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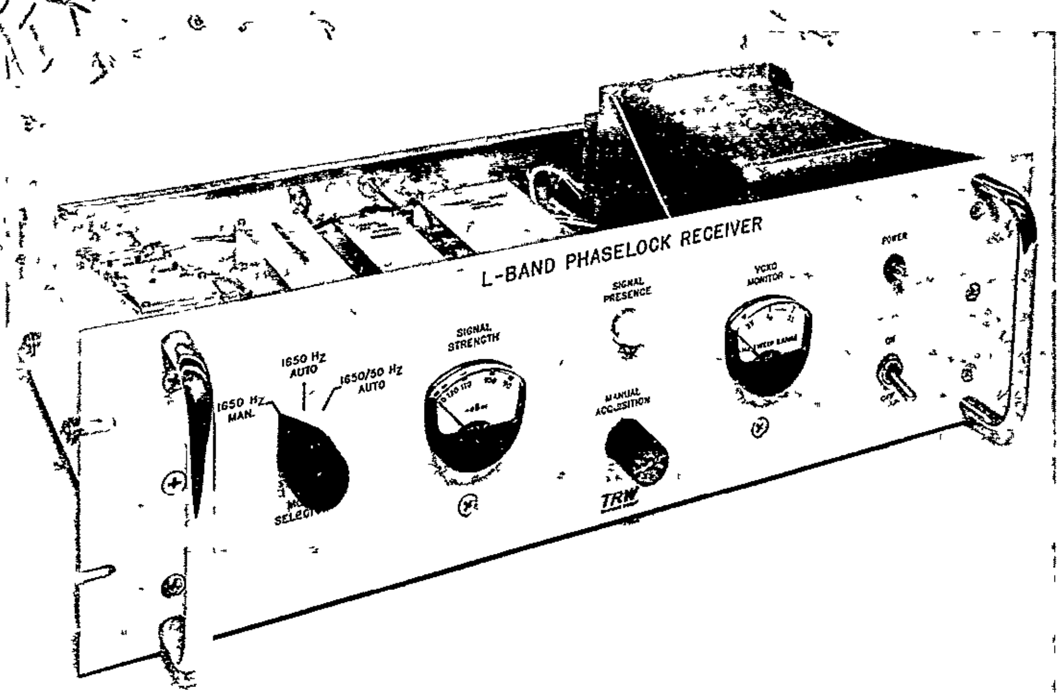

L-BAND PHASE-LOCK RECEIVER

FINAL REPORT

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ELECTRONICS RESEARCH CENTER
Cambridge, Massachusetts

Under

CONTRACT NO. NAS 12-539

TRW
SYSTEMS GROUP

ONE SPACE PARK REDONDO BEACH CALIFORNIA

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January 1970

Prepared by: R. V. Salcedo

R. V. Salcedo, Group Head
Telecommunications Dept.

Approved by: E. D. Dunford

E. D Dunford, Manager
Telecommunications Dept.

Approved by: T. Fine

T. I. Fine, Asst. Manager
For Advanced Systems
Guidance and Navigation
Laboratory

CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

This technical report documents the results to design, fabricate, test, and deliver a breadboard model of an L-band, phase-lock receiver. This project was performed by TRW Systems Group for the NASA Electronics Research Center under Contract No. NAS-12-539. The receiver is designed to be used in vehicles employing an operational navigation satellite system, although the receiver could be adapted quite easily for a number of applications. To meet the requirements of this project, TRW designed the receiver to employ automatic acquisition, tracking, and bandswitching. Additionally, TRW has integrated and successfully tested the L-band, phase-lock receiver with the BINOR digital processor.

Microelectronics is used extensively in this receiver to achieve low cost and high reliability. Microminiaturization is also used in some of the low-frequency circuits, such as the VCXO, reference oscillator, and second mixer. The balance of the circuitry is implemented with integrated circuits.

