplished by the coding of both the base station interrogation signals and the transponder reply signals. The coding, or pulse spacing, of the interrogation signal indicates the "mode" of operation. The airborne transponders can be manually set to accept only signals of a selected mode and reject or refrain from replying to all others. The coding of the reply signals is also manually set on the transponder to convey information back to the base station.

Decoding circuits within the base station evaluate the coded reply and allow the operator to select specific replies to be displayed. They also allow selection of the type of display, corresponding to the coding of the signal. In this manner, the operator may identify the aircraft without replying on voice or other types of communication.





The typical base station presentation consists of one pattern for transponder-equipped aircraft with unwanted signal coding, another for correctly coded replies and another for an emergency reply. A fourth change in presentation is produced when the aircraft is instructed to Identify its Position (I/P). This causes a short duration change in the reply pattern, initiated at the transponder, and usually lasting from 20 to 30 seconds.

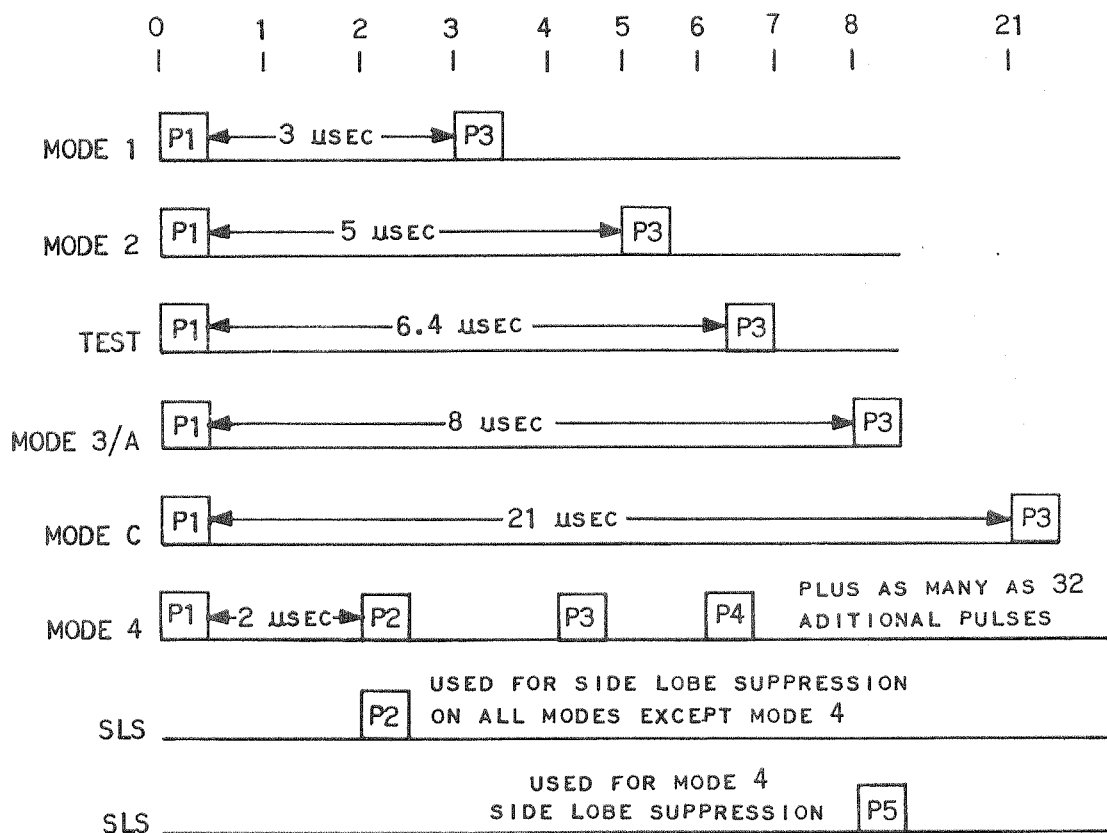
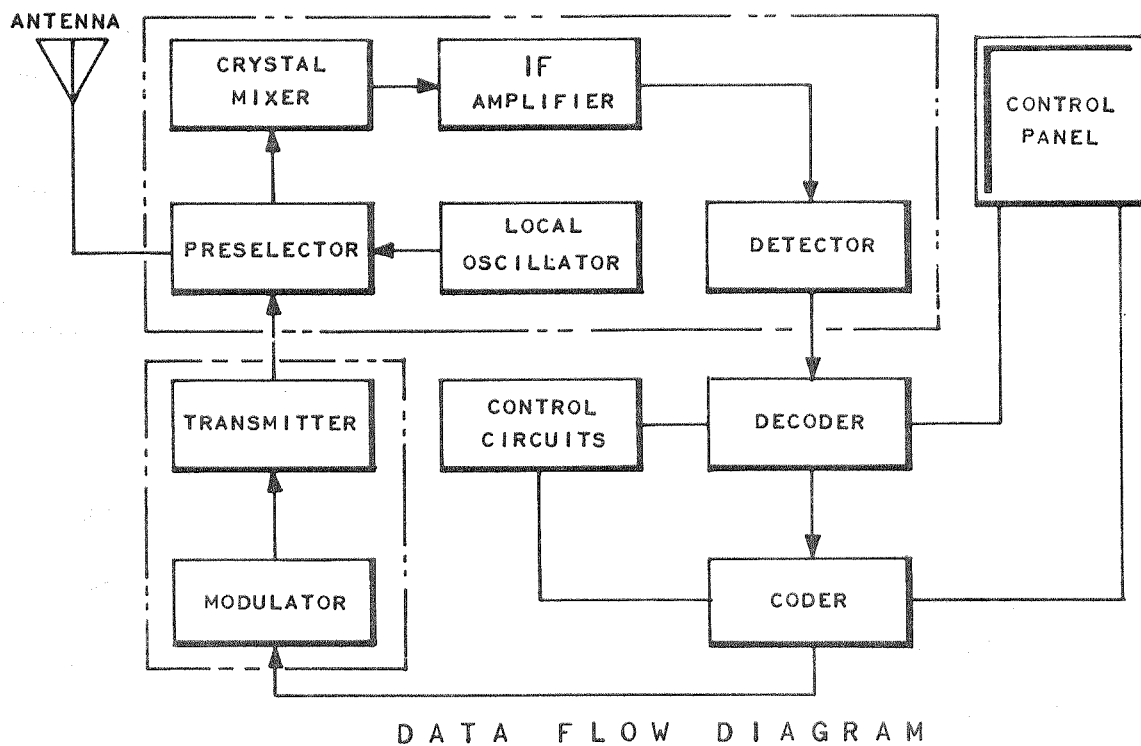
A conventional pulse echo radar is usually synchronized with the beacon system to provide a display of all aircraft in the area whether transponder-equipped or not.

#### AIRBORNE SYSTEM GENERAL

The APX-64 IFF radar system forms the airborne link in the radar beacon system. The interrogation signal from the base station is received by the antenna and coupled to the receiver-transmitter unit. The interrogation signal passes through the preselector in the receiver to a crystal mixer. A local oscillator signal also passes through the preselector and is heterodyned with the received signal in the mixer. The resultant intermediate frequency is amplified by the IF amplifier and coupled to the detector. The detector removes the high frequency components of the signal and couples the resultant video pulses to the decoder. The decoder in conjunction with the control circuits determines that the interrogation is valid and supplies an output signal to the coder. The coder in conjunction with the control circuits generates a group of reply pulses. The reply pulses from the coder are amplified by the modulator to a level sufficient to trigger the transmitter. The transmitter produces an RF pulse for each input trigger and couples the RF reply signal through the preselector to the antenna. The antenna radiates the signal back to the base station.

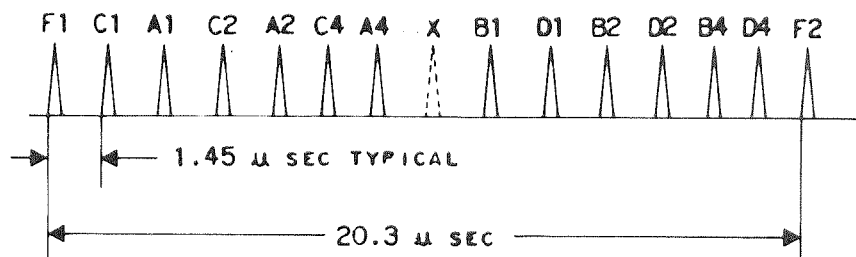
Proper operation of the APX depends on the coding of both the received interrogation signal and the transmitted reply signal. The APX-64 IFF Radar System can automatically transmit a coded reply in response to a received interrogation signal if the signal has the proper characteristics of the mode selected. Any of six different modes may be selected by switches on the control panel, but only four of these modes are used with the radar beacon system in the present APX-64 installation. The four active modes (1, 2, 3A, and C) consist of a pair of 0.8 usec pulses, the spacing of which corresponds to the selected mode. The TEST mode is used for maintenance checks and Mode 4 requires the installation of a transponder computer for operation. Pulse width and spacing for each of the six modes is illustrated in the Interrogation Pulses diagram.

If an interrogation signal is received which corresponds to the mode selected, a selected coded reply signal will be generated. MODE 1 and MODE 3/A reply codes are selected on the control panel. Mode 2 reply coding is preset by knobs on the front of the receiver transmitter. Mode C coding is controlled by an altitude



digitizer within the Central Air Data computer system and corresponds to aircraft barometric altitude. Mode 4 code will be generated within the external computer when installed.

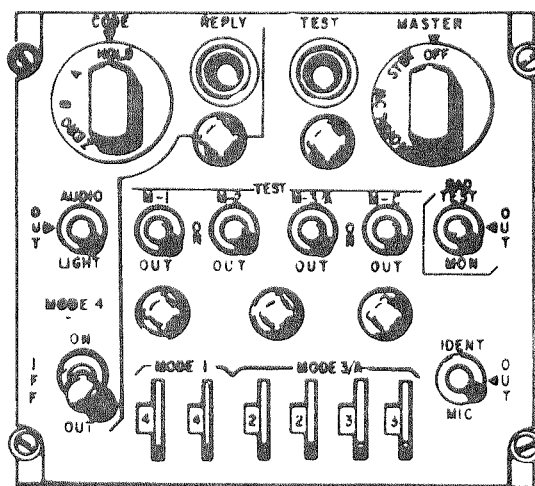
The reply signal, or pulse train consists of accurately spaced information pulses between two reference or framing pulses. This pulse train may consist of a maximum of 14 pulses (12 information pulses and 2 framing pulses) or a minimum of two pulses (framing pulses only). The framing pulses are spaced 20.3 usec apart. The spacing between the information pulses (if all are present) is 1.45 usec. The actual spacing between information pulses and the number of pulses is determined by the coding of the reply signal.



For code-identification purposes, the 12 information pulses are divided into four lettered groups A, B, C, and D. Each lettered group has three pulses which are identified by a sub number 1, 2, or 4. The MODE 1 code (selected on the control panel) is designated by code numbers 00 through 73. Five information pulses are used in Mode 1. These are A1, A2, A4, B1, and B2. The code digit assigned to the lettered group is a number equal to the group. For example, if 62 is selected, the information pulses for the "3" digit would be A2 + A4 = 6. Information pulse B2 would be present for the second digit of the code. Mode 2 and Mode 3 both use all 12 information pulses and the code numbers available in these modes are 0000 through 7777 which correspond to pulse groups A, B, C, and D respectively. Mode 1 has 32 possible codes and modes 2 and 3/A have 4096 possible codes. Mode C uses pulses from each lettered group with the exception of the D1 and D2 pulses. If the D4 pulse is present in the mode C reply, an additional pulse will be added to the reply train 4.35 usec after the last framing pulse. A TEST mode interrogation initiates the generation of a mode 3/A coded reply.

The system provides a means of changing the reply coding for aircraft identification purposes (I/P reply). This feature is used when a group of aircraft are being interrogated in the same area and it is desired to single out one aircraft from the group. An I/P reply is initiated on request by the base station operation. The mode 1 I/P reply consists of two complete pulse trains with 4.35 usec spacing between each train. The Mode 2 and Mode 3/A I/P reply consists of a single pulse train followed by an additional pulse spaced 4.35 usec after the last framing

pulse. Only these three modes provide an I/P function. The I/P reply signal is initiated by placing the IDENT-OUT-MIC switch in the "IDENT" position. The system will then automatically transmit the I/P reply when interrogated for approximately 30 seconds after the switch is released. If the switch is placed in the "MIC" position the I/P function will be initiated each time either UHF transmitter is keyed.



An emergency reply provision is also available in modes 1, 2 or 3/A. The Mode 1 or Mode 2 emergency reply consists of one pulse train followed by three sets of framing pulses with 4.35 usec spacing between each set. The mode 3/A emergency reply is a single reply train with a coding of 7700 followed by three sets of framing pulses regardless of the code set on the control box. The emergency reply is initiated by placing the function switch on the control panel in the "EMERG" (emergency) position.

## DESCRIPTION AND OPERATION

### FUNCTION OF CONTROLS AND INDICATORS.

#### IFF CONTROL PANEL

ITEM	SETTING AND FUNCTION
Master Switch	<p>"OFF:" All power is removed from the system except for panel lighting.</p> <p>"STBY:" Operating power is applied and the system is ready for immediate operation when the MASTER switch is set to "LOW" or "NORM."</p> <p>"LOW:" Receiver-transmitter operates on low sensitivity.</p> <p>"NORM:" Receiver-transmitter operates on normal sensitivity.</p> <p>"EMERG" system transmits an emergency reply when interrogated.</p>

DESCRIPTION AND OPERATION (continued)

FUNCTION OF CONTROLS AND INDICATORS.

IFF CONTROL PANEL

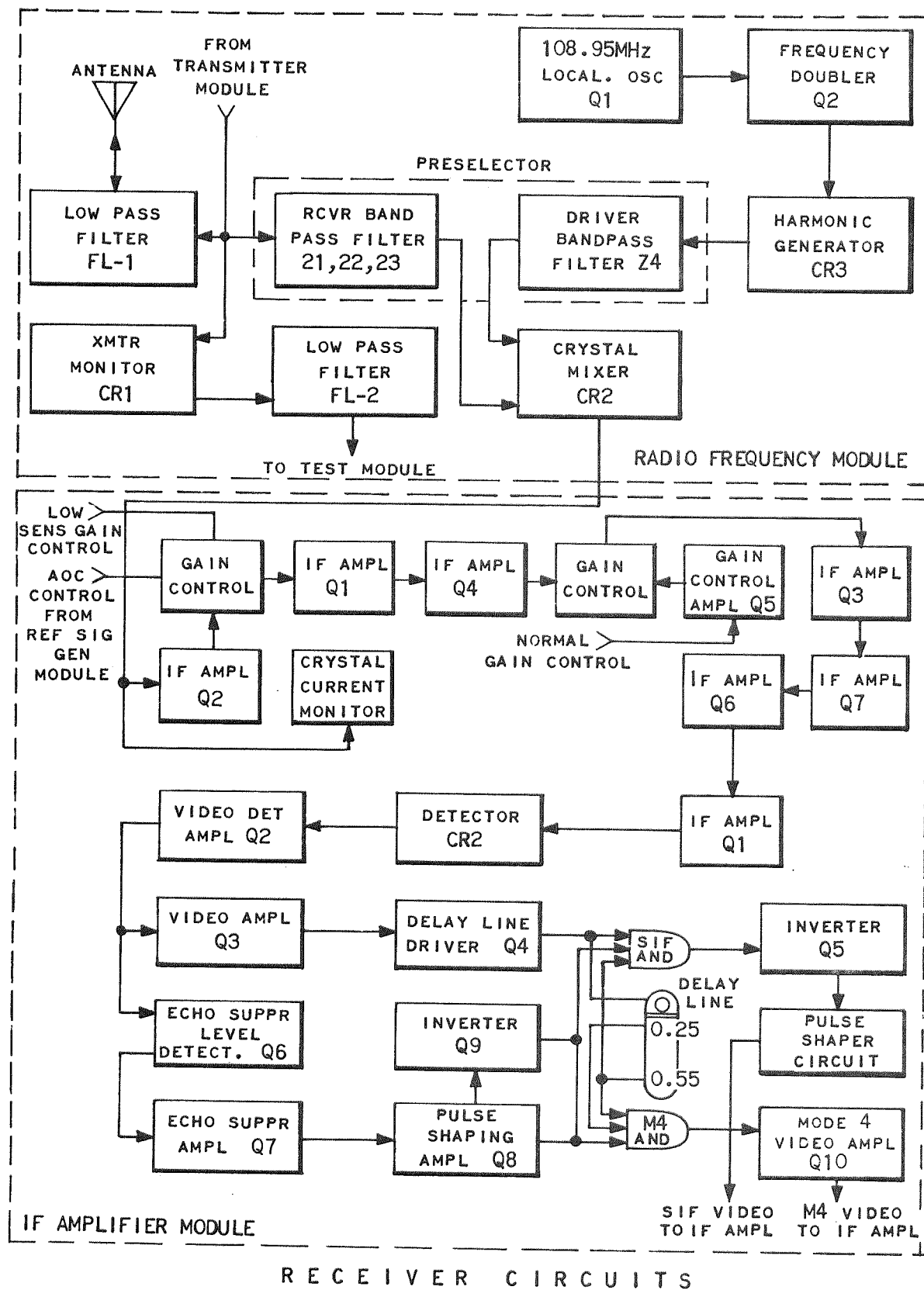
ITEM	SETTING AND FUNCTION
IDENT-OUT-MIC Switch	"IDENT" sets a code into the MODE 1 and MODE 3 coder group selector control which enables the system to generate coded replies for modes 1 through 3. "OUT" disables the I/P function. "MIC" transfers control of the I/P junction to a remote control.
MODE 1 TEST-ON-OUT Switch	"TEST" energizes the "go, no-go" airborne transponder inflight tester which generates MODE 1 interrogations. "ON" enables the MODE 1 function. "OUT" disables the MODE 1 function.
MODE 2 TEST-ON-OUT Switch	"TEST" energizes the "go, no-go" airborne transponder inflight tester which generates mode 2 interrogations. "ON" enables the MODE 2 function. "OUT" disables the MODE 2 function.
MODE 3 TEST-ON-OUT Switch	"TEST" energizes the "go, no-go" airborne transponder inflight tester which generates MODE 3 interrogations. "ON" enables the MODE 3 function. "OUT" disables the MODE 3 function.
MODE C TEST-ON-OUT Switch	"TEST" tests the altitude reporting mode. "ON" enables the MODE C function. "OUT" disables the MODE C function.
MODE 1, 2, 3, C REPLY indicator light	Lights to indicate satisfactory operation of the transponder for self-test of MODES 1, 2, 3, and C and for monitoring proper response to any interrogation.

# DESCRIPTION AND OPERATION (continued)

## FUNCTION OF CONTROLS AND INDICATORS.

### IFF CONTROL PANEL

ITEM	SETTING AND FUNCTION
MODE 4 ZERO-B-A-HOLD Switch	Enables operation of MODE 4.
MODE 4 Switch	Up and locked position enables the MODE 4 function. Unlocked and moved to "OUT" disables the MODE 4 function.
MODE 4 AUDIO-OUT- LIGHT	"AUDIO" enables both visual and audio reply indications. "OUT" disables the MODE 4 indication function of the system. "LIGHT" enables the visual indication of the system.
MODE 4 REPLY indicator light	Lights to indicate when MODE 4 replies are made with MODE 4 indication switch to "AUDIO" or "LIGHT" position.
RAD TEST-OUT- MONITOR Switch	"RAD TEST" energizes the test mode feature during check-out with the test set. "OUT" de-energizes the test mode feature. "MONITOR" energizes the monitor circuits of the "go, no-go" airborne transponder inflight tester and causes the self-test REPLY indicator light to go on when a reply is made to interro- gations in any mode.
MODE 1 code selector control	Permits selection of coded reply for MODE 1 interrogations.
MODE 3 code selector	Permits selection of coded reply for MODE 3 interrogations.



## RECEIVER CIRCUITS

The received interrogation signal is coupled to the Radio Frequency (RF) module in the receiver-transmitter. The 1030 MHz signal passes through a low pass filter (FL-1) to the first of three receiver bandpass filters (21, 22, 23) in the preselector assembly. These filters are tuned to 1030 MHz allowing the interrogation signal to pass and blocking undesired off-frequency signals. The received signal from the preselector is coupled to the crystal mixer (CR-2) where it is heterodyned with an internally generated signal from the local oscillator.

The crystal controlled local oscillator (Q1) generates a 108.95 MHz signal. The signal is doubled in the frequency doubler stage (Q2) to 217.9 MHz. A harmonic generator (CR-3) clips and distorts the 217.9 MHz signal producing many harmonic components. A driver bandpass filter (Z-4) in the preselector assembly couples the 5th harmonic component 1089.5 MHz through to the crystal mixer (CR-2).

The received interrogation signal when heterodyned in the crystal mixer with the local oscillator signal, will produce a difference frequency component of 59.5 MHz which is coupled out to the intermediate frequency IF module.

Another function of the RF module is to couple the reply signal from the transmitter module to the antenna. A portion of this signal is detected by the transmitter monitor crystal CR-1 and coupled through a low pass filter (FL-2) to the test module.

The 59.5 MHz signal from the RF module is coupled to the first of three dual-transistor cascode-amplifier stages in the IF module. A gain control circuit in the first cascode stage (Q1, Q2) receives an adjustable LOW SENS signal from the control panel and the Automatic Overload Control (AOC) signal from the reference signal generator module. The LOW SENS control signal when present reduces IF gain approximately 12 db. The AOC signal automatically reduces IF gain when the interrogation rate becomes excessive thereby permitting only the strongest signals to be accepted by the APX-64.

Another gain control circuit is located in the second cascode stage (Q3, Q4) and it receives its signal from the gain control amplifier Q5. The gain control amplifier receives an adjustable normal gain control signal to control IF gain. Both normal gain and low-sens gain may be adjusted by potentiometers on the front of the equipment chassis.

The output of the second cascode stage is coupled through the third cascode stage (Q6, Q7) to the detector and video processing circuits. The 59.5 MHz signal is coupled through a final, single transistor, amplifier stage (Q1) to the detector (CR-2). The detector stage removes the 59.5 MHz signal component leaving the video pulse envelope.



The video signal is amplified by Q2 and split into two separate paths. One signal path is through video amplifier Q3 and delay line driver Q4. The output of Q4 is coupled into the delay line and into the SIF video AND gate. The signal is delayed 0.55 usec and applied as a second input to the AND gate. The SIF AND gate rejects signals that are not wider than 0.55 microseconds, thus eliminating noise spikes. The third SIF video AND gate input is developed in the echo suppression circuits.

The second output of the video amplifier Q2 is coupled to the echo suppression level detector Q6. When a pulse is received, it is coupled to the output of Q6 and also sets the threshold level of this stage. The threshold, once set, slowly returns to zero in approximately 8 microseconds. Any succeeding video pulse that does not exceed the amplitude of the variable threshold will not be coupled to the output. Echo signals are low amplitude signals that are received slightly after the interrogation pulses and are produced by the reflection of the base station from adjacent objects. Since these signals are low in amplitude and coupled into the echo suppression level detector before the threshold has returned to zero, they are not coupled to the output.

A side lobe suppression pulse (discussed in more detail later), if present in the interrogation signal, will occur 2 usec after an interrogation pulse and therefore will arrive before the threshold has returned to zero. If this pulse is at least 9 db below the level of the first interrogation pulse it will not be coupled to the output. The removal of the side lobe suppression pulse indicates that the interrogation signal is from the main lobe (valid signal) to the base station antenna.

The output pulses from Q6 are amplified by the echo suppression amplifier Q7 and shaped by pulse shaper Q8. The pulses are then amplified by the inverter Q9 and coupled to the inputs of both the SIF AND gate and the M4 AND gate.

The coincident output pulse from the SIF AND gate is amplified by inverter Q5, shaped by a pulse shaping circuit and coupled out to the decoder module.

The two inputs to the mode 4 AND gate, in addition to the echo suppression pulse, are from the 0.25 and the 0.55 usec delay line taps. The delay line inputs prevent coincidence of pulses that are not at least 0.3 usec wide ( $0.55 - 0.25 = 0.30$ ) and thereby eliminate noise spikes from the mode 4 video signal. The output of the M4 AND gate is amplified by Q10 and coupled out to the decoder module.

## DECODING CIRCUITS

The video interrogation pulses from the receiver circuits are coupled into the decoder circuits. The decoder examines the spacing between the pulses to determine the mode of the signal. If the signals are on the mode(s) selected by

the control panel, gating signals will be produced. The gating signals initiate the generation of a coded reply signal in the coder circuits.

The mode recognition circuits are similar in operation and, therefore, only Mode 1 circuits will be discussed. A valid mode 1 interrogation signal from the receiver circuits will consist of two video pulses spaced 3 usec apart. Refer to the system specifications for pulse spacing and tolerances for each of the six available modes.

The mode 4 video output signal from the receiver circuits is coupled to a 1.0 usec signal switch that produces a sharply defined 1.0 usec output pulse for each received interrogation pulse. The pulses are then coupled to the input of the delay line within the delay line module. Each input pulse travels down the delay line and is picked off at various taps. The delay taps used in the mode 1 recognition circuits are 0.35, 3.0 and 3.55 microseconds. The delayed signals are then coupled back to the decoder module.

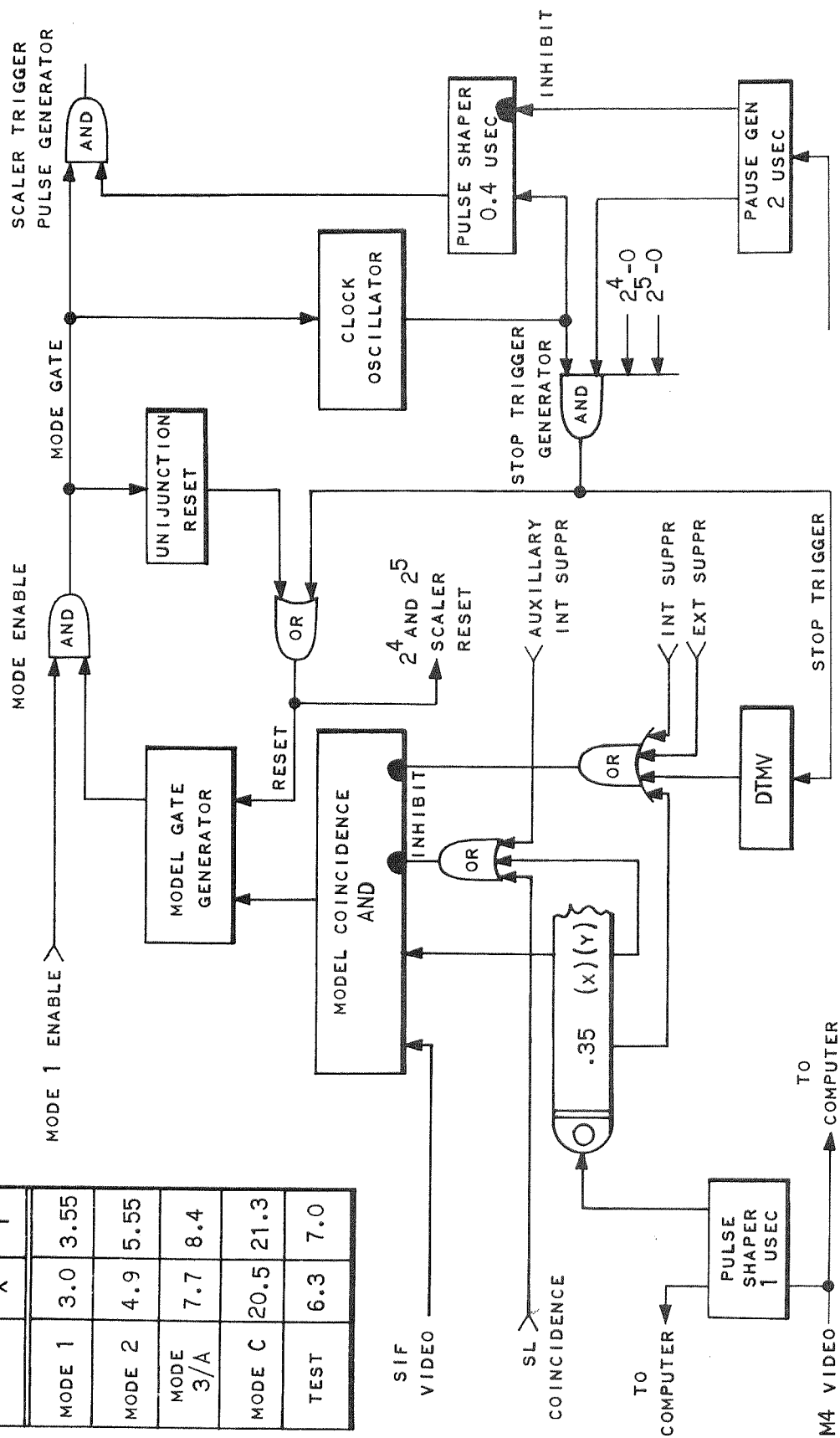
The first interrogation pulse (P1) arrives at the delay line input at the same time the SIF video pulse from the receiver circuits arrives at the mode 1 coincidence AND gate. Since two simultaneous inputs are required to produce an AND gate output no output is produced at this time.

Three microseconds later, the delayed P1 pulse from the delay line module arrives at the AND gate input in time coincidence with the undelayed last interrogation pulse P3 (SIF video). A mode 1 coincident pulse is then coupled to the mode 1 enable AND gate. Since we assume that "MODE 1" was selected on the control panel, the second AND gate (enable) input will be present. The output signal then triggers the mode 1 gate generator which is a bistable multivibrator. The gate generator switches which begins or initiates the gating signals.

To insure that the pulse spacing is within tolerance, inhibit signals are applied to the mode 1 coincidence AND gate and will prevent or inhibit the output when present. Inhibit pulses are received from the 0.35 and the 3.55 usec delay line taps. These pulses are coupled through their respective OR gates to limit the time period in which a mode 1 coincident output may be developed. If the last interrogation pulse is spaced too close or too far away (out of tolerance) from the first pulse, the inhibit pulses will prevent the generation of a mode gate trigger. Various suppression pulses are also coupled to the inhibit lines and will prevent the decoding of all interrogations when present.

One output from the mode gate generator is coupled out to the coder circuits. The other output signal is coupled to a clock enable AND gate and to a clock oscillator. The clock oscillator is gated on and generates a series of pulses spaced 1.45 usec apart. The clock pulses are coupled to a pulse shaping signal

	X	Y
MODE 1	3.0	3.55
MODE 2	4.9	5.55
MODE 3/A	7.7	8.4
MODE C	20.5	21.3
TEST	6.3	7.0



switch and to the stop trigger AND gate. The clock pulses trigger the signal switch which produces a sharply defined 0.4 usec output pulse for each input clock pulse. These pulses are then coupled through the clock enable AND gate to the coder module.

The coder module counts the pulses and returns an output pulse when the fifteenth clock pulse is generated. This pulse triggers the pause generator which inhibits the pulse shaping signal switch for approximately 2 usec and also applies a gate to the stop trigger AND gate. Assuming the other two inputs ( $2^4-0$ ,  $2^5-0$ ) are present, the stop trigger AND gate will produce an output pulse when the sixteenth clock pulse is generated. The coincident pulse is coupled through an OR gate and resets the mode 1 gate generator. The stop pulse is also coupled through another OR gate to trigger the "delay time multivibrator" (DTMV) which produces an inhibit pulse preventing any further decoding for 100 usec. When the system is in "IDENT" the  $2^4-0$  signal from the coder will not be present and the mode gate is allowed to run for another coder period. When the system is in "EMERG," both the  $2^4-0$  and  $2^5-0$  signals from the coder are not present and the gate will be extended to cover three additional coding cycles.

The clock gate signal from the mode 1 gate generator is also applied to a uni-junction reset trigger generator that will produce an output pulse approximately 250 usec after the beginning of the mode gate. This pulse will reset the mode gate generator if for some reason the normal resetting stop pulse is not generated.

The stop pulse signal is also coupled to the coder to re-enable the  $2^4-0$  and  $2^5-0$  pulse generators if these pulses have been removed due to "IDENT" or "EMERG" operation.

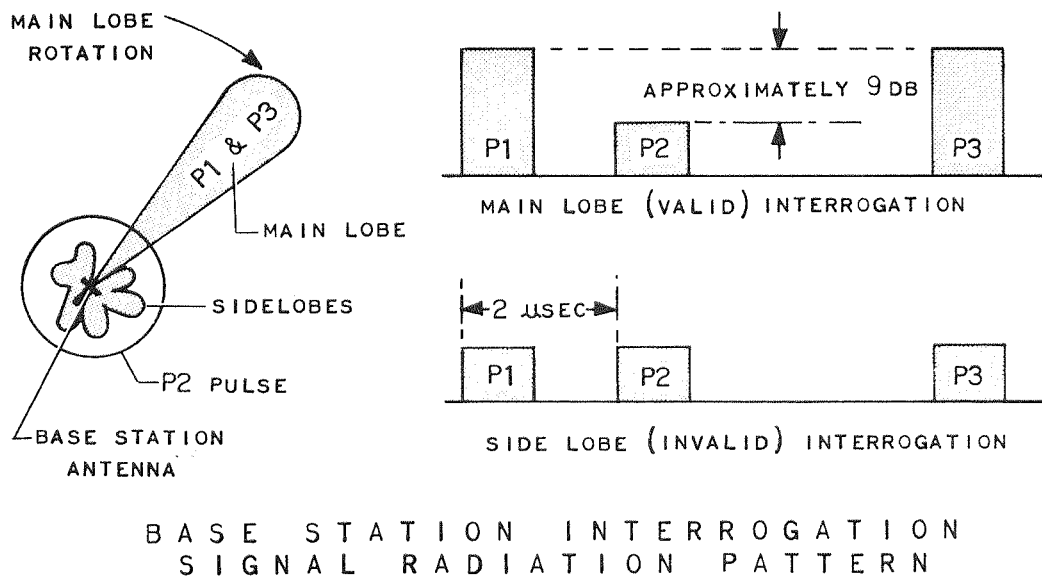
In summation, the decoding operation involves circuits in the decoder, delay line, reference signal generator and coder modules to complete its function. Mode enable signals from the control panel are also required. The decoding function provides a mode gate signal corresponding to the mode selected and a series of precisely spaced clock pulses to the coder module each time a valid interrogation is received. The length of the gate, and consequently, the number of clock pulses supplied depend on signals from the coder module that are produced by counting the clock pulses and by the I/P or emergency control signals. The clock pulses and mode gates are terminated and inhibited by a stop trigger at the end of the coding cycle.

The decoder module also contains circuits used in conjunction with the external computer in providing complete mode 4 operation. These circuits operate warning lights to indicate mode 4 operation. The mode 4 REPLY light will illuminate when the computer generated reply signal is transmitted. The mode 4 caution lights will illuminate when a mode 4 interrogation is received and no reply is transmitted. An audio signal is also provided to indicate that a mode 4 signal has been decoded.

