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).

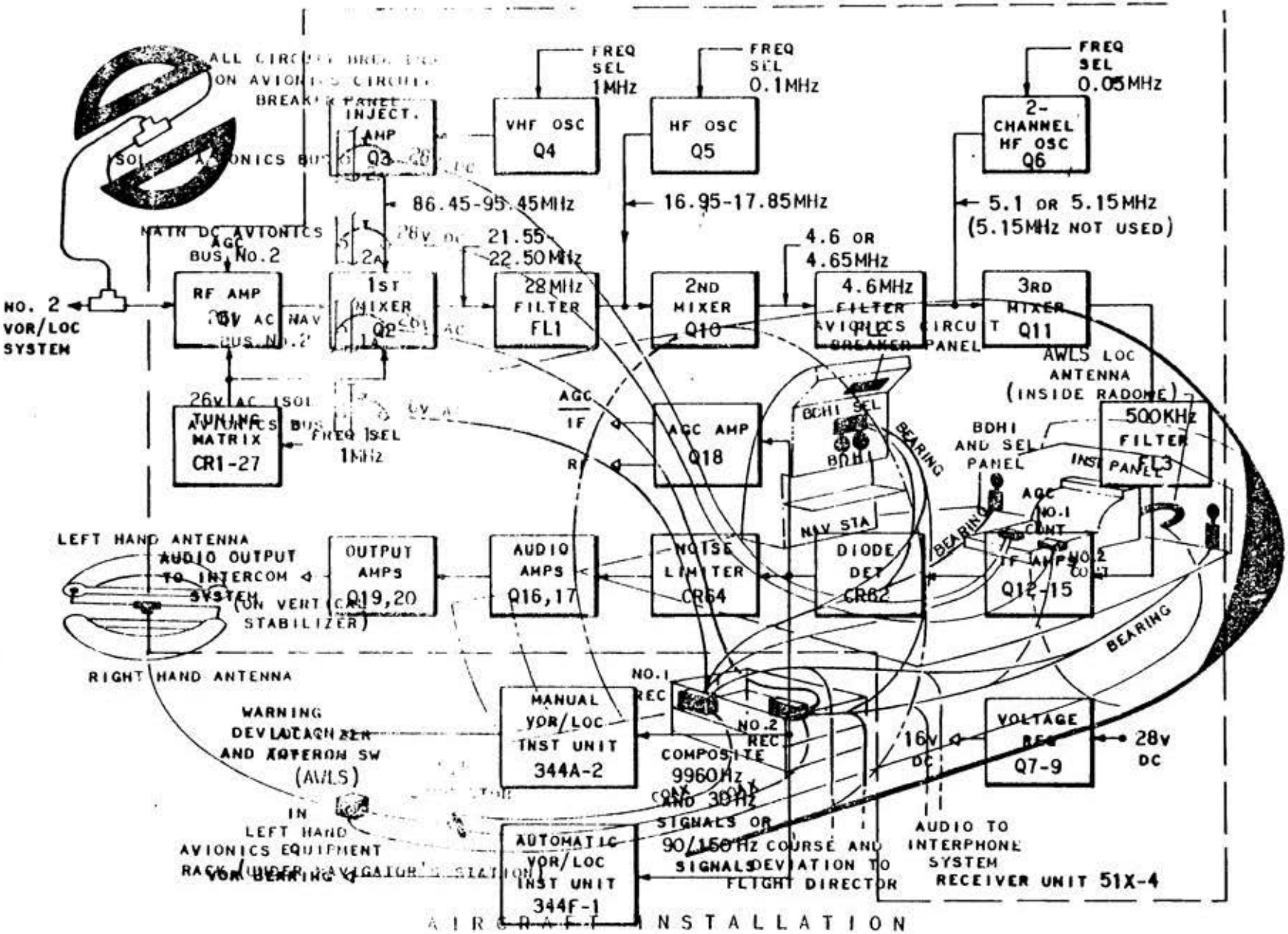
AIRCRAFT INSTALLATION

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 interchangable with no modification to aircraft wiring or operating procedure. The WILCOX 9765-100 radio set control and the COLLINS 3i3N-2 are also directly interchangeable and may be used with either receiver.



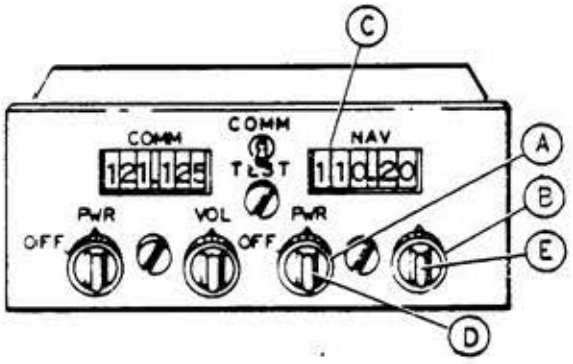
AIRCRAFT INSTALLATION

VOR/LOC RECEIVER BLOCK DIAGRAM

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.



