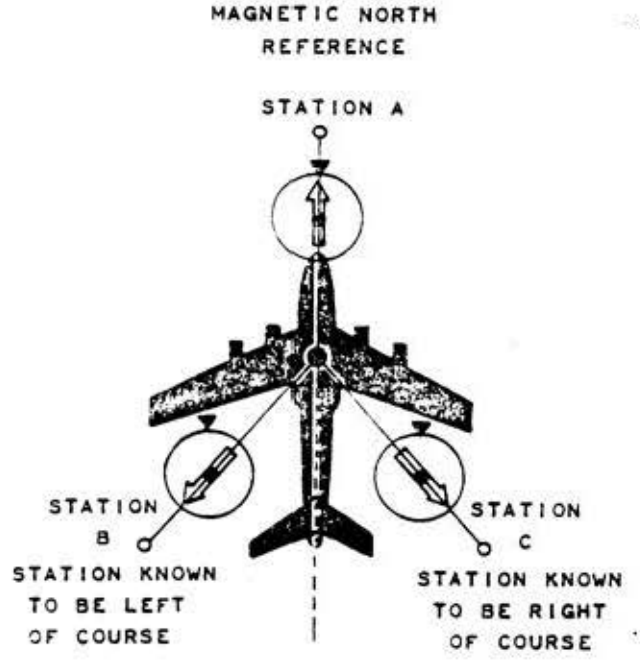
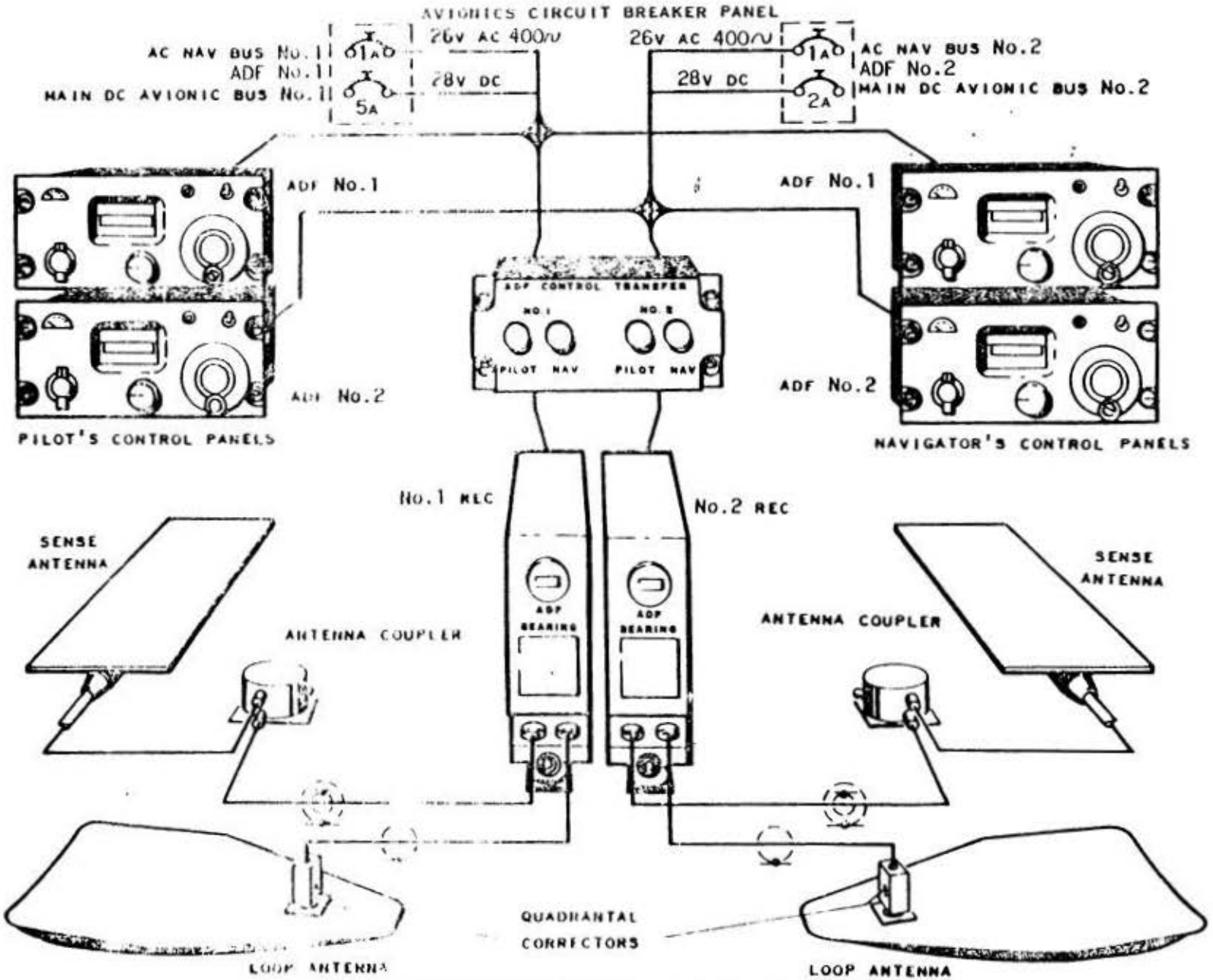
RADIO COMPASS SYSTEM