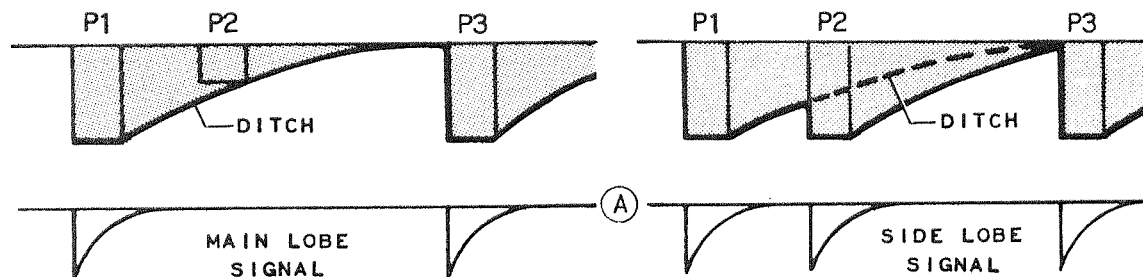
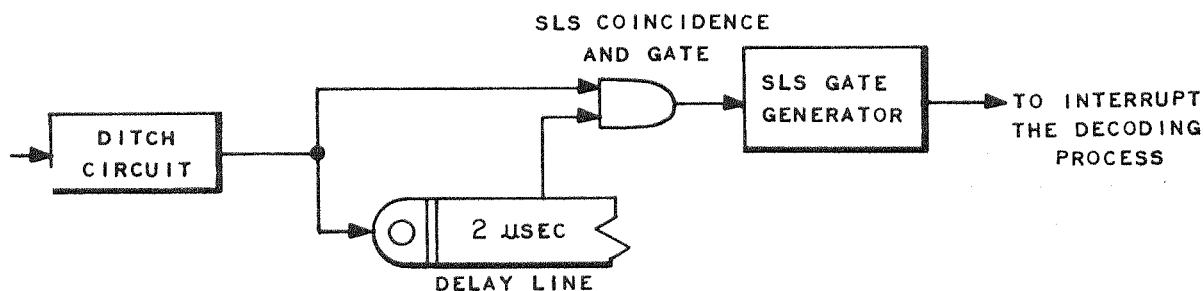
## SIDE LOBE SUPPRESSION CIRCUITS

Side Lobe Suppression (SLS) is a process of interrupting the decoding process and preventing the APX-64 from replying to side lobe signals from the base station antenna. Side lobes are low amplitude "splash over" signals that are radiated in directions other than the main lobe directional beam. These undesirable signals cannot be completely eliminated and can cause the APX-64 to reply at the wrong time, thus obscuring the bearing information. To enable the APX-64 to sense side lobe interrogations the base station transmits an omnidirectional SLS pulse (P2) two microseconds after the first interrogation pulse. The amplitude of the SLS pulse is approximately equal to the side lobes. The APX-64 compares the amplitude relationship between the received P1 and P2 pulses. If the interrogation is valid (main lobe) the P1 pulse will be many times larger in amplitude than the P2 pulse (at least 9 db) and the interrogation is accepted. If the P1 pulse is from a side lobe it will be equal to or smaller in amplitude than the P2 pulse and the interrogation is rejected.

Side lobe detection circuits in the APX-64 generate a ditch shaped waveform for each input pulse. The depth of the ditch is determined by the amplitude of the pulse. Any succeeding pulse that does not exceed the amplitude of the ditch will not be coupled to the output. If a side lobe interrogation is received, the P2 pulse will be large with respect to the P1 pulse and will be coupled to the output.



The pulses from the SLS detection circuit are applied to the decoder where an SLS gate generator will be triggered when the P2 pulse is present. The SLS gate circuit will produce a 35 usec suppression pulse to prevent a reply from being generated.



# SIDE LOBE DETECTION CIRCUITS AND WAVEFORMS

The SLS trigger is produced in the same manner as the mode trigger (previously discussed). The delayed P1 pulse will be coincident with the P2 pulse to trigger the SLS gate generator.

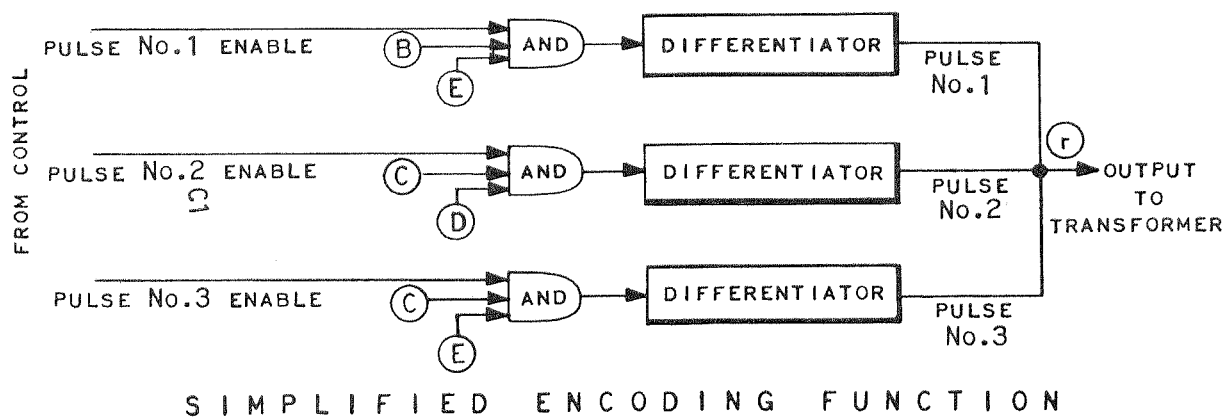
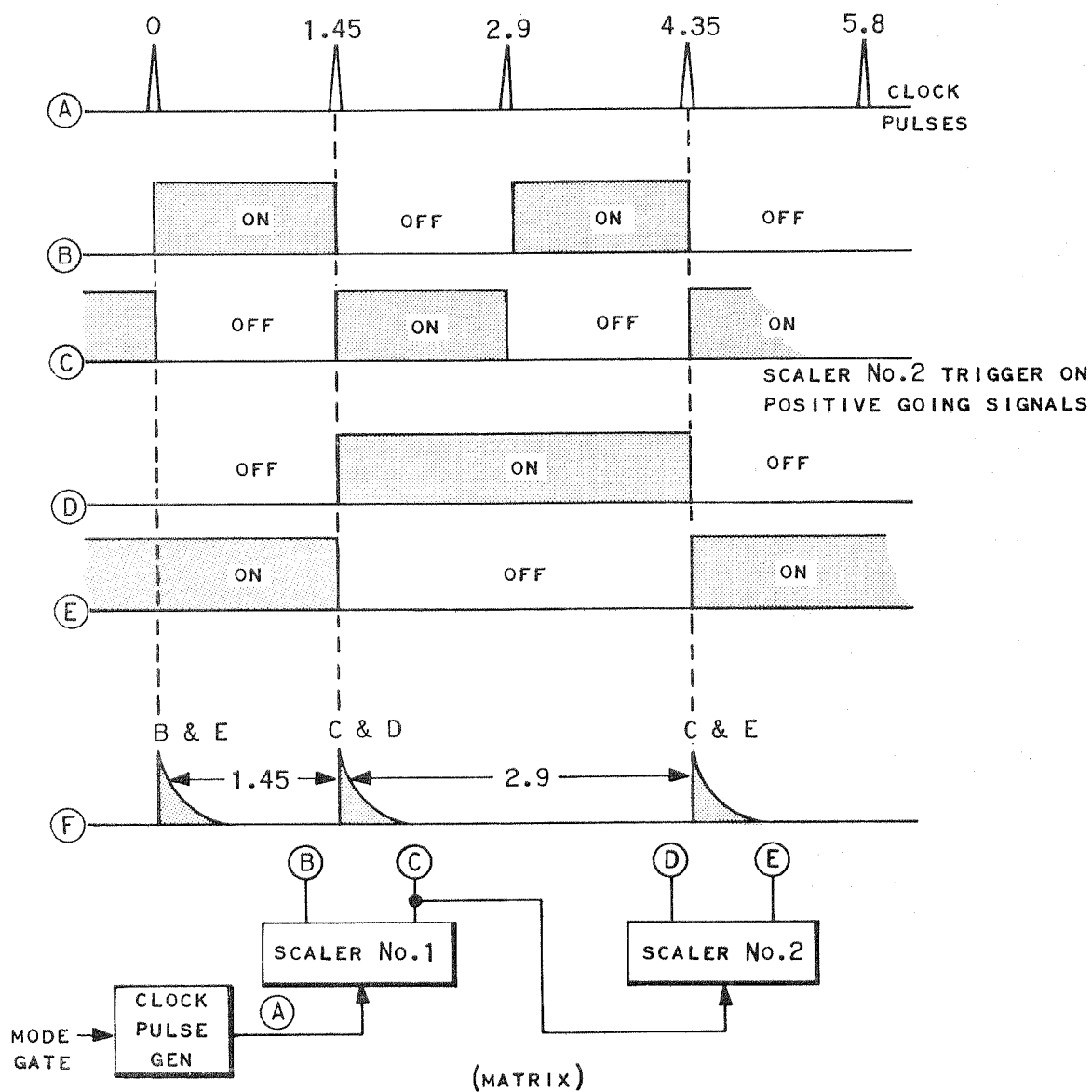
## ENCODING PROCESS

Encoding the reply signal is a process of producing a train of precisely spaced pulses, the number of which is manually selected on the APX-64 controls. A reply train is produced for each valid interrogation received by the system. The mode gate generator in the decoder initiates the generation of a series of pulses spaced 1.45 usec apart from a clock pulse generator. The clock pulses are applied to a series of scalars which are in effect frequency dividers. Each scalar is an electronic switch that changes its state (switches) each time it receives a "positive going" input pulse. The outputs of the scalars are then applied to a pulse enabling matrix that will allow the selected clock pulses to appear at the output. The selection of output pulses is provided by control signals corresponding to the code selected. For example, suppose three output pulses with 1.45 usec between the first and the second and 2.9 usec between the second and the third are desired.

The first pulse will be produced when the outputs B and E of the scalars are positive and a pulse No. 1 enable signal is provided. Similarly, pulses No. 2 and No. 3 will be produced when scalar outputs C and D, plus C and E are positive and the corresponding enable signals are present. The coincident positive signals from each AND gate are differentiated, producing a spike at the time of coincidence. These spikes are the generated reply train that will be used to trigger the transmitter.

The actual encoding circuits used in the APX-64 contain three pulse-counting scalars that produce two outputs each. All the zero outputs are positive and all the one outputs are negative at the beginning of the encoding count down. The scalar output chart indicates the condition of the six output terminals at various stages of the count down. Only the positive (1) outputs are operating signals in the time matrix AND gates. From the chart and the encoder block diagram note the process of enabling the fourteen time matrix AND gates in stepped sequence as the count down progresses. Each time, matrix AND gate requires an additional pulse-enabling signal that is produced by the code select knobs on the control panels, or by the altitude coding computer. Mode gates from the decoder module must also be present to enable the pulse selecting circuits to enable the various pulses.

Automatic enabling or disabling of the time matrix and gates is controlled by signals from the I/P and emergency control circuits in the reference signal generator. When "EMERG" is selected on the control panel and a mode 3/A interrogation signal is received and decoded, a control signal is produced to

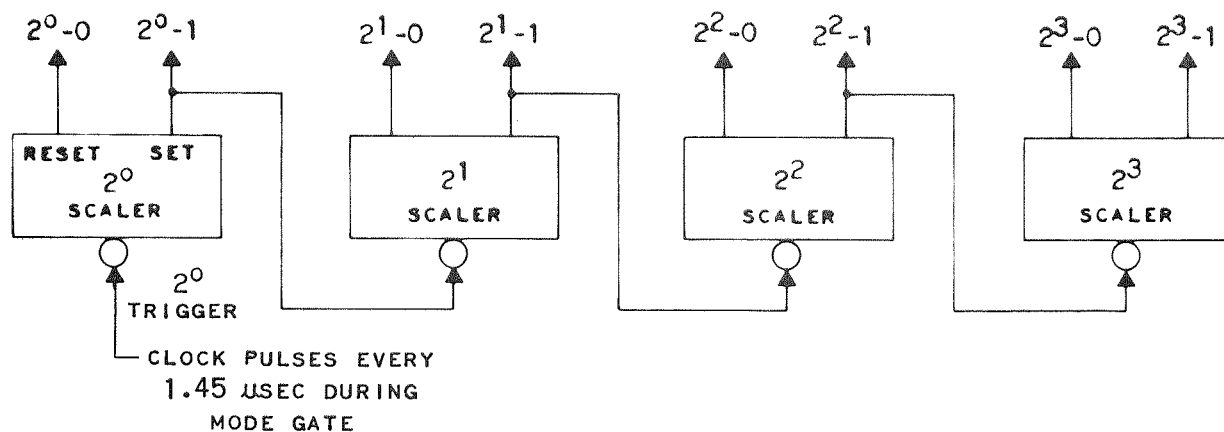




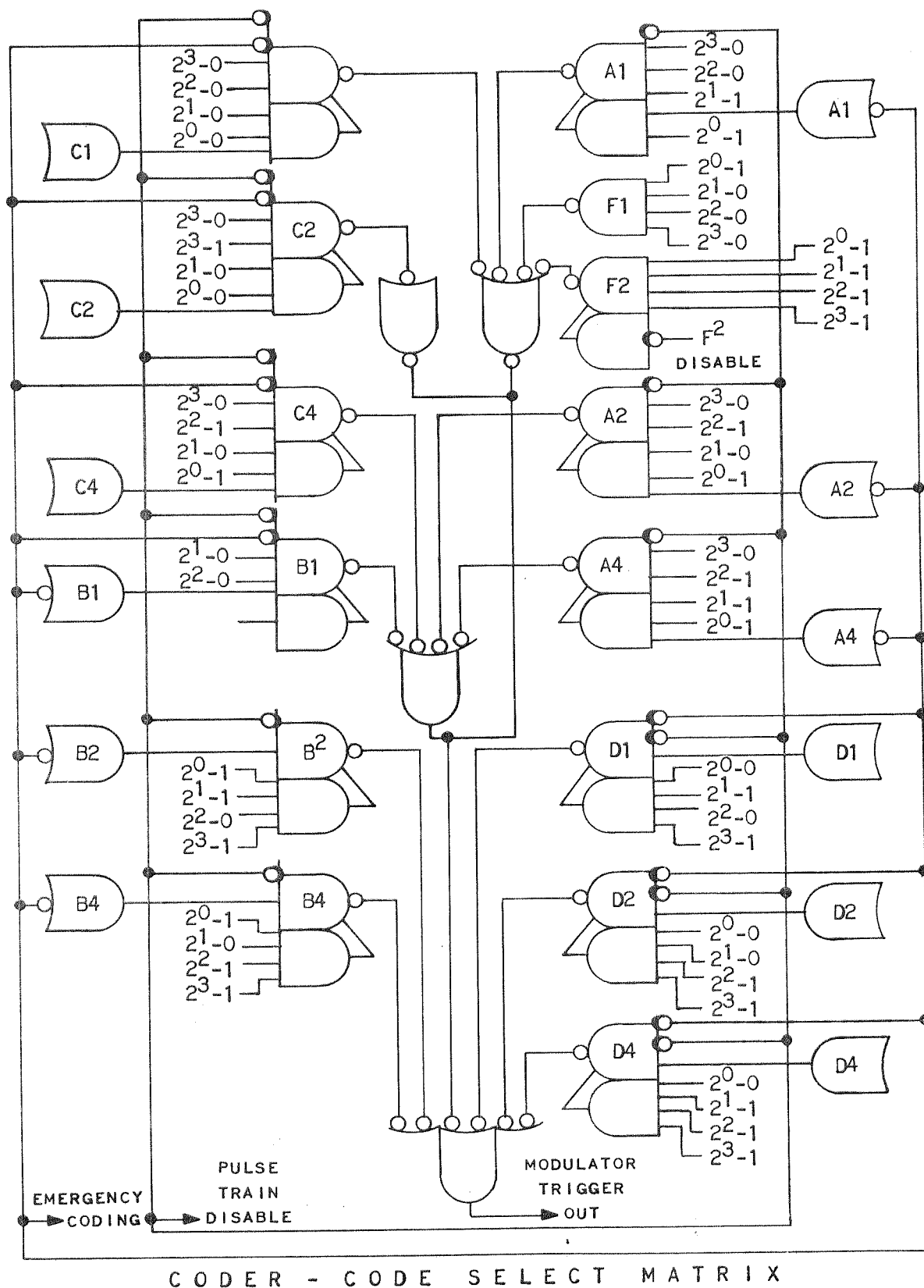
automatically enable all A and B time matrices and disable all C and D time matrices. This produces a 7700 output code regardless of the code selected by the MODE 3/A control knobs. The second control signal input will disable all information pulses when present and the F2 disable control signal will remove the second framing pulse when present.

## I/P AND EMERGENCY CONTROL CIRCUITS

The I/P and emergency control circuits generate signals that change the generated reply signal. Closing either the IDENT or the EMERG switch on the control panel or by having the D4 pulse enabled by the external altitude coding computer will initiate the reply code change. The actual changes that take place depend on the mode of the received interrogation signal.



	$2^0-0$	$2^0-1$	$2^1-0$	$2^1-1$	$2^2-0$	$2^2-1$	$2^3-0$	$2^3-1$	
0	1	0	1	0	1	0	1	0	—
1	0	1	1	0	1	0	1	0	F1
2	1	0	0	1	1	0	1	0	C1
3	0	1	0	1	1	0	1	0	A1
4	1	0	1	0	0	1	1	0	C2
5	0	1	1	0	0	1	1	0	A2
6	1	0	0	1	0	1	1	0	C4
7	0	1	0	1	0	1	1	0	A4
8	1	0	1	0	1	0	0	1	X
9	0	1	1	0	1	0	0	1	B1
10	1	0	0	1	1	0	0	1	D1
11	0	1	0	1	1	0	0	1	B2
12	1	0	1	0	0	1	0	1	D2
13	0	1	1	0	0	1	0	1	B4
14	1	0	0	1	0	1	0	1	D4
15	0	1	0	1	0	1	0	1	F2
0	1	0	1	0	1	0	1	0	—



If either the IDENT switch is closed or the mode C D4 pulse is enabled, the mode gate will stay open long enough for two complete coding cycles. The IDENT switch operates with a received model, mode 2 or mode 3A interrogation and the mode C D4 enable operates with a received mode C interrogation.

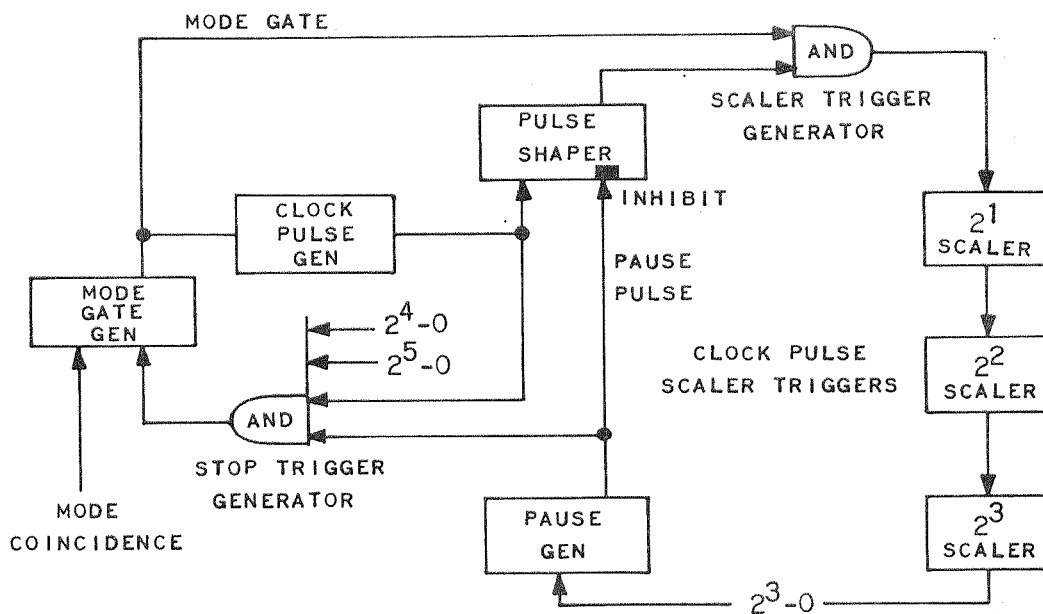
If the EMERG switch is closed the mode gate will stay open long enough for four complete coding cycles.

Mode gate extension is produced by triggering the  $2^5$  scaler and/or the  $2^4$  scaler in the coder module at the end of the first generated reply train. If the  $2^4$  scaler is triggered the gate will stay open two coding cycles and if both the  $2^4$  and the  $2^5$  scalers are triggered the gate will stay open for four coding cycles. When either scaler is in the set or triggered state the gate stop generator in the decoder module is disabled. Disabling the stop trigger generator prevents normal gate stoppage at the end of the first reply train. The  $2^4$  and  $2^5$  scalers will be retriggered at the proper time changing them back to the reset state thereby re-enabling the gate stop generator. Therefore, the first function of the I/P and emergency control circuits is to trigger the  $2^4$  and  $2^5$  scalers at the proper time to produce the required mode gate extension.

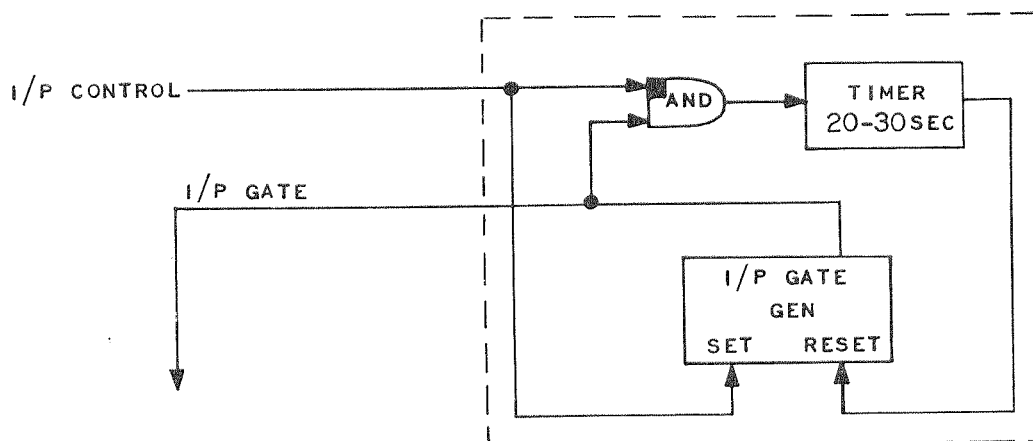
The second function of the I/P and emergency control circuits is to supply control signals to the code enable matrix in the coder module. These control circuits will automatically enable and/or disable the required information and framing pulses to correspond to the desired reply.

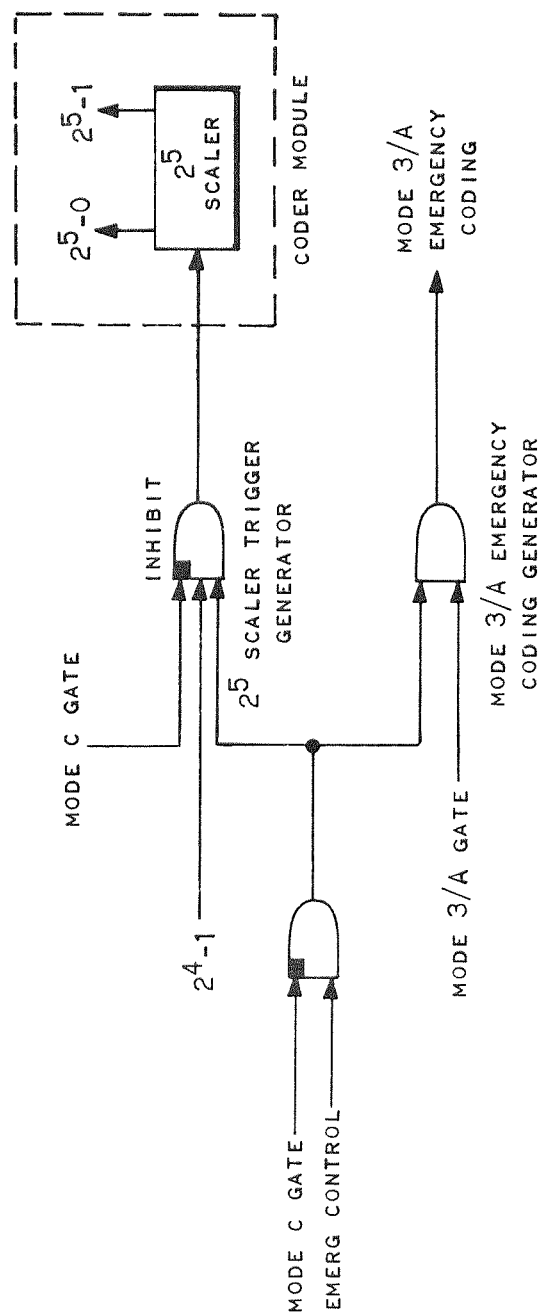
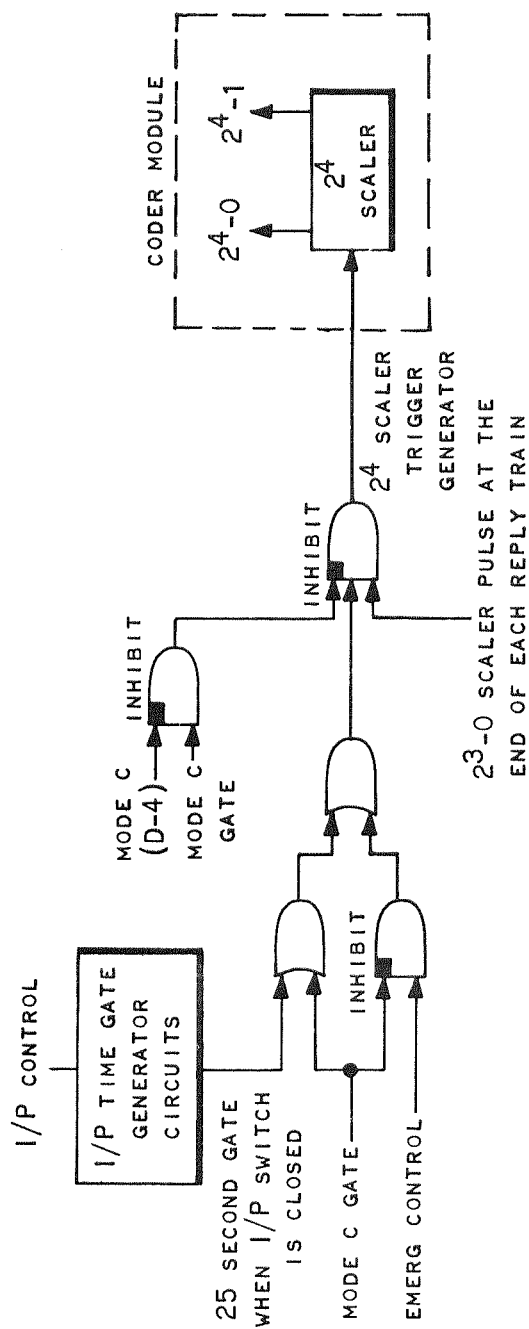
Before proceeding with the discussion of mode gate extension a brief review of normal mode gate generation will be given.

When an interrogation signal is decoded a trigger pulse is supplied to the mode gate generator multivibrator. The mode gate generator changes to the set state which begins the mode gate. The mode gate signal enables the clock pulse generator which produces a series of pulses spaced 1.45 usec apart. Each clock pulse is one count in the coding cycle count down. The mode gate also enables the scaler trigger AND gate and allows the clock pulses to trigger the pulse counting scalers ( $2^0$ ,  $2^1$ ,  $2^2$ ,  $2^3$ ) in the coder module. On the sixteenth count or when the sixteenth clock pulse is produced, the  $2^3-0$  output of the  $2^3$  scaler will go positive supplying a trigger signal to the 2 usec pause gate generator. The pause gate signal inhibits the scaler triggers and enables the mode gate stop trigger generator. The next clock pulse (count No. 17) then passes thru the stop trigger generator, resetting the mode gate generator and thereby ending the mode gate. Note that the stop trigger generator is an AND gate requiring a positive  $2^4-0$  and  $2^5-0$  signal from the coder scalers to be present. If either of these inputs are removed, the stop trigger will not be generated and the mode gate will remain open.



The I/P gate generating circuits produce an I/P enabling gate signal for approximately 25 seconds each time the IDENT switch is closed. The I/P signal from the control panel supplies a trigger to the I/P gate generator and an inhibit signal to the I/P AND gate. The I/P gate generator is a bistable multivibrator that produces the I/P gate when triggered. When the IDENT switch is released, it returns to the "off" position, re-enabling the I/P AND gate. The I/P gate signal then passes through the AND gate to a timer circuit. Approximately 25 seconds later the timer supplies an output pulse that resets the I/P gate generator ending the I/P gate. The I/P gate signal is supplied to the I/P and emergency control circuits to generate the required code changing signals.





When the emergency switch is closed and no mode C signal is decoded, the emergency signal will be supplied to one input of the  $2^5$  scaler trigger generator. The  $2^5$  scaler trigger will then be generated when the  $2^4$  scaler is triggered due to the  $2^4-1$  input. At the end of the second reply train the  $2^4$  scaler will be triggered as explained before, removing the  $2^4-1$  input to the  $2^5$  scaler trigger generator. The  $2^5$  scaler is still in the set state and therefore the mode gate stop trigger generator is still inhibited. The mode gate will therefore remain open through the third coding cycle. At the end of the third coding cycle the  $2^4$  scaler is again triggered which supplies a trigger to the  $2^5$  scaler to change it back to its original state. At the end of the fourth coding cycle the  $2^4$  scaler is triggered again and at this time both the  $2^4$  and the  $2^5$  scalars will enable a stop pulse to be generated ending the mode gate.

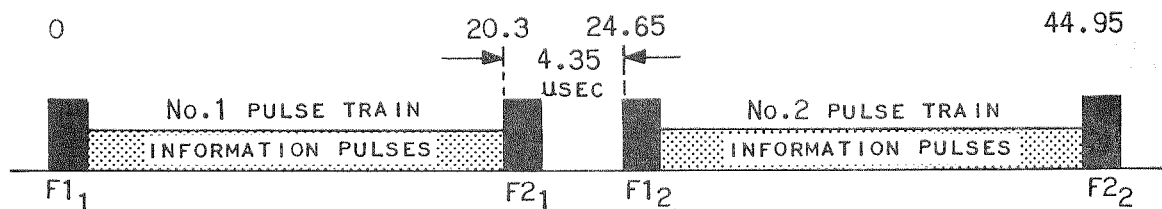
If a mode 3/A interrogation signal is decoded when the EMERG switch is closed, the mode 3/A emergency coding generator will be enabled which will supply a reply code changing signal to the coder module. This signal will automatically enable all A and B reply pulses and disable all C and D reply pulses regardless of the coding set on the control panel. The reply signal produced will then be a 7700 signal.

The I/P gate passes through two OR gates to the input of the  $2^4$  scaler trigger generator. At the end of the first reply train a  $2^2-0$  pulse from the coder module is supplied to the other AND gate input. If no input is supplied to the inhibit terminal, a  $2^4$  scaler trigger is generated. If a mode C interrogation is decoded the mode C gate passes through the two OR gates to the AND gate. If no D4 pulse is present in the reply, the  $2^4$  trigger generator is inhibited. If the D4 pulse is present the inhibit pulse to the  $2^4$  trigger generator is inhibited by the mode C D4 AND gate. Therefore, a mode C interrogation with the D4 pulse present will allow the  $2^3-0$  pulse to produce a  $2^4$  scaler trigger at the end of the first coding cycle. The  $2^4$  trigger will set the  $2^4$  scaler removing the  $2^4-0$  input to the mode gate stop trigger generator (as mentioned before). At the end of the second coding cycle the  $2^4$  scaler is triggered back to its original condition allowing the mode gate stop trigger to end the mode gate.

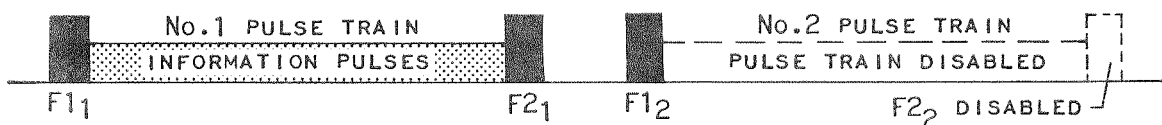
When the EMERG switch on the control panel is closed and an interrogation signal is decoded other than mode C the emergency control signal passes through an OR gate to the  $2^4$  trigger generator allowing the  $2^4$  scaler to be triggered at the end of each reply train. If mode C is decoded the mode C gate inhibits the emergency control signal.

When the EMERG switch is closed and a mode 1, 2 or 3/A interrogation is received the information between the two framing pulses will be removed in the second, third, and fourth pulse trains. The pulse train disable signal is produced when the emergency signal is supplied by the control panel and not inhibited by a mode C gate. The emergency gate is supplied as one input to the pulse



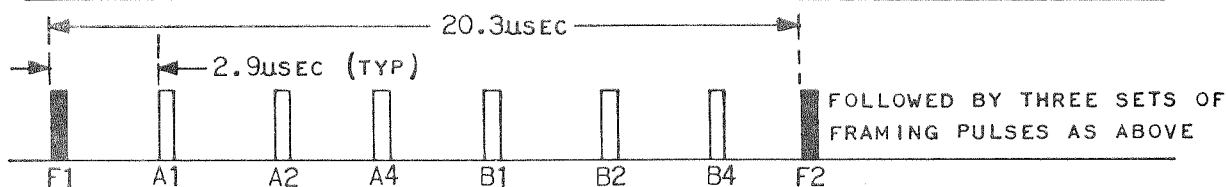
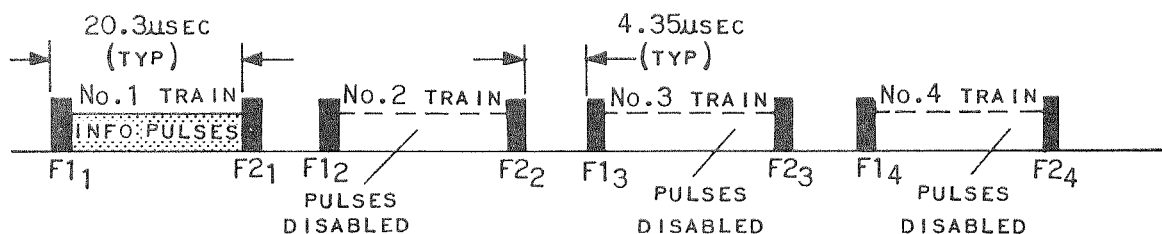


MODEL I/P REPLY



MODE 2 AND 3/A I/P REPLY  
MODE C REPLY WHEN D4 PULSE IS PRESENT IN FIRST TRAIN

MODE 1 AND 2 EMERGENCY REPLY



ALL C AND D PULSES DISABLED

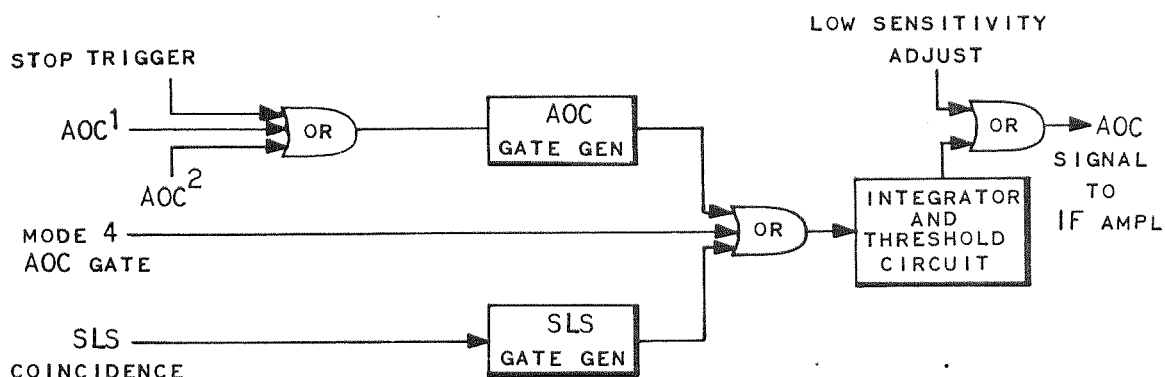
MODE 3/A EMERGENCY REPLY

NOTE:  
NO I/P OR EMERGENCY  
CODING IN MODE C

# I / P AND EMERGENCY CODING



This signal limits the transmitted reply signal rate to any preset value between 500 and 1500 replies per second. Reply rate reduction is accomplished by gradually reducing the sensitivity of the IF amplifier as the limiting level is approached. In this way, weaker interrogation signals are discriminated against in favor of stronger signals. Standardized pulses received from various circuits in the receiver-transmitter are applied to an integrator circuit followed by a threshold circuit. When the input pulse rate becomes excessive, the output of the integrator will exceed the threshold level. The signal from the threshold circuit is the control voltage that is coupled to the IF amplifier module. Since the level of the AOC control signal is proportional to pulse rate, the gain reducing AOC signal will increase in proportion to the pulse rate.



#### A O C C O N T R O L S I G N A L G E N E R A T O R

Three input signals are fed to the integrator circuit. A pulse from the AOC gate generator is produced at the beginning of the clock gate ( $AOC^1$ ) and at the end of the reply signal (stop trigger). When the system decodes and transmits a mode 2 emergency signal an additional pulse will be produced by the  $2^5$  scaler ( $AOC^2$ ). The output of the AOC gate generator will limit a mode 1, 2, or 3A reply rate to 1500 per sec. Mode 2 emergency replies are limited to 800 per sec. The second input is applied each time the system receives an invalid sidelobe interrogation signal (SLS coincidence). The third input is applied each time the mode 4 interrogation is decoded (mode 4 AOC gate).