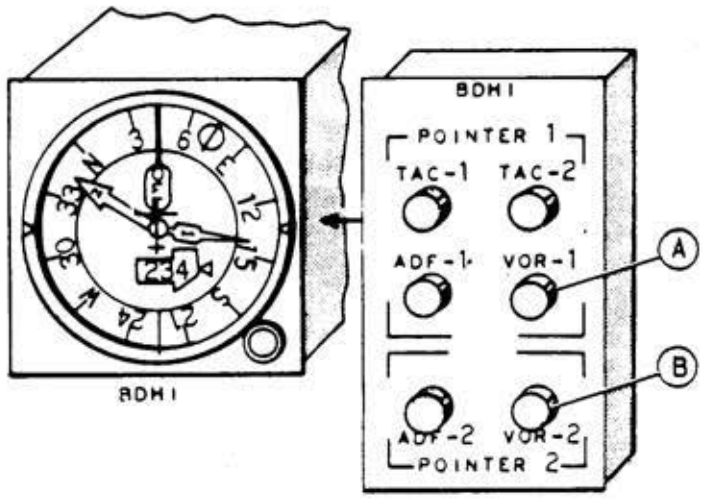
PILOT'S AND COPILOT'S RECEIVER CONTROLS (TWO)

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

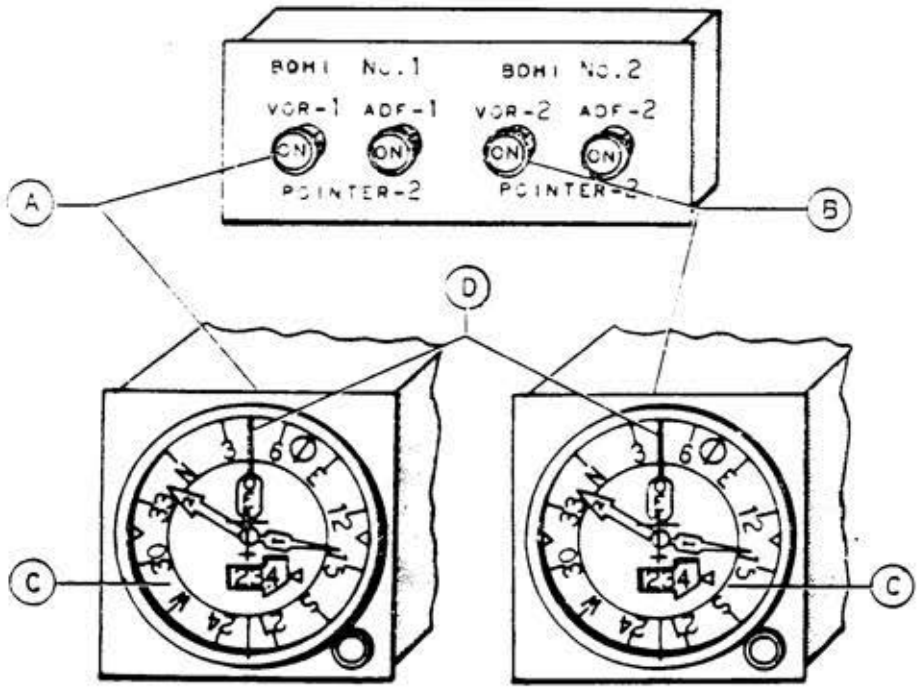
In VOR operation the bearing signal can be selected to drive pointers on Bearing Distance Heading Indicators (BDHI) and Horizontal Situation Indicators (HSI). Switch panels on the pilot's and copilot's instrument panels are used to select information displayed on their BDHI. System No. 1 information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

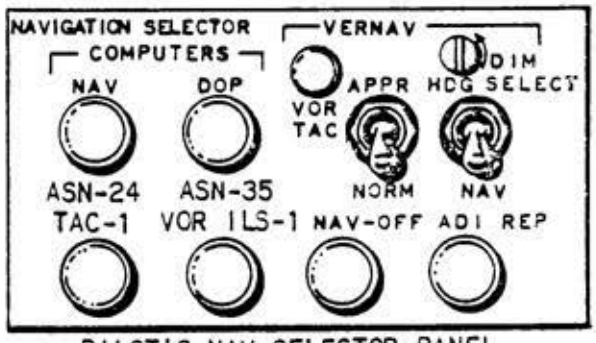
The bearing to the VOR station, relative to magnetic north, is indicated when the pointer position is read directly from BDHI compass card Ⓒ . When the pointer is read with respect to the indicator top index Ⓓ , the indication is the bearing of the VOR station relative to aircraft heading.



NAVIGATOR'S BDHI'S & SELECTOR PANEL

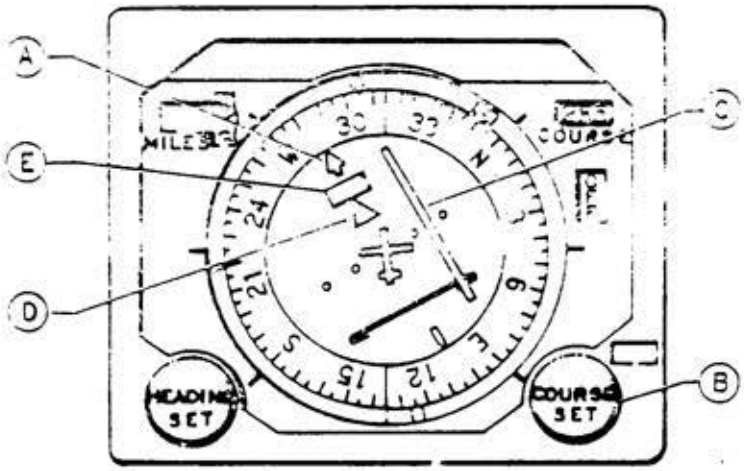
The VOR signals can also be selected for use by the flight director systems. Two navigation selector panels on the glare shield enable the pilot and copilot to select VOR-ILS (A) signals for their flight director systems. The pilot can select signals from the No. 1 system and the copilot from the No.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



PILOT'S NAV SELECTOR PANEL
(COPILOT'S IDENTICAL EXCEPT USES TACAN-2 & VOR/ILS-2)

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 (± 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 ± 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	±20.4 KHz wide (MIN) at 6 db down; ±35 KHz wide at 60 db down.
Altitude	To 55,000 ft.
Bearing accuracy	Manual 0.50 degree; automatic 0.50 degree.