GENERAL

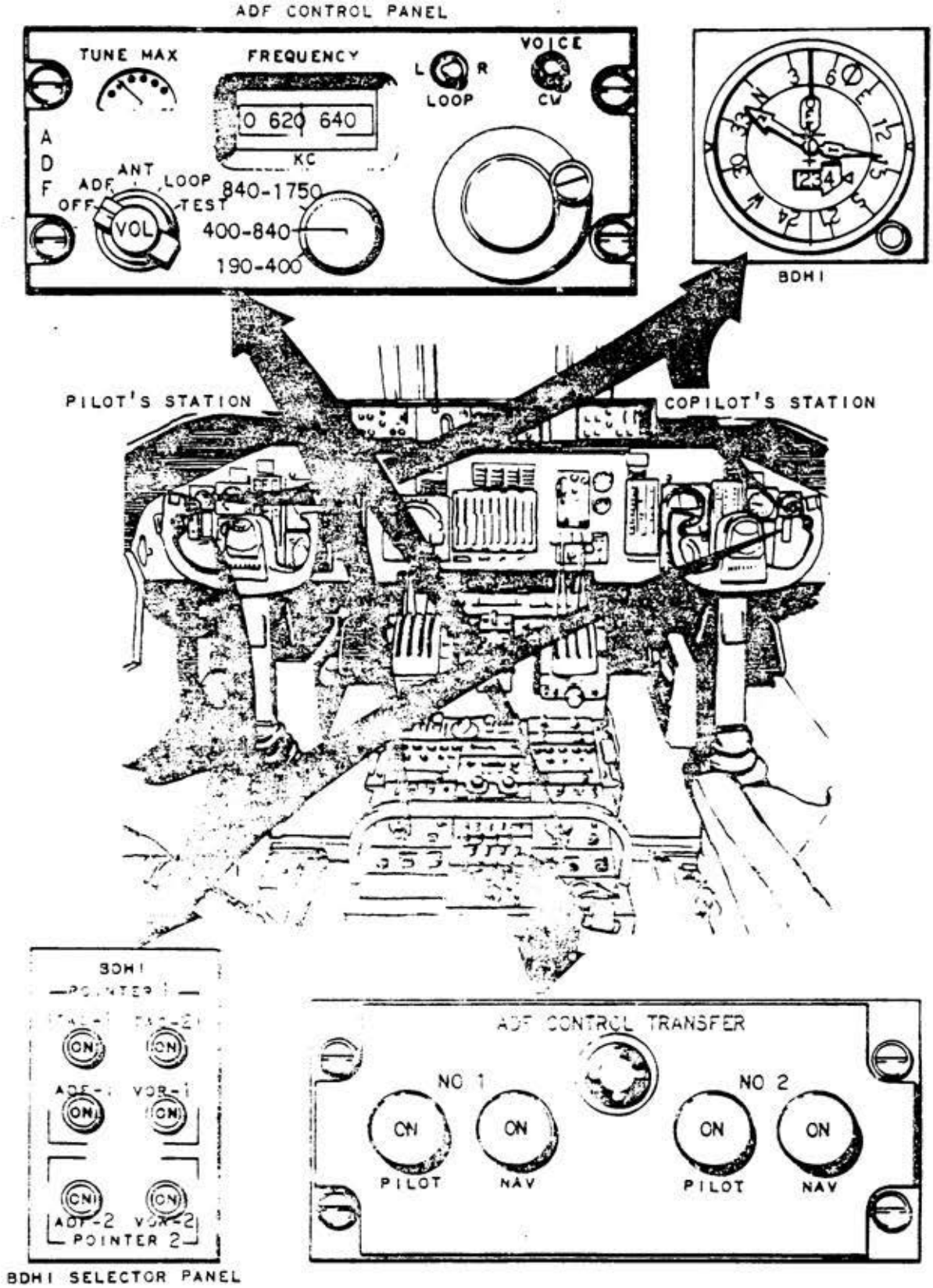
Two complete and independent Automatic Direction Finder (ADF) systems are installed on the StarLifter. Each system provides automatic or manual radio direction finding as an aid to navigation. During radio compass homing the system supplies continuous visual relative-bearing to a selected ground radio 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.