Modular packaging is used for the breadboard receiver with the modules attached to an aluminum chassis. Interconnections are made with coaxial cabling. The power supply and the voltage regulator card are included in the receiver chassis.

Photographs of the packaged receiver are shown in Figures 1, 2, and 3.

Figure 1. Receiver Front View

2. SPECIFICATIONS AND DESCRIPTION

The receiver was designed to have overall electrical performance as shown in Table I (Exhibit A of the contract). It is a double-conversion, narrowband, phase-lock configuration with search, acquisition, and band-switching capabilities. Figure 4 shows the block diagram of the receiver that meets the performance specifications listed in Table I. The nominal carrier frequency is 1550 MHz ±25 kHz, with a 5-MHz data channel bandwidth. The receiver threshold is -130 dBm with a 40-dB dynamic range.

The differential time delay specification is ±15 nsec. To meet this fundamental requirement, a nonlimiting broadband first IF amplifier with coherent AGC is used, followed by a second nonlimiting broadband second IF amplifier.

A phase-lock loop with bandswitching is incorporated, allowing a rapid carrier acquisition prior to data transmittal and correcting any frequency uncertainties associated with the receiver's oscillators or by doppler.

The acquisition bandwidth of 1650 Hz allows the receiver to acquire the nominal carrier level of -125 dBm in 0.38 sec with a reliability equal or better than 95%.

After carrier acquisition and prior to data transmittal, both the loop and quadrature channels switch to a 50-Hz noise bandwidth to improve the signal-to-noise (S/N) ratio by 15 dB in both channels to accommodate the 9-dB reduction of carrier power during data transmission. It also diminishes the loop sensitivity to the lowest frequency component of the BINOR code.

At the completion of the code and the receiver-processor data updating interval, the carrier is removed, allowing the receiver to return to carrier search mode.

A schematic diagram of the L-band receiver is shown in Figure 5.