SPECIFICATIONS

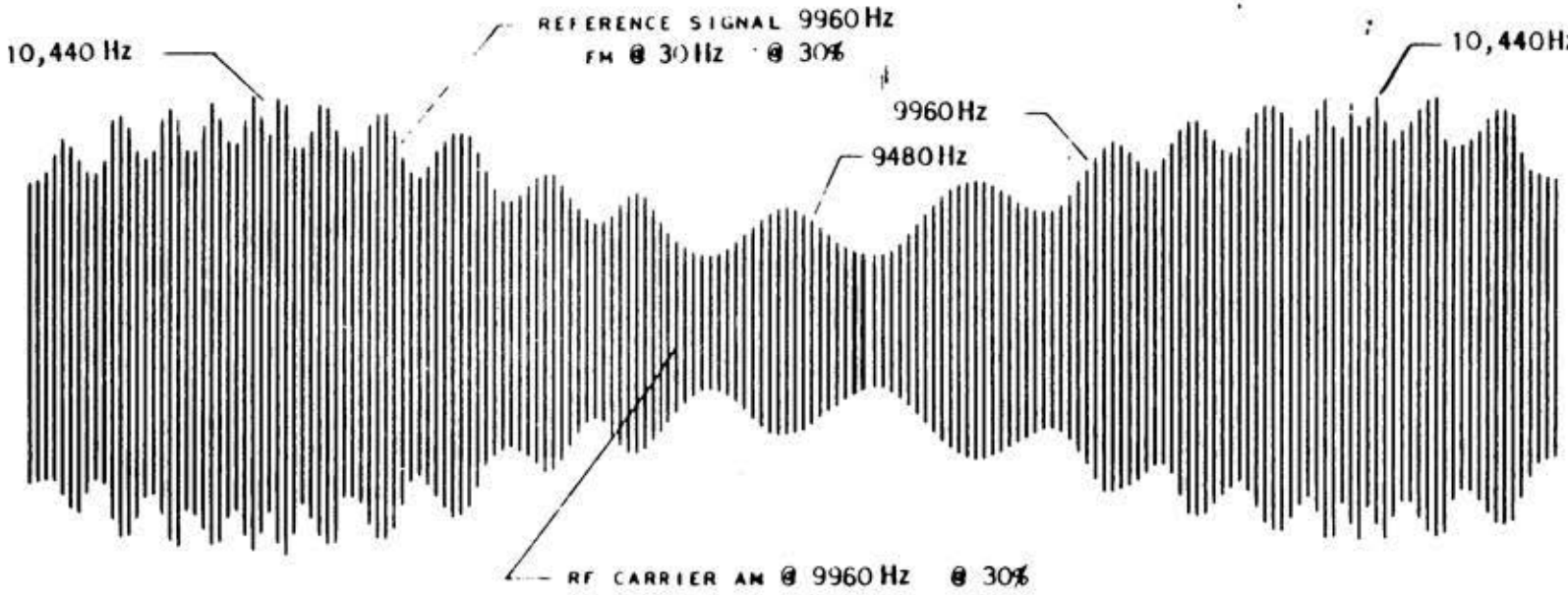
COLLINS 51R-6

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)