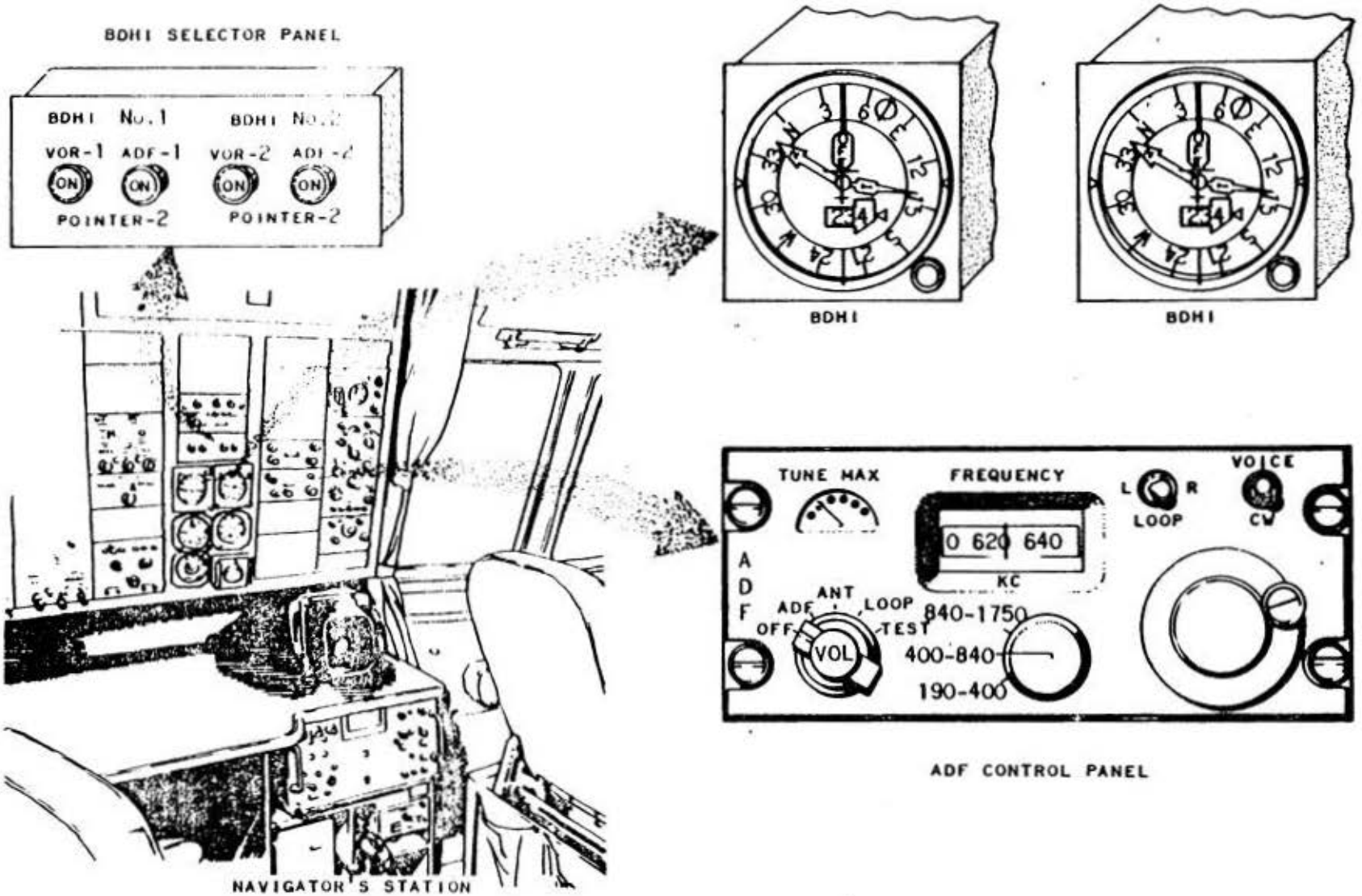
DETERMINING POSITION OF AIRCRAFT



ADF COMPONENTS AND CABLING

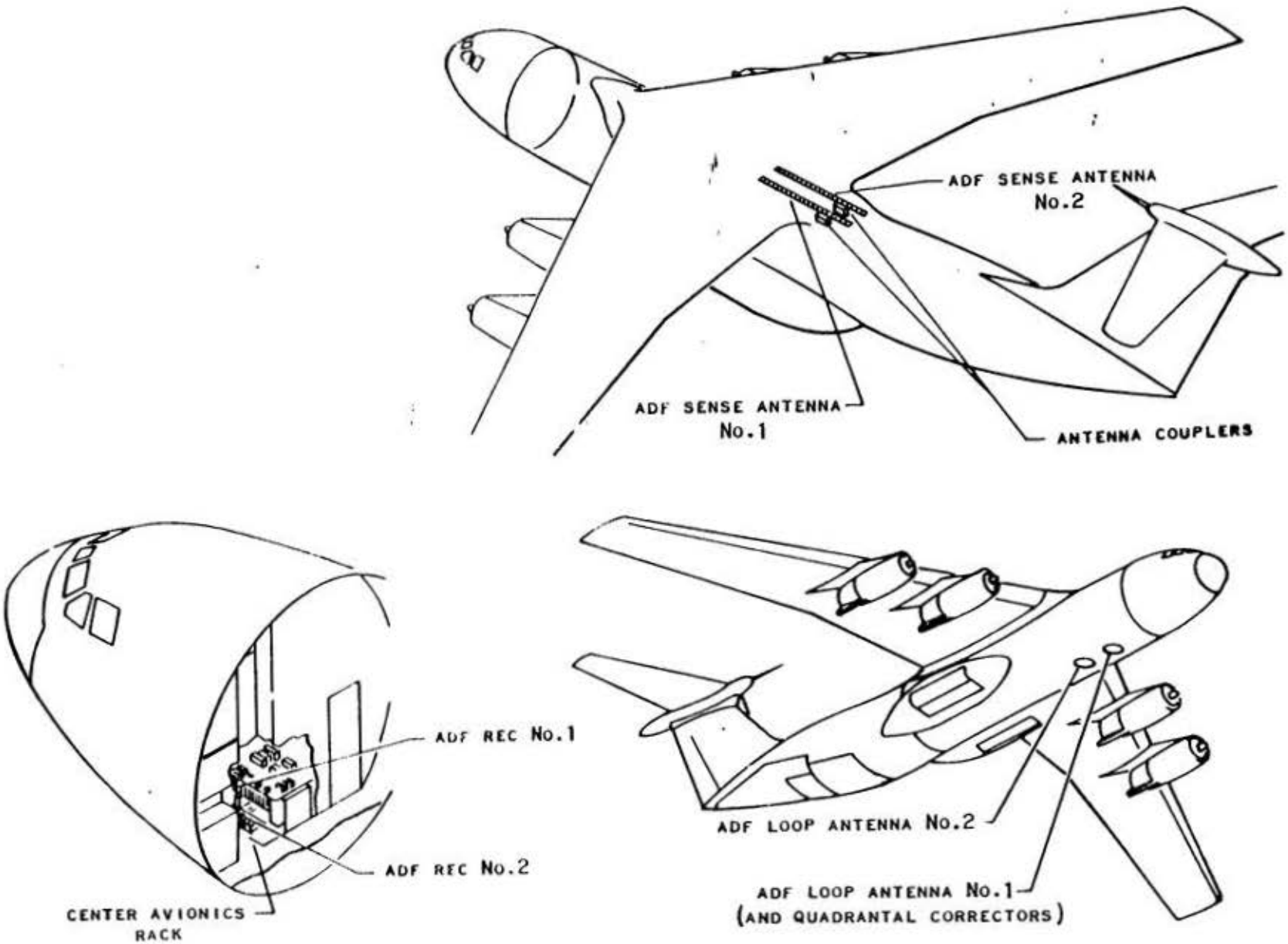


PILOT'S AND COPILOT'S
CONTROLS AND INDICATORS



ADF CONTROL PANEL

NAVIGATOR'S CONTROLS AND INDICATORS



ADF RECEIVER AND ANTENNA LOCATIONS

AIRCRAFT INSTALLATION

The 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
• Quandrantal 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)

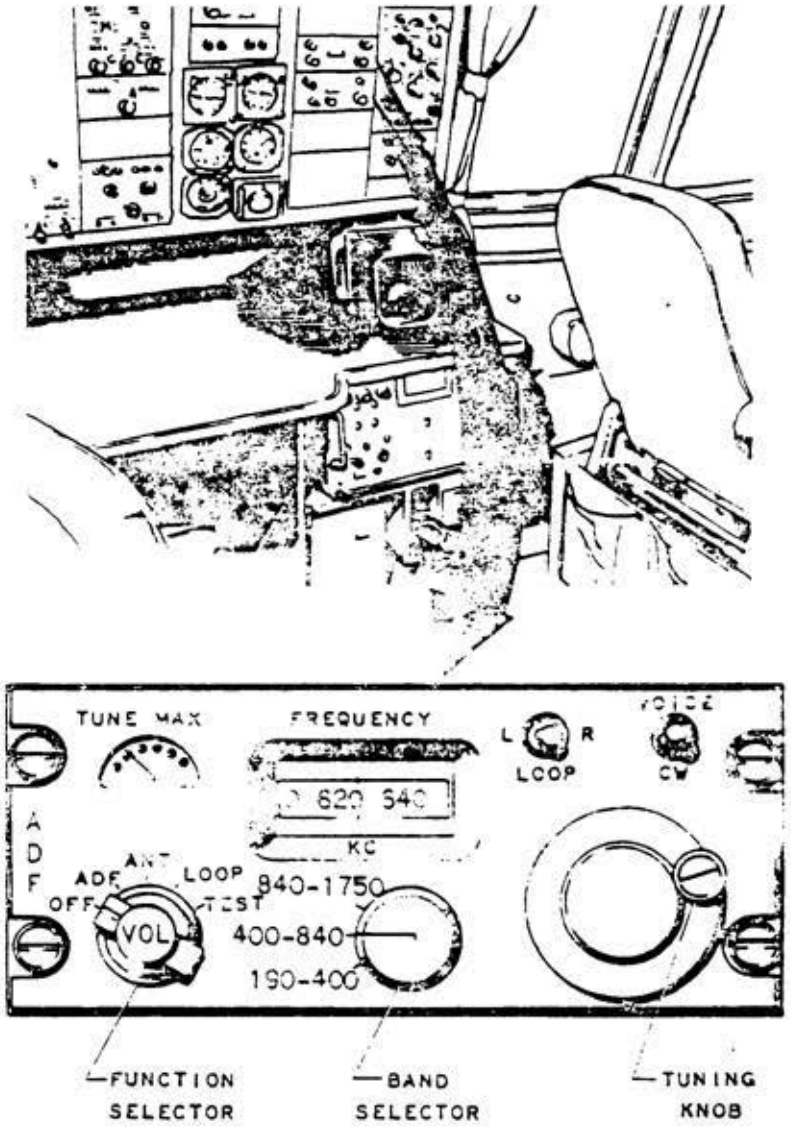
Control Panel

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.