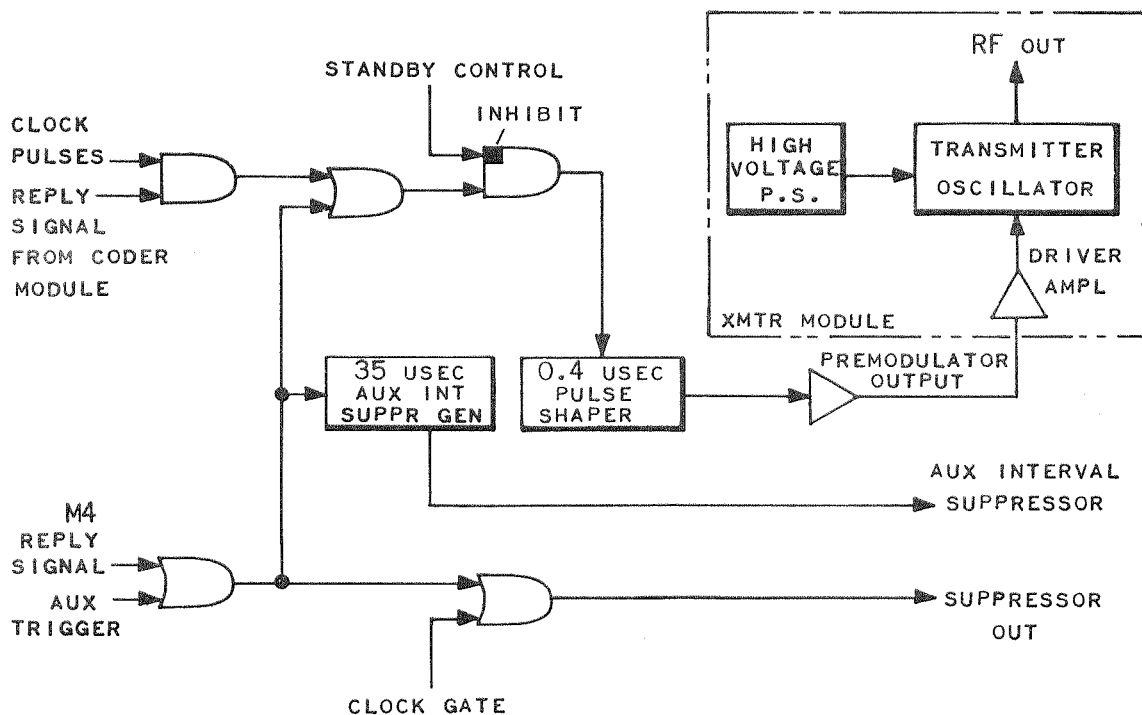
The quiescent (no signal) output level of the AOC control circuit is adjusted by the RCVR-SENS level adjust resistor on the front panel of the receiver-transmitter.

#### M O D U L A T O R - T R A N S M I T T E R C I R C U I T S

The modulator increases the reply signal gain to a level sufficient to trigger the transmitter. The transmitter consists of a lighthouse triode vacuum tube

installed in a resonant cavity. Each trigger pulse from the modulator shock excites the transmitter which produces a high level 1090 MHz RF signal for the length of the trigger pulse. The RF pulses from the transmitter cavity are coupled through the preselector in the RF module to the antenna and radiated.

The modulator circuits are divided between two modules. The circuits that initially receive input signals are located in the reference signal generator module and are called the premodulator. The premodulator output signals are then coupled to the final modulator or driver circuits within the transmitter module.



## MODULATOR - TRANSMITTER CIRCUITS

The generated reply signals from the coder module are coupled to the input of an AND gate with the output of the clock pulse generator. Each coincident pulse is coupled through an OR gate to the standby control AND circuit. When the function switch on the control panel is in "STBY" (standby), the inhibit signal prevents further processing of the modulator signal. The reply signal is coupled to a pulse shaper that develops a sharply defined 0.4 usec output pulse for each input pulse. The reply signal is then amplified further and coupled out to the transmitter module.

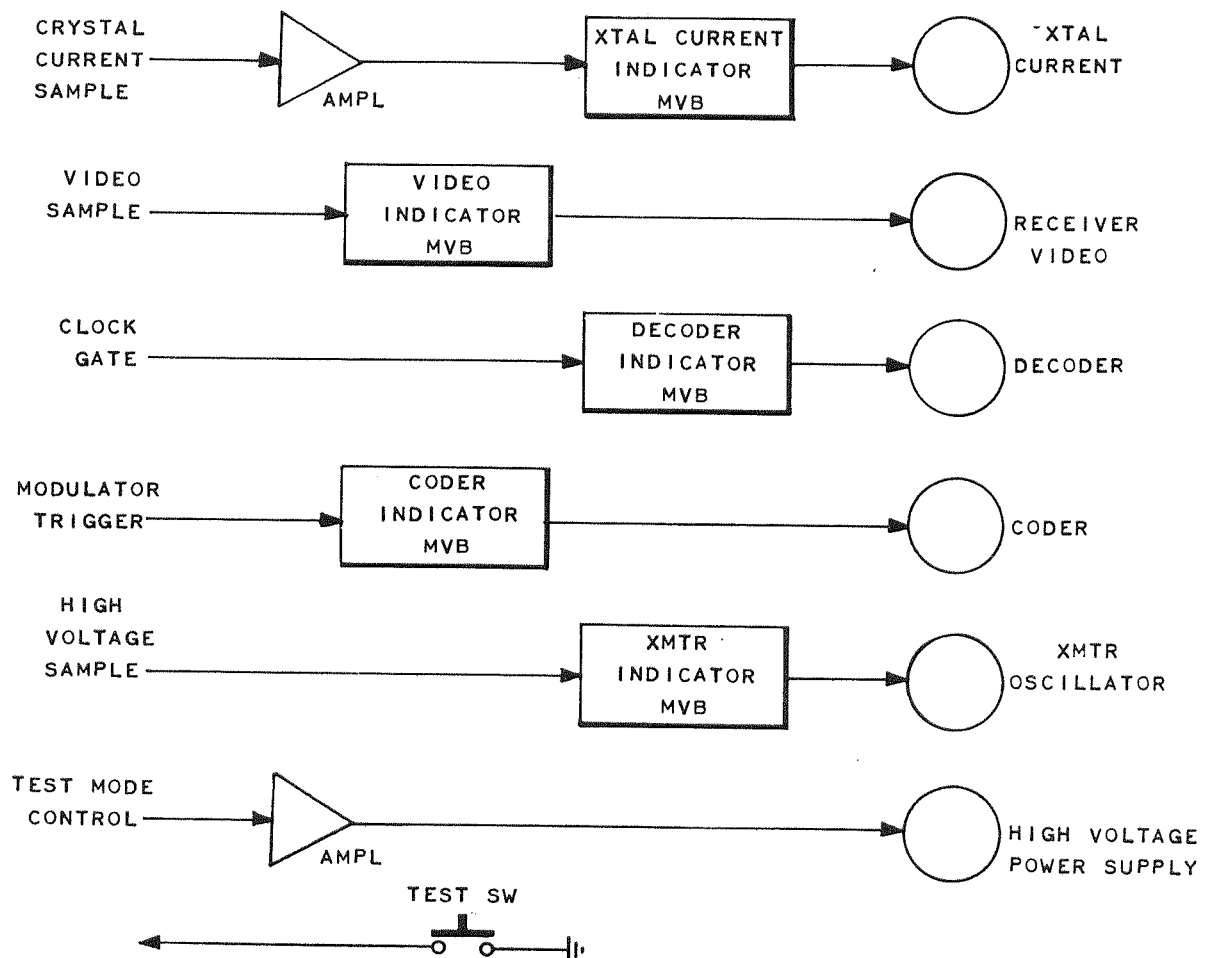
Mode 4 reply signals and auxiliary trigger signals are also coupled to the premodulator circuits. These signals follow the same path as the coder generated

pulses after triggering the auxiliary internal suppressor multivibrator. Each pulse is also coupled to the suppressor output terminal.

The auxiliary internal suppressor produces a 35 usec gate to inhibit further signal decoding. The suppressor output signal may consist of mode 4 or auxiliary input signals or the clock gate signal from the decoder module.

## TEST MODULE

The test module receives input signals from various circuits throughout the receiver-transmitter unit. Each input signal will light its corresponding monitor light indicating that the circuit monitored is operating correctly. The input signals whose time duration is too short to keep the monitor lamp illuminated



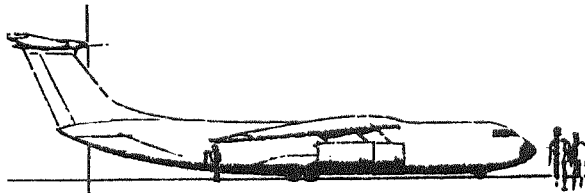
are used to trigger monostable multivibrators in the test module. Each multivibrator will produce an output pulse with approximately 5 MS duration when triggered by an input signal. The multivibrator outputs are then coupled to the indicator lights. The circuits monitored are as follows:

- Crystal Current
- Receiver Video
- Decoder
- Coder
- Transmitter Oscillator
- High Voltage Power Supply

A test switch on this module will induce noise in the IF amplifier of sufficient magnitude to trigger any selected mode gate generator when pressed. The receiver-transmitter will then generate a reply signal.

#### POWER SUPPLY

The power supply module furnishes regulated and unregulated voltages for the system. Input voltage is 115 volts, AC. The unregulated output voltages are +45 volts, DC, 6.3 volts, AC, and 1 volt, AC. The regulated output voltages (D-C) are +100, +20, +10, +6, +4, -2, -4, -6, and -20 volts, DC. The power supply contains transient suppressor circuit that will automatically reduce the input voltage to a safe value if it rises above 140 volts, AC.



## DOPPLER NAVIGATION RADAR

### GENERAL

The problem of navigation resolves itself into several fundamental questions. Where am I, where am I going, and how fast am I going there? Under ideal conditions, the airspeed indicator and compass would furnish precise answers to the last two questions. However, under normal flying conditions, wind adds a factor which causes the compass and airspeed indication to vary greatly from true ground track and ground speed. The APN-147 Doppler radar system gives the answer. Its advantages are that it operates without the need of any auxiliary ground station; it is capable of operating day or night; it is capable of operating in any weather condition; and it is capable of operating at any latitude.

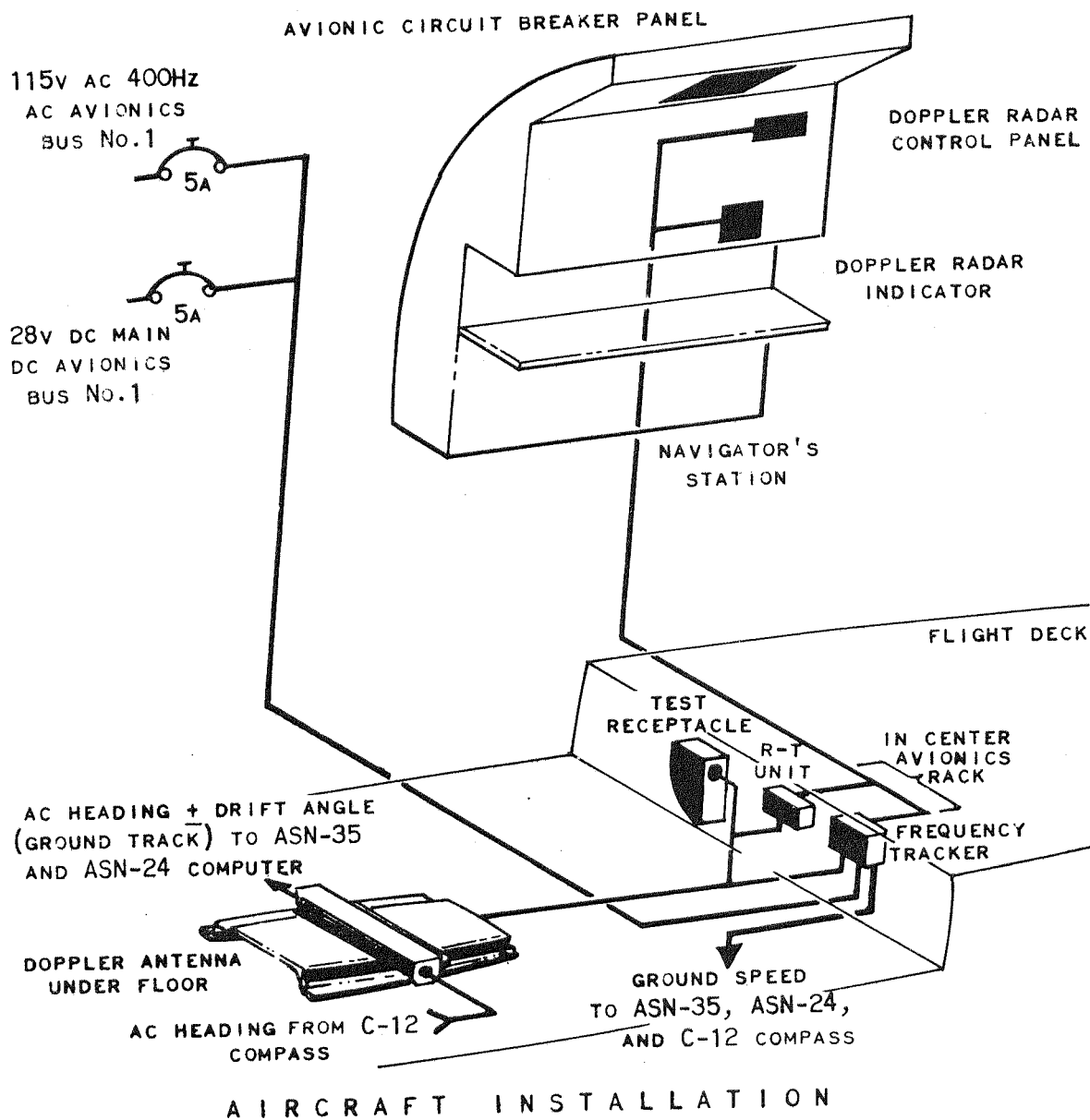
The APN-147 measures and displays aircraft ground speed and drift angle. Ground speed is the actual rate of travel over the earth's surface. Drift angle is the angular difference between aircraft heading and the path that it follows over the earth. Ground speed is displayed in nautical miles per hour (knots) on the navigator's instrument panel. It is also supplied to the ASN-35 Doppler computer, the ASN-24 computer and the C-12 compass. Drift angle is displayed on the navigator's panel as degrees left or right of ground track. Drift information is also supplied to the ASN-35 and ASN-24 computers.

### AIRCRAFT INSTALLATION

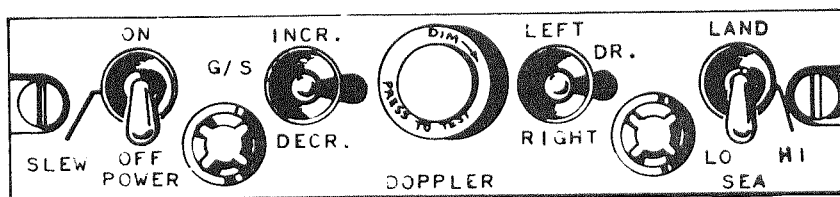
The Doppler system consists of five components. They are as follows:

- |                     |            |
|---------------------|------------|
| • Transceiver       | RT-625 ( ) |
| • Antenna           | AS-1168    |
| • Frequency tracker | CV-1181    |
| • Indicator         | ID-938     |
| • Control panel     | C-3818 ( ) |

A test receptacle is also provided on the side of the navigation J box. The location, power sources, and cabling is shown on the "Aircraft Installation" illustration.



## SYSTEM OPERATION



C O N T R O L   P A N E L

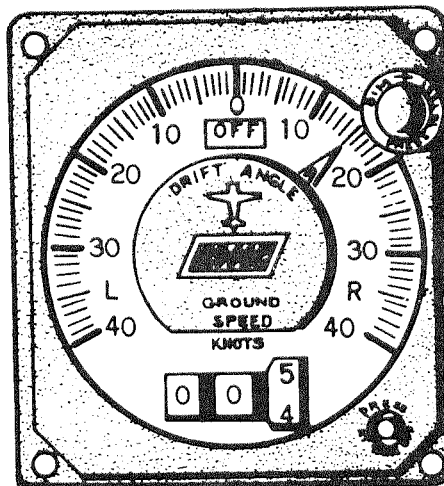
The control panel and indicator at the navigator's station contains the necessary controls for system operation. The POWER switch is used to energize the system for manual slewing ("SLEW" position) and automatic operation ("ON" position). In the "SLEW" position ground speed and drift angle momentary slew switches are enabled. The slew switches allow the operator to manually insert estimated aircraft ground speed and drift angle values into the system. If the inserted values are near actual values the radar will acquire "lock-on" in flight after the POWER switch is placed to "ON". After "lock-on" the radar will automatically track any change in ground speed or drift angle and will continuously maintain drift angle and ground speed indications. The slew switches are disabled when the POWER switch is in the "ON" position.

The LAND-SEA switch provides proper corrections of ground speed readings for the type of surface over which the aircraft is flying. The "LAND" position of the LAND-SEA switch is used when the set is operated over land. When flying over water sea-state error results in the reduction of the Doppler shift as the radar waves are reflected from the water. This reduction of Doppler shift would result in a decreased ground speed read-out if it was not compensated. 1.25 percent correction is necessary due to this error. The "SEA-LO" switch position is used when flying low over water and when returns are sufficiently strong to maintain constant "lock-on", however the ground speed reading is corrected 1.25 percent and remains accurate. At higher altitudes where return signal strength is lower, the "SEA-HI" position is used. Depending on the sea condition (smooth) the amplitude of the received signals is also reduced. In the "SEA-HI" position two modes of operation are possible: "SEA-HI" operation which is similar to "SEA-LO" operation, and Smooth Sea operation where antenna beam angle is increased in order to maintain "lock-on". Smooth Sea is less accurate than "SEA-HI". In actual operation the set automatically cycles between the two modes approximately every 60 seconds unless "lock-on" is achieved in the "SEA-LO" operation. In this event "SEA-LO" operation is maintained until loss of the return signal occurs.

NOTE: The automatic cycling described occurs only when the LAND-SEA switch is in the "SEA-HI" position.

Insufficient signal or system malfunction are indicated by memory lights on the control panel, and by an OFF flag and memory light on the indicator. The indicator displays drift angles of 40 degrees left or right and ground speed up to 999 knots. Maximum drift is limited to 38 degrees left or right in the antenna.

A pre-takeoff pushbutton on the indicator, when momentarily pressed, provides preset selection of ground speed and drift angle. The ground speed indicator will slew to 165 knots and the drift indicator will slew to 0 degrees. The pre-takeoff pushbutton is disabled by a touchdown relay when pressure is relieved from the main landing gear at lift-off.



GROUND SPEED  
INDICATOR

## SPECIFICATIONS

### DOPPLER RADAR APN-147

CHARACTERISTIC	SPECIFICATION
Operating frequency	8.8 GHz
Nominal Doppler frequency shift	20.66 Hz/knot (LAND mode) 20.48 Hz/knot (SEA mode) 6.67 Hz/knot (smooth Sea mode)
Emission type	FM-CW
Modulation	Sinusoidal 0.67 or 1.08 MHz
Power output	500 Milliwatts nominal 370 Milliwatts nominal
Operating altitude	100 feet to 50,000 feet
Drift angle	Up to maximum 40 degrees L or R $\pm 1/4$ degrees



SPECIFICATIONS (continued)

DOPPLER RADAR APN-147

CHARACTERISTIC	SPECIFICATION
Ground speed	70 KT to 1000 Kt $\pm$ 5 percent
Antenna attitude limits	Pitch $\pm$ 20 degrees, stabilized $\pm$ 1 degree Roll $\pm$ 30 degrees
Antenna drive rates	Pitch 1 degree per second Drift 3 degrees per second

BLOCK DIAGRAM THEORY OF OPERATION

The Doppler radar measures groundspeed and drift angle using the "Doppler Effect". The "Doppler Effect" is the frequency shift induced into a signal when the transmitter or receiver, or both, are in motion in relation to each other. The amount of Doppler shift is directly proportional to the aircraft velocity (groundspeed) and can be expressed by the mathematical formula:

$$\text{Doppler shift} = F \frac{V}{C}$$

Where F = frequency transmitted

V = velocity of aircraft (groundspeed)

C = speed of light (propagation velocity of radar wave)

The Doppler shift is upward ("Up-Doppler") on a beam transmitted forward of a moving aircraft and downward ("Down-Doppler") on a beam transmitted aft. Two other factors must be considered when the Doppler shift is measured by a radar set in an aircraft. First, since both the transmitter and receiver are located in the aircraft, two Doppler shifts are created. One when the wave is transmitted and the second as it is reflected back to the aircraft. A factor of two must now be added to the Doppler formula.

$$\text{Doppler shift} = 2 F \frac{V}{C}$$

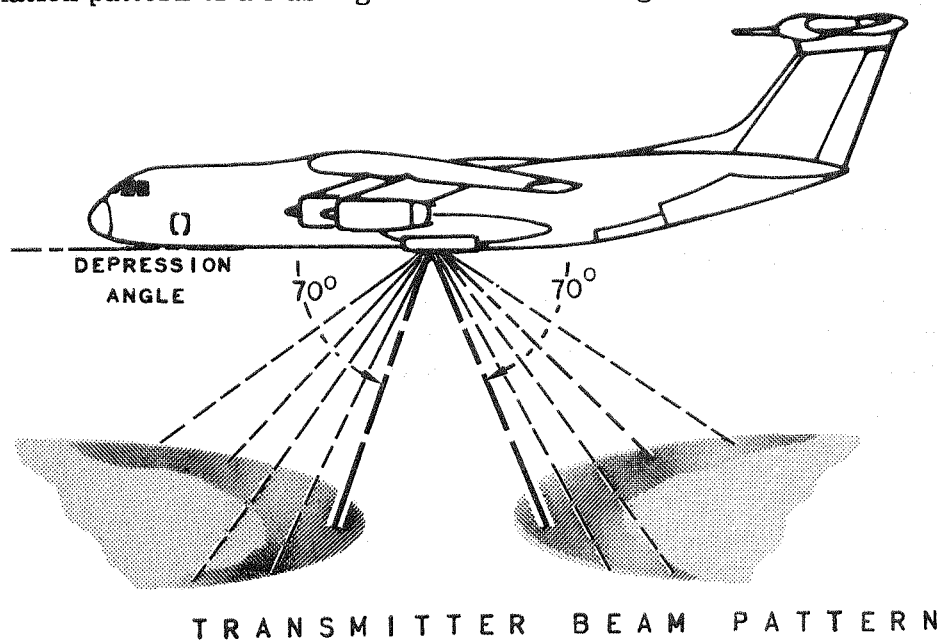
The second factor that must be considered is the angle of antenna radiation. Maximum Doppler shift would be received if the antenna beam was transmitted dead ahead. If the beam was directed straight down at the earth, the Doppler shift would be minimum. Since in the aircraft the beam is directed to the ground at an angle between dead ahead (0 degrees) and straight down (90 degrees), we introduce a factor to compensate for this. The factor used is the cosine of the radiating

angle. The complete Doppler formula then becomes:

$$\text{Doppler shift} = 2 F \frac{V \cos \text{radiating angle}}{C}$$

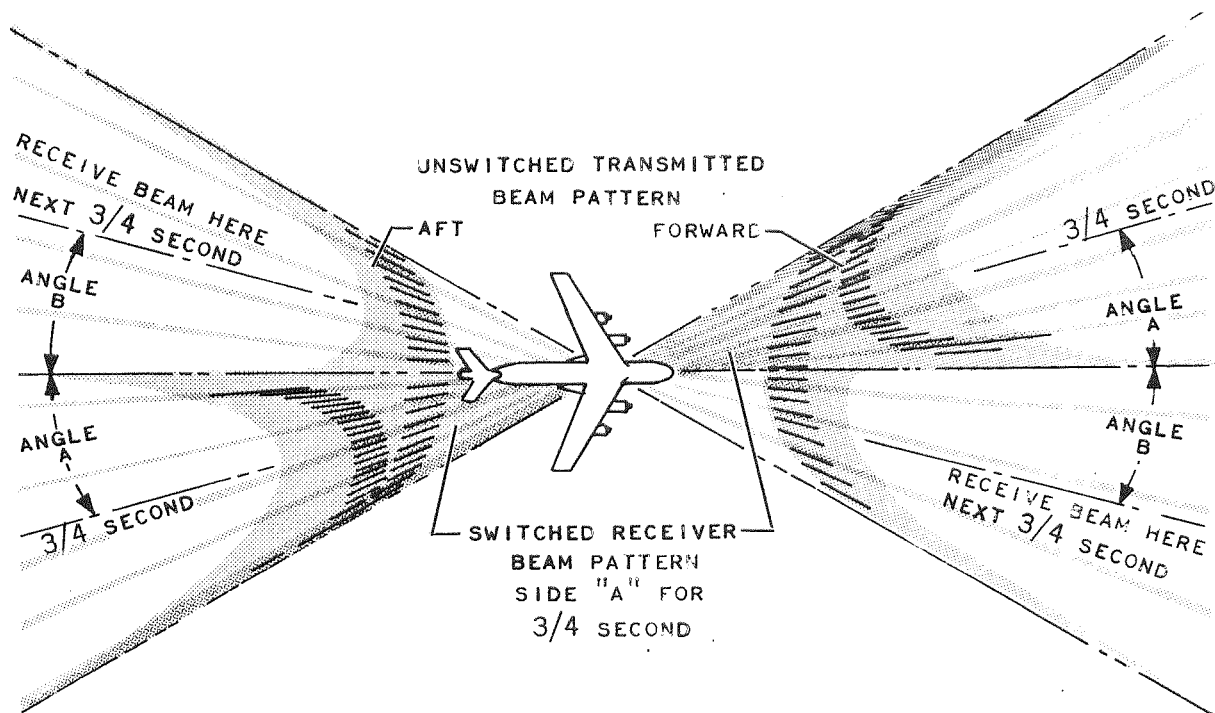
The Doppler shifts incurred, above and below the transmitted frequency, are detected and converted into an audio signal within the Doppler system at the nominal frequency of 10.33 Hz per knot of groundspeed. The audio signal is used for groundspeed and drift angle computations.

The Doppler system transmits one fan-shaped beam forward and one aft. The transmitted beams are angled below the aircraft, fore and aft at a 70 degree depression angle. This creates an RF energy pattern on the ground much like the illumination pattern of a flashlight beamed at an angle onto a tabletop.



Two receiver beams are utilized simultaneously, one looking forward, the other looking aft. This ability of a radar set to look in two directions at once is called "Janus" operation. The fore and aft beams are offset from the centerline of the aircraft and are switched from side to side at a 3/4 second rate. During the first 3/4 second period the received beams cover the right forward and left aft segments of the transmitted patterns. For the next 3/4 second the beams cover the left forward and right aft segments.

The tracker circuits measure groundspeed by determining (frequency tracking) the Doppler shift. The difference between the Up-Doppler and Down-Doppler frequencies is detected to produce a Janus Doppler audio signal which is the sum of the two Doppler shifts and is representative of groundspeed. The Janus Doppler signal is used to drive a servo. Rotation of the servo shaft, which is analogous to groundspeed, controls a servo loop which positions the digital groundspeed readout on the indicator.



In "LAND" mode each knot of ground speed creates a Doppler shift of 20.66 Hz Janus audio. Janus audio is 20.40 Hz per knot in either "LO SEA" or "HI SEA" modes. "Smooth Sea" is an automatic function of the manually selected "HI SEA" mode. Smooth Sea operation occurs when the received signal strength is inadequate to provide normal "SEA" operation. In Smooth Sea operation the forward beams tilt down an additional 7 degrees and the rear receiver beams are disabled. The additional depression angle and loss of the rear beams results in a lower Doppler shift (6.67 Hz/knot non-Janus). For one minute out of every two, the system returns to normal Janus operation. If, during this one minute period adequate signal is being received, the system remains in Janus operation and does not return to Smooth Sea until the received signal again decreases below a usable level. If sufficient signal is received only in Smooth Sea mode it is normal for the memory light to illuminate approximately one minute out of every two.

Drift angle is measured by comparing the average Doppler shift incurred in one 3/4 second period to the shift incurred in the alternate 3/4 second period. Assuming a drift condition exists (aircraft heading and ground track are not the same) the Doppler shift will be greater in one receiver beam position than in the other. As long as a 3/4 second change in Doppler shift exists, a servo within the tracker will position the antenna, right or left from the aircraft centerline, until a steady Doppler condition is reached. The antenna centerline will then be along the ground track. Drift angle is the angular difference between aircraft centerline and antenna centerline. A synchro loop, controlled by antenna movement, positions the drift angle needle on the indicator.

A built-in sampling (lock-check) circuit determines if the displayed information is accurate by introducing errors into the system and checks for the correct response. If the response is incorrect or the received signal is inadequate to sustain Janus or Smooth Sea operation the system goes into memory. While in

memory the indicator is automatically locked to the last valid ground speed and aft angle readings. The warning flag appears and the memory lights are illuminated. While the system is in memory, a continuous check of the received signal is made to determine whether its strength is adequate to restore normal Janus or Smooth Sea operation.

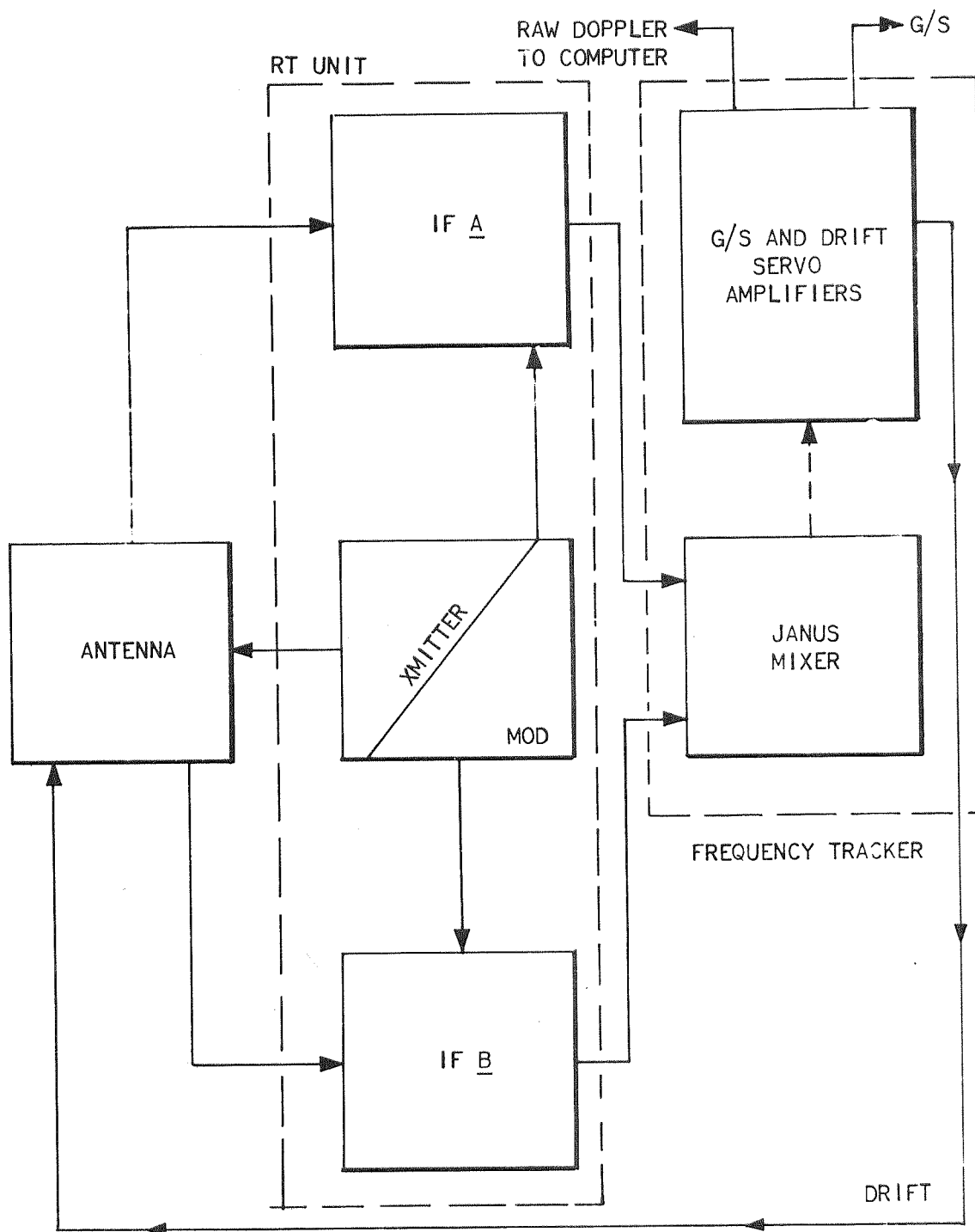
The Doppler transmitter produces a Frequency Modulated (FM) Continuous Wave (CW) carrier. The modulation signal is generated in the modulator and applied to the transmitter klystron. The klystron output is applied to the transmitting antenna.

The returned signals are amplified in two IF strips and sent to the Janus mixer. The Janus mixer adds the Up-Doppler and Down-Doppler from the IF strips. The Janus Doppler then supplies the frequency comparator. The frequency comparator locks a linear voltage controlled audio oscillator to the Doppler audio frequency. The shaft angle of the oscillator-driving servo is transmitted to the indicator as an analog of groundspeed.

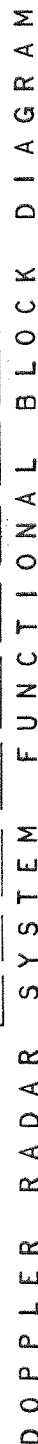
The modulator generates signals of 0.67 or 1.08 megahertz (MHz). The frequencies are switched alternately at a 15 Hz rate. Multiplying stages select harmonics nearest 3.3 MHz from each signal. These multiplied frequencies are used by the receiver. The 15 Hz time-shared 0.67 or 1.08 MHz signal is superimposed upon the D-C repeller voltage supply of the transmitting klystron. The klystron output is an 8,800 MHz, frequency modulated carrier with the modulating signal plus harmonics of the modulating signal appearing in the sidebands of the carrier. The klystron output is fed through a coupler to the transmitting array. This array consists of a slotted waveguide with a horn reflector. The slots are cut to direct a fan-shaped beam forward and aft at equal angles to the aircraft centerline. The coupler directs a small sample of the transmitted energy to the receiver mixers.

The receiving array consists of two slotted waveguide sections joined back to back. One is slotted to receive forward, the other aft. The received beamwidth is approximately one-half the width of the transmitted beams. The reflectors are shaped to direct the received beams to the left or right half of the transmitted beams. When the forward beam is being reflected left, the aft beam is reflected right. Three-quarters of a second later the waveguide assembly is rotated 180 degrees. Now the forward beam is reflected right, the aft beam left.

A waveguide switch connects the output from the arrays to the balanced mixers. The balanced mixers beat the sample of the transmitted energy from the coupler, with the incoming reflected energy. The result is a broad spectrum of frequencies consisting of the harmonic sidebands and the Doppler frequencies. Included is the IF plus or minus the Doppler. This signal is the third or fifth harmonic of the 0.67 or 1.08 MHz modulating frequencies. This signal is fed to the IF amplifiers. The IF is stagger-tuned for broad-band operation. The IF plus or minus Doppler frequency is mixed with the signal from the multiplier in the modulator.



DOPPLER RADAR SYSTEM BLOCK DIAGRAM



Rectifying and filtering yields the Doppler frequencies. The output of the right IF amplifier will be Up-Doppler, while the output of the left IF amplifier is Down-Doppler. Three-quarters of a second later this condition is reversed as antenna switching occurs.