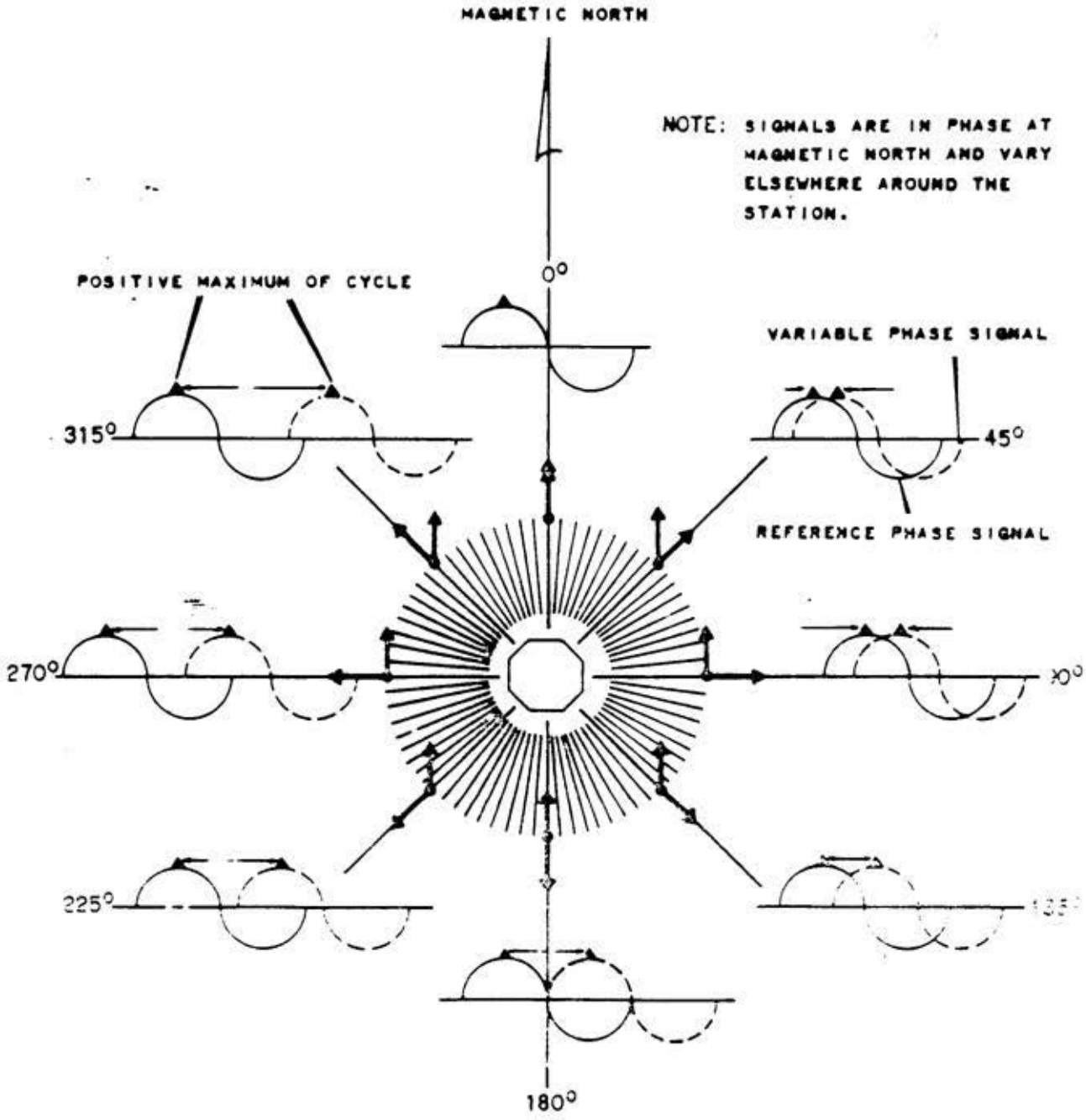
COLLINS 51R-6

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 milliwats 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



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 omni-directional 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 omni-directional antenna. The 30 Hz variable signal is produced by the rotating directional pattern varying the signal field strength (space modulation) at the receiver antenna.

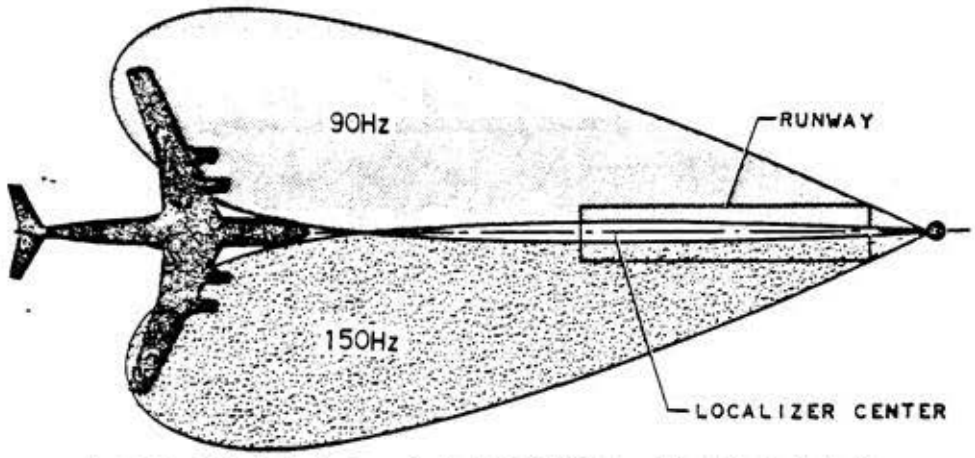
RECEIVED SIGNAL

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 strengtn.