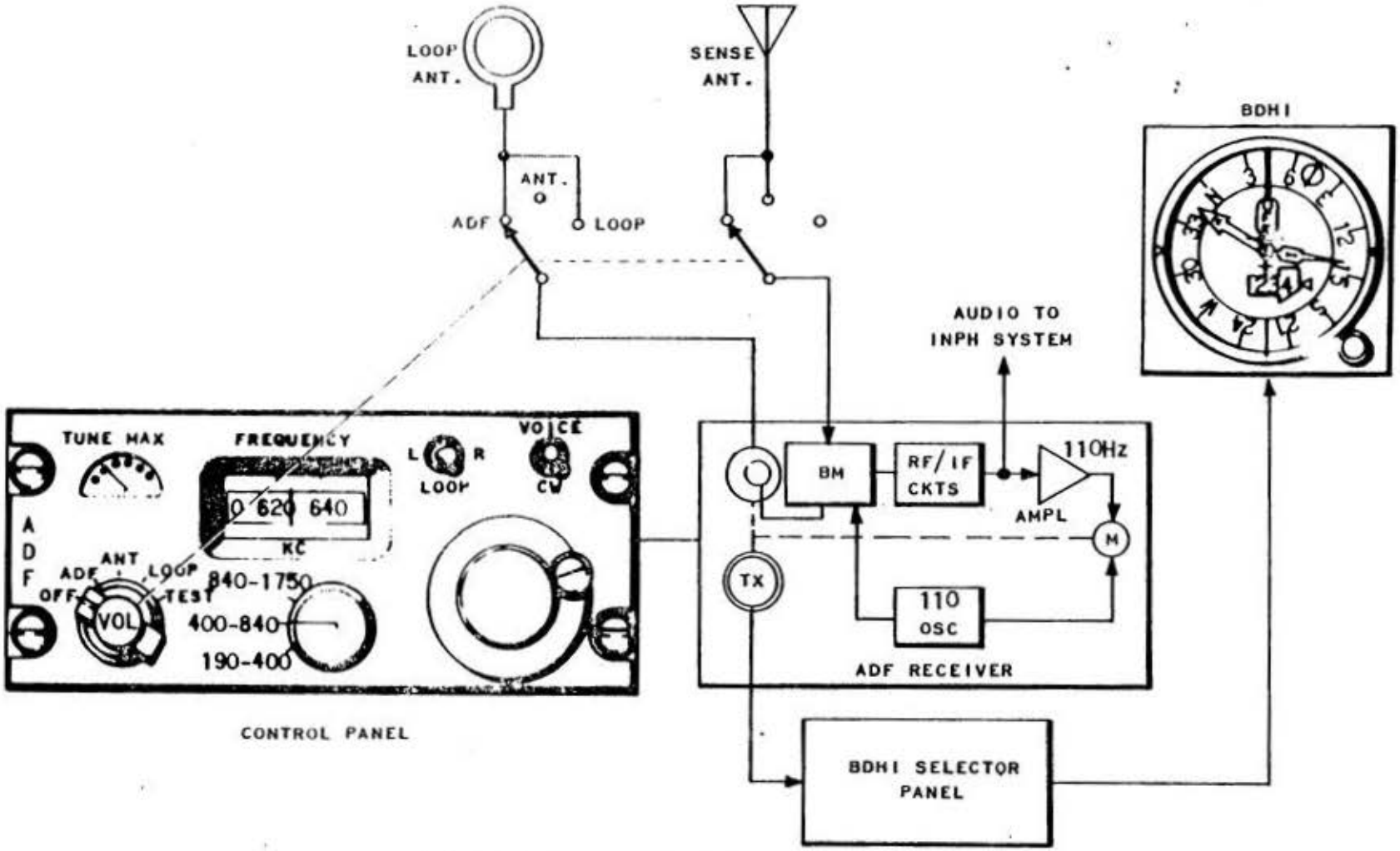
In the "ADF" position the system uses the sense and loop antenna signals to produce automatic bearing information. In "ANT" position only the sense antenna is used and the system provides standard radio reception. Normally "ANT" mode is used for exact tuning to a station before selecting "ADF" or "LOOP" 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

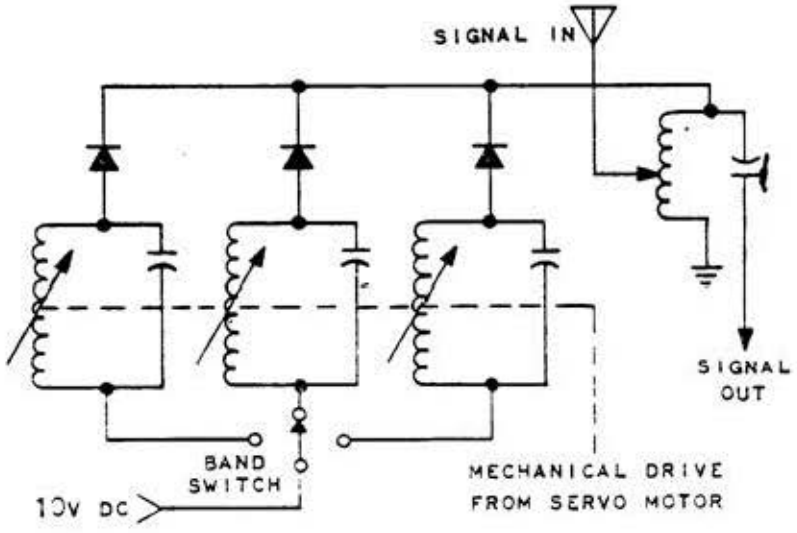
CHARACTERISTIC	SPECIFICATION
Audio	
Response	Within 9 db, 300-2000
Level	Adjustable up to 100 mw
Impedance	500 ohms
Distortion	Less than 10 percent at 100 mw (measured at 1000∼ , 30 percent modulation)
Tuning Indications:	Tuning meter
Function switching	Solid state
Intermediate frequency	142.5 KHz
BFO	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.