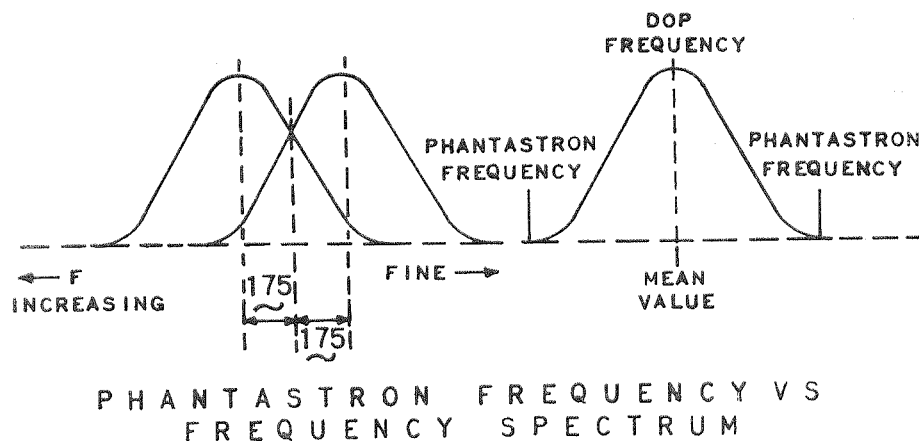
The outputs of the IF amplifiers are connected to the frequency tracker unit, where they are applied to the Janus mixer. The purpose of the Janus mixer is to add the Up-and-Down Dopplers. This is accomplished by producing single sideband signals using approximately 100 kilohertz as the carrier frequency. By selecting the upper sideband of one balanced modulator and the lower sideband of the other, the sum of the Doppler shifts can be obtained through a "square law detector".

In the amplifier and phase splitter circuits the Up Doppler and Down Doppler is added to a carrier from the crystal oscillator. For explanation purposes we will assume that the Crystal Oscillator frequency is 100 KHz. In the balanced modulator and filter circuits the sum and difference frequencies are obtained and the carriers are suppressed. Upper Sideband (USB) filters eliminate the lower sideband. As an example if Up Doppler and Down Doppler were both 5 KHz then the output of each of the USB filters would be 105 KHz. The crystal oscillator frequency is doubled (200 KHz) and mixed with the output from one of the USB filters. In our example 105 KHz out of the USB filters would result in sum and difference frequencies of 305 and 95 KHz being applied to the Lower Sideband (LSB) filter. The LSB filter then passes 95 KHz to the square law detector where it is mixed with the 105 KHz from the other USB filter to produce a Janus Doppler signal of 10 KHz (difference frequency). In actual usage the input Doppler frequency will vary from 1 to 10 KHz as groundspeed changes. This results in a change of 2 to 20 KHz of Janus Doppler.

The bandwidth of the USB filters is approximately 100.5 to 106 KHz. If the Crystal oscillator frequency was maintained at 100 KHz then at higher Doppler frequencies the sum of the crystal oscillator and Doppler frequencies would be above the USB filter range. To compensate for this the actual frequency of the crystal oscillator is changed from 99.8 to 96.9 to 95.1 as groundspeed is increased.

The Janus Doppler is then fed through an amplifier to the frequency comparator. The frequency comparator generates a shaft position analog of groundspeed by slaving a linear-voltage-controlled audio oscillator (phantastron) to the Doppler frequency. This shaft position is used by the navigator's groundspeed indicator. Frequency comparison is accomplished by mixing the output of a phantastron with the incoming Doppler signal through a diode mixer. The output of the mixer is amplified and fed to low-pass filter. If the phantastron frequency is considerably larger or smaller than the Janus Doppler frequency, the filter rejects the beat note produced in the mixer. As the phantastron approaches the Doppler frequency, the beat note is reduced in frequency until it is within the bandpass of the filter. The filter output is rectified, producing a D-C voltage when the phantastron is near the Doppler frequency.

The phantastron may be either above or below the Doppler frequency and produce a beat note within the bandpass of the filter. A five-cycle switch alternately shorts out and opens around a resistor in series with the phantastron potentiometer. This superimposes a five-Hz square wave upon the D-C phantastron control voltage. This change in control voltage causes an up and down shift in the phantastron output frequency at a five cycle rate. If the mean value of the phantastron frequency is centered in the spectrum of Doppler frequencies the phantastron shifts equal amounts above and below the Doppler frequency. The beat note is of the same frequency and amplitude during both frequency periods. A constant D-C voltage is produced. The five cycle switch causes the DC to charge



the two capacitors at the input to the magnetic modulator. Since the D-C voltage is constant, both capacitors have equal charges and no current flows in the magnetic modulator input.

If the phantastron frequency is not centered about the Doppler frequency, the beat note is higher in frequency during one switching period than the other. The output of the filter is greater during half the cycle; therefore, the DC produced is also greater. The action of the five cycle switch causes one capacitor to be charged to the higher voltage and the other to the lower voltage. Since the switch controlling the charging of the capacitors is operated at the same rate as the switch causing the phantastron frequency shift, one capacitor receives the higher charge if the mean phantastron frequency is above the Doppler frequency. This reversing D-C current flows in the input of the magnetic modulator when an unbalance in capacitor charge exists. The direction of the current flow depends upon the relative location of the mean phantastron frequency with respect to the Doppler frequency.

The magnetic modulator converts this DC into an A-C output with phase controlled by the polarity of the D-C input. This AC is applied through a cathode follower to a phase sensitive detector whose output controls a magnetic amplifier. The output of the magnetic amplifier is an A-C signal of sufficient amplitude to drive the groundspeed motor. The direction of motor rotation is controlled by the phase of the driving voltage. The motor drives the phantastron control potentiometer



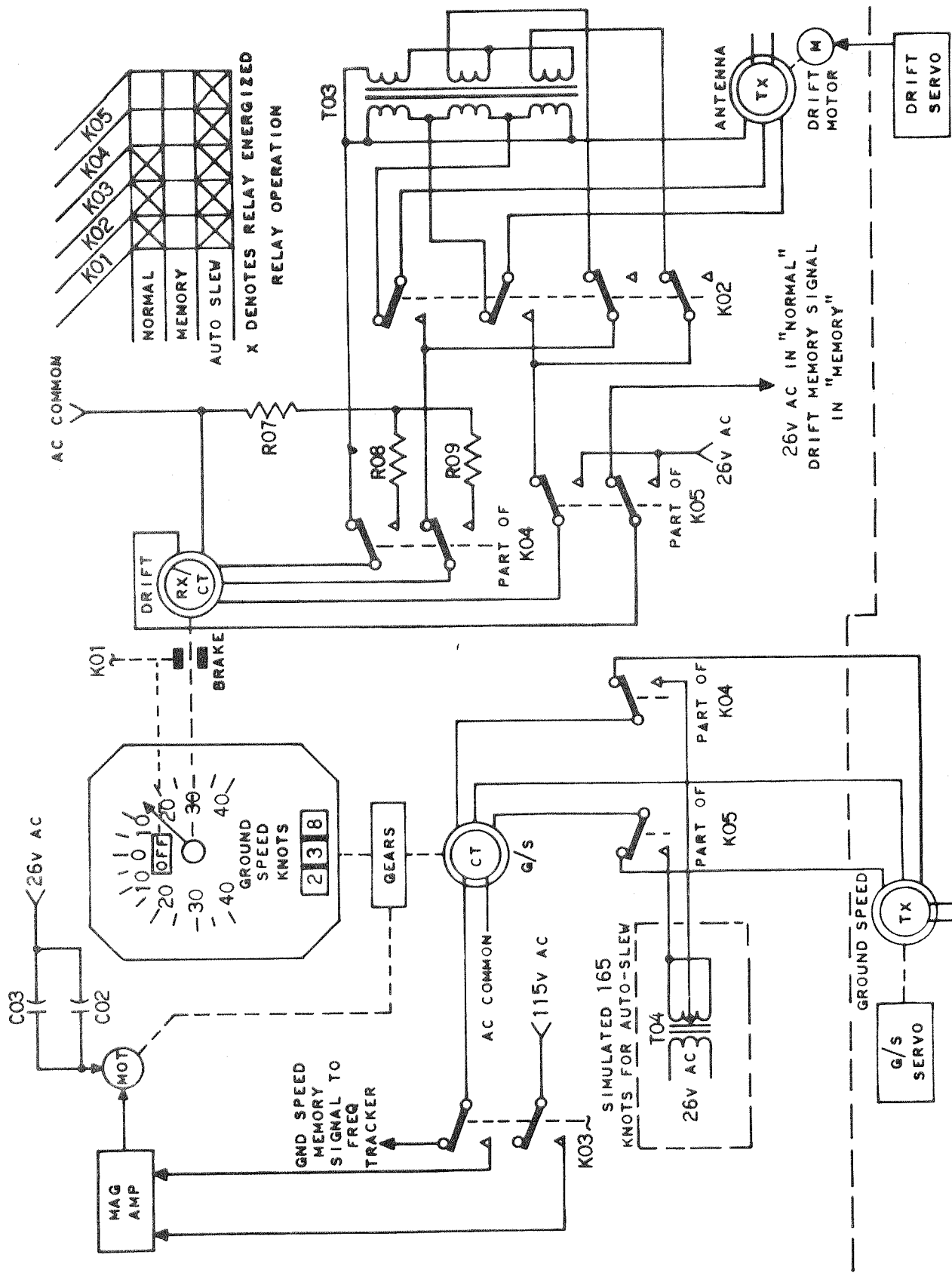
either in an increasing or decreasing frequency direction until the mean frequency is centered about the Doppler frequency. Switches on the groundspeed shaft change the carrier frequency in the Janus mixer crystal oscillator to the different valves needed to keep the mixed signal within the USB filter ranges. A synchro mounted on the shaft transmits an analog of groundspeed to the navigator's indicator.

The foregoing discussion presumed that the Doppler frequency remained constant. If there is an antenna drift error, the Doppler frequency is higher for one period of antenna switching than the other. The frequency tracker therefore tends to track upward (in frequency) for approximately three-quarters of a second, then downward for three-quarters of a second. This is due to the effect of the beam angle on the Doppler. Since the voltage causing the frequency to track upward and downward is related to the antenna switching rate, the same voltage can be used to position the antenna to null out the difference in frequency. The two halves of a drift reversing stage are alternately enabled by a switch on the antenna. The drift reversing stage will either pass the signal as is or reverse the signal phase, depending on the instantaneous antenna switching state. This process keeps the antenna driving in the proper direction until the frequency differences due to antenna switching are nulled out.

Drift angle is determined from the antenna position and is transmitted to the navigator's indicator by a synchro. The synchro rotor is geared to the antenna; its stator is clamped to the antenna saddle.

If the phantastron is initially positioned too far from the Doppler frequency, the filter output would be zero. The capacitors at the magnetic modulator input would not be charged and the system would appear to be locked on. To prevent this, a lock-check system is used. The lock-check system adds or subtracts resistances every 3.5 seconds in series with the phantastron potentiometer. This causes the groundspeed servo to be driven briefly upward then downward at a 3.5 second rate. A tachometer generator is connected to the groundspeed shaft. The tachometer output is connected to a detector which is gated by the lock-check switches. If the motor turns according to the error introduced by the lock-check switches, the detector output will hold the lock-check relay energized. If the motor does not drive, or turns in the wrong direction, the relay will deenergize and place the system in memory operation.

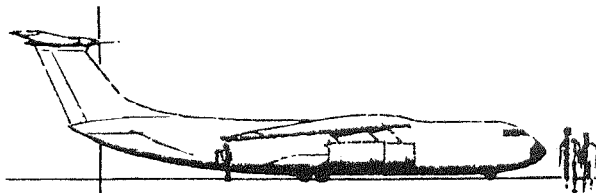
The navigator's indicator normally receives groundspeed and drift in the form of synchro signals. A control transformer and servo displays groundspeed on a drum-type counter. Drift is displayed by a synchro repeater and pointer. In memory operation, the drift pointer and groundspeed drums are locked. The synchros in the indicator are then used as a reference to hold the groundspeed and drift servos in the frequency tracker in their last position. The position is held until the radar is able to lock on the returned signal. The memory outputs of the indicator are fed into the phase sensor in the electronic control amplifier.



GROUND SPEED DRIFT ANGLE INDICATOR CIRCUITS

Outputs from the radar to the ASN-35 and ASN-24 computers are "raw Doppler" and "ground track". Raw Doppler is taken from the phantastron through the cathode follower. Ground track is obtained by passing the No. 1 compass synchro information through a differential generator operated by the antenna drift angle servo. A second output of the APN-147, to the C-12 compass system, is "ground-speed" which is taken from a potentiometer on the groundspeed motor. This output voltage is used as coriolis correction for the compass system to improve accuracy.





## DOPPLER NAVIGATION COMPUTER

### GENERAL

This computer system provides the navigator indications of distance to go to a preselected destination as well as distance from his preselected flight path (distance crosstrack). This system requires ground speed and ground track information from the Doppler radar system.

### AIRCRAFT INSTALLATION

The aircraft installation diagram shows general cabling and component locations. Those components are as follows:

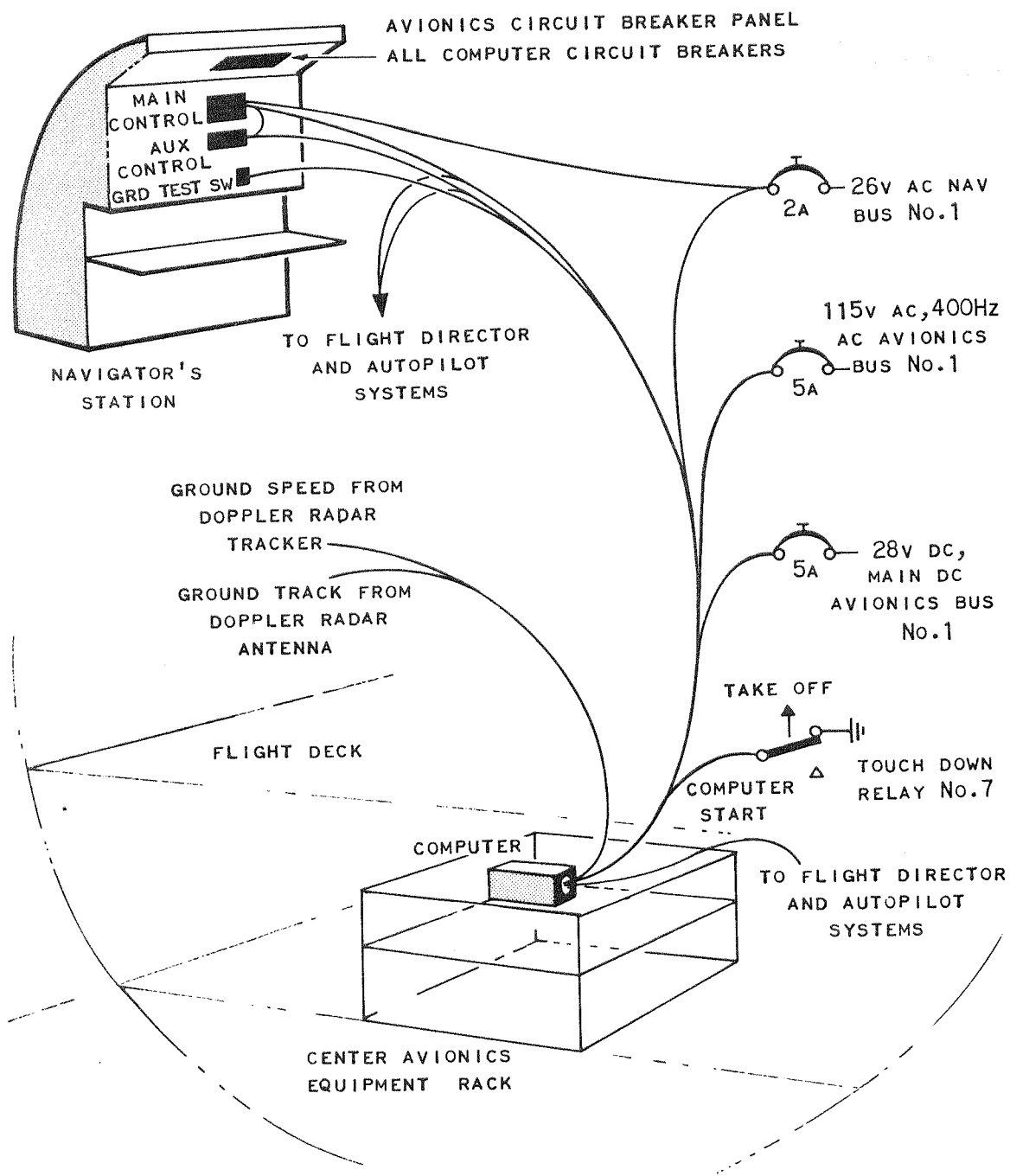
- Computer CP-622
- Main Control Panel C-3819
- Auxiliary Control Panel C-3820
- Ground Test Switch

### SYSTEM OPERATION

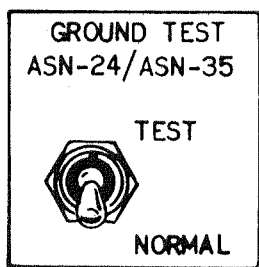
Doppler computer operation requires Doppler radar groundspeed (audio signal at 20.66 Hz per knot in radar land mode) and Doppler radar ground track (compass heading  $\pm$  drift angle).

Ground operation of the computer is only provided when the ground test switch is in "TEST" position. For inflight operation the switch must be placed to "NORMAL" before takeoff.

When the navigator determines his departure and destination points, he presets knob (B) or (D) on the main control panel to the desired track angle between the two points. The desired track indicators do not change with computer operation. The nautical mile distance to go between the points are preset by knob (F) or (G). If he desires presetting the angle on Knob (D)

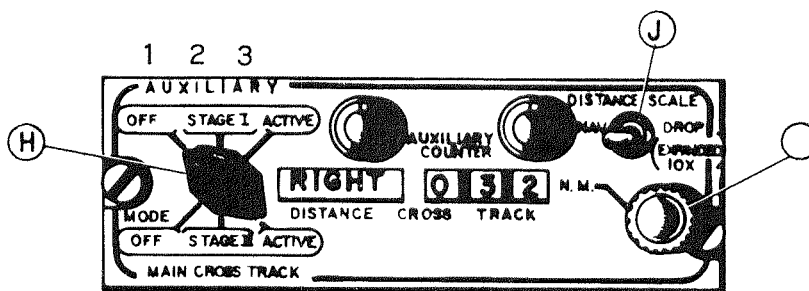


## AIRCRAFT INSTALLATION

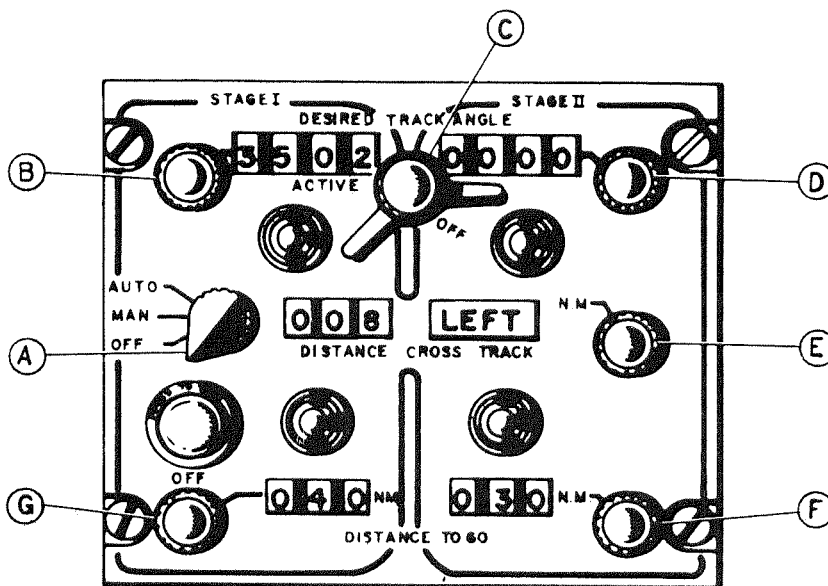


GROUND TEST  
SWITCH

(STAGE II) he must use the STAGE II distance-to-go knob (F). Knobs (E) and (I) must be set to 000 miles crosstrack. The navigator may preset two flight legs. He determines his first leg and presets it as explained previously. His second leg may be preset in the same manner on the opposite stage.

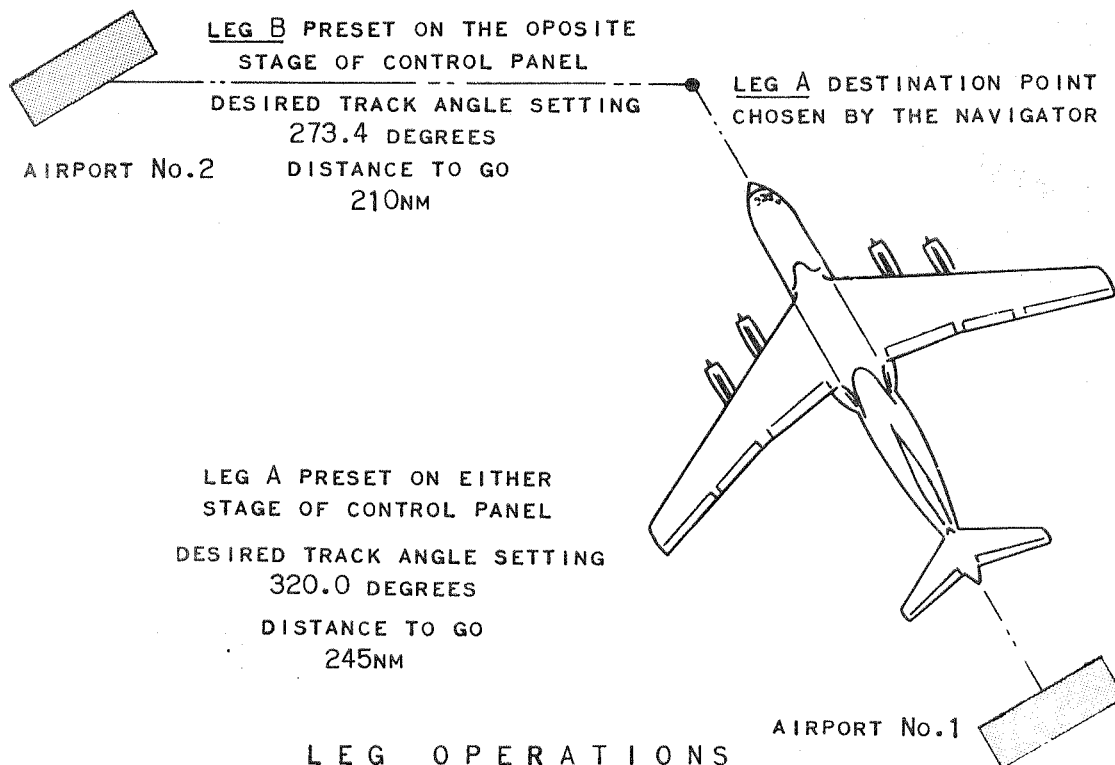


AUXILIARY CONTROL



MAIN CONTROL

# ASN-35 CONTROL PANELS



For a two leg operation, as shown in the "Leg Operations" illustration, the navigator places Knob (C) to the stage he has preset for leg A and switch (J) in the "NAV" position. To activate the system, Knob (A) is placed to manual ("MAN") or automatic ("AUTO").

With the Doppler radar preslewed or operating the computer begins counting when the aircraft lifts off airport 1. With Knob (H) as shown, the main control panel CROSSTRACK indicator will constantly display the left or right nautical miles distance in tenth mile increments from the preselected leg A. The pilot will see deviation from the leg on his flight director and attempt to keep the aircraft on course. When the leg A stage counts down to 000 NM CROSSTRACK and DISTANCE-TO-GO, the navigator knows the aircraft is over the leg A destination. He then transfers stages manually with Knob (C) if Knob (A) was preset to "MAN." If "AUTO" had been preset, stage switching would be automatic when the leg A stage counted down to 000 NM distance-to-go. When the system is switched to the leg B stage the main panel will stop counting on the leg A stage and begin counting on the leg B stage. The main panel CROSSTRACK will now read distance from leg B. Accuracy of the CROSSTRACK reading for leg B will only occur if the indicator was 000 NM crosstrack upon stage switching. It is necessary therefore for the aircraft to be over destination No. 1 upon stage switching.

When the aircraft reaches airport 2 the leg B stage will read 000 NM crosstrack and 000 NM to go. If the pilot chooses to pass over airport 2 automatic stage



switching will not re-occur if the navigator leaves the previous leg A stage set to 000 NM distance to go. With knob (H) preset to "3," CROSSTRACK display for both stages reads only on the auxiliary panel. This would be required if the main panel crosstrack counter was inoperative. In position "2," the auxiliary panel displays STAGE I CROSSTRACK and the main panel will display STAGE II CROSSTRACK depending on the selected stage at the main panel. This position provides a complete set of counters for each stage.

The drop position of switch (J) increases counting speed by 10. Therefore preset values of crosstrack and distance-to-go on the stage being preset for a drop leg must be 10 times greater than normal for "NAV" (cross country) operation to obtain 000 NM readings over the target.

### SPECIFICATIONS

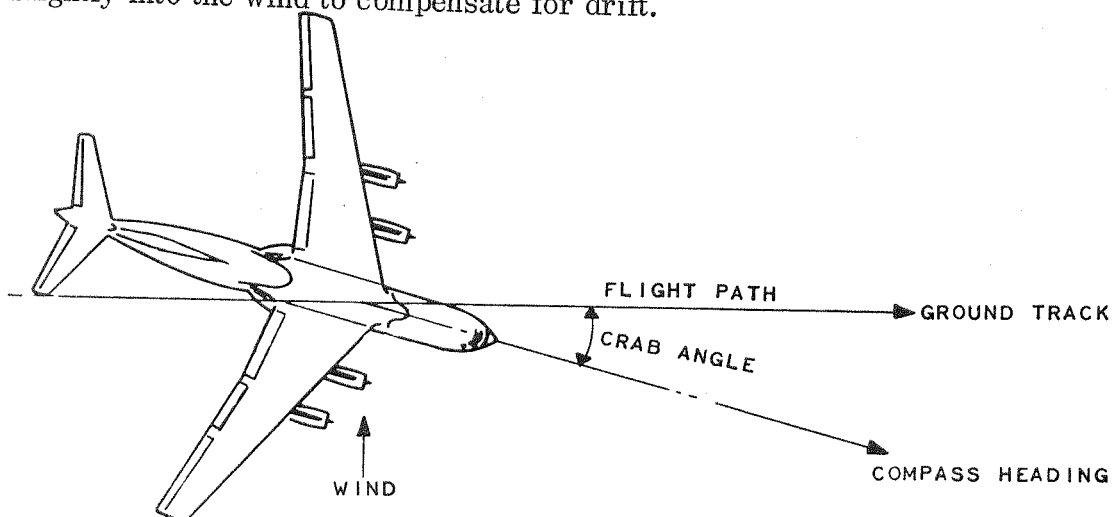
#### DOPPLER COMPUTER ASN-35

CHARACTERISTIC	SPECIFICATION
Power requirements	28 volts, DC 115 volts, AC, 400 Hz 26 volts, AC, 400 Hz
Maximum DISTANCE-TO-GO Readout	999 NM (99.9 NM in DROP mode) (1 NM steps in NAV 0.1 NM steps in DROP)
Maximum CROSSTRACK Readout	99.9 NM (9.99 NM in DROP mode) (0.1 NM setp in NAV 0.01 NM steps in DROP)
Desired track angle	000.0 to 359.9 degrees
Altitude	50,000 feet maximum
Ambient temperature	-55°C (-67°F) to + 55°C (+131°F)

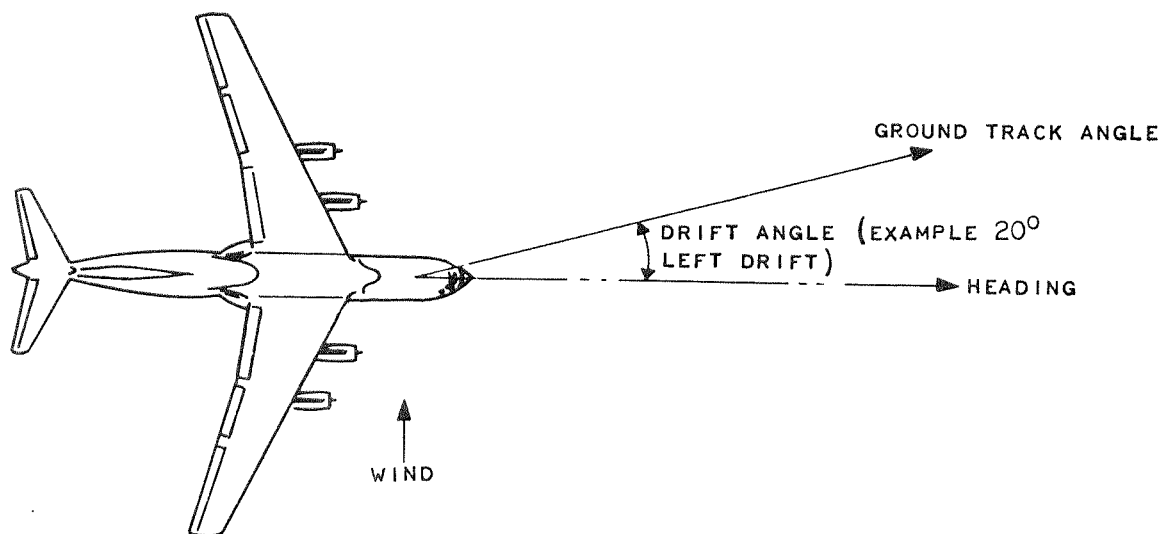
### BLOCK DIAGRAM THEORY OF OPERATION

The ground track (course) information from the Doppler radar antenna is

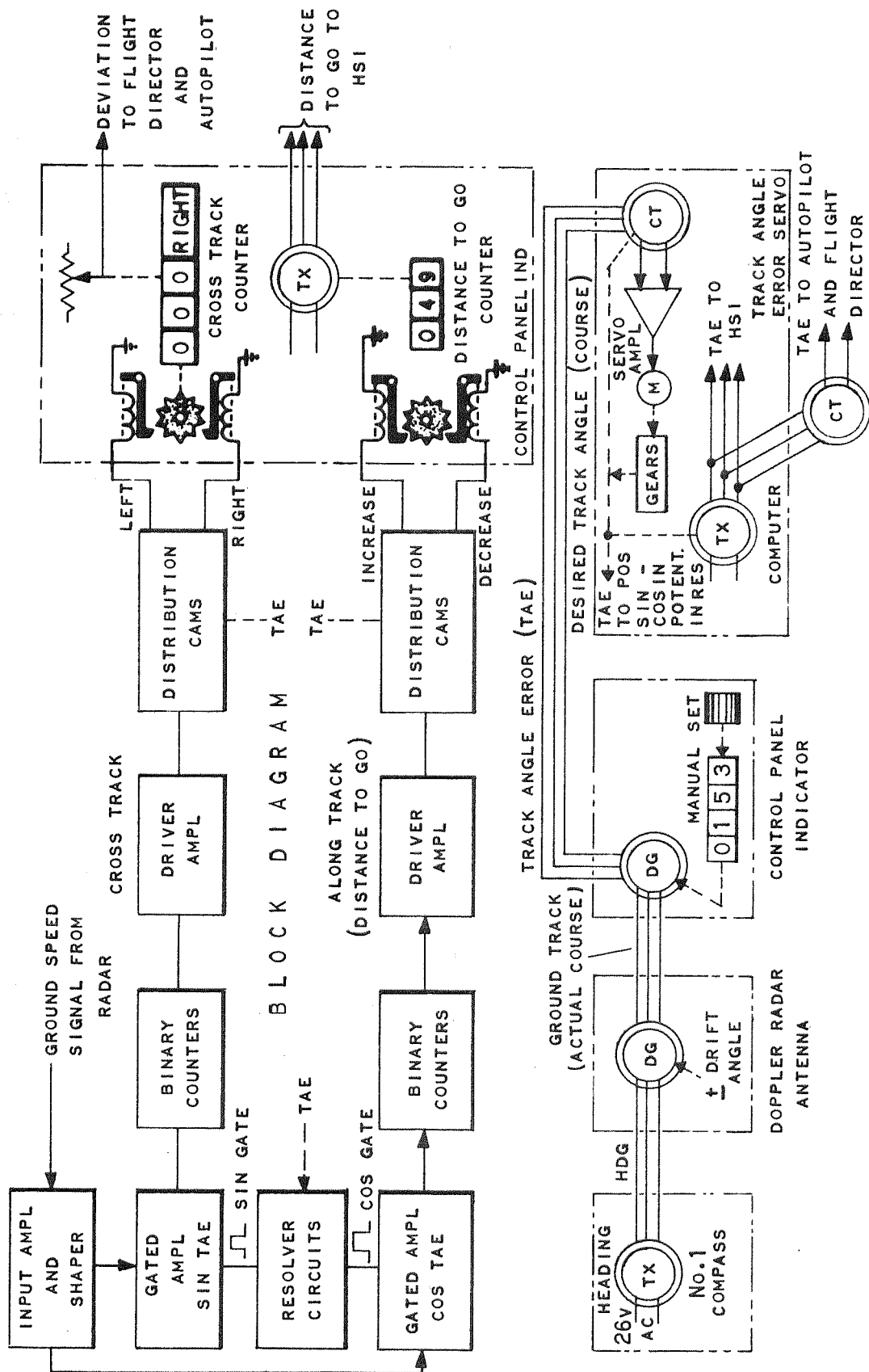
compass heading plus or minus the drift angle of the aircraft. The ground track information represents the actual path of the aircraft over the earth regardless of aircraft heading. The aircraft illustrated is crabbing (heading) slightly into the wind to compensate for drift.



If the aircraft is not crabbed to compensate for wind, it will be blown off course at the drift angle. Drift angle is therefore opposite the crab angle.



The radar ground track information representing the actual path of the aircraft is a 400 Hz 3 wire synchro signal. The track angle error loop diagram will show that the actual ground track is compared with the desired track the navigator manually selects at the control panel. The resultant signal from the Differential Generator (DG) is 3 wire, 400 Hz, representing the off course difference between the actual track and the selected track. Difference between the two is called



TRACK ANGLE ERROR LOOP

Track Angle Error (TAE). TAE will adjust the computer for proper control panel readings for any difference (TAE) in actual course (track) and selected course (track).

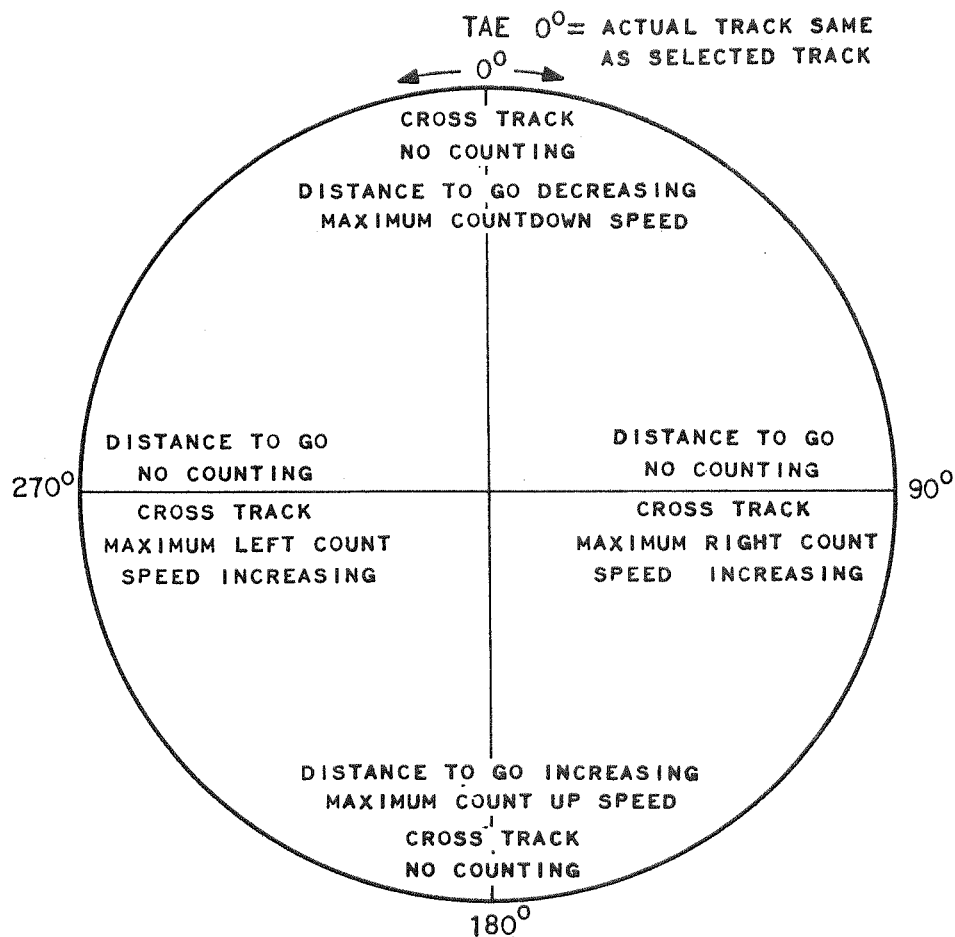
The TAE signal positions a servo in the computer. The TAE servo motor shaft positions a sine-cosine potentiometer in the resolver circuits. The sine-cosine potentiometer effectively multiplies the Doppler ground speed signal by the sine (cross track) and cosine (along track distance to go) of the TAE. When the aircraft is on course TAE is zero degrees. The ground speed signal will be multiplied by 0 (sine) and 1 (cosine). Ground speed information will drive the selected stage distance to go counter at the rate determined by the cosine ground speed. No cross track counting will occur. When the aircraft is not on course, TAE will occur multiplying the ground speed signal to the distance to go circuits by a cosine less than 1 slowing the distance to go countdown.