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

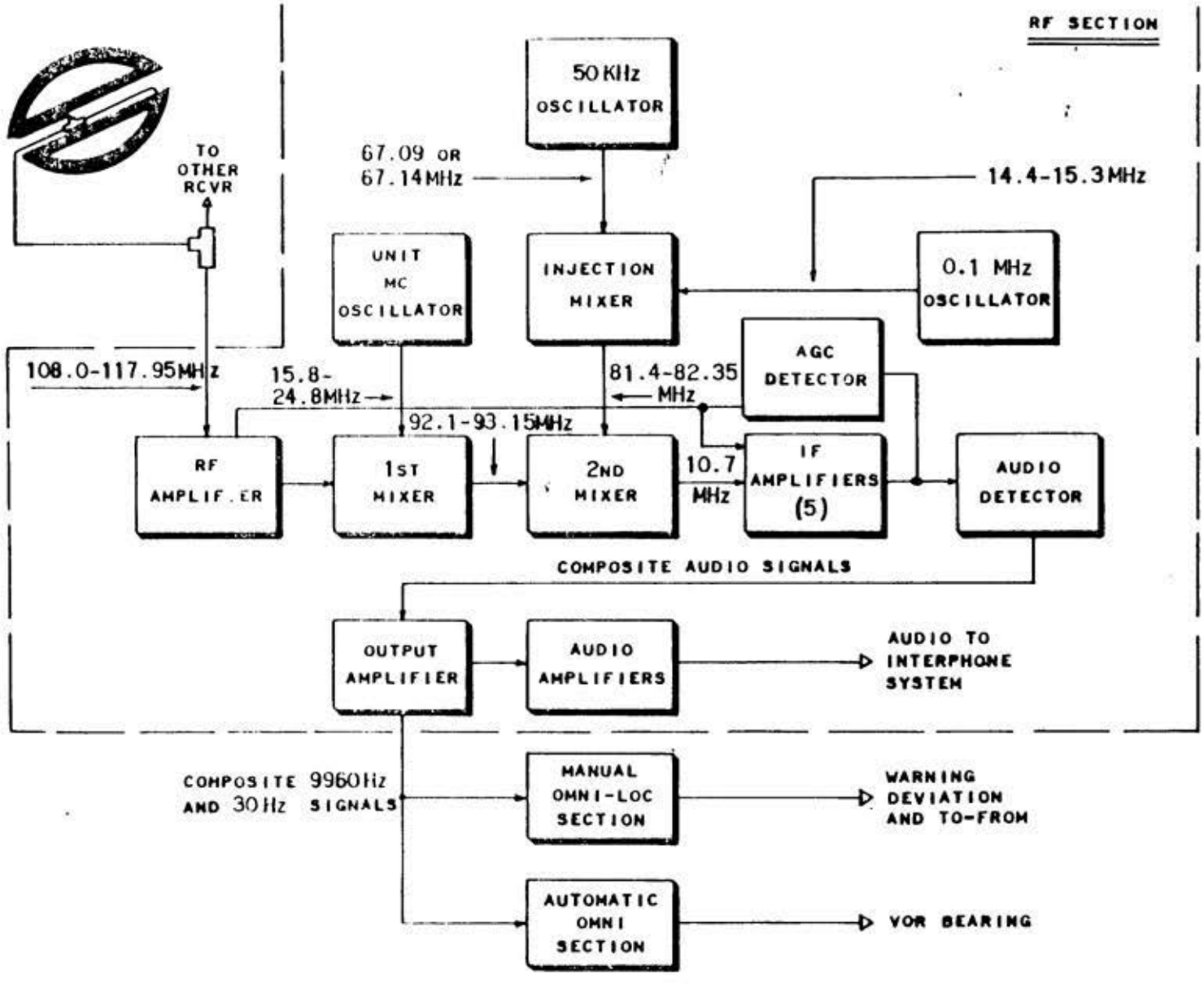
RF SECTION 806A WILCOX

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

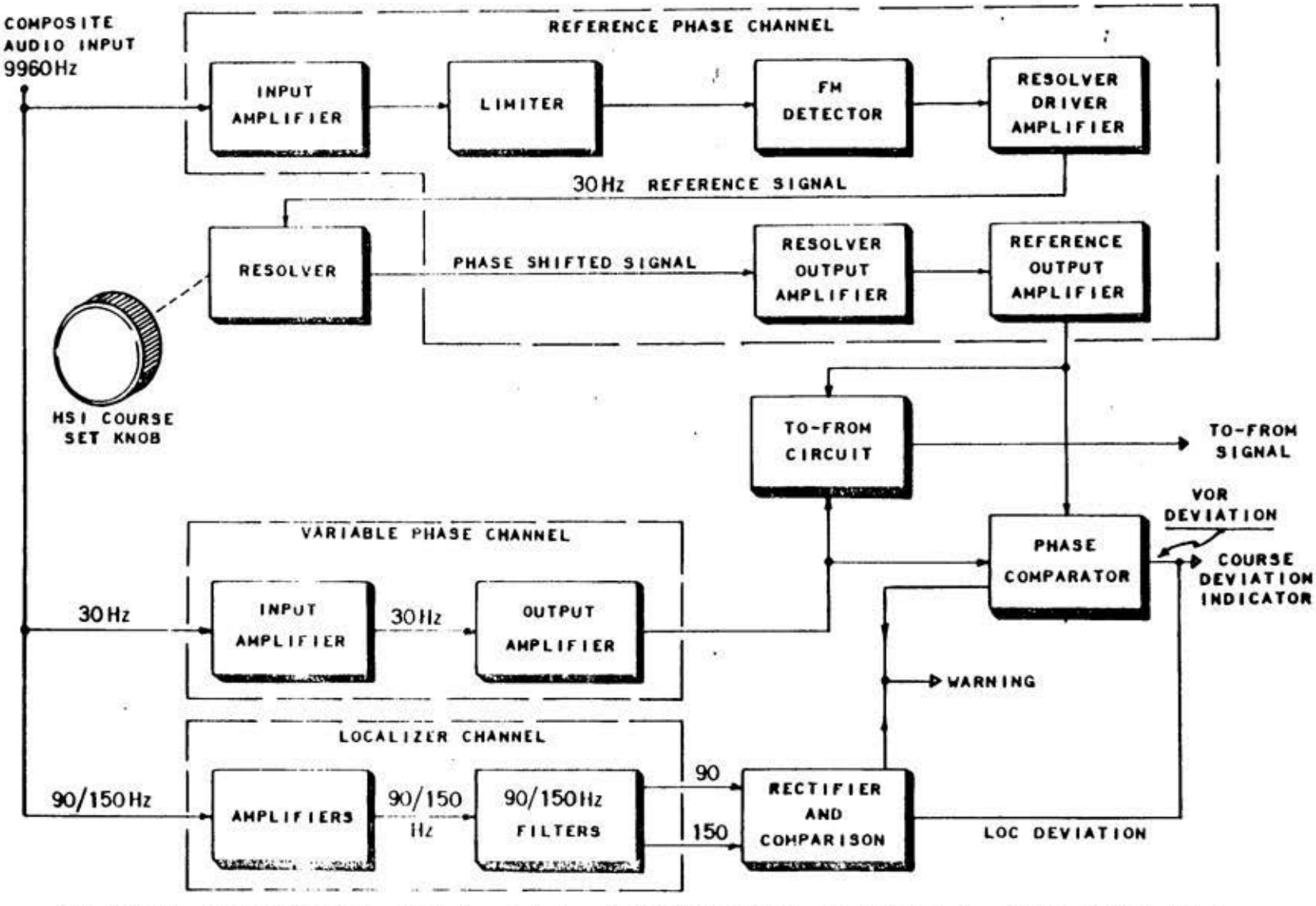


BLOCK DIAGRAM VHF NAV RECEIVER, RF SECTION

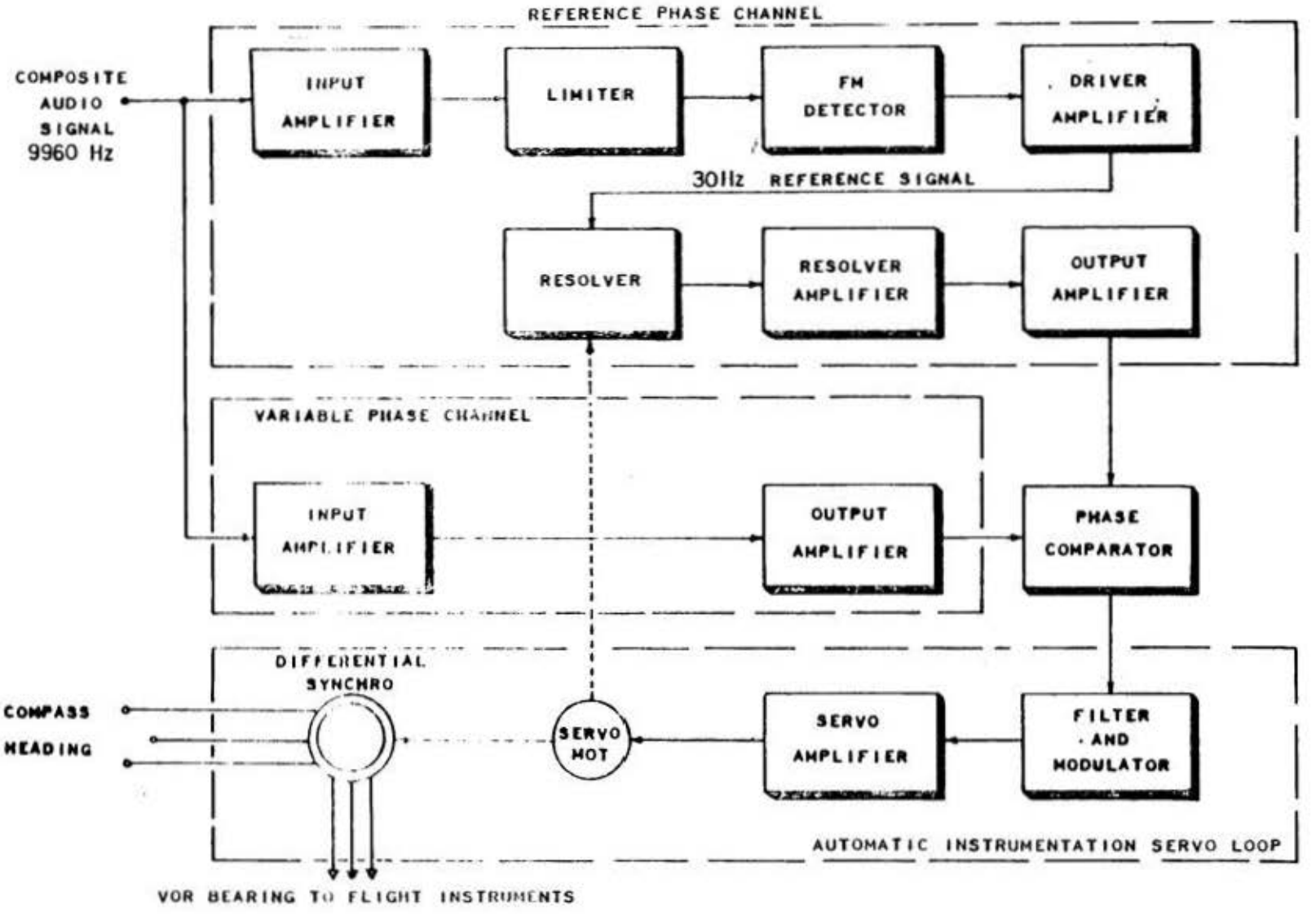
phase channel, and localizer channel. In VOR operation the reference phase and variable phase signals are applied to their respective channels. The reference phase signal is a Frequency-Modulated (FM) sub-carrier which is amplified in the reference phase channel. After amplification and limiting, the 30 Hz modulation is reproduced in an FM detector. The 30 Hz reference signals 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 produced 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 instrumentaion 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, MANUAL SELECTION



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.