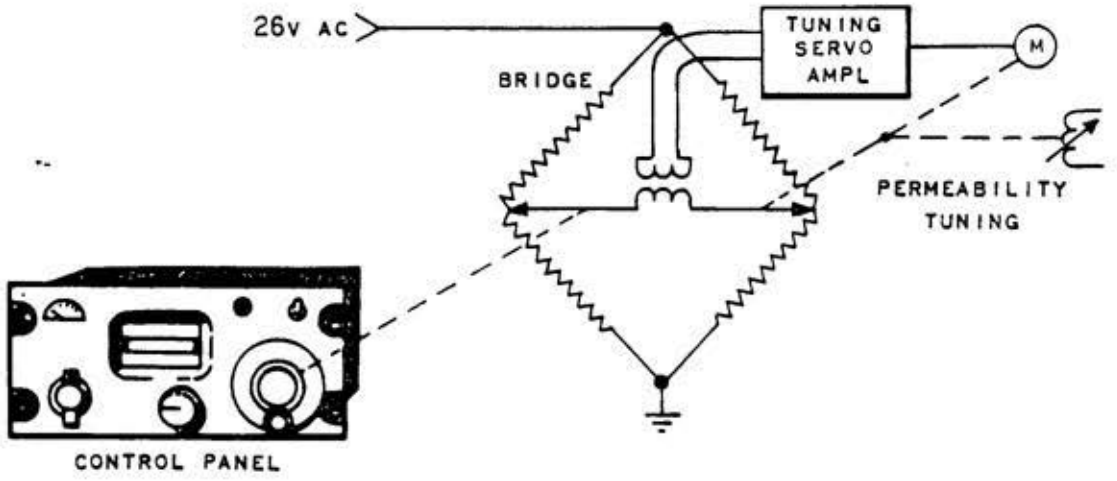
BAND SWITCHING - TUNING

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.



SIMPLIFIED BANDSWITCHING FOR TYPICAL STAGE

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.



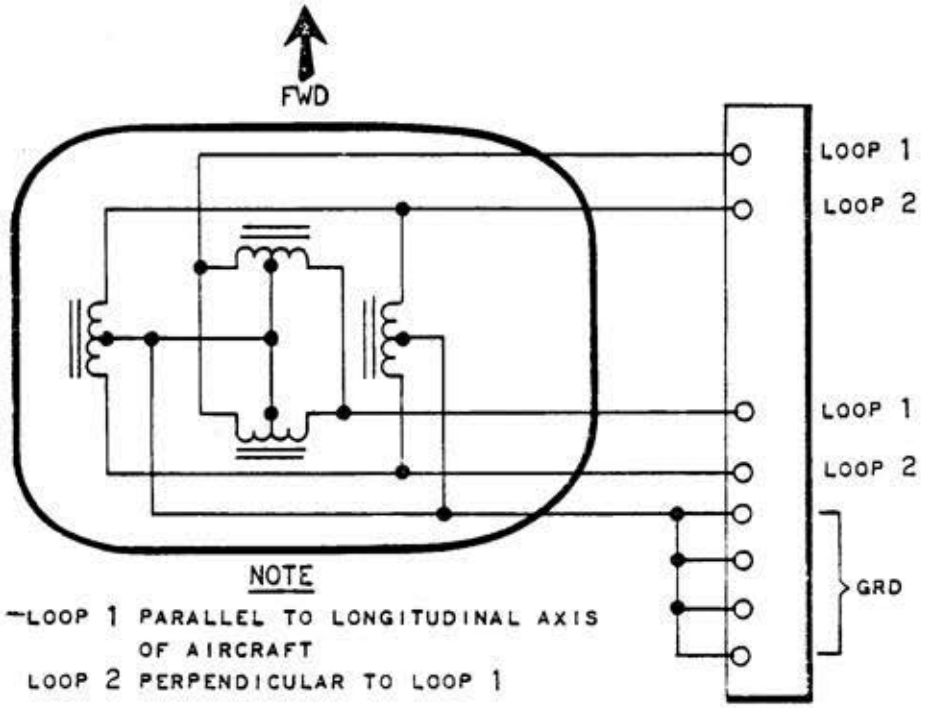
SIMPLIFIED TUNING CIRCUITS

ADF OPERATION

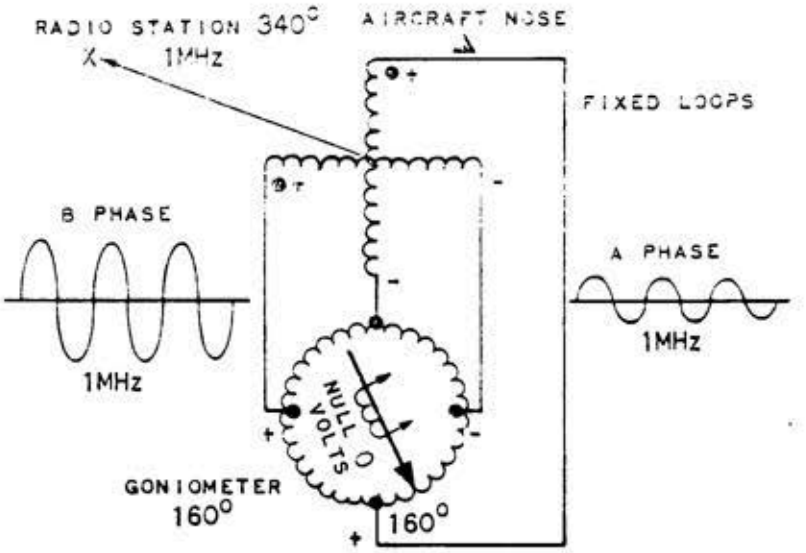
Radio direction finding is based on the directional characteristics of loop antennas. A fixed loop (now rotating) antenna having two windings on ferrite cores perpendicular to each other provides the directional characteristics. The amplitude of the voltage inducted in each winding depends on the angular 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 of 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 modulater loop signal will be in phase (adding) or out of phase (subtracting) if the goniometer is not at null.