Cross track (LEFT or RIGHT) will occur at a rate determined by off course flight (TAE) because the ground speed to the cross track circuits is multiplied by a sine more than 0. If the aircraft course is to the right of the desired course (clockwise TAE) RIGHT CROSS TRACK counting will occur. If the TAE is counterclockwise LEFT CROSS TRACK counting will occur.

Since TAE results from off course conditions the TAE illustration shows the control panel counting for four TAE angles. At intermediate angles the ground speed must be multiplied by the sine and cosine of the TAE to determine rate of counting.

The radar ground speed square wave audio signal is converted to pulses which are coupled to sine and cosine gated amplifiers. The turn on (gated) times for these amplifiers are determined by the sine-cosine potentiometer. There is an exact number of pulses for each nautical mile the aircraft travels. At 0 or 180 degrees TAE (cosine = 1, sine = 0) the cosine amplifier is turned on passing the pulses to the along track binary counters. The number of pulses per mile is divided by the counters and produce one pulse output to the control panel distance-to-go solenoid indicator for each mile traveled in "NAV" mode and for each tenth mile traveled in "DROP" mode.

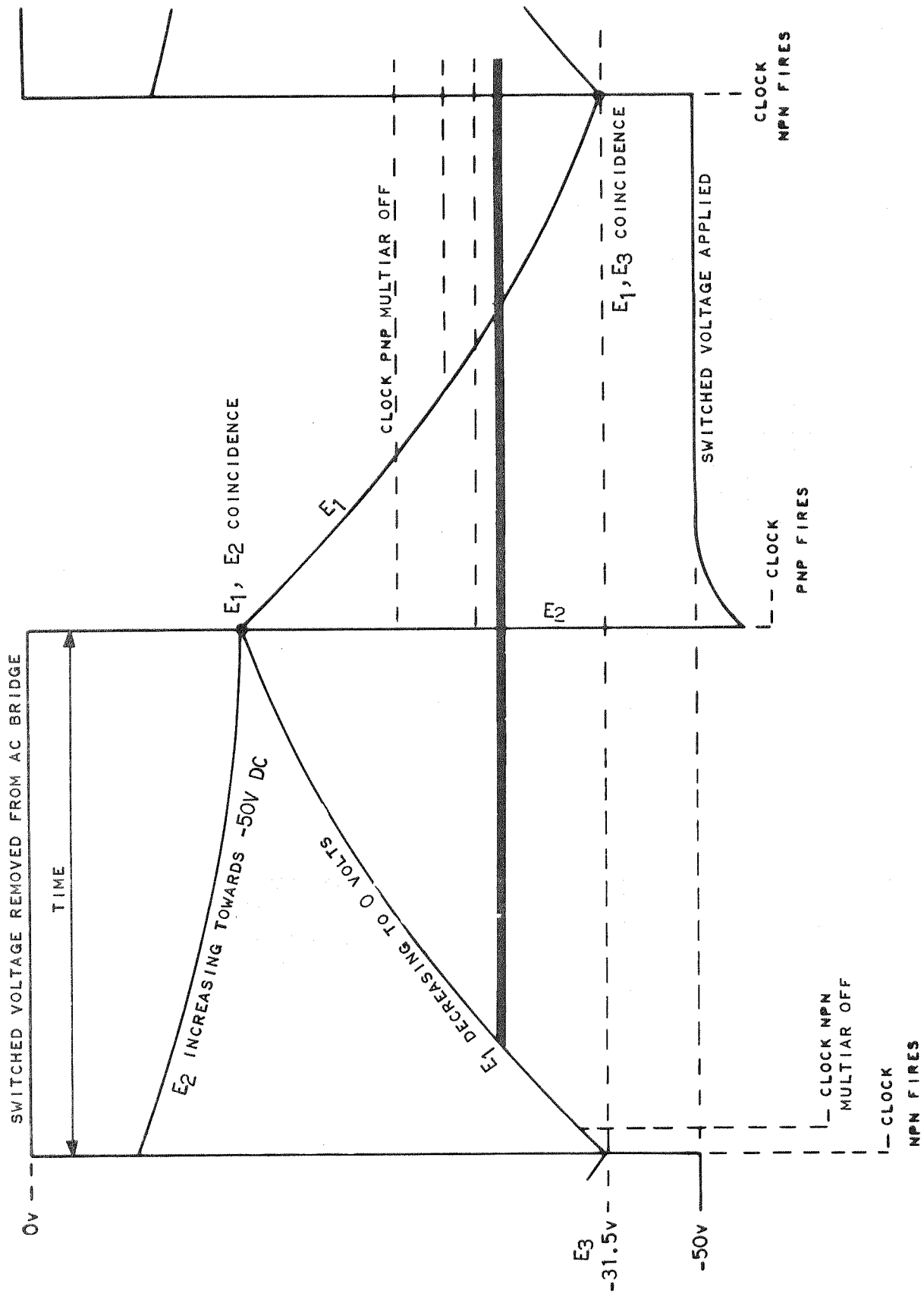
Since the sine is 0, the crosstrack binary counters receive no pulses and no cross track counting occurs. At 90 or 270 degrees TAE (cosine = 0, sine = 1) the sine amplifier is "ON," passing the pulses to the cross track binary counters which produce one pulse output to the control panel CROSS TRACK solenoid indicator for each tenth mile traveled in "NAV" mode and for each hundredth mile traveled in "DROP" mode. TAE shaft driven cam switches select the proper solenoid in the CROSS TRACK and DISTANCE TO GO indicators on the control panels.



At 0 to 90 degrees TAE the RIGHT cross track and decrease distance-to-go solenoids are selected. At 90 to 180 degrees TAE the RIGHT cross track and increase distance-to-go solenoids in the control panel are selected. At 180 to 270 degrees the LEFT and increase solenoids are selected. At 270 to 360 degrees the LEFT and decrease solenoids are selected. The choice of STAGE I or STAGE II groups of solenoids are selected at the control panel by switch C.

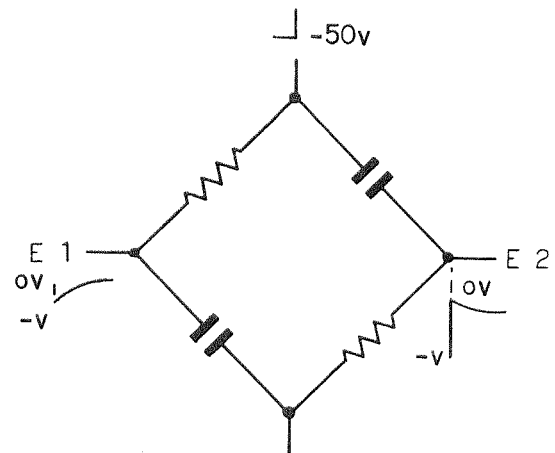
#### DETAILED ANALYSIS OF RESOLVER OPERATION

The ground speed frequency from the APN-147 passes through a computer start relay that is energized at lift-off. The ground speed audio frequency square wave is converted into pulses by the Schmitt trigger circuit. Pulse width is constant throughout the range of the Doppler frequencies. In order for the ground speed signal to be resolved into distance to go, a time base (clock) must be used. The clock will turn the computer counting on and off 16 times per second. An



RESOLVER CLOCK WAVEFORMS

A-C bridge is used as a clock reference. As shown on the Resolver Clock Waveforms diagram, a 50-volt, D-C switched level is removed from the bridge. Terminal E-1 is exponentially decreasing to zero volts while E-2 is exponentially increasing to a negative 50 volts. At some point in time the two voltages will coincide. A PNP clock multiar detects this coincident point and starts to oscillate. A multiar is basically a blocking oscillator whose firing point is determined by comparing



S I M P L I F I E D C L O C K  
A - C B R I D G E

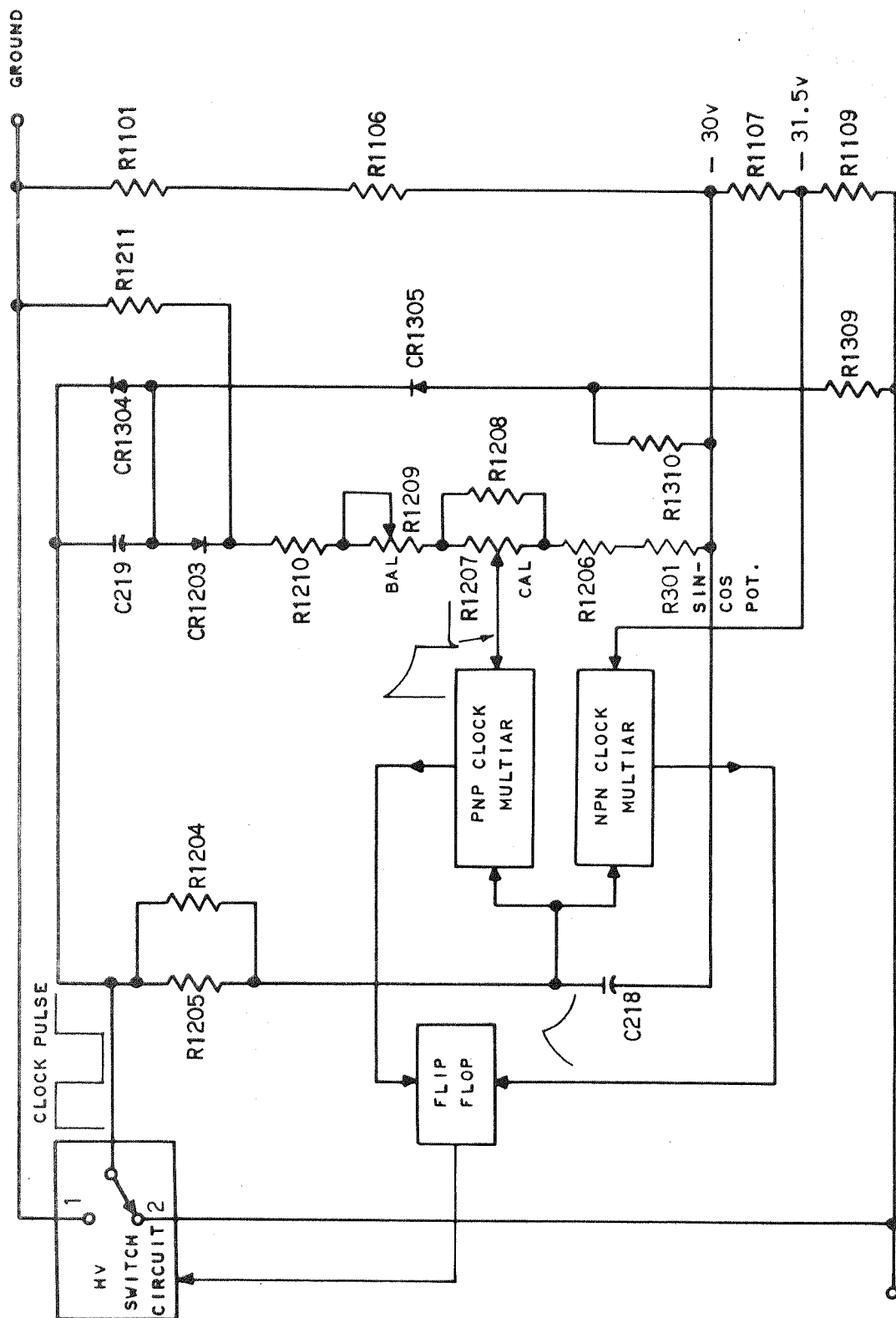
two input voltages, one increasing and one decreasing at an exponential rate. The oscillation is used to operate a flip-flop which then operates a high voltage switch to reapply the minus 50-volt level. The capacitors in the bridge then are driven towards minus 50 volts. At some point in time as E-1 increases (negatively), it will coincide with a minus 31.5-volt reference (E3). An NPN clock multiar detects this coincident point and starts to oscillate, returning the flip-flop and high voltage switch to the initial condition. This process continues, generating a 16 Hz square wave clock on pulse at each cycle. The clock on half of this square wave is the active time for the computer.

Using the clock as a time reference the resolver will produce a fixed delay gate, a variable cosine gate, and inversely variable sine gate. The delay gate momentarily turns off the delay gated amplifier at the beginning of each clock on time to assure that the Doppler ground speed pulses reach both the cosine and sine gated amplifiers simultaneously.

As the high voltage switch applies voltage to the A-C bridge (clock on), E-1 decreases and E-2 increases. E-1 decreases toward 0 volts exponentially from the minus 31.5-volt reference. When E-1 reaches minus 30 volts, the delay multiar oscillates, triggering the delay flip-flop ending the delay gate, allowing the delay gated amplifier to pass the ground speed pulses to the cosine and sine gated amplifiers.

The function of the sine-cosine resolver is to resolve track angle error into its sine and cosine components.

Each clock on time enables the start of the sine and cosine gates. As E-1 decreases toward 0 volts, it will reach a variable amplitude portion of E2, which is picked off by the sine arm of the sine-cosine potentiometer whose



SIMPLIFIED CLOCK CIRCUIT







shaft is positioned by the track angle error servo. The coincidence of E1 and E2 fires the sine multiar which triggers the sine flip-flop ending the sine gate. The voltage E1 decreases further, meeting another variable amplitude portion of E2 picked off by the cosine arm. The cosine multiar oscillates at the coincidence of E1 and E2 triggering the cosine flip-flop ending the cosine gate. A still further decrease of E1 permits the clock multiar to oscillate, triggering the clock flip-flop ending the clock on time.

The number of ground speed pulses that pass to the binary counters is controlled by the time length of the sine and cosine gates. At 20.66 Hz from the radar with a ground speed of one nautical mile per hour (knot) there are 74,376 ground speed pulses from the pulse shaping circuits. Since the maximum on time of the cosine and sine gated amplifiers is less than clock on (50 percent of time) only 40.33 percent (30,000) of the pulses are passed to the binary dividers.

When the Doppler radar set control is in "SEA" mode the Doppler ground speed signal is 20.48 Hz/knot. Radar "SEA" mode activates a sea mode relay in the computer changing the clock reference voltage from minus 50 to minus 50.9 volts, DC, increasing the sine and cosine gate lengths allowing more pulses to pass to the binaries, thus compensating for lower ground speed signal. All other radar mode switching will change the binary counting.

#### DETAILED ANALYSIS OF DISTANCE COUNTING

The 30,000 pulses per mile traveled along track must be reduced (divided) to one (1) pulse per mile (computer "NAV" mode) to actuate the DISTANCE-TO-GO solenoid indicator. The along track binaries divide by 30,000. The cross-track binaries divide by 3,000 providing 10 pulses per cross track mile traveled actuating the cross track solenoid. In computer "DROP" mode the along track binaries, dividing by 3,000, produce 10 pulses per mile traveled while the cross-track binaries, dividing by 300, produce 100 pulses for each crosstrack mile traveled.

In radar "Smooth Sea" mode the binary division is changed as follows:

10,000	-	along track	-	computer "NAV" mode
1,000	-	cross track	-	computer "NAV" mode
1,000	-	along track	-	computer "DROP" mode
100	-	cross track	-	computer "DROP" mode

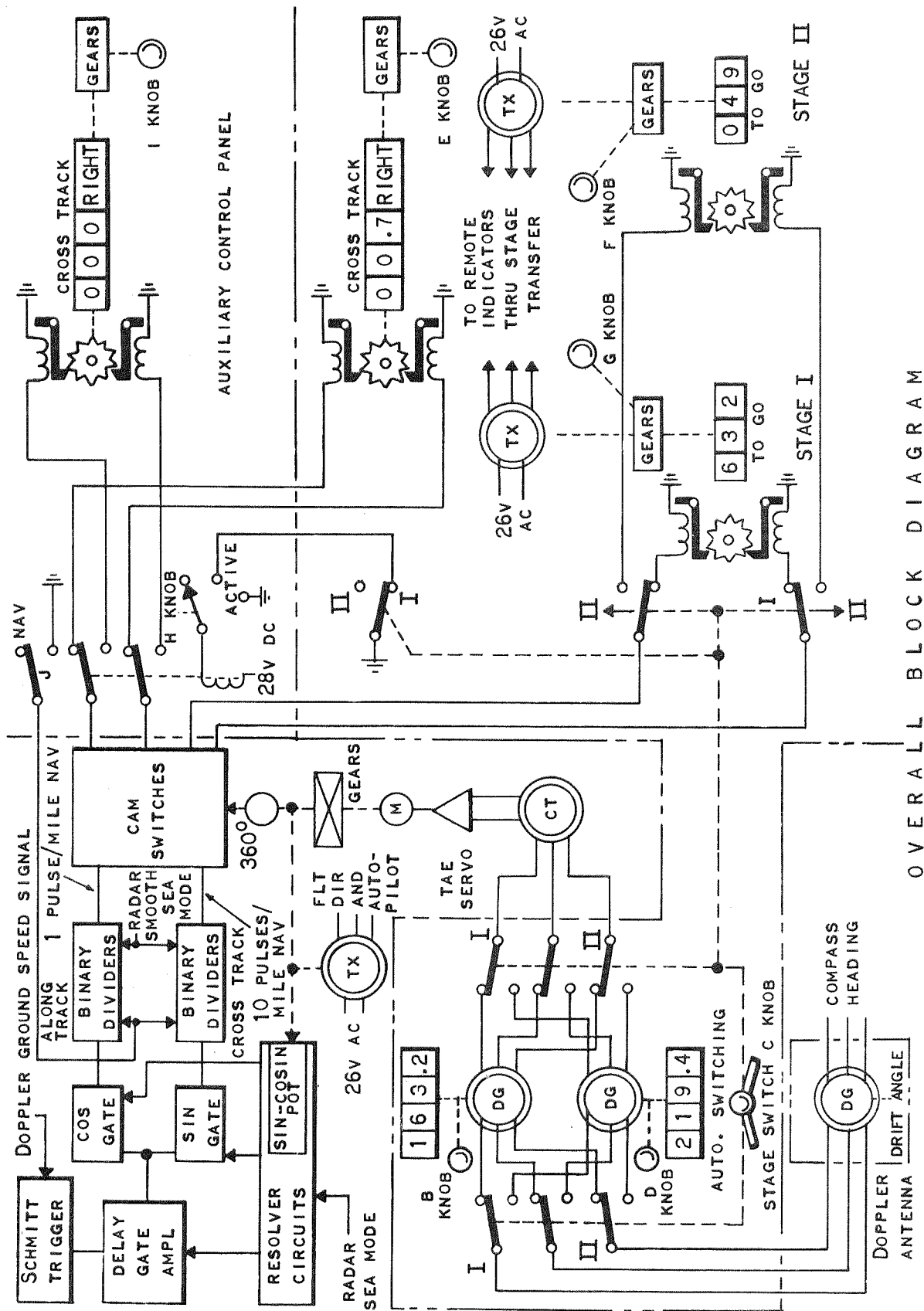
This change in division compensates for the low ground speed signal produced by the radar in Smooth Sea. The control panel indicators remain normal as determined by the computer "NAV-DROP" mode.

The changes in binary division are accomplished by relays. The relays are controlled by Smooth Sea or not Smooth Sea radar modes and by "NAV-DROP" computer modes. The relay contacts alter binary divider feedback circuits changing the binary division.

Since the sine and cosine functions repeat in TAE changes up to 360 degrees, it is necessary for TAE to position cam operated switches to select the proper indicator solenoids. As mentioned earlier, there are four combinations of solenoid selections.

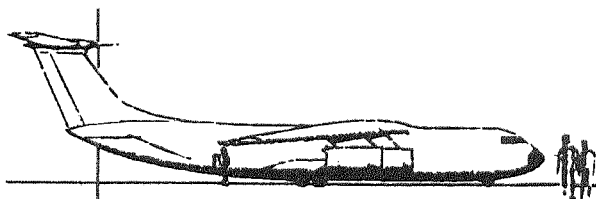
TAE	Distance-to-go Solenoid	Crosstrack Solenoid
0 to 90 degrees	Decrease	RIGHT
90 to 180 degrees	Increase	RIGHT
180 to 270 degrees	Increase	LEFT
270 to 360 degrees	Decrease	LEFT

It can be seen from the overall block diagram that TAE is fed by a synchro transmitter to the autopilot and flight director system. The distance to go is also transmitted to the flight director. The cross track gear boxes in both control panels mechanically drive potentiometers providing the flight director with plus or minus D-C deviation voltage and the autopilot with reversable phase, A-C deviation voltage.



OVERALL BLOCK DIAGRAM





## NAVIGATIONAL COMPUTER SET

GENERAL

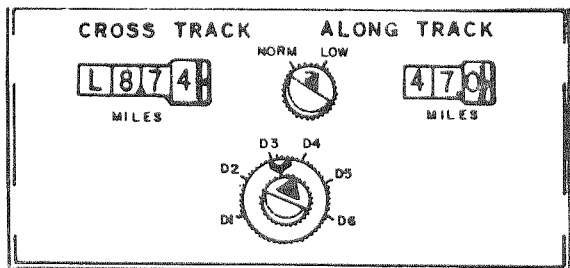
The ASN-24 is a general purpose, airborne, serial digital computer used to provide automatic solutions to aircraft navigation problems. Inputs inserted manually and from associated navigational sensors (TACAN, LORAN, etc.) are used to provide a continuous present position indication. Great circle range and bearing to a primary destination or to any of five intermediate or alternate destinations are available for readout by the navigator and for autopilot command. Control indicators provide for readouts of wind, ground speed, track, cross track, and along track distance, true heading and celestial parameters.

Track angle error, cross track deviation and distance to go are also provided as outputs for pilot's displays and autopilot guidance. Distance-to-go information is also supplied to the vertical navigation systems.

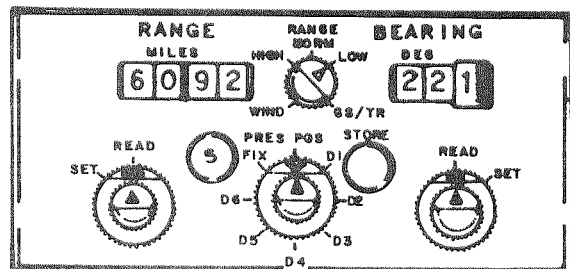
AIRCRAFT INSTALLATION

Eleven components of the ASN-24 navigational computer are installed as follows:

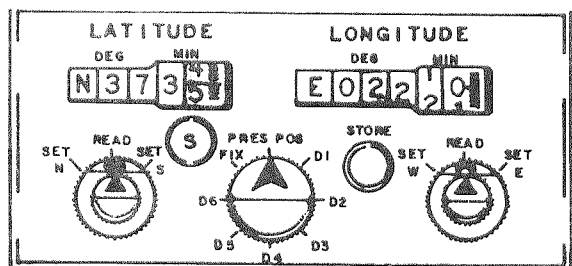
<u>Part No.</u>	<u>Name</u>	<u>Installation</u>
CP-641/ASN-24	Computer	Left Hand Avionics Rack
PP-3214/ASN-24	Power Supply	Left Hand Avionics Rack
C-3961	Control Indicator	Navigator's Inst. Panel
C-3962	Control Indicator	Navigator's Inst. Panel
C-3963	Control Indicator	Navigator's Inst. Panel
C-3964	Control Indicator	Navigator's Inst. Panel
C-3965	Control Indicator	Navigator's Inst. Panel
C-6214	Control Indicator	Navigator's Inst. Panel
C-6213	Control Indicator	Navigator's Inst. Panel
	Switch, Ground Test	Navigator's Inst. Panel
	Control Input Selec.	Navigator's Inst. Panel



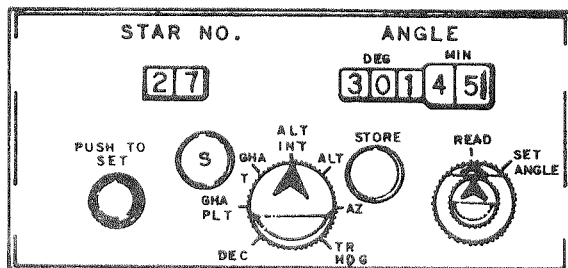
ALONG TRACK-CROSS TRACK CONT IND



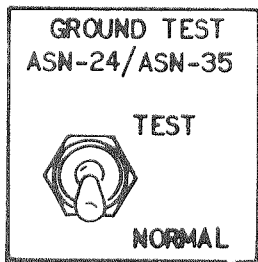
RANGE-BEARING CONTROL IND



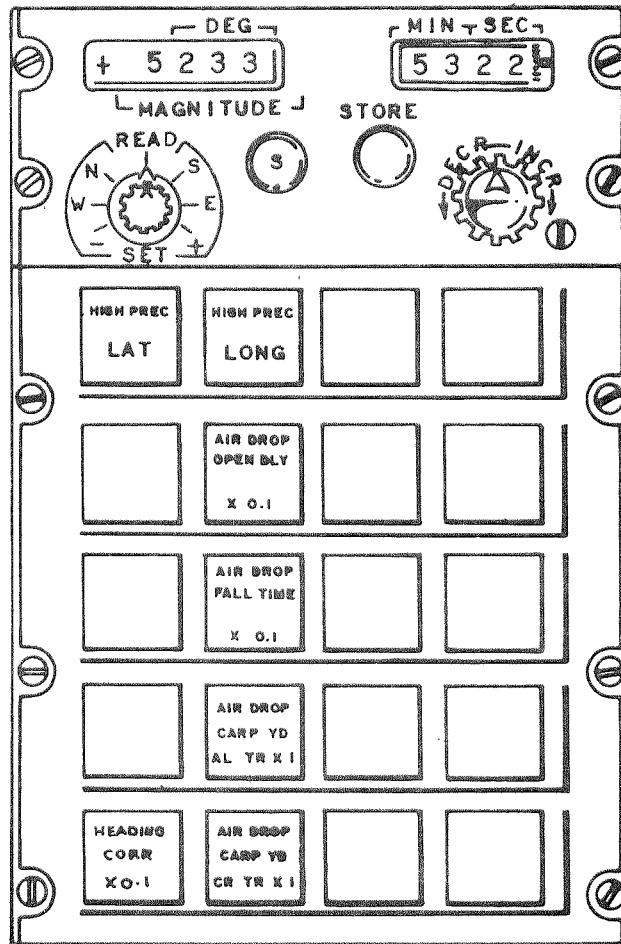
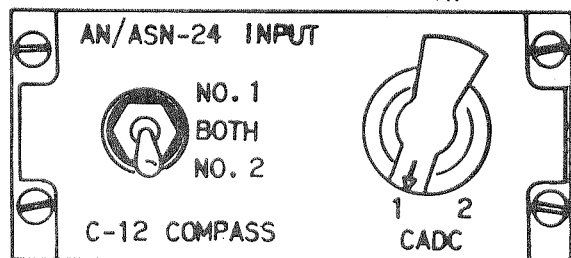
LATITUDE-LONGITUDE CONTROL IND



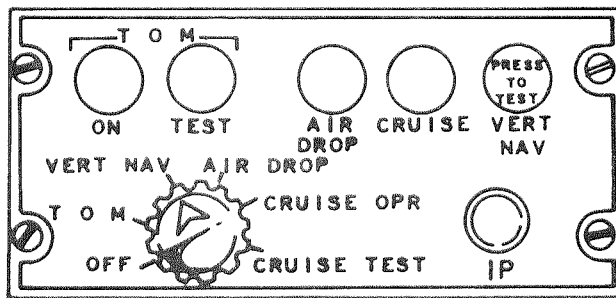
CELESTIAL DATA CONTROL IND



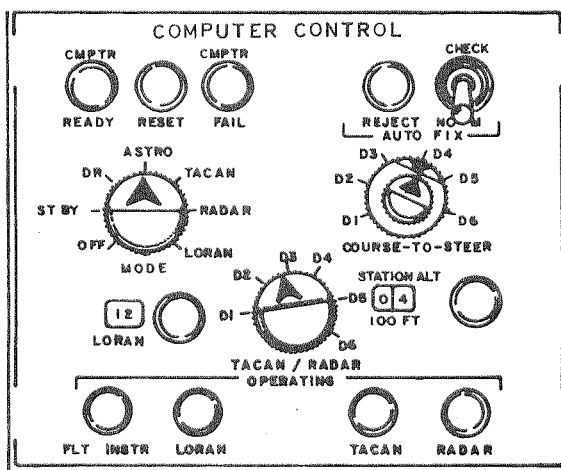
CONTROL INPUT SELECTOR



INITIAL CONDITION CONTROL IND



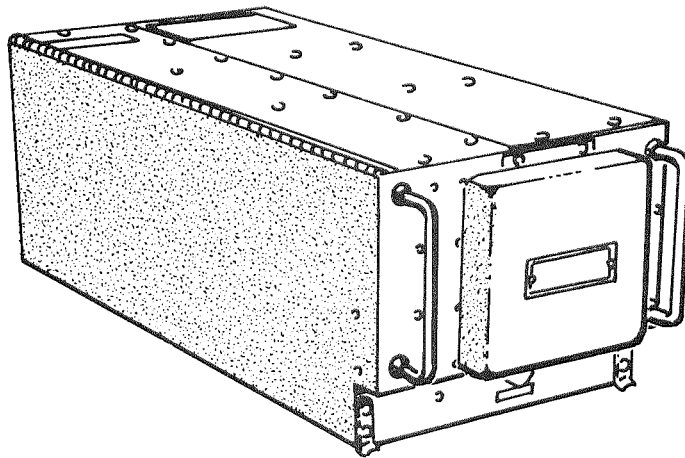
MODE CONTROL INDICATOR



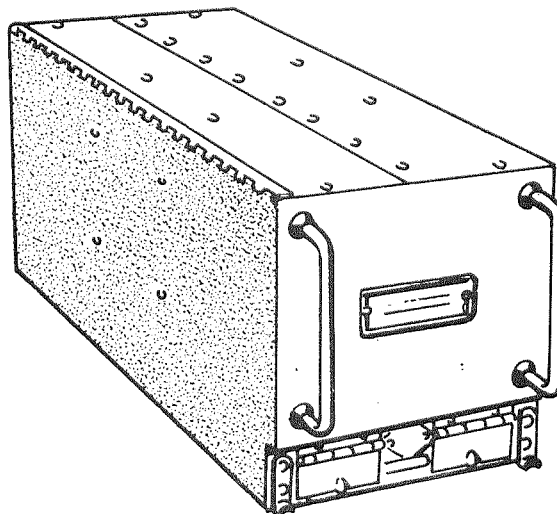
ASN-24 CONTROL PANELS



CONVERTER CHASSIS - POWER SUPPLY PP3214



NAVIGATIONAL COMPUTER CP641



ASN - 24 COMPUTER AND  
POWER SUPPLY

Power required for system operation is supplied from the main avionics bus No. 1 (115 volts, AC, 400 Hz), navigation bus No. 1 (26 volts, AC, 400 Hz), and the main avionics bus No. 1 (28 volts, DC). Circuit breakers for the system are on the avionics circuit breaker panel at the navigator's station.

## SYSTEM OPERATION

The navigational computer operates in five different modes and controls the air-drop operation. The mode selected is dependent upon navigational requirements, operators settings, and operational status of associated equipment. Inputs to the computer system include:

SENSOR	INFORMATION
TACAN No. 1	Bearing and range of TACAN stations. TACAN validity.
LORAN C	Time delay of Slave A and B. LORAN validity.
Search Radar	Ground range and azimuth of selected Radar target: Radar transfer information.
Central Air Data Computer	True airspeed, mach number and pressure altitude.
Gyro Compass	Heading (gyro or magnetic) and heading validity.
Doppler Radar	Ground speed and drift angle. Validity and system mode (land, sea, or smooth sea) operation.

Outputs from the computer include the visual readouts on navigator's and pilot's navigational indicators, autopilot steering signals and distance-to-go to the vertical navigation computer.

### DEAD-RECKONING MODE

In dead-reckoning (DR) the computer set utilizes the best available combinations of magnetic and directional gyro inputs. A true heading is derived from the magnetic-heading input by applying corrections for magnetic variation. True heading is also obtained from the directional-gyro input corrected by an offset angle and continuously corrected for the earth's rate and the earth's transport-precession effects. Wind information is computed from the Doppler Radar input. In the event of invalid Doppler Radar information, DR continues using the CADC true airspeed and the last remembered wind or manually inserted wind.

## TACAN MODE

The TACAN (Tactical air navigation) mode provides an automatic computation of present position using TACAN range and bearing data. The resulting positions fix is used to correct the present position determined by dead-reckoning. The TACAN bearing received by the computer set is corrected for magnetic variations. The TACAN slant range is converted to ground range using aircraft altitude and TACAN station altitude. TACAN station altitude is manually set in by the operator. TACAN computations are automatically interrupted if the aircraft enters the cone of confusion. When "TACAN" information is selected to update dead-reckoning information, a credibility test is applied to validate it. If the credibility test is passed, a weighing factor is applied and the present position is automatically corrected.

## RADAR MODE

The geographical coordinates of a selected radar target are set into the computer when operating in the "RADAR" mode. The distance and azimuth of the target are selected by converging crosshair-type markers upon the target in the APN-59B search radar presentation. The exact geographical coordinates of the target are set into the computer prior to insertions of the radar fix. A credibility test is applied to the fix information from the APN-59 and if it is valid the fix information is used to update the dead-reckoning position.