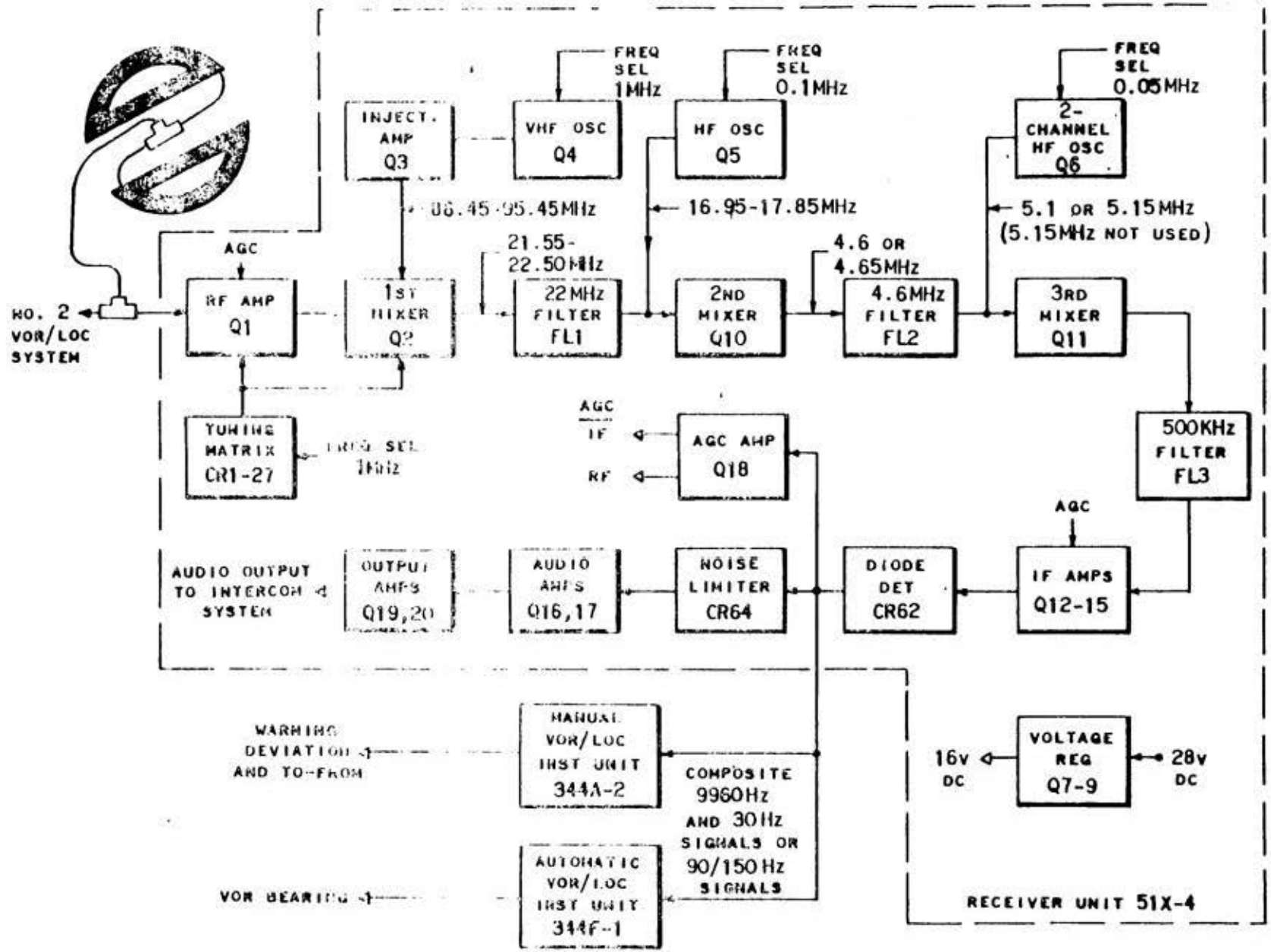
RECEIVER SECTION 51R-6 COLLINS

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.