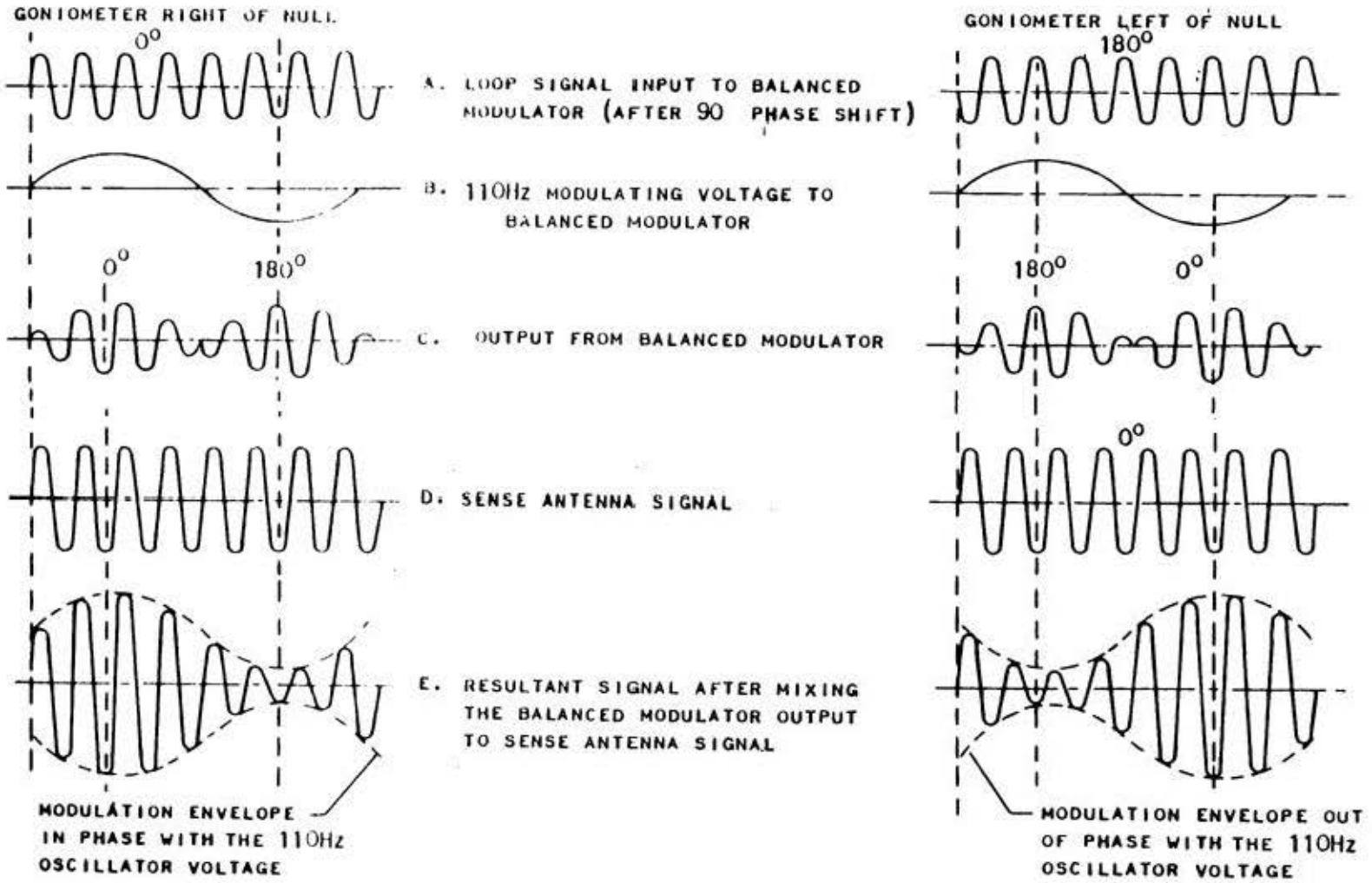


On one side of the goniometer null an adding condition will exist and on the other side a subtracting condition. The addition and subtraction of the loop and sense signals results in a 110 Hz amplitude modulation. The phase of the modulation will depend on whether the goniometer is left or right of null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

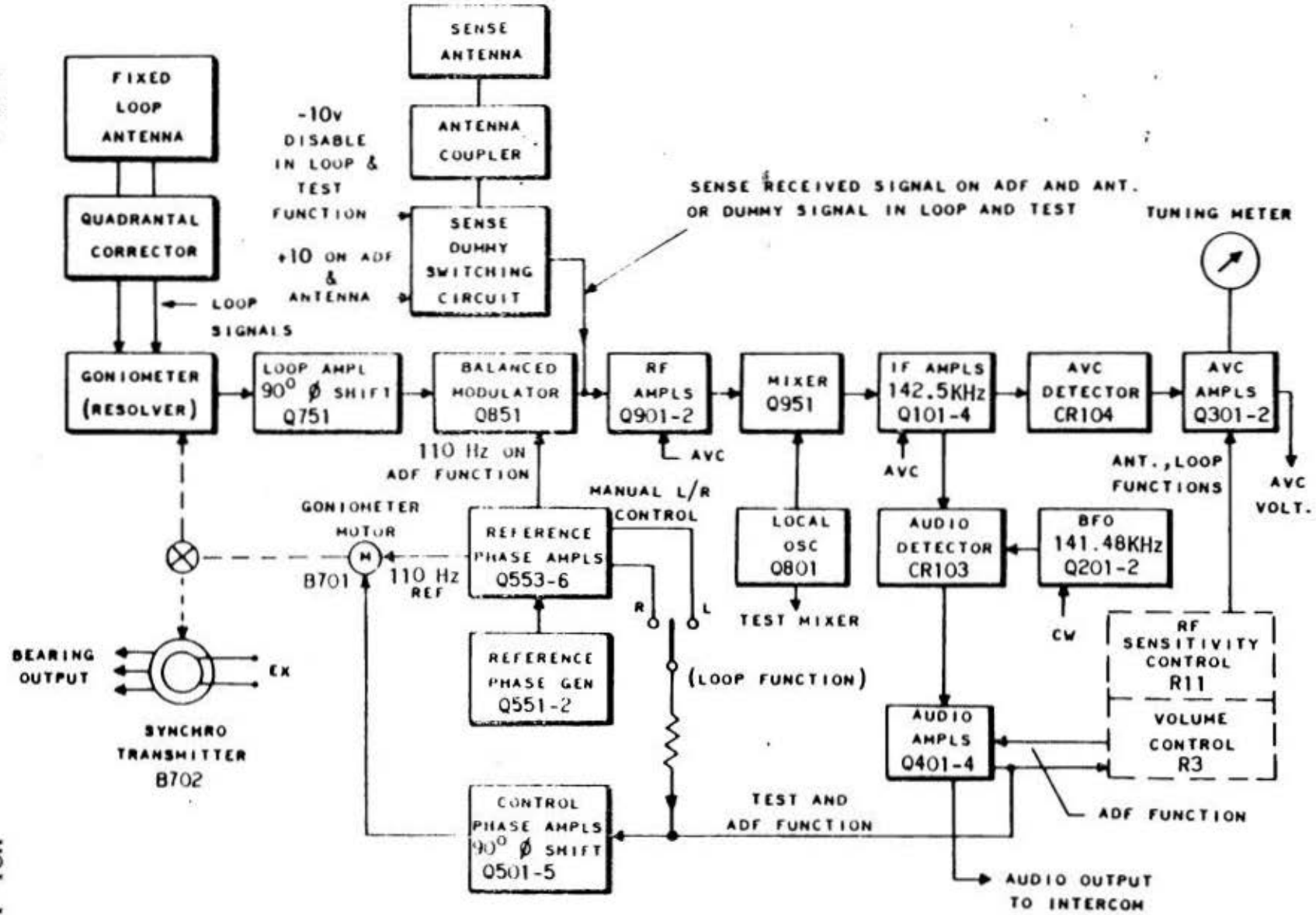
The composite antenna signal is amplified by the RF amplifier and combined with a local oscillator signal in the mixer. The difference frequency of 142.5 Hz is selected by the tuned circuits in the mixer output. Band switching and tuning circuits maintain a 142.5 Hz difference between the local oscillator 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 siganls 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