## LORAN MODE

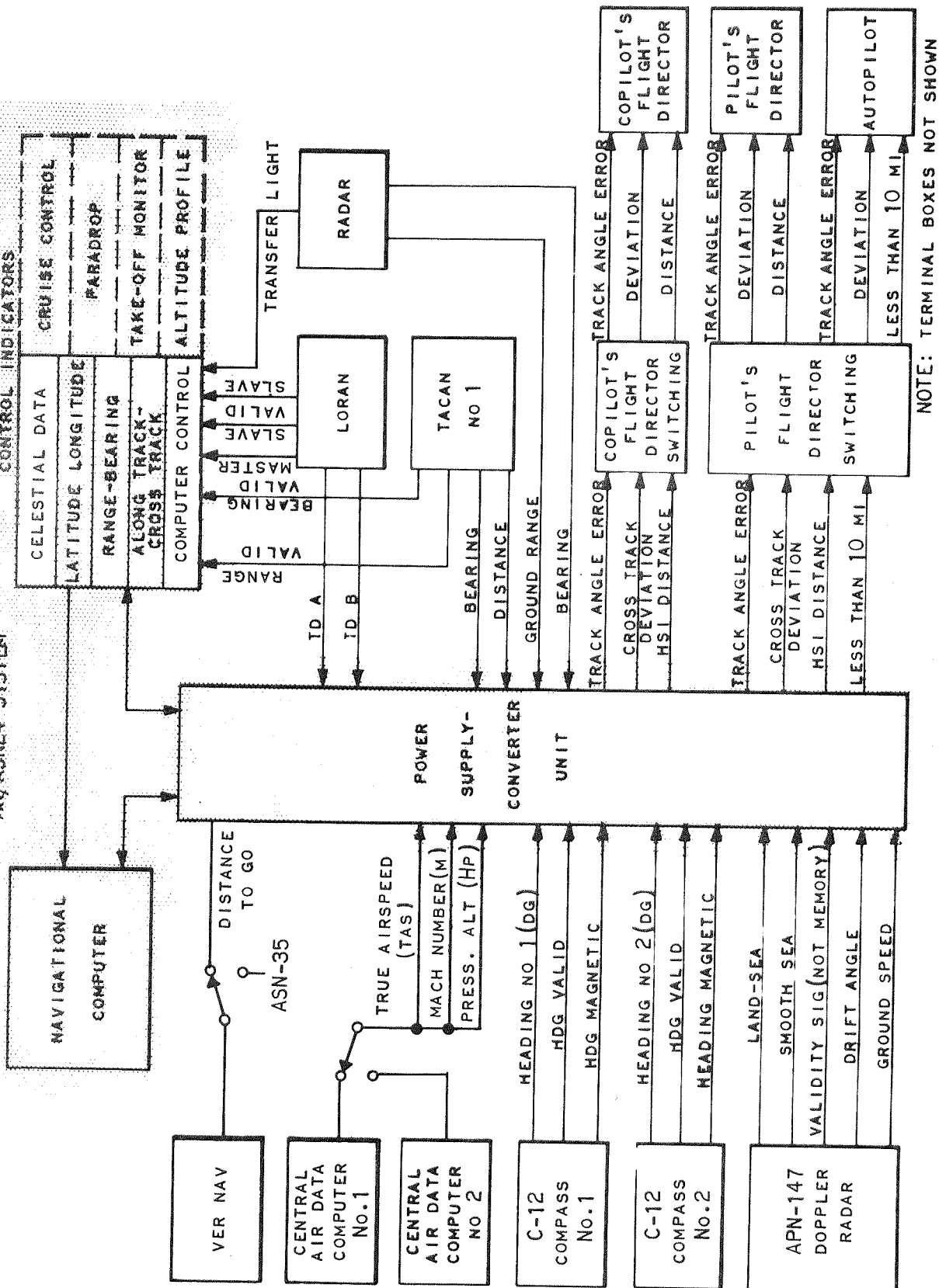
The computation of a navigational fix, using the LORAN receiver, is accomplished in the "LORAN" mode of operation. Geographical positions for the LORAN C master ground station and slave A and B are manually inserted by the operator. The LORAN position is computed and compared with the dead-reckoning position. If the LORAN fix is within the credibility limits, then a series of corrections are made to the dead-reckoning computations. Radio propagation and earth's spheroidal shape correction values are applied to the computed great circle range of each LORAN transmitter.

## ASTRO MODE

Provisions are made in the computer to control and accept star data from an external Astro-Tracker. Celestial data may also be manually inserted into the computer. Presently the Astro-Tracker is not installed in the StarLifter.

## AIRDROP FUNCTION

In the airdrop submode the computer provides a high-precision, continually updated, Computed Air Release Point (CARP) and steering information for guiding the aircraft to that CARP. Information stored by the navigator include the



NOTE: TERMINAL BOXES NOT SHOWN

AN / ASN - 24 DATA FLOW DIAGRAM

geographical coordinates of the Initial Point (IP), parachute ballistics and coordinates of the drop zone.

## COMPUTER SET INPUTS

Inputs and outputs of the navigational computer set are shown in the simplified Data Flow Diagram. Inputs to the set are as follows:

- Central Air Data Computers No's. 1 and 2
- Gyro-Magnetic Compasses No's. 1 and 2
- APN-147 Doppler Radar System
- APN-157 LORAN
- APN-59 Search Radar
- ARN-21C TACAN No. 1

In addition to the navigational sensor inputs listed, many parameters may be inserted manually. Manual inputs will be discussed with the appropriate control indicator.

Outputs of the computer are displayed on the control indicators. In addition to these indications the following signals are furnished for pilot's indicators, auto-pilot guidance, and the vertical navigation system:

- Track Angle Error
- Cross Track Deviation
- HSI Distance
- Distance-to-go to the Vertical Navigation Computer

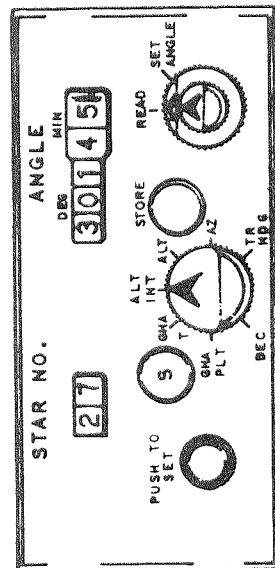
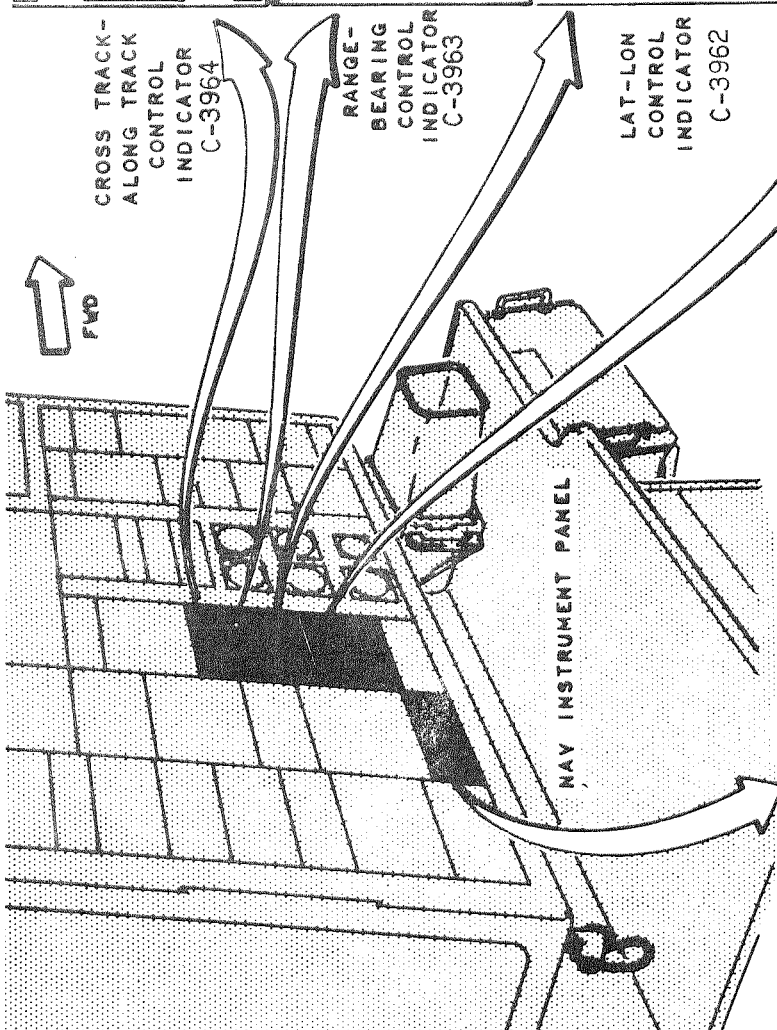
## CONTROL INDICATORS OPERATION

### COMPUTER CONTROL C-3961

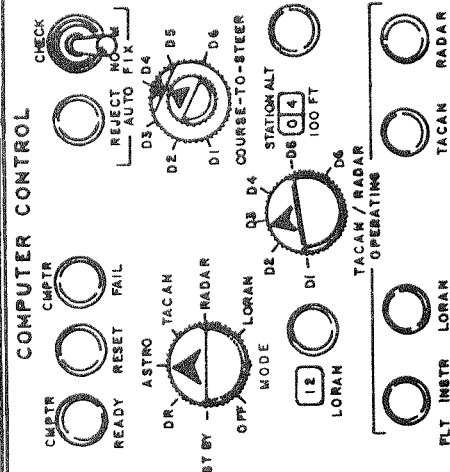
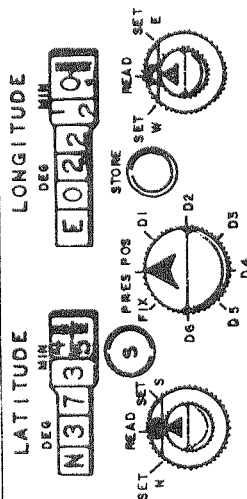
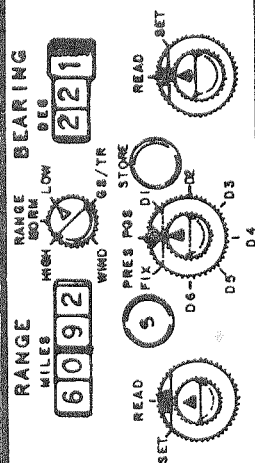
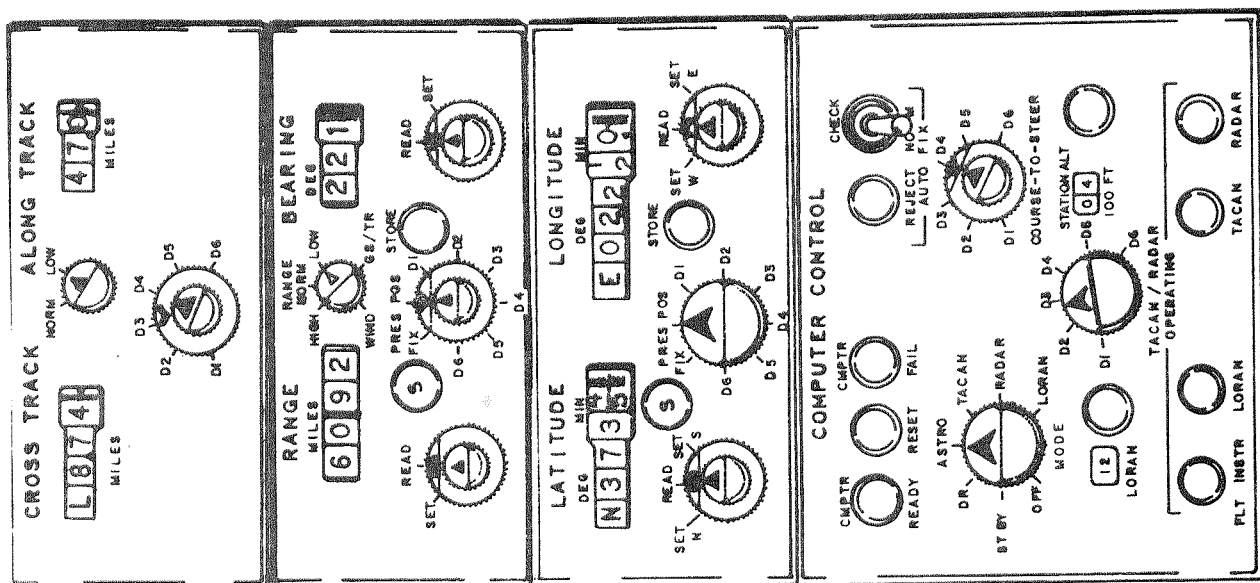
This control is used to energize the computer and to establish the operational mode. It is also used to indicate the validity of a fix and the operational status of associated navigational equipment. The operational mode is selected by the MODE switch. The positions of the switch are:

- "OFF" - Computer deenergized.
- "STBY" - Computer on standby basis.

No updating of dead-reckoning position but information may be inserted into the computer.



CELESTIAL DATA CONTROL INDICATOR  
C-3965



AN / ASN - 24 NAVIGATIONAL COMPUTER  
SYSTEM CONTROL PANELS

- "DR" - Computer is operational and dead-reckoning is updated according to heading, ground speed, and drift information.
- "ASTRO" - Provisions for updating of dead-reckoning information by an external Astro-Tracker (not installed at present).
- "TACAN" - Dead-reckoning navigation is updated by range and azimuth information from a TACAN station. The geographical coordinates of the TACAN station must be inserted by the operator.
- "RADAR" - Dead-reckoning information is updated by fixes made by the APN-59 Radar system. Insertion controls are part of the APN-59 Radar system. The operator must manually store the coordinates of the Radar target prior to updating the dead-reckoning position.
- "LORAN" - Position fixes of the APN-157 are used to update the dead-reckoning position. Coordinates of the LORAN master and slave stations must be inserted by the operator.

It may be noted that the LORAN and TACAN positions provide continuous updating. The Radar position is a "one-time" update but may be repeated each time the operator places the APN-59 cross hairs upon the selected target and depresses the coordinate insertion button on the APN-59 precision marker control panel.

The CMPTR READY indicator signifies, when lit, that the computer has finished its warmup period and is ready to operate. The CMPTR FAIL indicator, when illuminated, shows that the computer has failed to correctly solve an internal test problem. The RESET button is used to reset the CMPTR FAIL circuit. In the event of continued failure of the computer to solve the self-check test the CMPTR FAIL indicator will re-light. The AUTO-FIX-REJECT indicator will illuminate when the computer determines that the fix being used to update dead-reckoning position is not credible. The credibility test is a 30-nautical-mile limit on the acceptable difference between dead-reckoned present positions and the position determined by the latest selected fix. If the distance is greater than 30 miles, the AUTO-FIX-REJECT indicator will illuminate and the fix is rejected by the computer unless it is stored manually by the operator. Manual storage is used when it is determined that the computer dead-reckoning position is not correct. The AUTO-FIX-CHECK-NORM switch allows the inspection of a fix before inserting into the computer. In the "CHECK" position, the auto-fix is read out on the LATITUDE-LONGITUDE control indicator but is not used to update dead-reckoned present position. In the "NORM" position credible fixes are accepted by the computer.

The COURSE-TO-STEER control consists of two concentric knobs. The outer or larger knob with the symbol ◀ (from) selects the coordinates of the departure or base point. The smaller or inner knob with the symbol ▶ (to) selects the coordinates of the desired destination. Selections on these knobs will control track angle error, cross track deviation and distance data utilized by flight instruments and autopilot.

The TACAN/RADAR selector switch is used to define the longitude, latitude and altitude of a TACAN station or Radar fix location that the computer will use when the MODE selector switch is in "TACAN" or "RADAR" position.

The LORAN switch and indicator are used to insert or read out the coordinates of LORAN master and slave stations. Present usage of the different numerical position is as follows:

<u>LORAN Selector Position</u>	<u>Selects for Storage or Readout</u>
1	Loran Master
2	Loran Slave A
3	Loran Slave B
4	Initial Point
5-12	General fixes

Readouts or insertions are made on the LATITUDE-LONGITUDE control indicator.

The STATION ALT indicator and knob are used to insert the altitude of a radar fix point or of a TACAN station when the coordinates are being stored into the computer. The value of altitude is automatically stored with the geographical coordinates and is used in converting slant range to ground range.

The OPERATING indicators show auxiliary equipment status and are illuminated under the following conditions:

- FLT INSTR - Illuminated when ASN-24 is selected to control the autopilot and/or the flight instruments.
- LORAN - Illuminated when the APN-157 is locked on to a master station and slave A and/or B. Sky wave reception will also cause the lamp to extinguish as well as loss of lock-on.
- TACAN - Illuminated when TACAN No. 1 is locked on in range and/or azimuth.



## LATITUDE-LONGITUDE CONTROL INDICATOR C-3962

This control indicator provides the capabilities of storing or reading out latitude and longitude of selected locations. The LATITUDE and LONGITUDE counters indicate the coordinates selected by the destination switch. "PRESENT POSITION-FIX" coordinates may be selected by the destination switch in lieu of the "D1-D6" destinations. Each counter has an associated pair of concentric knobs. The outer knob in each set will determine if the counters are used for readout or insertion of data.

The inner knob is used to manually slew the counter to the value to be inserted into the computer. The STORE button initiates storage of the selected values of latitude and longitude. The STORE indicator will illuminate when storage information has been accepted by the computer. The STORE button should not be released until the STORE indicator illuminates. Storage of LORAN fixes is accomplished with the destination switch in the "FIX" position. When the LORAN switch on the COMPUTER CONTROL panel is in No's. "1, 2, 3, or 4", and the destination switch on the C-3962 control indicator is on "FIX" the counters will readout the coordinates of the selected LORAN fix. Storage of LORAN coordinates is also accomplished with the destination selector on "FIX" and the LORAN switch on positions "1, 2, 3, or 4". Storage is initiated on the C-6214 initial condition indicator. When the LORAN selector switch is in positions "5" through "12" and the destination switch in the "FIX" position the counter readout will be the selected Radar or TACAN fix. Storage of Radar and TACAN coordinates is accomplished by placing both destination dials in the C-3962 and C-3961 to the same "D" number. Slew the counters to the appropriate values and depressing the STORE button on the C-3962 until the store light illuminates. After insertion the value of the coordinates may be checked by returning the counter READ-SET controls to "READ".

## RANGE AND BEARING INDICATOR C-3963

This indicator is used to display range and bearing between points selected on the destination dial. (There are the same D1 -- D6 coordinates which were inserted on the C-3962 and C-3961 control indicators). Wind direction and magnitude and true ground speed are also selectable readouts.

Range and bearing readouts are available when the range selector switch is in the "HIGH", "NORM" or "LOW" position. The counter will indicate 0 - 9998 NM, 0 - 999.8 NM, and 99.98 NM respectively for the different positions. Range and bearing displayed is between the points selected on the concentric destination dials. The outer destination dial is marked ◀ (from). The inner dial is marked ▶ (to). Any combination of destinations as previously stored by the computer control and latitude-longitude control may be displayed. In addition, if the "from" dial is placed on "PRES POS" the range and bearing of any of the destinations

from present positions may be readout. When the selector switch is in the "WIND" position wind speeds of 0 to 1000 KN may be read on the RANGE counter. The wind direction will be readout on the BEARING counter. Wind values may be manually stored by moving the outer dials of the counter control knobs to "SET", slewing to desired values with the inner knobs and depressing the STORE button until the store lamp lights.

When range and bearing to a destination are known, they can be stored by way of the RANGE-BEARING control indicator. Range and bearing between positions selected on the destination selector switch are stored in the same manner as wind information except RANGE scale selector switch must be in the "HIGH", "NORM", or "LOW" position. When this store operation is performed the latitude and longitude of the destination (to) is automatically computed and stored in the "D" location.

The "GS/TR" position of the selector switch allows display of a ground speed and track on the range and bearing counters. Data cannot be stored manually in the range bearing control indicator when the selector switch is in the "GS/TR" position.

Wind values are normally computed from Doppler Radar information. If Doppler becomes inoperative or goes to memory the computer uses last known wind values. The operator can manually insert winds when the Doppler is inactive but valid Doppler information has priority and will override all previously inserted wind values. TACAN or LORAN fixes will also provide the computer with sources of wind information. Correction applied to presently indicated winds will be one-fourth of difference between wind from fix and last-remembered wind information. This weighing of data ensures smooth wind correction.

#### CROSS TRACK - ALONG TRACK CONTROL INDICATOR C-3964

This instrument indicates distance to go to the destination selected on the "to" dial of the destination dial and lateral deviation from the selected course (cross track). When the NORM-LOW switch is in the "NORM" position, ALONG TRACK counter indicates 0 to 1000 NM in .2 NM increments, CROSS TRACK scaling is 0 to 100 NM in 0.02 NM increments. When the switch is in the "LOW" position, scales are 0 - 100 NM, 0.02 increments for ALONG TRACK and 0 - 10 NM in 0.002 NM increments for CROSS TRACK.

#### CELESTIAL DATA CONTROL INDICATOR C-3965

This control indicator is used to set in the "read" celestial parameters. The PUSH TO SET button is used to select a particular star for insertion or readout of data. Storage of data is accomplished in a manner similar to the other control indicators. The READ-SET ANGLE outer knob is positioned to "SET ANGLE".

The counter is slewed to the desired value by the inner knob and the STORE button is depressed until the store light illuminates. The selector knob allows various parameters to be stored or read. The available positions are as follows:

- "DEC" - Read or store declination of celestial body selected by PUSH TO SET button.
- "GHA PLT" - Read or store Greenwich Hour Angle of selected sun or planet.
- "GHA T" - Store or read the Greenwich Hour Angle of the first point of Aries.
- "ALT INT" - Read altitude intercept, (difference between the calculated and actual elevation angle of the selected celestial body.
- "ALT" - Elevations cycle of the celestial body.
- "AZ" - Read true bearing of the celestial body.
- "TR HDG" - Read aircraft true heading.

#### MODE CONTROL INDICATOR C-6213

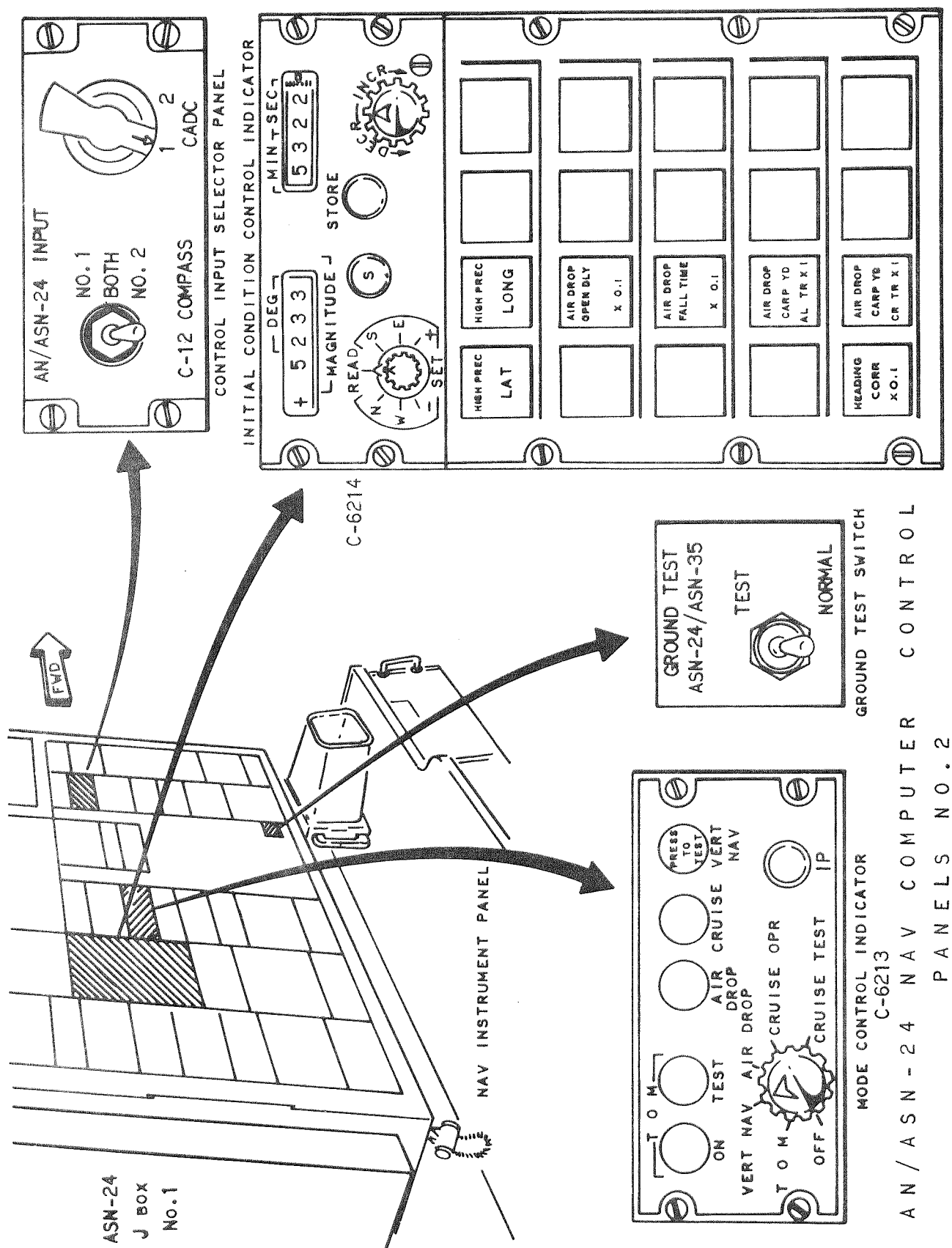
This indicator is used in the air drop mode of operation, "TOM", "VERT", "NAV", "CRUISE OPR" and "CRUISE TEST" positions of the selector switch are not presently used. The "VERT NAV" position should not be confused with the AWLS Vertical Navigation which is a different system.

When the mode control selector switch is in the "AIR DROP" position, the computer is alerted to compute air drop functions. The AIR DROP indicator illuminates when the aircraft has arrived at the CARP and extinguishes when the aircraft has passed the last effective parachute release point.

The IP button is used to notify the computer that the aircraft is passing over the Initial Point (IP) and updates the dead-reckoned position to the coordinates of the IP.

#### INITIAL CONDITION CONTROL INDICATOR C-6214

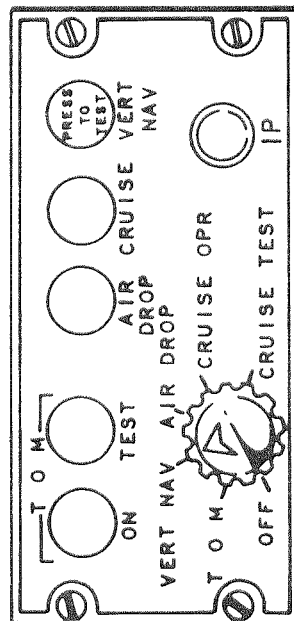
The indicator provides for storing and monitoring parameters in the AIR DROP mode. It can also be used in storing LORAN station coordinate information. When the HIGH PREC LAT or the HIGH PREC LONG button is depressed and the READ-SET knob is placed in the appropriate "SET" position (N or S for latitude,



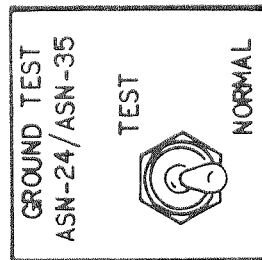
AN/ASN-24  
J BOX  
No. 1

NAV INSTRUMENT PANEL

C-6214



MODE CONTROL INDICATOR  
C-6213



GROUND TEST SWITCH

AN/ASN-24 NAV COMPUTER CONTROL  
PANELS NO. 2

E or W for longitude) high precision coordinates may be installed as IP (LORAN Station 4), and "D" number, or LORAN Master and Slave locations (LORAN Stations 1, 2 and 3). Storage is accomplished by depressing the STORE button until the store light illuminates. Two slew knobs are provided, one for the DEG - MAGNITUDE counter and one for the MIN-SEC counter. When AIR DROP CARP YD AL TR x 1 button is depressed the DEG-MAGNITUDE counter will display distance remaining along track between the initial impact point and final impact point. When the AIR DROP CARP YD CR TR x 1 push button is depressed the DEC-MAGNITUDE counter will indicate computer cross track distance from initial impact point and final impact point.

The AIR DROP OPEN DLY x 0.1 and AIR DROP FALL TIME x 0.1 push buttons permit storage of parachute ballistics into the computer memory. The HEADING CORR x 0.1 button is depressed when a correction to the ASN-24 true heading is to be stored for readout.

The GROUND TEST switch is used to bypass the touchdown relay which disables the ASN-24 when the aircraft is on the ground. In "NORMAL" position the computer will not update dead-reckoning position while the aircraft is on the ground. However coordinates may be stored. In "TEST" position the ground disabling lines are bypassed and tests may be performed upon the computer.

The AN/ASN-24 INPUT selector switch is used to select "CADC 1" or "CADC 2", and "C-12 COMPASS NO. 1 - NO. 2 - BOTH" as inputs to the computer.

### SPECIFICATIONS

#### ASN-24 NAV COMPUTER SET

CHARACTERISTIC	SPECIFICATION
Number of components	9 and 2 switch panels
Total weight	121 lbs.
Type memory	Rotating drum
Drum speed	6000 RPM nominal
Drum tracks	70
Words per track	64
Bits per word	25
DC power requirements	145 watts 28 volts, DC
DC power limits	21 to 29 volts, DC

SPECIFICATIONS (continued)

CHARACTERISTIC		SPECIFICATION
AC power requirements		130 VA 26 volts, AC 380 to 420 Hz
		410 VA $\phi$ A 300 VA $\phi$ B, $\phi$ C 115/200 volts, AC 3 phase 380 to 420 Hz 58 watts 5 volts, AC
AC voltage limits		26 volts, AC 24.5 - 26.5 volts, AC 115 volts, AC 108.5 - 117.5 volts, AC 5 volts, AC 3 - 6 volts, AC
Fuses (converter chassis)		F1-F10 2 amperes F11 4 amperes F12, 13, 15, 16, 17 1.5 amperes F14 0.25
FUNCTION	RANGE	ACCURACY
Present position latitude	N 90 - S 90 degrees	$\pm 0.5$ percent of distance traveled plus 0.3 minute of arc
Present position longitude	W 180 - E 180 de- grees	$\pm 0.5$ percent of distance traveled plus 0.3 minutes of arc
Multiple destinations storage	N 90 - S 90 latitude E 180 - W 180 longitude	$\pm 0.2$ minute of arc
Range		
Flat earth	0-100 NM	$\pm 0.5$ NM
Great circle	100-1,000 NM 1,000 - 10,000 NM	$\pm 0.52$ NM $\pm 1.3$ NM
Bearing		
Flat earth	0-100 NM	$\pm 0.2$ DEG

## SPECIFICATIONS (continued)

FUNCTION	RANGE	ACCURACY
Great circle	100 - 1,000 NM 1,000 - 10,000 NM	$\pm 0.2$ DEG
Along Track distance	0 - 100 NM 100 - 10,000 NM	$\pm 0.02$ NM $\pm 0.2$ NM
Cross Track distance	0 - 10 NM 10 - 100 NM	$\pm 0.002$ NM $\pm 0.02$ NM
TACAN fix	5 - 75 NM 75 - 200 NM	$\pm 0.4$ NM $\pm 0.7$ NM
Radar fix	0 - 30 NM 0 - 300 NM	$\pm 0.4$ NM $\pm 0.4$ NM
LORAN fix	0 - 1000 NM (day) 0 - 1500 NM (night)	$\pm 0.25$ NM $\pm 0.25$ NM

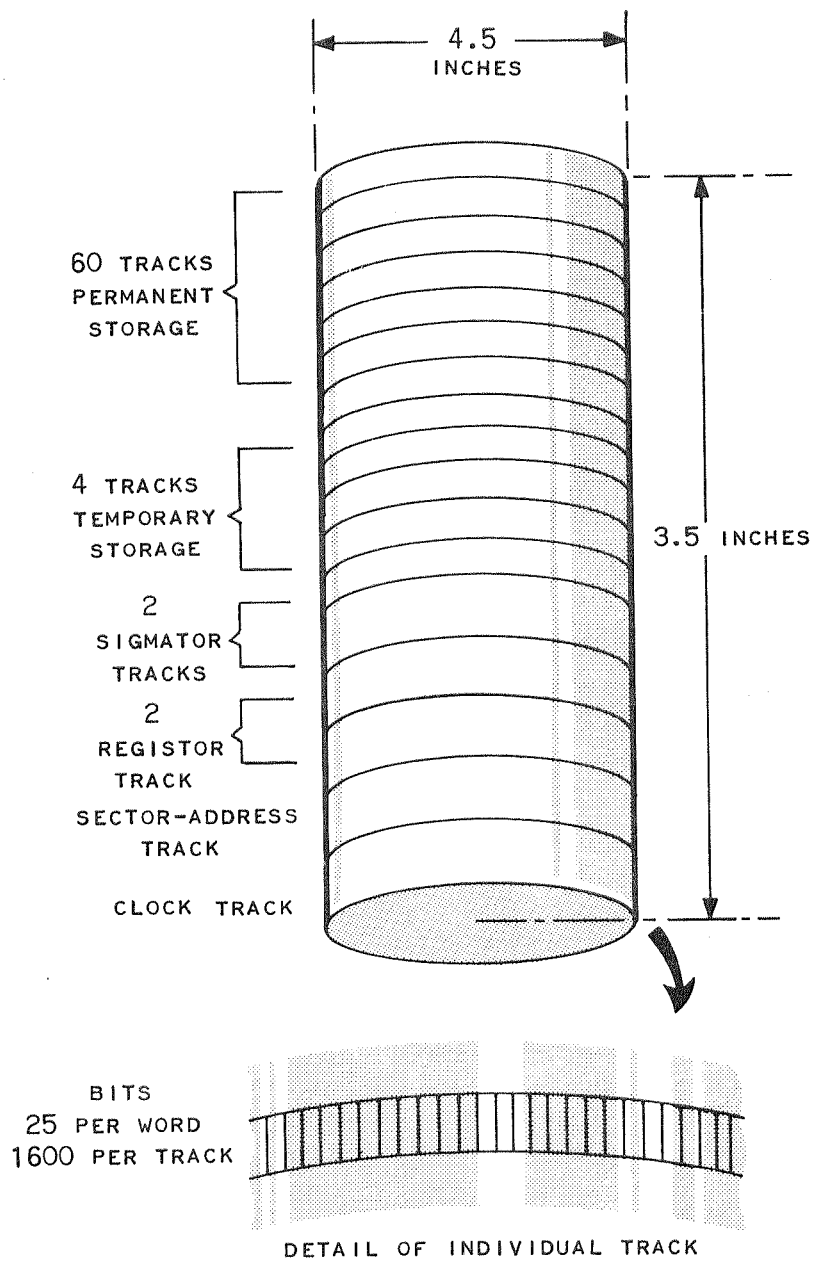
### BLOCK DIAGRAM THEORY OF OPERATION

The heart of the computer is a small, rotating magnetic drum. Information is stored in binary form upon the drum. Facilities are provided for temporary and permanent storage of information. Information is retrieved as needed for computations and displays.

Read and write heads are spaced to provide 70 tracks on the storage drum. 1600 slots are scribed vertically and equally spaced around the drum circumference. The 1600 slots thus formed are filled with magnetic material and acts as 112,000 miniature magnets (70 tracks x 1600 lines). Write heads are used to provide a source of magnetization of the individual magnets (bits). The direction of magnetization, NM or SM indicates a 1 or 0. When the magnetic drum is rotated past a read head the polarity of the magnetization is sensed and a signal corresponding to a 1 or 0 is produced. Since the drum is rotated past the read and write heads at a 6000 RPM rate, storage and retrieval is accomplished at a rapid rate.

The 70 available tracks are used for various purposes, while 60 tracks are used for permanent storage of information. Temporary storage of data such as a sum or product which is needed for a larger scale problem solution is provided by 4 tracks.

The 2 sigmator (summation integrator) tracks are used to store incremental pulse accumulation, real time accumulations, integration, extrapolation, etc.



MEMORY DRUM

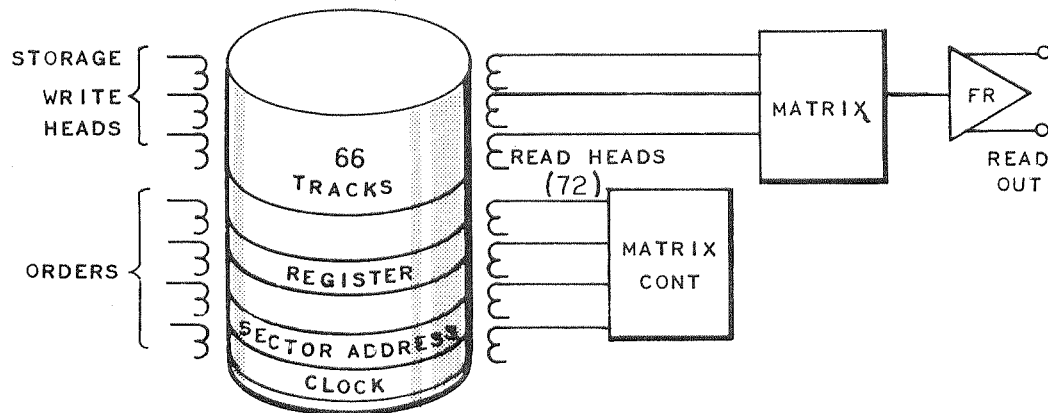


Drum register tracks are used to hold words being manipulated as either operands or instructions. (An operand is any one of the quantities entering into or arising from an argument, a result, a parameter, etc.).

The Sector-Address tracks primary purpose is to define each of the 64 sectors, or words around the drum. (25 bits per word x 64 words = 1600 bits per track.) The sector-address track is also used as a synchronizing device in determining individual bit location within a word.

The Clock track supplies timing pulses required by the computer. By synchronizing computer circuits to the clock pulses, slight variations in drum speed will not adversely affect operation. The clock track is pre-recorded with all of its 1600 bits magnetized in the same direction. Each bit then will initiate a pulse which is in synchronization with that particular bit in the other 69 tracks.