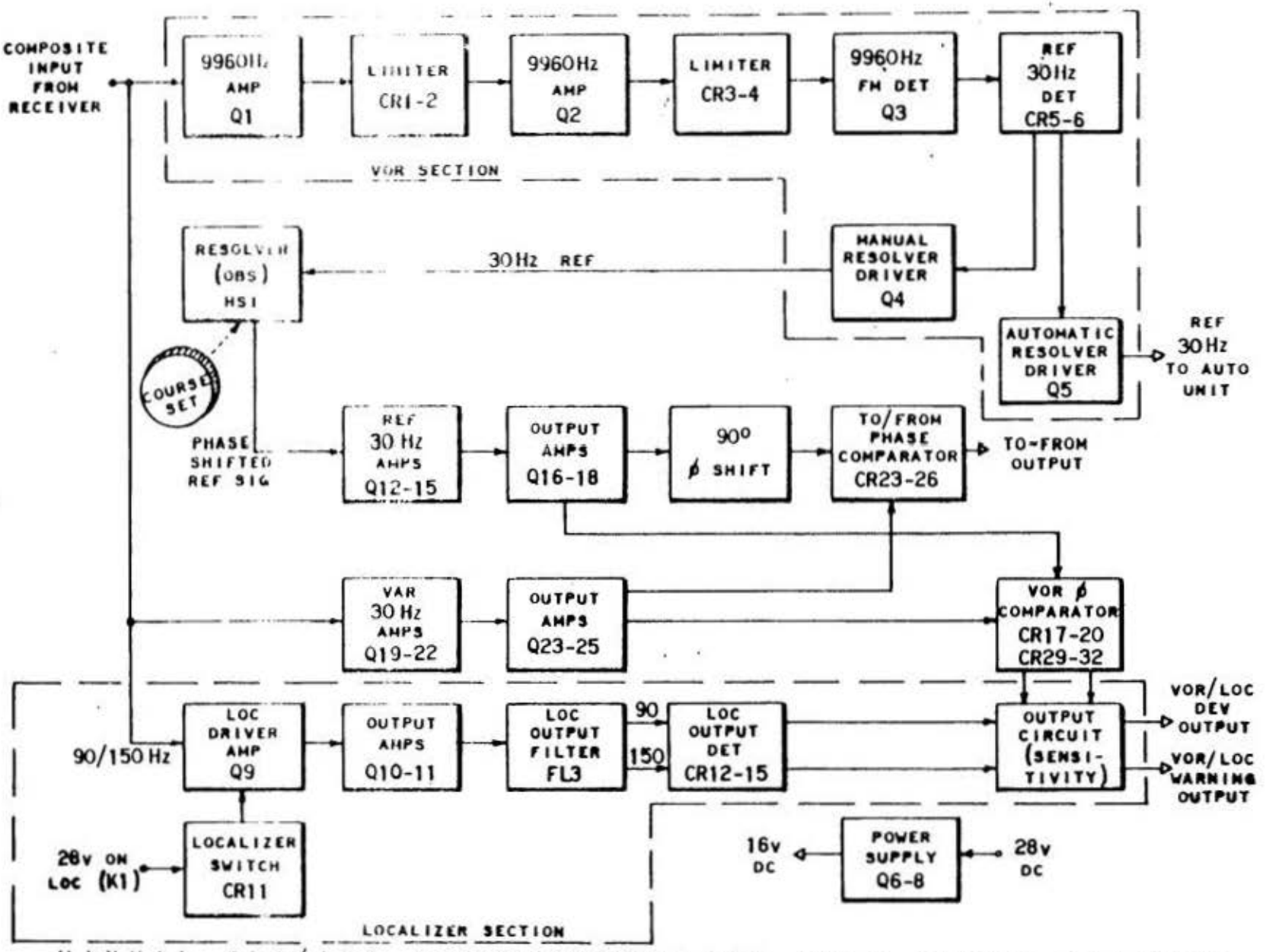
MANUAL INSTRUMENTATION UNIT

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



MANUAL VOR/LOC INSTRUMENTATION UNIT 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

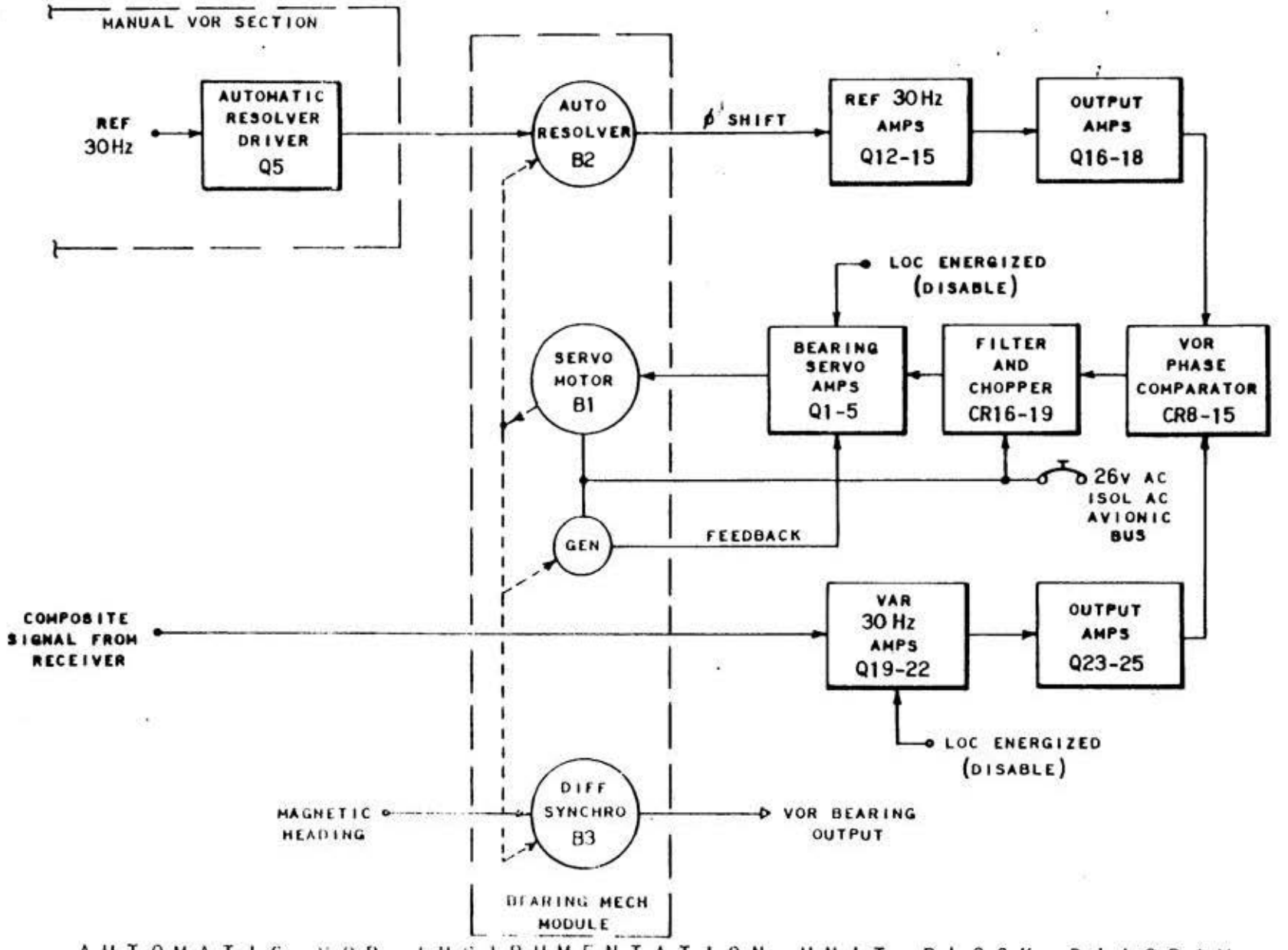
When a localizer frequency is selected, a diode switch allows the localizer signals to be amplified and applied to the 90 Hz and 150 Hz filters. The two signals are AM and are compared in the localizer output circuits to produce a deviation signal. The amplitudes are summed to produce a localizer reliability 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