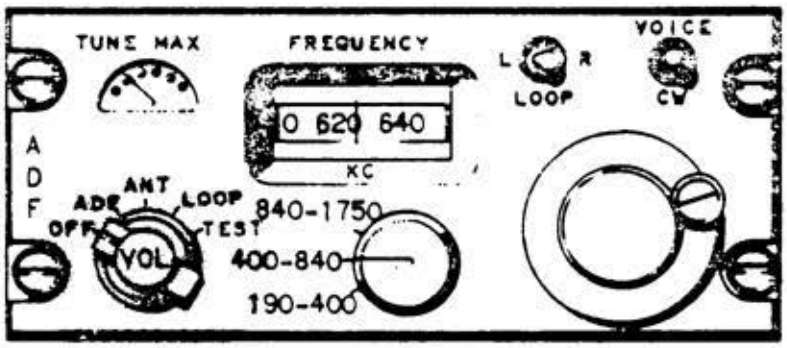
RECEIVER ADF AND LOOP FUNCTION BLOCK DIAGRAM

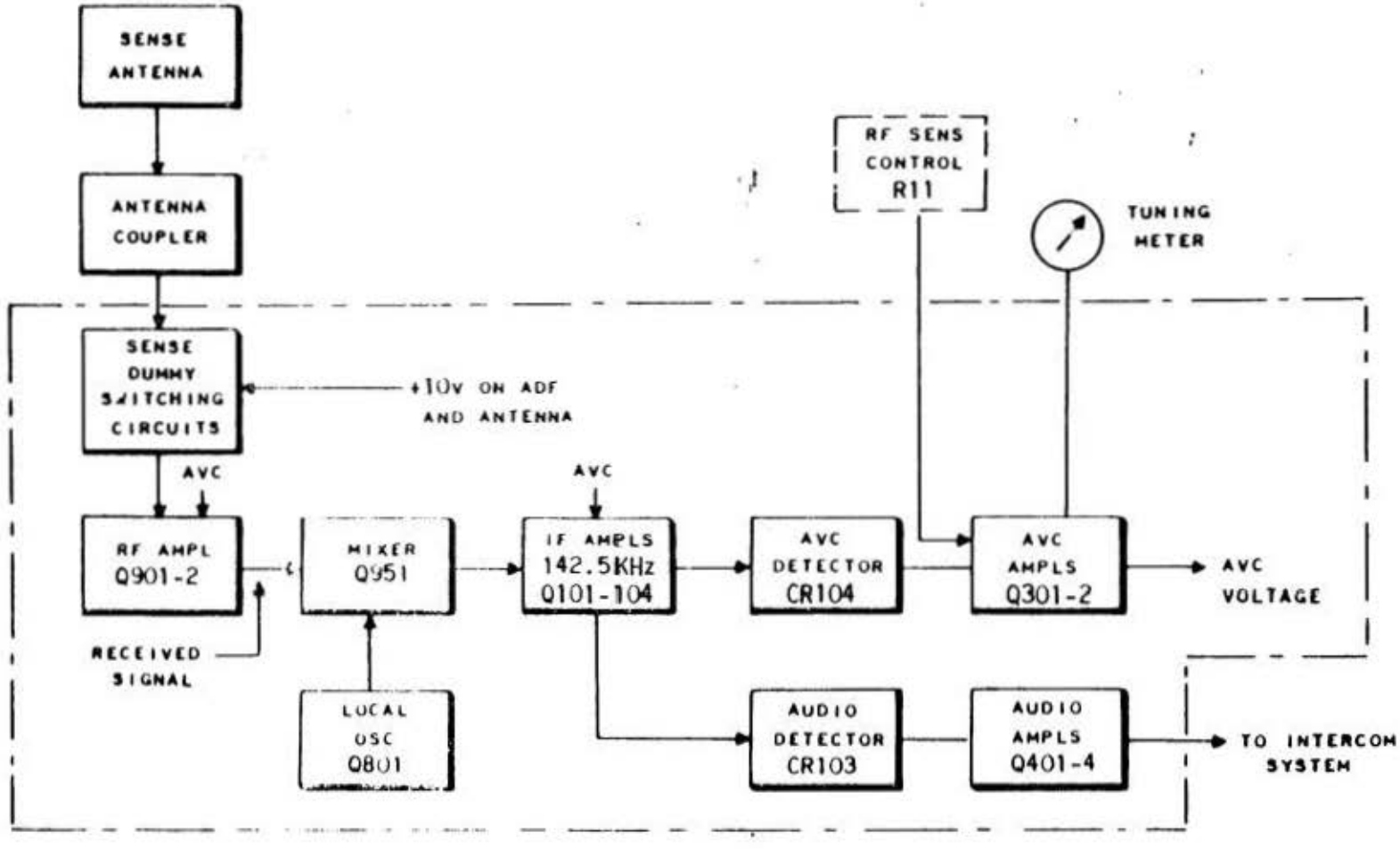
ANTENNA OPERATION

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 superheterodyne receiver connected only to the sense antenna. The antenna coupler provides impedance matching between the antenna and the receiver.