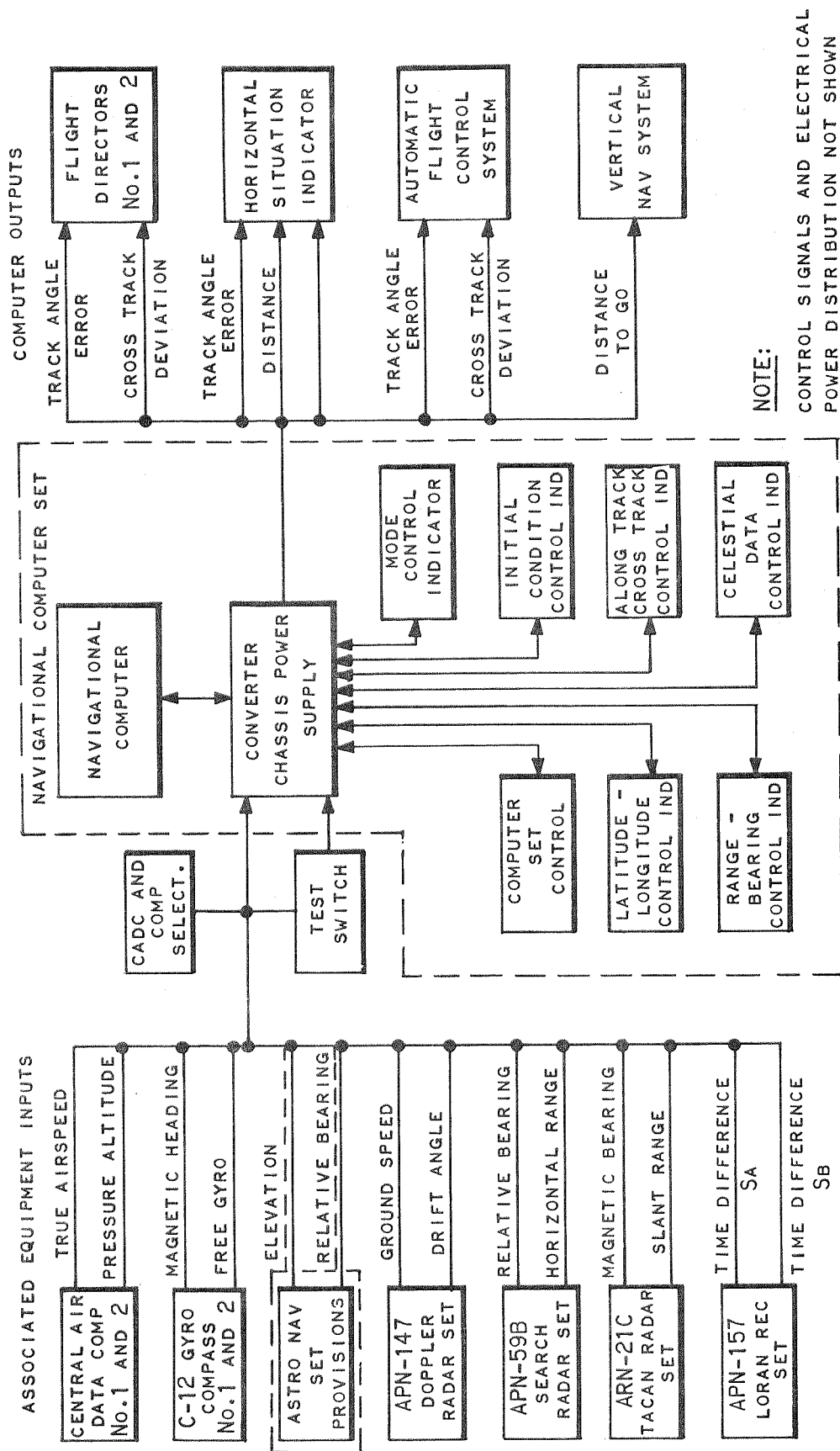
Outputs from the 66 storage tracks (permanent, temporary and signator) are controlled by the Register, Sector-Address and Clock tracks. Read heads provide a continual output to a matrix which is controlled by the remaining tracks. Since readout is accomplished by one Flip Flop (FF), it is readily apparent that



S I M P L I F I E D M E M O R Y R E A D O U T

one portion of one track can be read at one time. The anomaly of 72 read heads on 66 tracks is explained by the fact that some tracks have more than one read head. Multiple head on a single track allow recirculation of data to that track.

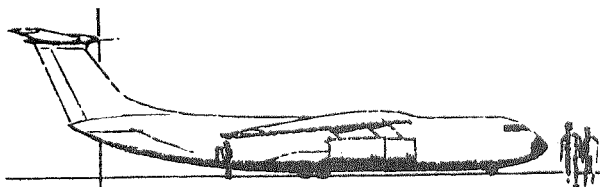
Information is inserted into the drum by write heads which furnish a magnetomotive force of approximately 15 ampere-turns to the drum bit which is located 0.001 of an inch from the write head. The applied force is sufficient to saturate the bit magnetically. South-north polarization of the bit represents a zero. Polarity of the magnetization of the bit depends on the direction of current flow in the write head. All bit information may be erased by writing new information over the old.



DATA FLOW AND SYSTEM TIE-IN

Much of the information used by the computer is of analog type. An input-output unit (which is part of converter chassis - power supply PP-3214) is used to translate the input analog signals to binary digital form for the computer. Reconversion of the binary signals going from the computer to analog form is also accomplished in this unit. A typical example of this conversion is the changing of an input synchro signal such as the C-12 compass output to digital form for use of the computer.

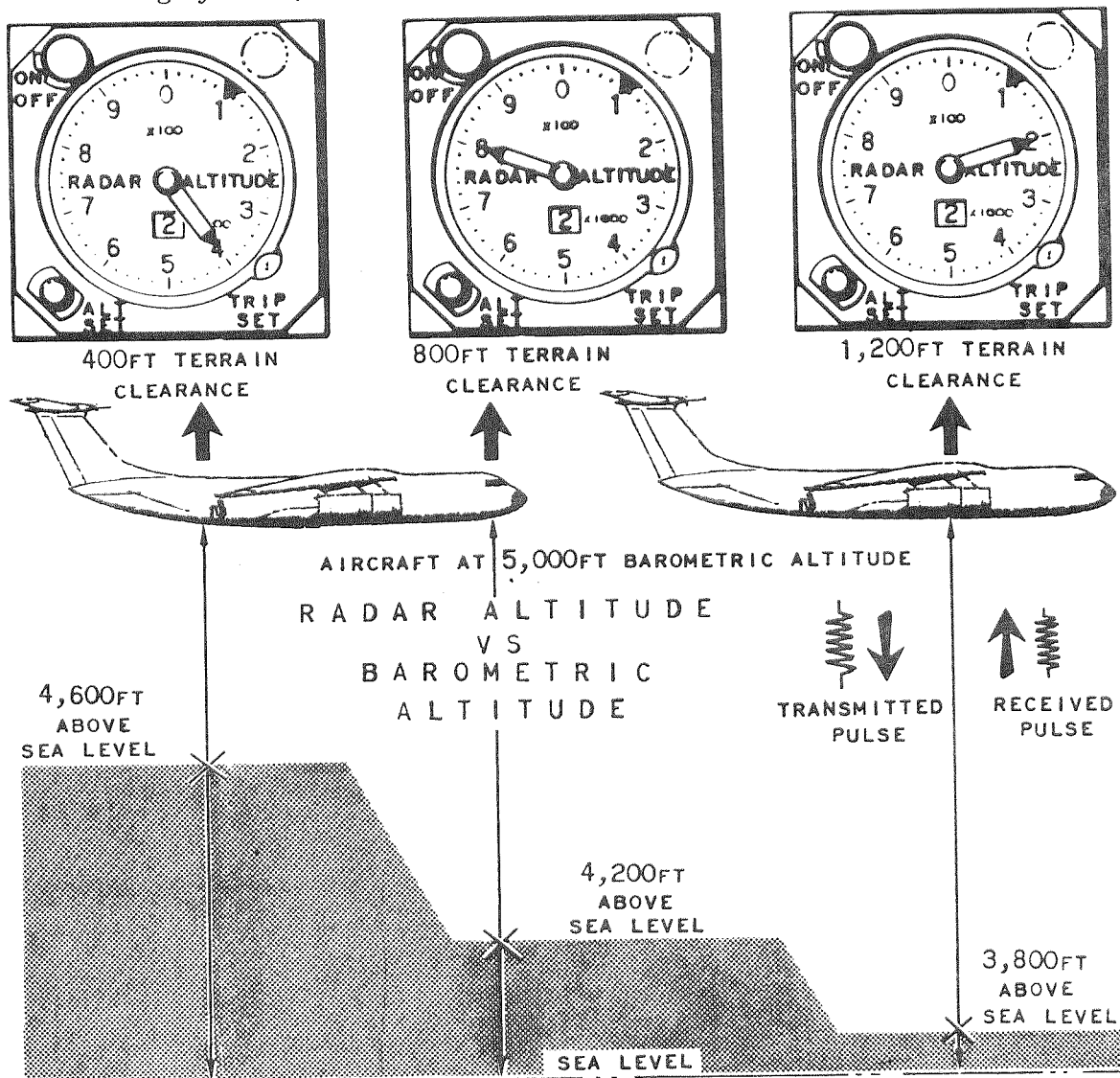




## LOW-RANGE RADAR ALTIMETER

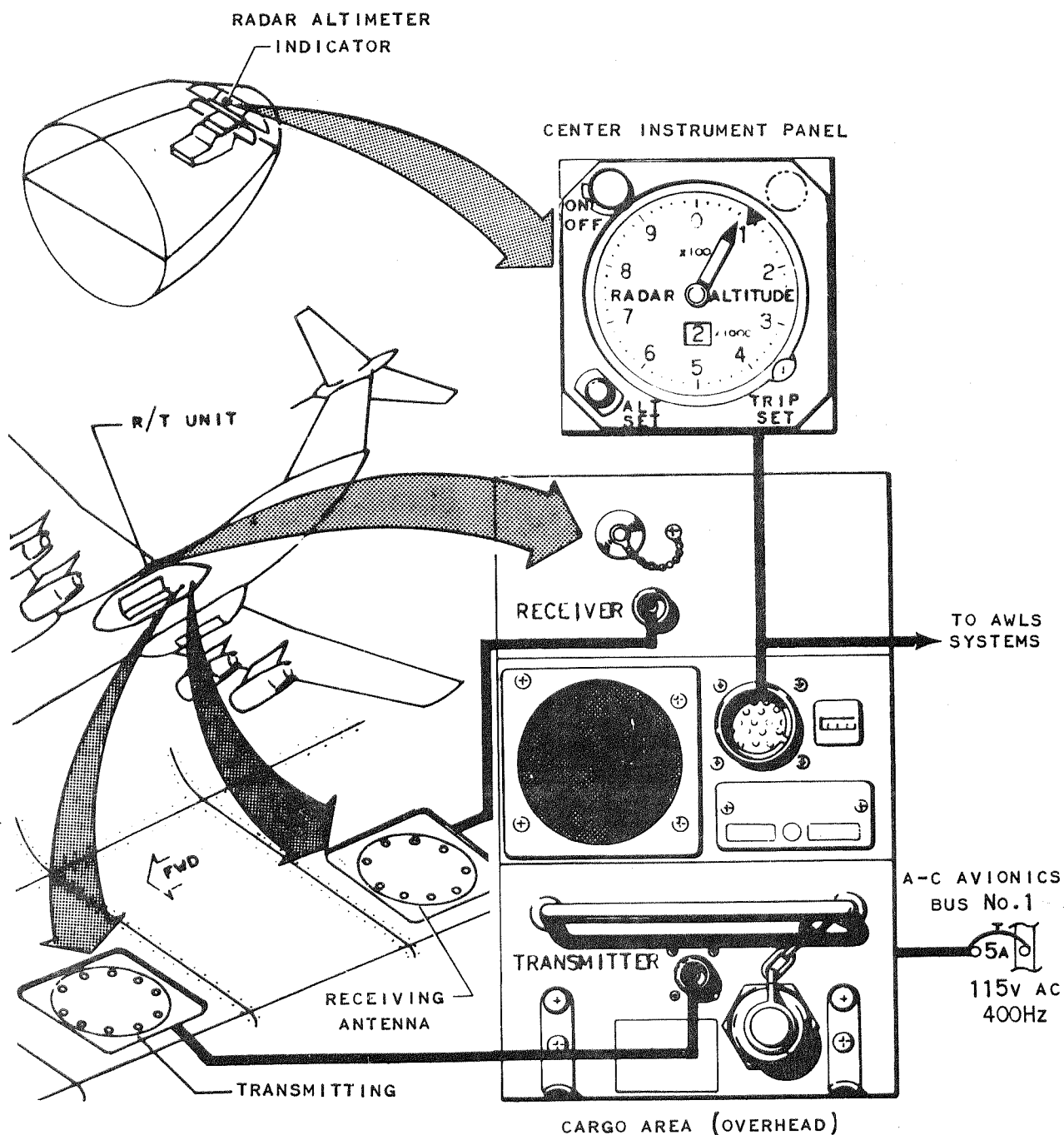
### GENERAL

The radar altimeter used on the StarLifter is a low-level altitude tracking and indicating radar. It instantaneously senses absolute altitude above the terrain within the range of -10 to 2,500 feet. Radar altimeter operations are not affected by atmospheric or barometric conditions. The altimeter is interconnected with other aircraft systems such as the All Weather Landing System (AWLS).



## AIRCRAFT INSTALLATION

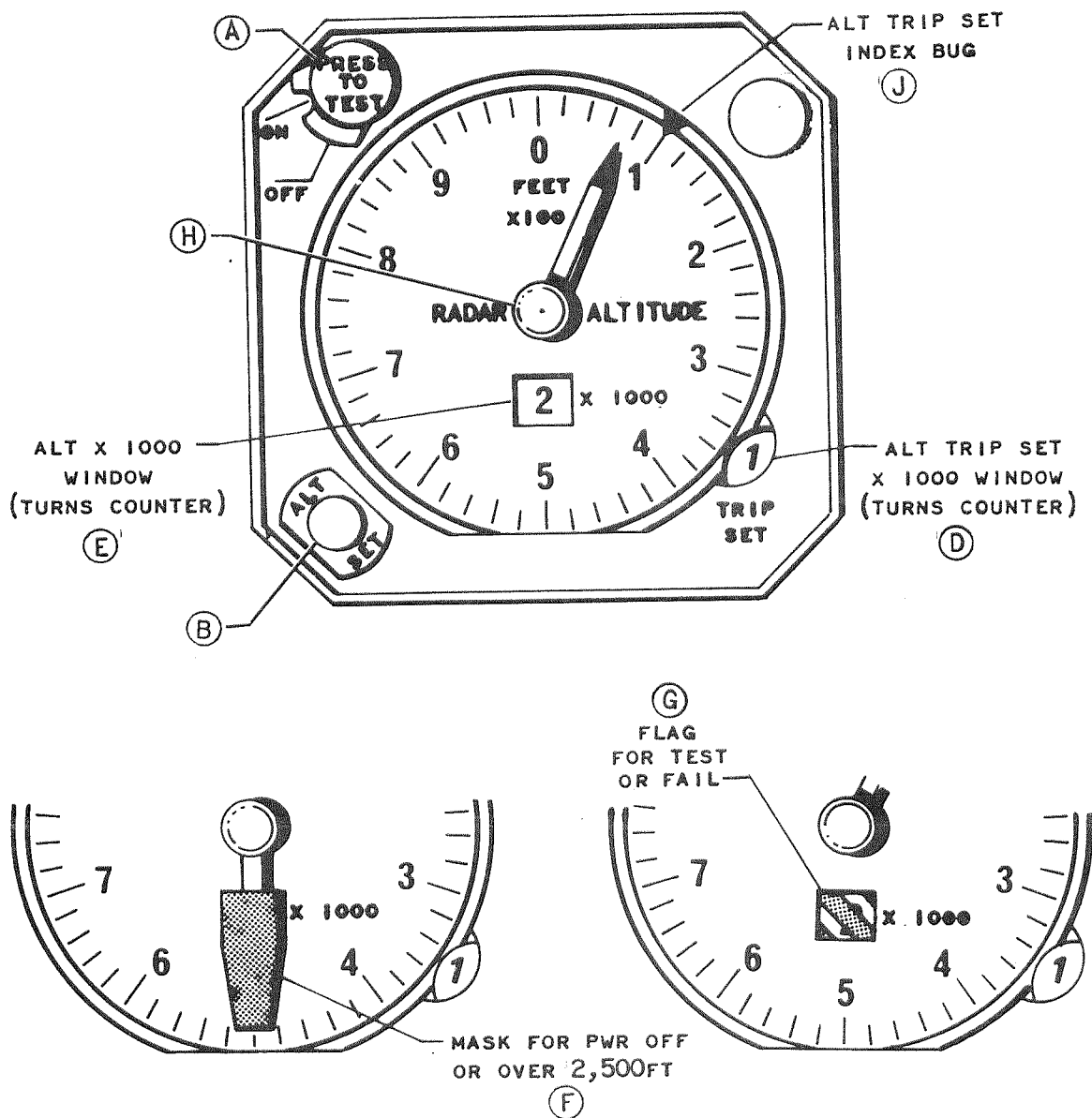
The radar altimeter system consists of a receiver-transmitter unit, an indicator, and two antennas. The following diagram shows component locations and general cabling of the system.



RADAR ALTIMETER SYSTEM

## SYSTEM OPERATION

All controls necessary for operating the altimeter are located on the indicator.



RADAR ALTIMETER INDICATOR

They are; an ON-OFF/PRESS-TO-TEST switch and an ALT-SET knob. When the ON-OFF switch A is placed in the "OFF" position, the fail flag (G) will appear and the indicator pointer (H) will drive to 2,500 feet where a mask (F) appears and covers the pointer. The system is de-activated only after the mask has appeared. The ON-OFF switch is also used to self-test the altimeter by pressing in on the knob. The indicator shows a 40 foot altitude in self-test.

The ALT-SET knob (B) is used to preset a Minimum Desired Altitude (MDA). When the aircraft descends below the preset altitude an MDA signal is produced and sent to the pilot's and copilot's MDA lights and to the Ver Nav system. The ALT-SET index bug (J), located on the outer periphery of the dial scale, can be set to any altitude between 0 and 2,500 feet with the ALT-SET knob. The ALT-SET turns counter (D) is used in conjunction with the index bug to indicate the altitude at which the MDA is set. The turns counter consists of a disc segment carrying digits 2, 1, and a "blank". When the index bug is set below 1,000 feet, the turns counter shows the "blank". No. 1 is in view when the index bug is set between 1,000 and 2,000 feet. No. 2 is shown when the index bug is set above 2,000 feet.

A flag alarm (G) provides an indication of altimeter failure. It is also displayed during self-test operation. The mask (F) on the indicator is springloaded to the out-of-view position. It is held in view to obscure the pointer and altitude window when the system has been turned off and primary power is still available, or when the altimeter is operating above 2,500 feet. The mask is removed from view and the flag alarm is in view when the system is in self-test operation.

The indicator displays absolute altitude by using a servo driven pointer and a turns counter. The pointer (H) indicates in hundreds of feet and the turns counter (E) indicates in thousands of feet. The scale of the indicator is graduated in 20 foot increments.



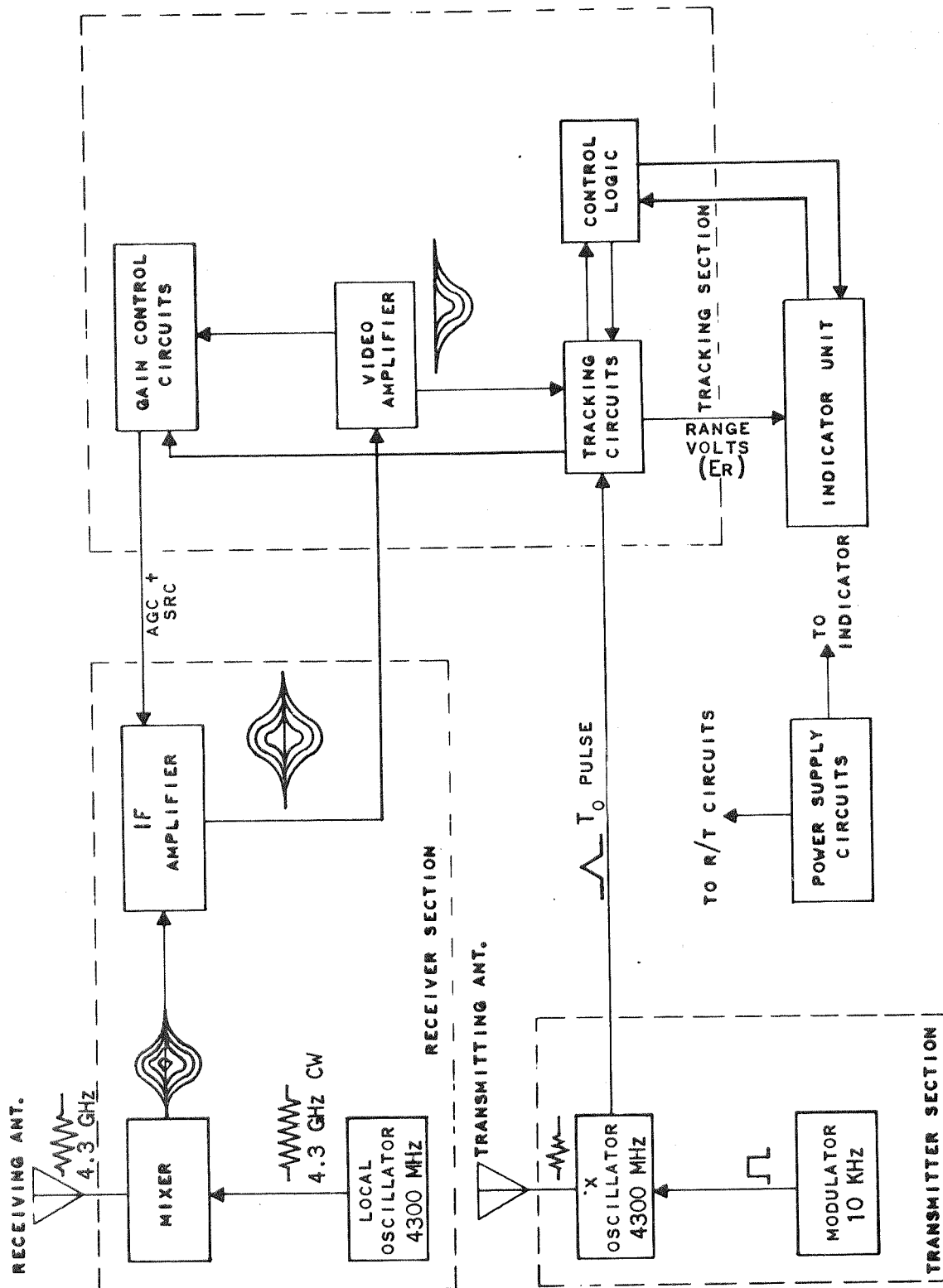
## SPECIFICATIONS

### MINNEAPOLIS HONEYWELL HG9025B-1

CHARACTERISTIC	SPECIFICATION
Power requirements	115 volts, AC, 400 Hz, 1 $\phi$
Altitude range	-10 feet to +2,500 feet
Altitude accuracy	$\pm 2$ ft/s or $\pm 2$ percent of altitude
TRANSMITTER	
Carrier frequency	4,300 MHz
Peak output power	100 W
Pulse width	
0-500 ft.	$35 \pm 10$ ns
500-2,500 ft.	$125 \pm 25$ ns
Pulse repetition frequency	10K pulses/sec
RECEIVER	
Receiver frequency	4,300 MHz
Local oscillator frequency	4,300 MHz
Bandwidth	
0-500 ft.	30 MHz
500-2,500 ft.	10 MHz
Track rate (maximum)	2,000 ft/sec
INDICATOR	
Track rate (maximum)	600 ft/sec

## BLOCK DIAGRAM THEORY OF OPERATION

The Low Range Radar Altimeter is a high resolution pulse radar operating at 4,300 MHz. Its purpose is to automatically locate the closest terrain returns. It also has the ability to precisely track the rate of altitude change (terrain irregularities or changes in actual aircraft altitude).



RADAR ALTIMETER SIMPLIFIED BLOCK DIAGRAM

The operation of the radar altimeter is based on the precise measurement of the time required for an RF energy pulse to travel from the aircraft to the nearest ground and to return. The arrival time of the received pulse is compared with its transmitted time. The time differential is processed in the tracking circuits to provide range (altitude) information. The Receiver-Transmitter (RT) unit is the main component of the system. All electronic circuits are contained in this unit with the exception of the indicator servo system.

The RT unit is divided into three sections; the Transmitter, the Receiver, and the Tracker.

### TRANSMITTER

The transmitter section consists of a transmitter oscillator and a modulator (PRF generator). The modulator is a free running multivibrator operating at 10 KHz. Each pulse from the modulator triggers the transmitter oscillator which emits a short RF pulse with a carrier frequency of 4,300 MHz. The RF pulse is sent to the transmitter antenna. A portion of the transmitted pulse is detected and fed to the tracking section to start the timing circuits. This signal is called the "time reference" ( $T_0$ ) pulse.

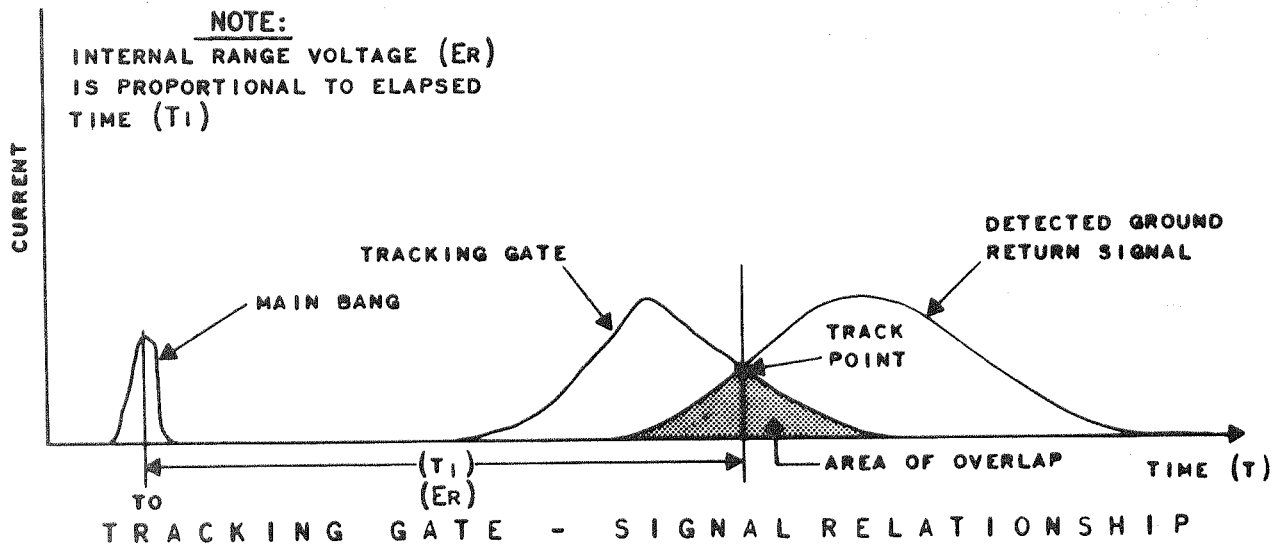
### RECEIVER

When the RF pulse emitted by the transmitter antenna reaches the ground, it is partially reflected back to the aircraft where it is picked up by the receiving antenna and applied to the receiver. The receiver section consists of a balanced mixer, a local oscillator, and an IF amplifier circuit. The type of receiver used in the altimeter is a "zero IF" superhetrodyne receiver. In this type system, the receiver local oscillator is operated at approximately the same frequency as the transmitter. Both the transmitter and the local oscillator are of the same basic design, using planar triodes. They inherently have identical frequency tracking characteristics and require no Automatic Frequency Control (AFC) circuit. The local oscillator signal is mixed with the received RF signal (echo pulse) in the balanced mixer. The output is bipolar (A-C) pulses similar to video. The IF amplifier is then, for all practical purposes, a video amplifier. The bipolar pulses are amplified and detected to an unipolar (single direction or D-C) pulse. The detected video pulses are then sent to the tracking circuits where they will be used to measure altitude.

### TRACKER

The function of the tracker is to produce a voltage proportional to the time between the leading edges of the transmitted pulse and the echo pulse. The tracker consists of a video amplifier, tracking circuits, AGC circuits, and logic circuits. The tracking circuit is a "leading edge" tracker.

The circuit is designed so that the current ( $I_e$ ) is proportional to the overlap of the leading edges of the tracking gate and the ground return. Further, the circuit is



designed to sense this current and use it to position the tracking gate on the leading edge of the ground return pulse as it moves back and forth with changes in altitude. Thus, it is the function of the tracking loop to move the track gate at whatever rate necessary to keep it in coincidence with the leading edge of the ground return pulse. The elapsed time ( $T_1$ ) from the transmission of a pulse until it returns from the ground is thus measured and presented as an analog voltage ( $E_a$ ). A radar range measurement is sent to the indicator to drive the altitude pointer.

## MODES OF OPERATION

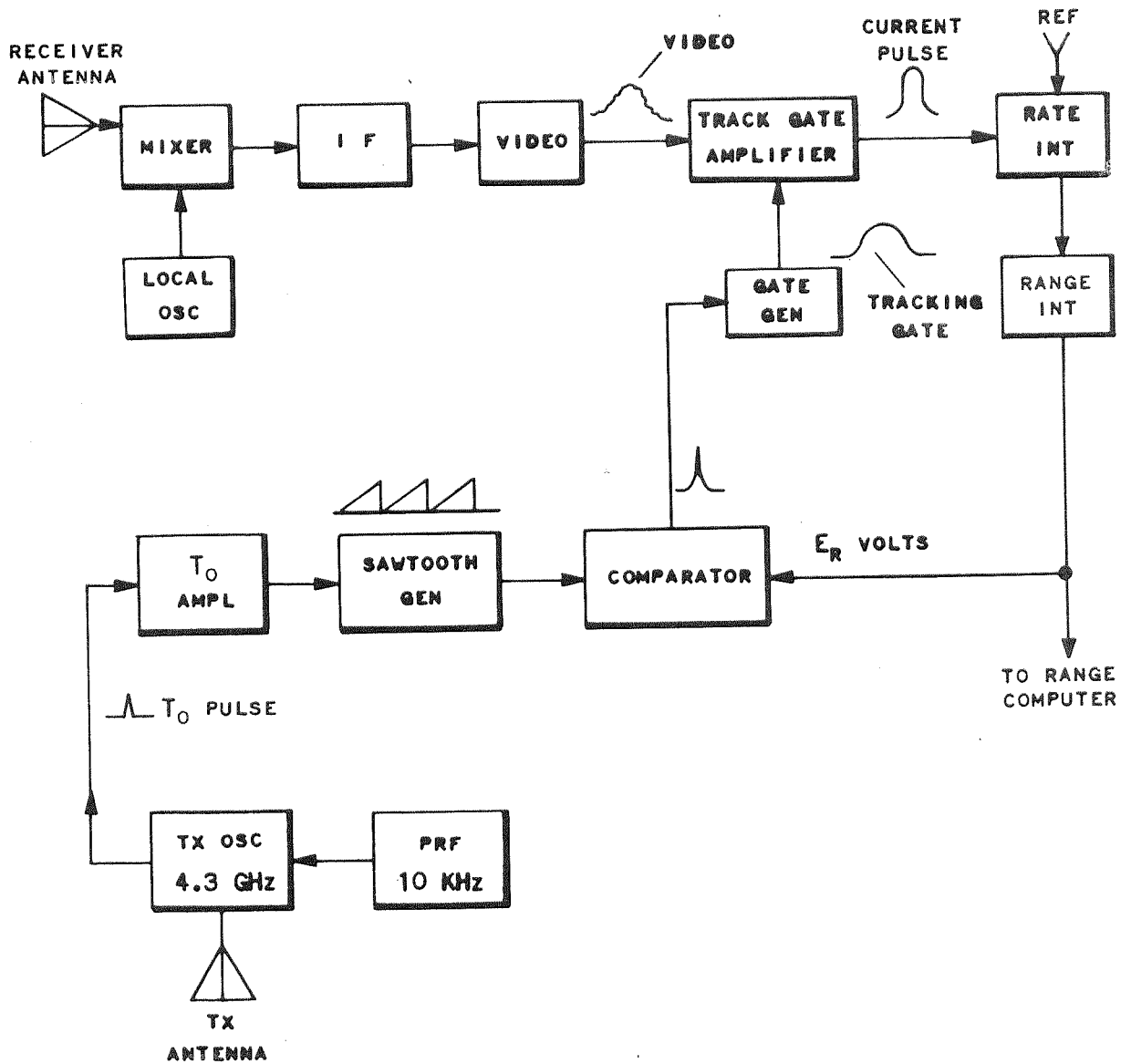
The altimeter has four different modes of operation:

- Tracking Mode
- Search Mode
- Confidence Check Mode (Self Test)
- Failure Monitor Mode

The different modes of operation pertain mainly to the tracker circuits.

## TRACKING MODE

When the altimeter is operating in the tracking mode, its output represents the actual distance downward to the nearest object as a function of time. The following block diagram shows the circuits that are operational in the tracking mode.

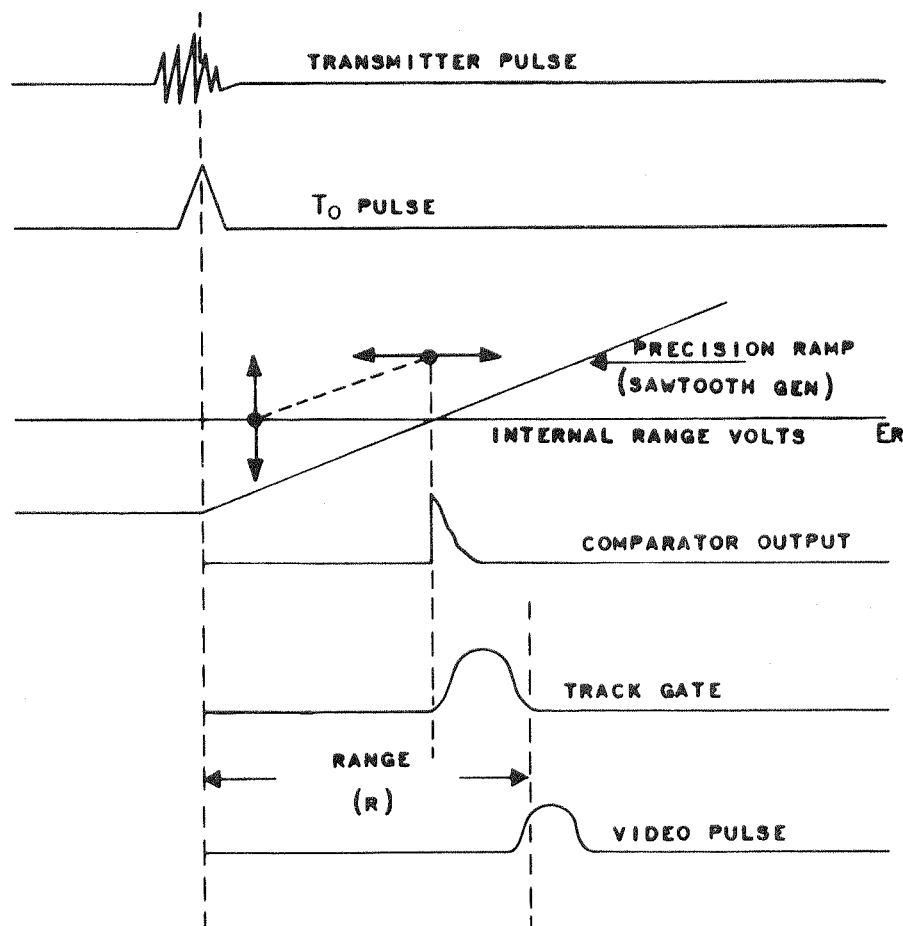


S I M P L I F I E D   B L O C K   D I A G R A M - T R A C K   M O D E

As stated before, each time the transmitter is triggered by the modulator, a time reference pulse ( $T_0$ ) is applied to the  $T_0$  amplifier. The  $T_0$  pulse triggers a sawtooth generator which supplies a calibrated linear voltage ramp. The instantaneous voltage of this precision ramp is directly proportional to the elapsed time since  $T_0$ . The sawtooth voltage is fed to a voltage comparator circuit where it is compared to the internal range voltage ( $E_r$ ). At the instant of time when the sawtooth voltage equals  $E_r$ , the comparator applies a short pulse to the gate generator circuit. At this time, the tracking gate is generated by the gate generator circuit.