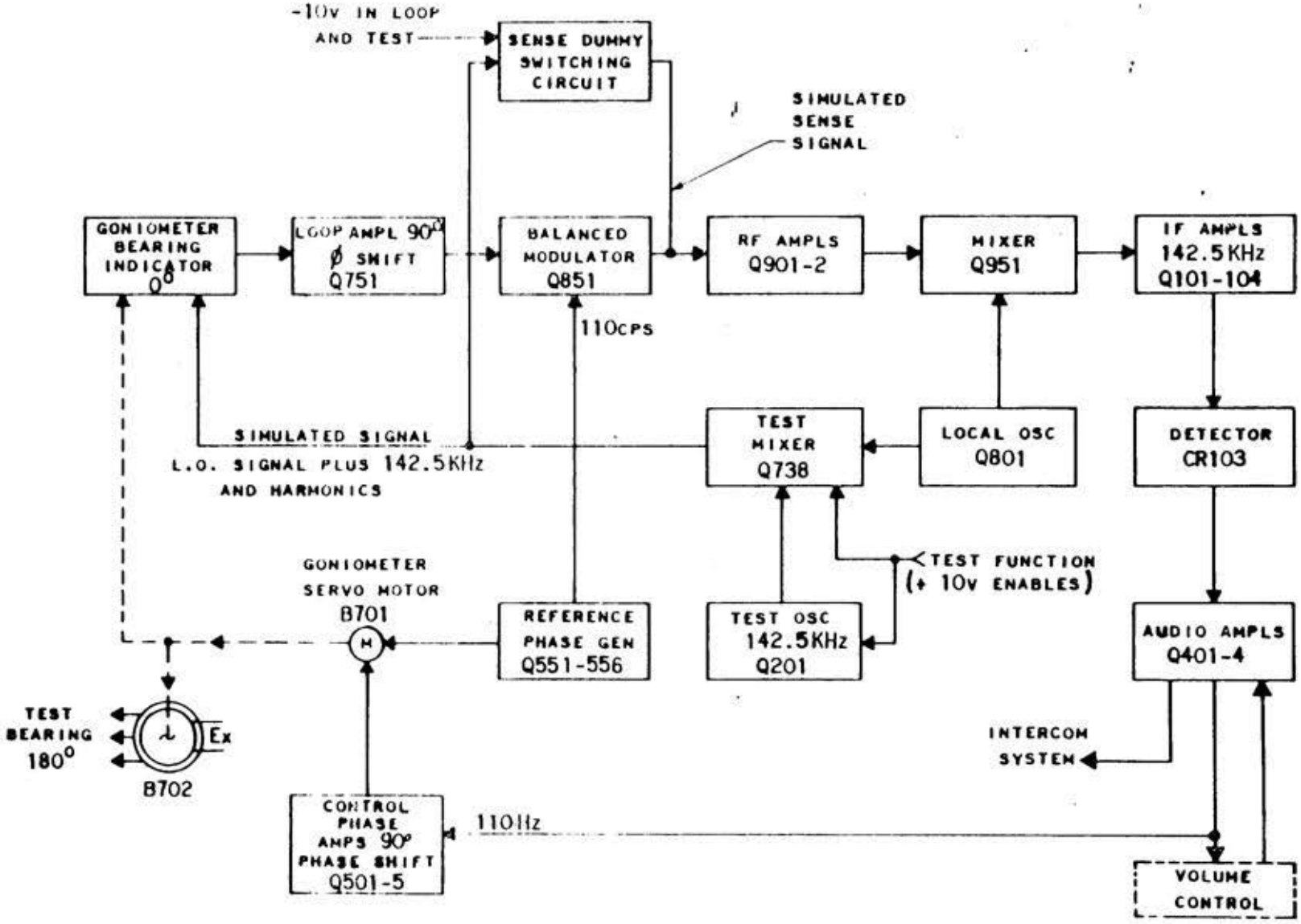
TEST OPERATION

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.

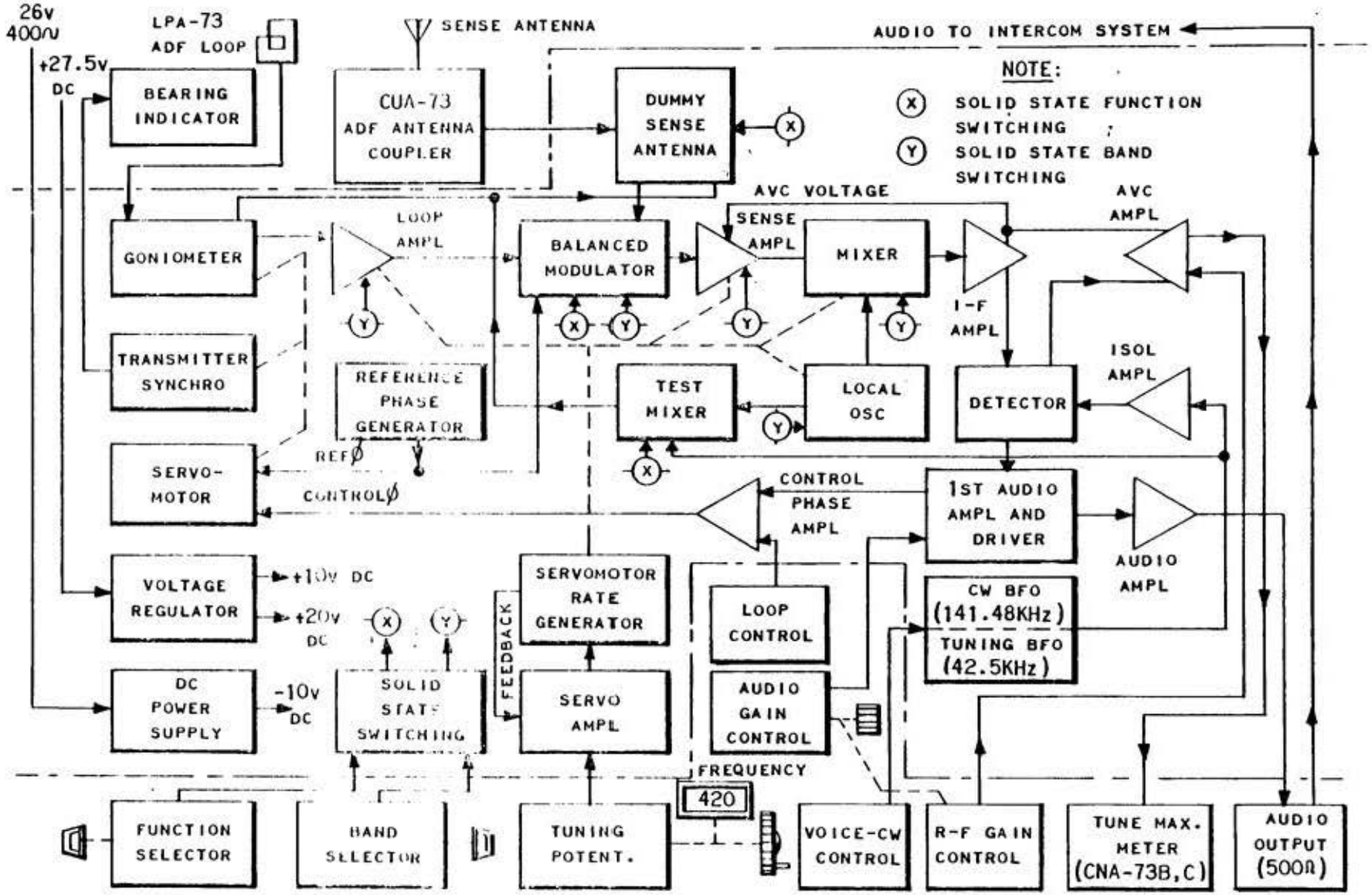




RECEIVER, ANTENNA FUNCTION BLOCK DIAGRAM



BLOCK DIAGRAM, ADF RECEIVER, TEST FUNCTION



ADF-73 AUTOMATIC DIRECTION FINDER SYSTEM BLOCK DIAGRAM