When the RF pulse emitted by the transmitter at  $T_0$  reaches the ground, it is partially reflected back to the receiving antenna. The antenna feeds the echo

pulse into the receiver where it is amplified, detected, and presented to the Track Gate Amplifier (TGA) as a video signal.



### TRACKING GATE GENERATION

The TGA functions as an AND gate. The time coincidence between the video signal and the tracking gate allows the video signal to pass as a current pulse to the rate integrator. Since  $E_R$  determines the sawtooth level at the time of comparison, and since the time position of the video signal is a direct function of the distance to the ground, coincidence of the video and tracking gate at the TGA means that  $E_R$  is proportional to range. It is important to note that since this is a "leading edge" tracker,  $E_R$  represents the shortest range to ground. The TGA produces a current into the rate integrator proportional to the overlapped area of the video pulse and the gate. A reference input equal to the average overlap current will hold the gate positioned on the leading edge of the video pulse. The leading edge is composed of the earliest ground return.

## SEARCH MODE

If the return signal falls below a minimum level required to maintain the track point current to the rate integrator, the video pulse and the tracking gate will separate and the tracker "loses track". Tracking can only be re-established when the tracking gate overlaps acceptable video. Therefore, it is necessary to provide a means to establish this condition. That is the purpose of the search mode. The tracking gate is caused to "sweep" from minimum to maximum range until it intercepts a video signal. If the video signal is acceptable, the tracking gate will lock on it. Thus tracking is re-established.

The simplified block diagram on page 12 shows the circuits that are operational in the search mode.

The following additional blocks are used in this mode of operation:

- Tracking AGC (TAGC) Gate Amplifier
- TAGC Integrator
- 0.2 Second Hold Circuit
- Search Generator

The TAGC Gate Amplifier is similar to the tracking gate amplifier. It is an AND gate for the video signal and the TAGC gate from the gate generator. Its output is proportional to the video and gate overlap. An important difference is that the TAGC gate is about twice as wide as the tracking gate. The leading edge of the two gates are in time coincidence. The output of the TAGC gate amplifier is applied to the TAGC integrator.

The TAGC Integrator integrates negative pulses from the TAGC gate amplifier. Amplitude of the pulses is equal to the TAGC gate and the video overlap current. These pulses occur at the PRF rate. Pulses are integrated in the TAGC integrator to establish a threshold voltage ( $E_0$ ). For normally good video, about 20 pulses per second will maintain  $E_0$  at the tracking threshold. If a loss of video occurs, the integrator will maintain  $E_0$  for approximately 2 milliseconds (ms).

The 0.2 Second Hold Circuit is an additional delay time of 200 ms to the decay time of the TAGC integrator. Together they will allow a short term loss of video (200 ms) to pass without losing track. If a signal fade lasts for more than 200 ms, the 0.2 second hold will trip and turn on the search generator. A signal is also sent to the rate integrator to clamp the output to zero. This prevents  $E_r$  from changing during the 0.2 second hold period.

The Search Generator is a controlled multivibrator governed by the 0.2 second hold circuit. If the 0.2 second hold trips, the search generator supplies input current to the range integrator which causes  $E_r$  to sweep back and forth from





minimum range to maximum range. This search cycle continues until it is stopped by the 0.2 second hold circuit. In addition, the search generator provides an inhibit signal to the 0.2 second hold during inbound sweeps. The 0.2 second hold can only stop the search generator on outbound sweeps. The following diagram will clarify the sequence of events during search and acquisition of the video target.

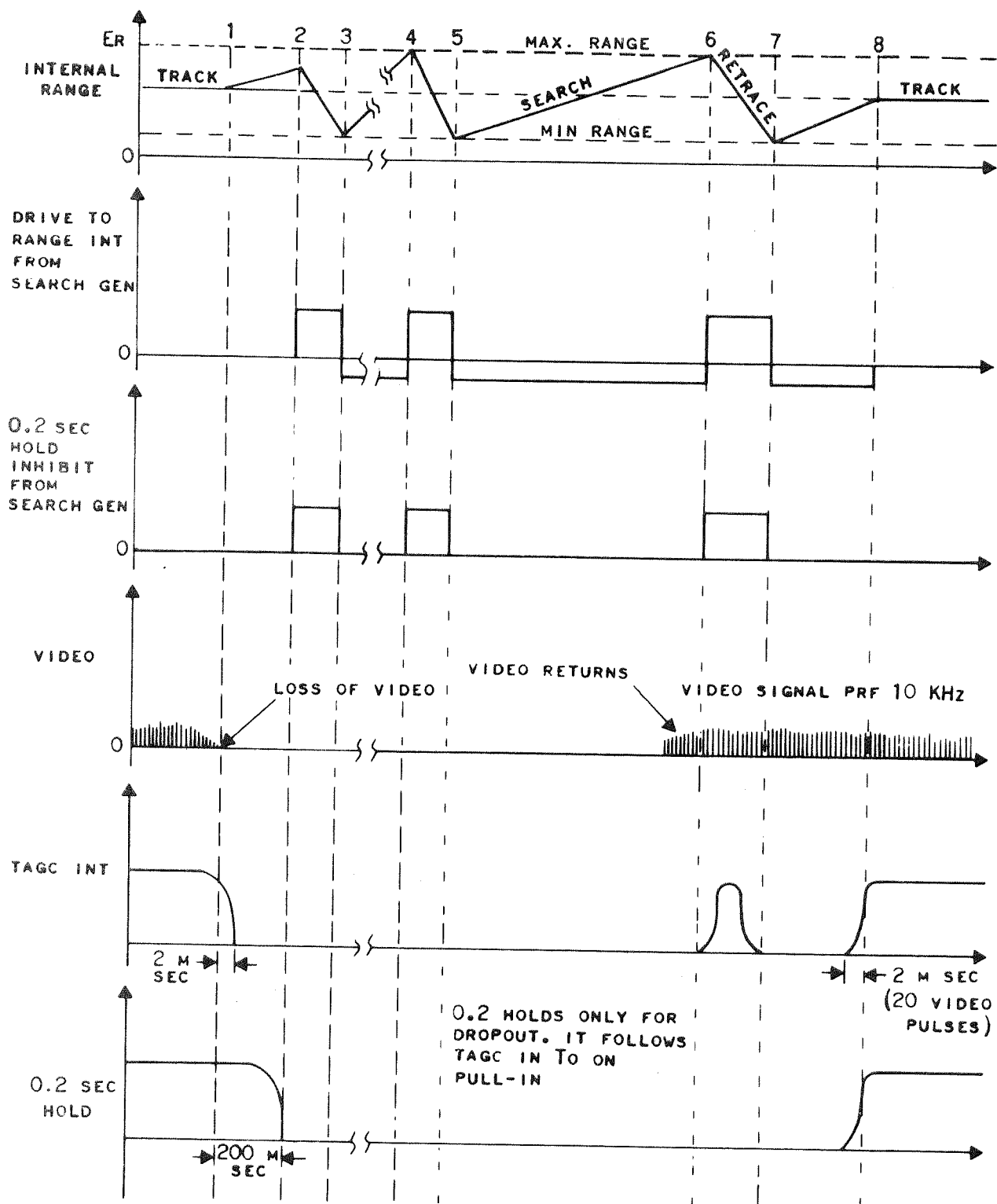
Refer to the numbers at the top of the Search and Acquisition Waveforms illustration for the sequence of events.

1. Loss of video. The current drive from the track gate amplifier to the rate integrator vanishes. The TAGC integrator loses its drive and discharges. The 0.2 second hold initiates its hold cycle.
2. After 200 milliseconds, the search generator is activated driving  $E_r$  to minimum altitude.
3. The drive to the range integrator is reversed and  $E_r$  starts toward 2,500 feet.
4. The upper limit reverses  $E_r$  and inhibits the 0.2 second hold.
5. Repeat of search cycle.
6. Reversal of  $E_r$  occurs. Video is regained. The gates overlap but because the 0.2 second hold is inhibited lock on will not occur.
7.  $E_r$  reverses again and sweeps outward.
8. Assuming that the actual range remains constant during the loss of video, the gates overlap again, the TAGC integrator charges, resetting the 0.2 second hold, stopping the search generator. The tracking loop is now closed and the altimeter is again in the tracking mode. The above search cycle occurs at approximately a 3 Hz rate.

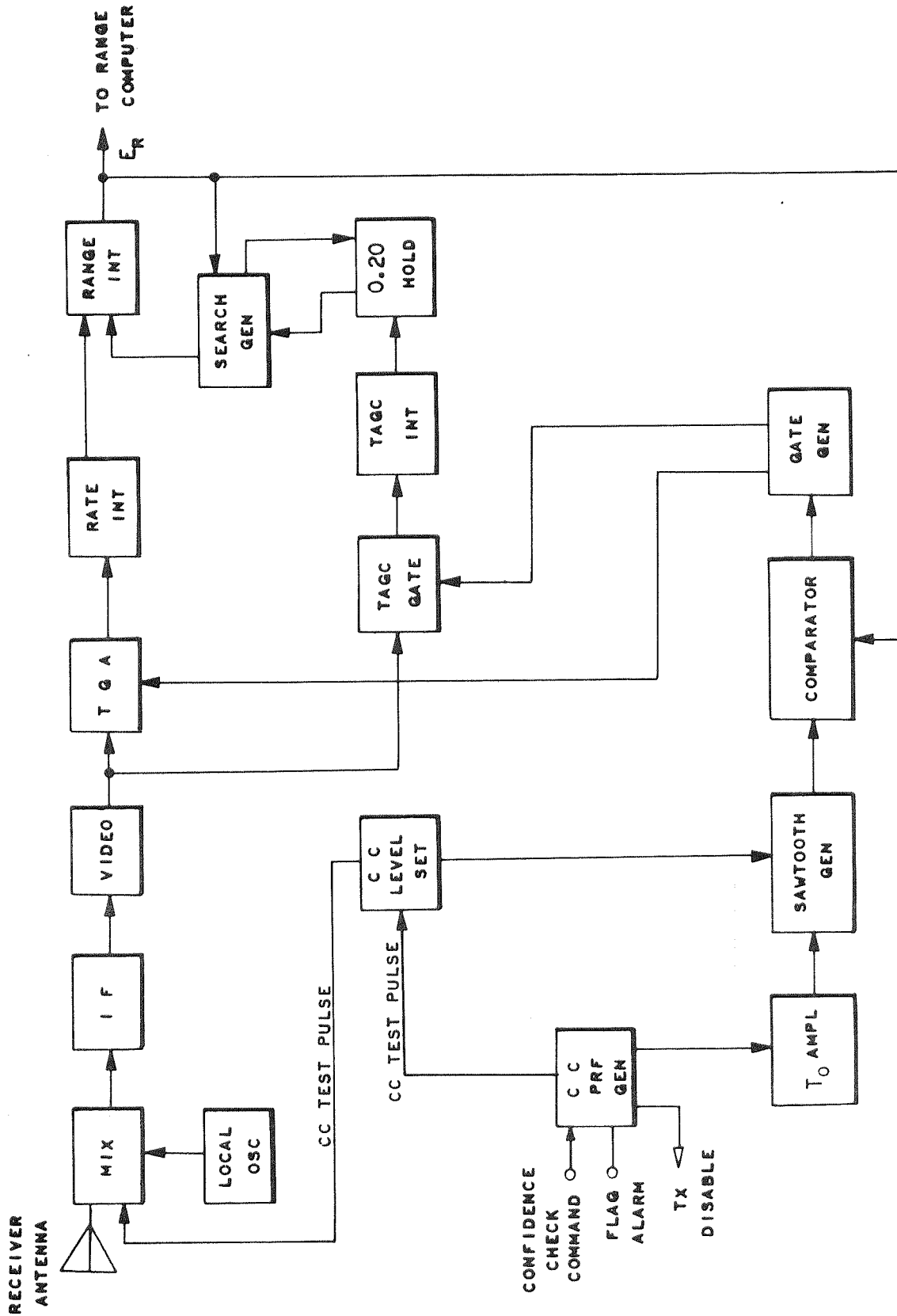
#### CONFIDENCE CHECK MODE

The confidence check (self-test) mode is designed and built into the system to provide a quick comprehensive test of system operation. The following block diagram shows the circuits used in this mode of operation. Two additional circuits used are the confidence check PRF generator, and the confidence check level set.

When the Confidence Check (CC) command is given; the transmitter is disabled, a flag alarm signal is given, the sawtooth level is set, and the CC-PRF generator is enabled. The CC-PRF generator applies the  $T_o$  pulse to the  $T_o$  amplifier



SEARCH AND ACQUISITION WAVEFORMS



SIMPLIFIED BLOCK DIAGRAM - CONFIDENCE CHECK MODE

and a confidence test pulse to the mixer. The test pulse acts as a gate to open the mixer. This allows a portion of the Local Oscillator (LO) energy through to the IF amplifier where it is amplified, detected, and presented as a synthetic video target to the video amplifier.

Disabling the transmitter eliminates the normal video from the TGA input and the tracker goes into the search mode. The synthetic video is passed to the gate amplifiers and the loop will search until  $E_r$  corresponds to the test altitude. The tracker will then acquire and track the synthetic video pulse. The amplitude of the pulse fed to the mixer is set to a minimum level for reliable track. Thus, the CC mode also checks the system sensitivity.

#### FAILURE MONITOR MODE/BUILT IN TEST EQUIPMENT (BITE)

The failure monitor mode is used to detect failures in the track and search loops and in the output circuits.

In the normal track condition, the two range output signals and the internal range voltage ( $E_r$ ) are continually compared to verify the accuracy of the output circuits. If either of these differ from each other by a voltage equivalent to 15 feet or more, a signal is sent to the alarm generator and a failure indication is provided. The track loop monitor is activated at any time that the tracking loop cannot maintain a reliable track condition for more than 0.2 second (time period of 0.2 second hold).

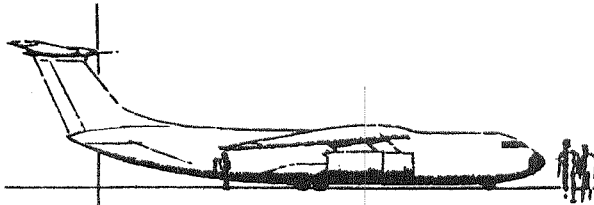
When the 0.2 second hold deenergizes, the system goes into the search mode. The track loop monitor decreases the AGC signal to the IF for approximately 0.5 second. This allows the RF leakage signal from the transmitting antenna to the receiving antenna to pass through the IF amplifier. If the track loop is functional, this will appear as a video signal. The track loop will regain a track condition and no failure alarm will be provided. If a fault has occurred in the track loop or if the transmitter power or receiver sensitivity has reached an unsafe level, a track condition will not be obtained within the 0.5 second. During this time, an RF leakage signal is provided and a signal is sent from the track loop monitor to the alarm generator which provides a failure indication to the indicator. If no failure is indicated at the end of this 0.5 second period, the system will return to the search mode and attempt to reacquire the ground return for up to 4.5 seconds. In the absence of a ground return the failure monitor will continue to gate out the AGC signal for 0.5 second at 5 second intervals, thus continuously checking the tracking loop operation.

#### ANTENNAS

Two identical antennas are used with the radar altimeter system. Each antenna consists of a flared horn and a coax-to-waveguide adapter. The units are sealed







## CRASH POSITION INDICATOR

### GENERAL

The AN/URT-26 Crash Position Indicator (CPI), is an aircraft installed radio beacon which operates at the international distress frequency of 243 MHz. The radio beacon and battery power source are encapsulated in a polyurethane airfoil which is ejected from the aircraft upon actuation of one of five frangible (breakable) switches, a hydrostatic switch, or the DEPLOY switch on the CPI control panel.

### AIRCRAFT INSTALLATION

The CPI is made up of six major components. They are as follows:

- CPI Tray
- Airfoil
- Frangible and Hydrostatic Switches
- Control Panel
- Battery Pack
- Beacon Battery Shutoff

### CPI TRAY

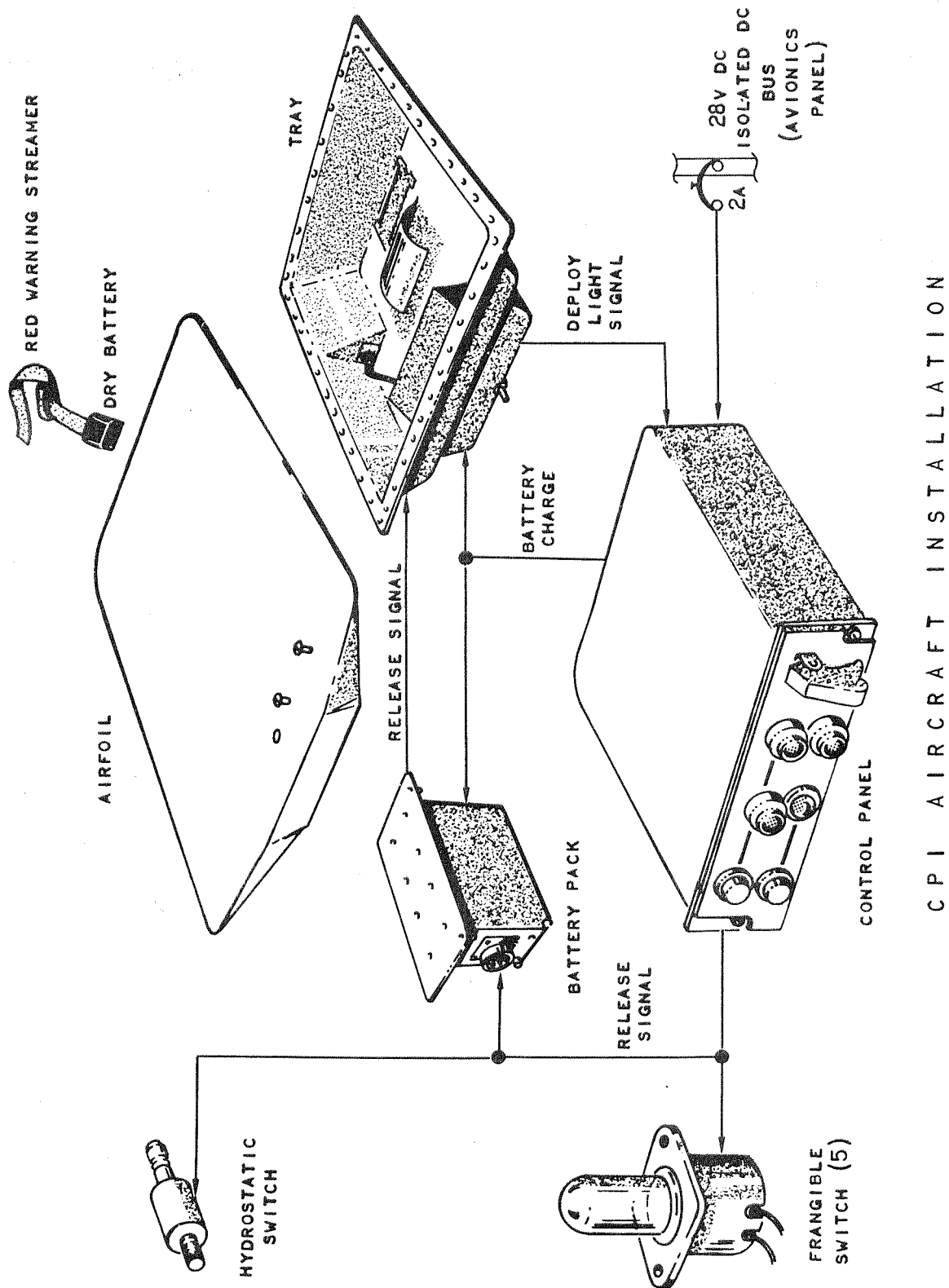
The CPI tray, (or mount) is located in the number four escape hatch directly above the left-hand jump door at FS1218. Installation of the CPI tray in the number four escape hatch does not obstruct exit in case of emergency. The tray houses the airfoil, airfoil release mechanism, and hydrostatic switch.

### AIRFOIL

The airfoil contains the radio beacon, battery power source and provisions for a tape recording mechanism.

### SWITCHES

Five frangible switches and one hydrostatic switch are located at strategic points on the aircraft. Two frangible switches are located on the forward side of the radome bulkhead, one in each wing tip and one in the aircraft lower fuselage at FS958. The hydrostatic switch is mounted on the inside of the airfoil tray and is set to close at six feet of seawater pressure. The frangible switches close whenever the glass housing of the switch is cracked or broken.



CPI AIRCRAFT INSTALLATION

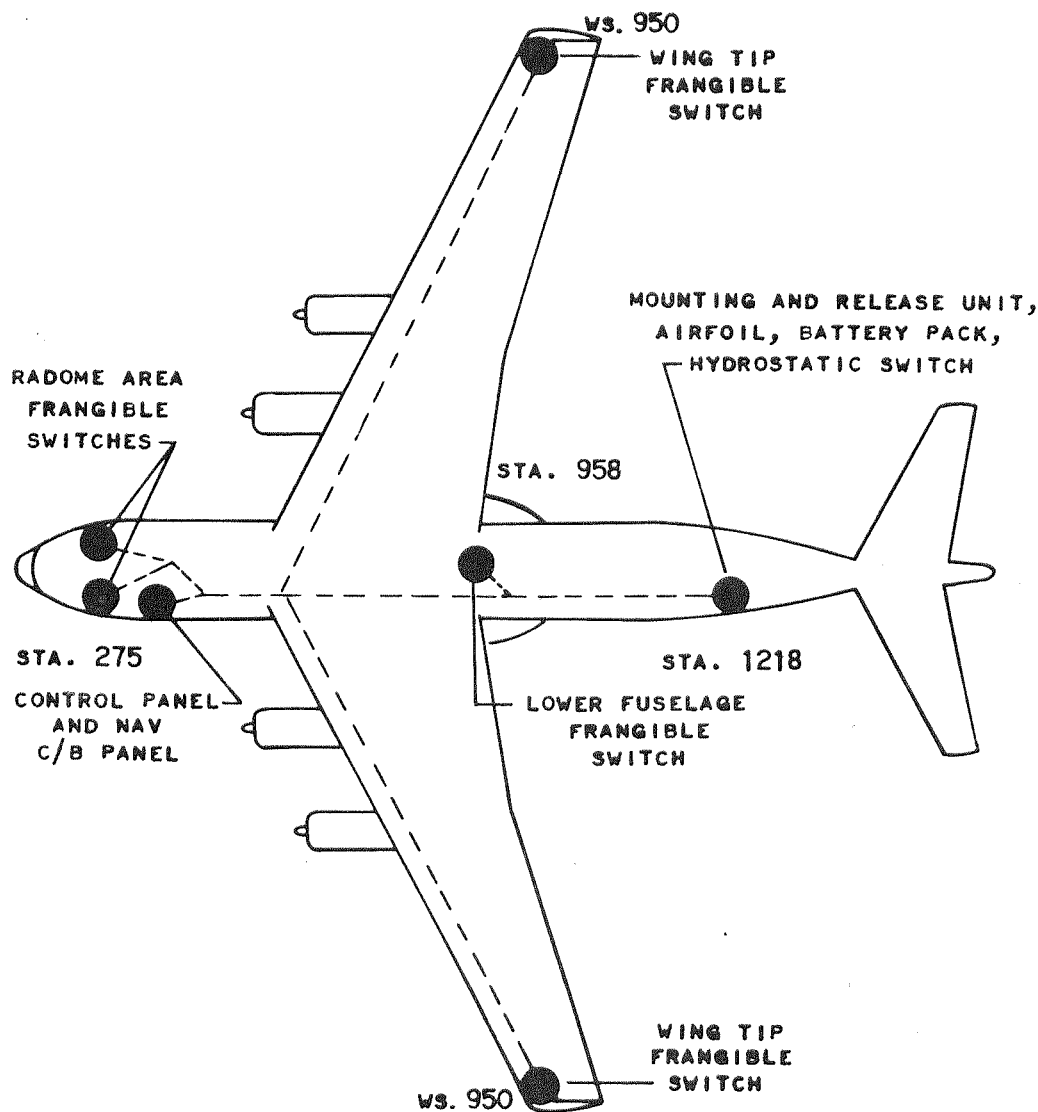


## CONTROL PANEL

The control panel is located in the upper left-hand portion of the navigator's control panel. This unit houses lights and switches for testing the battery charge and transmitter circuits. The airfoil can be manually deployed by actuating the DEPLOY switch.

## BATTERY PACK

The battery pack is mounted on the aft side of the wing box adjacent to the CPI tray, and supplies power to the release mechanism.



AN/URT-26 CPI AIRCRAFT  
EQUIPMENT LOCATIONS

## BEACON BATTERY SHUTOFF

The beacon battery shutoff unit is stowed near the battery pack, above the left-hand jump door. A two ampere circuit breaker is installed in the avionics circuit breaker panel.

The beacon battery shutoff unit is attached to the airfoil to prevent undesirable transmissions when the airfoil is removed from the aircraft.

## SYSTEM OPERATION

The CPI is completely independent of other avionic equipment operation and will be ejected into the aircraft slip-stream automatically upon actuation of one of the switches.

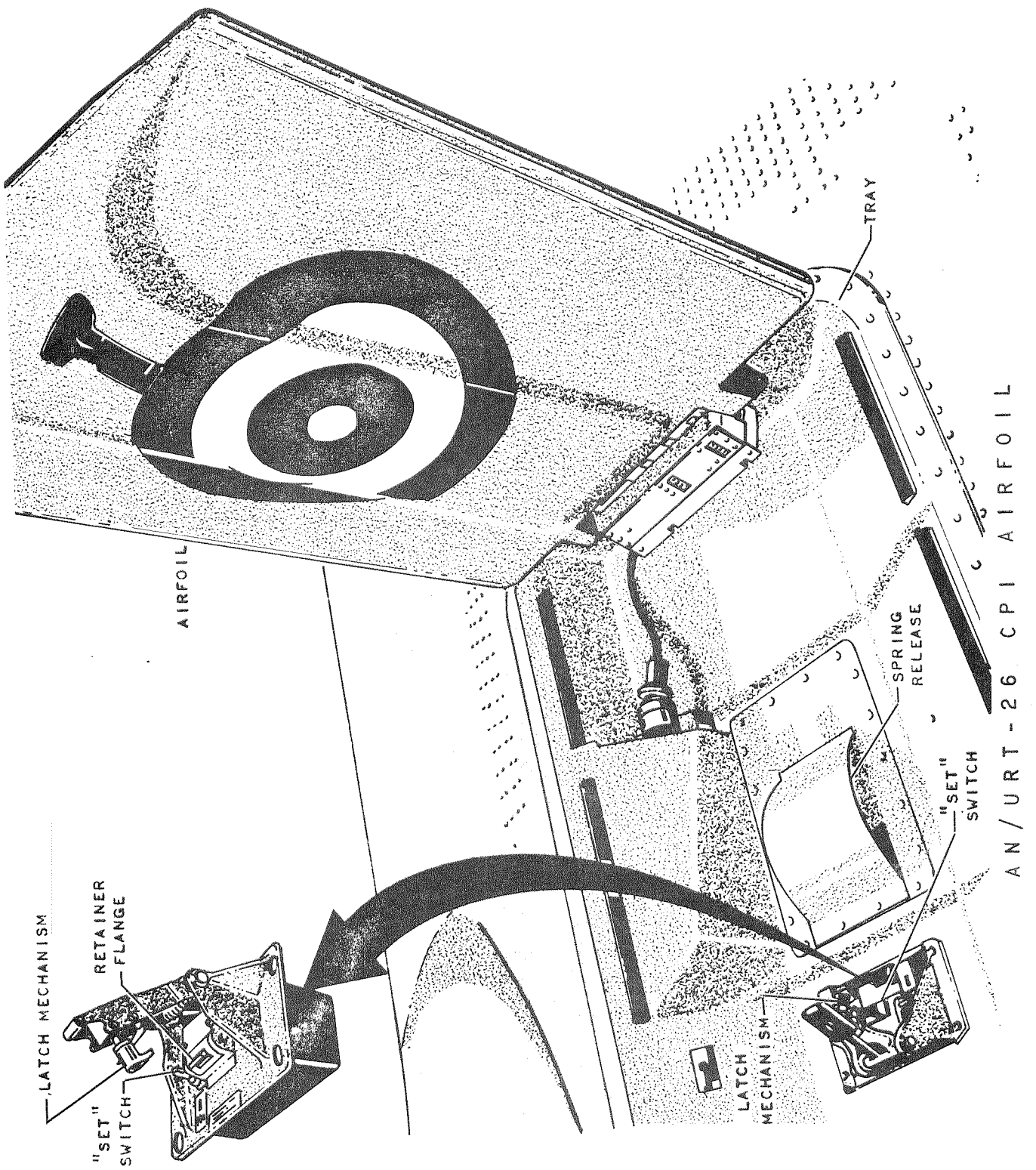
To install the airfoil it is first necessary to reset the release mechanism. Resetting the release mechanism positions a retainer flange. When the latch, which holds the airfoil, is depressed, it will engage the retainer flange. With the latch mechanism in its raised position and while holding the retainer flange back against spring tension, momentarily press the SET switch. This passes a D-C signal thru an electromagnetic holding coil which creates a magnetic field positioning the retainer flange in its "locked" position. The system is now in its armed configuration.

Note: The "strength" of the latch made during airfoil installation is directly proportional to the current of the release unit battery pack at the time the SET switch is pressed. Charging the battery pack after latch will not increase the holding power of the latch.

When aircraft power is on the CPI control panel supplies a trickle charge to the airfoil beacon battery and the release unit battery pack. This function can be tested from the control panel by depressing the CHARGING TEST switch and observing that both the RELEASE and BEACON lights illuminate. Proper transmitter operation can be verified by depressing the XMIT TEST switch and listening for a short duration tone thru a headset connected to the headset jack on the control panel. Anytime aircraft power is on and the airfoil is not installed in its mount the DEPLOY light will be on.

## FUNCTIONAL OPERATION

The airfoil is a self-contained unit requiring external power only to hold the radio beacon "off" while installed in the aircraft or undergoing tests. During static conditions (airfoil installed) the release unit battery pack (ABP-1) constantly supplies a voltage to the airfoil beacon holding it in the "off" condition. When the airfoil is ejected this voltage is removed and the 243 MHz, 250 mw radio beacon starts



transmitting. The transmitter will continuously transmit a swept tone between 300 and 1000 Hz at the carrier frequency of 243 MHz.

The airfoil is held in by an electromagnetic holding coil which receives its magnetizing voltage from the APB-1 during "SET".

Note: Repeated or prolonged use of the SET switch can run-down the release unit battery pack. It should be pressed very briefly.

Under static conditions the 5.2 volts, DC from the APB-1 is routed through the normally-open contacts of the five fragile switches, the hydrostatic switch and the navigator's DEPLOY switch. Closure of any one of these switches will supply power from the APB-1 to trigger a Silicon Controlled Rectifier (SCR) in the release mechanism circuit. When the SCR fires, voltage from the SCR passes thru the electromagnetic coil in the reverse direction, de-magnetizing the coil and releasing the airfoil.

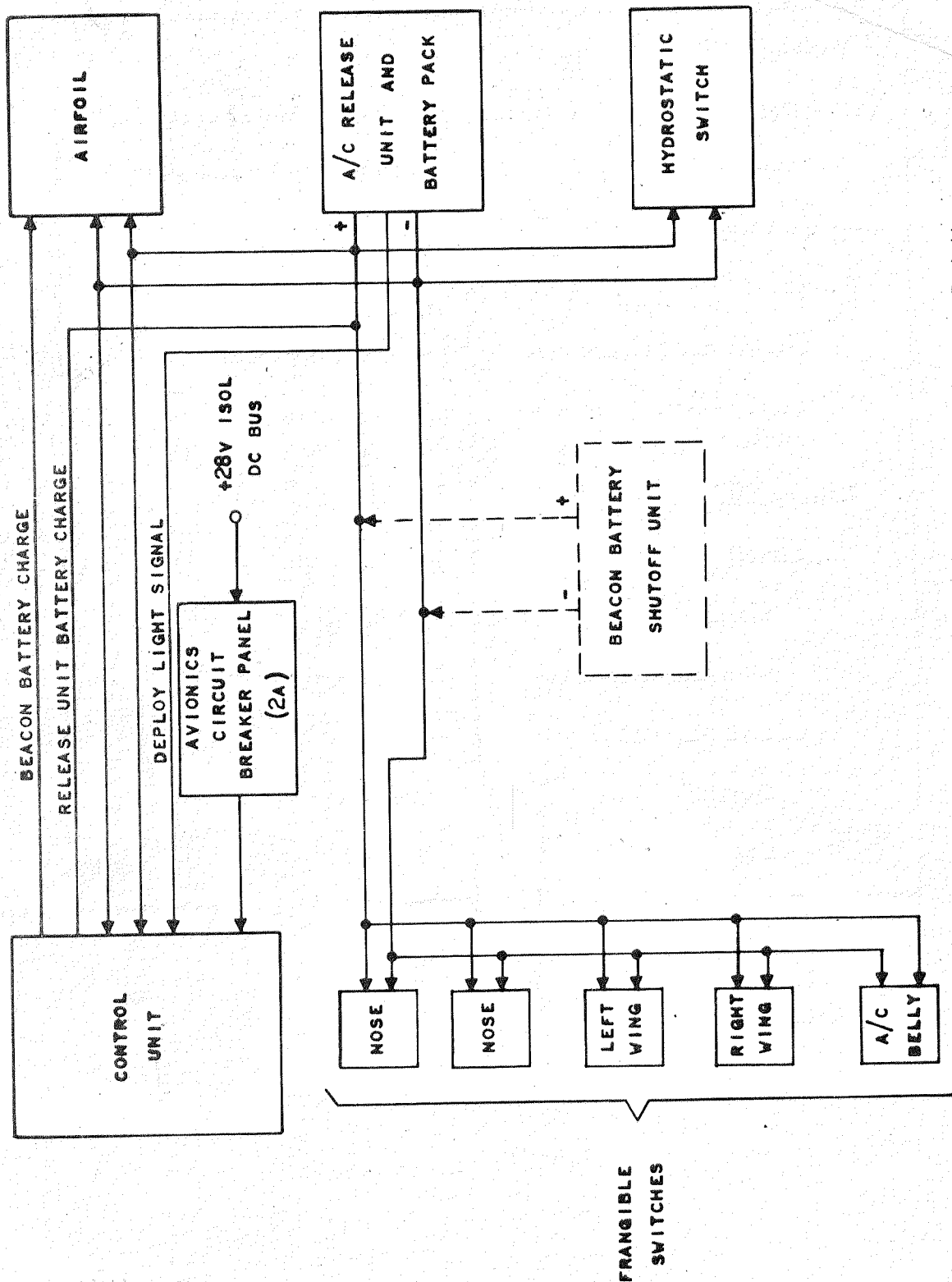
The leaf spring in the tray provides enough thrust to eject the airfoil clear of the aircraft without the aid of the aircraft slip-stream.

#### SPECIFICATIONS

CHARACTERISTIC	SPECIFICATION
Operational altitude	0 to 50,000 feet
Range (at 10,000 ft. and working with AN/ARA-25, AM-3259/ARC, and AN/ARC-34)	
ADF	50 nautical miles
Tone	80 nautical miles
Antenna radiation pattern	Omnidirectional
Transmitter frequency	243.0 MHz $\pm 0.003$ percent
Power output (unmodulated)	250 milliwatts minimum
Type of transmission	AM
Modulation	Chopped carrier

SPECIFICATIONS (continued)

CHARACTERISTIC	SPECIFICATION
Modulating Frequencies	
High	1000 Hz +30 -10 percent
Low	300 Hz +10 -20 percent
Sweep rate	2 to 3 Hz
Power	
Airfoil and release unit	Battery operated
Storage battery charging voltage	28 volts, DC
Battery Life	
Airfoil	
Storage	Rechargeable
With transmitter on	48 hours at 0° C
Beacon Shut Off	
Storage	2 years
Use	3 months



AN / URT - 26 BLOCK DIAGRAM