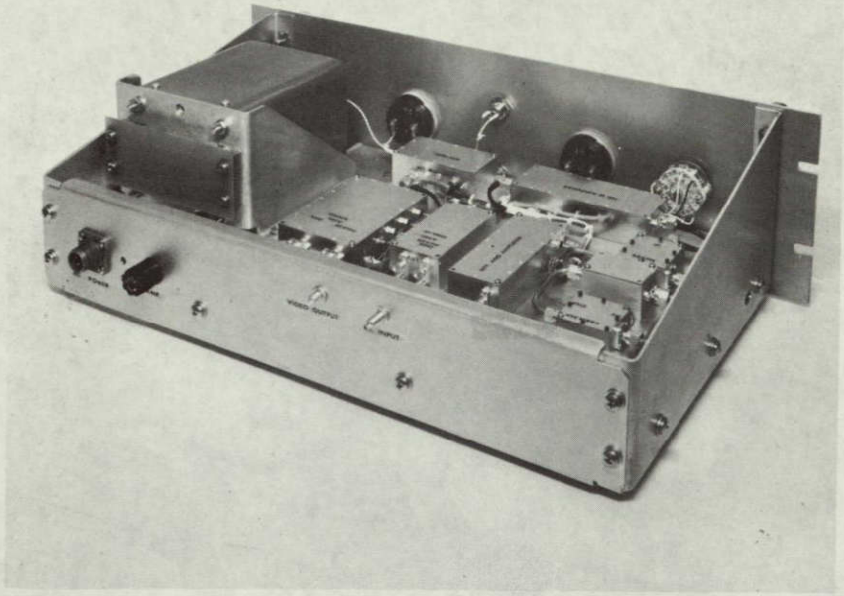

Figure 2. Receiver Rear View

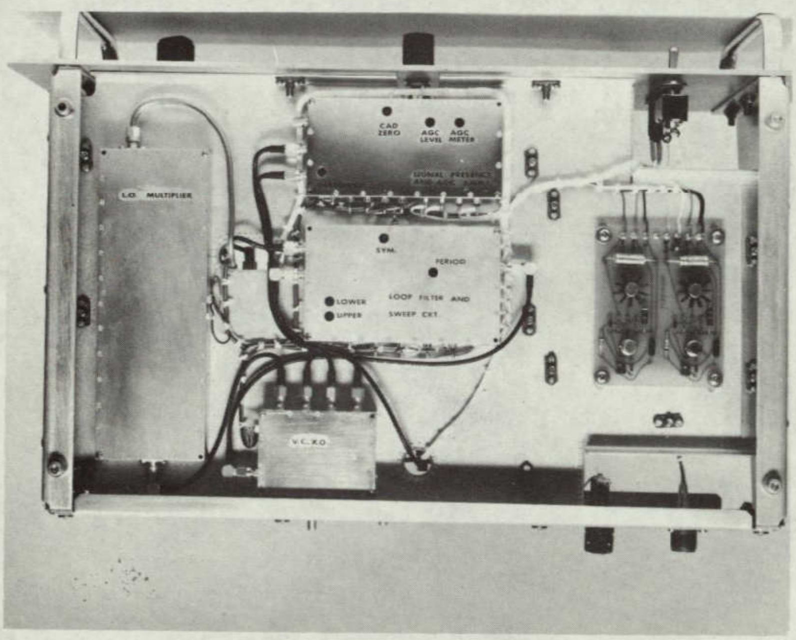

Figure 3. Receiver Bottom View

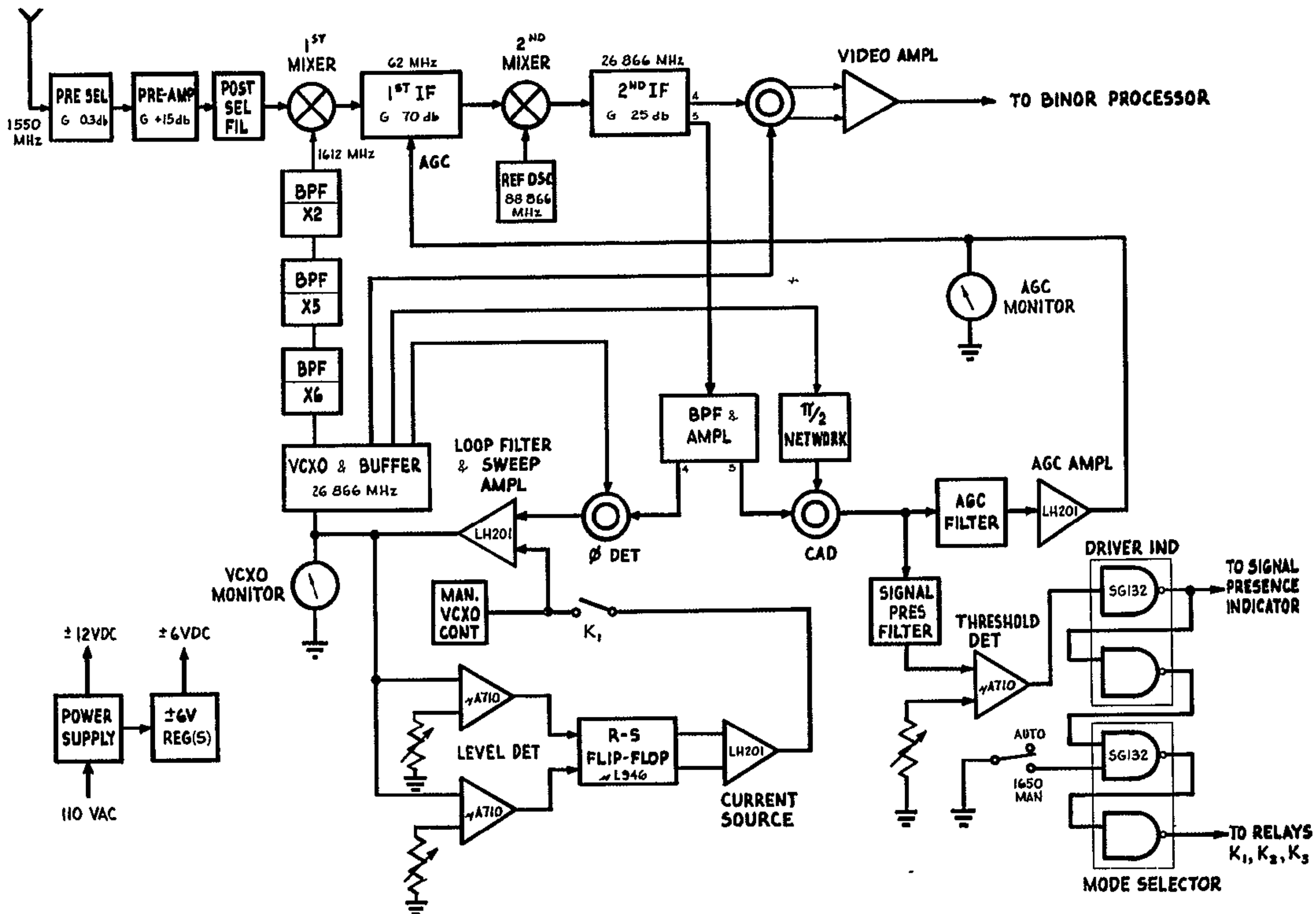

Figure 4. L-Band Phaselock Receiver

TABLE I.

L-BAND RECEIVER SPECIFICATION

General	
Carrier frequency	1550 MHz ±25 kHz
Receiver carrier acquisition threshold	-130 dBm
Nominal carrier acquisition level	-125 dBm
Nominal carrier tracking level	-134 dBm
Signal dynamic range	40 dB
Receiver noise figure	6.0 dB
IF bandwidth, data channel	5 MHz
VCXO stability over temperature	±10 ppm
VCXO sweep range	±25 kHz
Probability of lock (-127 dBm)	0.999 on one sweep
Differential time delay	±15 nsec variation for dynamic range of signal
Receiver operating temperature range	$10^{o}C$ to $40^{o}C$
Carrier Acquisition	
Loop noise bandwidth, $2B_L$	1650 Hz
Carrier Tracking (with Modulation)	
Loop noise bandwidth, $2B_L$	50 Hz
Carrier modulation loss (mod index ±1.2 rad)	8.8 dB
Available carrier power	-135.6 dBm
Loop tracking threshold S/N ratio	+ 15.2 dB
Power Supply	110 Vac, 60 Hz

3. CIRCUITRY

The circuitry of the receiver uses a combination of TRW microelectronics circuits, standard integrated circuits, and discrete miniature components for all the filters. All TRW microelectronic circuits were built using sapphire substrate to predict more accurately the uniformity and performance characteristics. Some of the integrated circuitry are mounted on printed-circuit boards for easier maintenance. Each of the circuits are described below.

3.1 PRESELECTOR

The preselector is a two-section, high-pass filter, having an attenuation of 0.3 dB at L-band frequencies and attenuation of 65 dB at 400 MHz. Figure 6 is a photograph of the preselector module without the cover, and Figure 7 illustrates the frequency response.

3.2 PREAMPLIFIER

The preamplifier is a two-stage, wideband preamplifier built on a sapphire substrate of 1 x 0.5 x 0.040 in. (see Figure 8). The preamplifier characteristics are:

Gain at L-band:	15 dB
Noise figure:	4.7 dB
Gain variation ±100 MHz:	0.5 dB
1 dB compression point:	-1 dBm (output)
Power dissipation:	96 mW

3.3 POST SELECTOR

The post selector is a miniature discrete two-pole bandpass filter that reduces the image frequency therefore improving the S/N ratio. Figure 9 shows the post selector module and Figure 10 the frequency response.

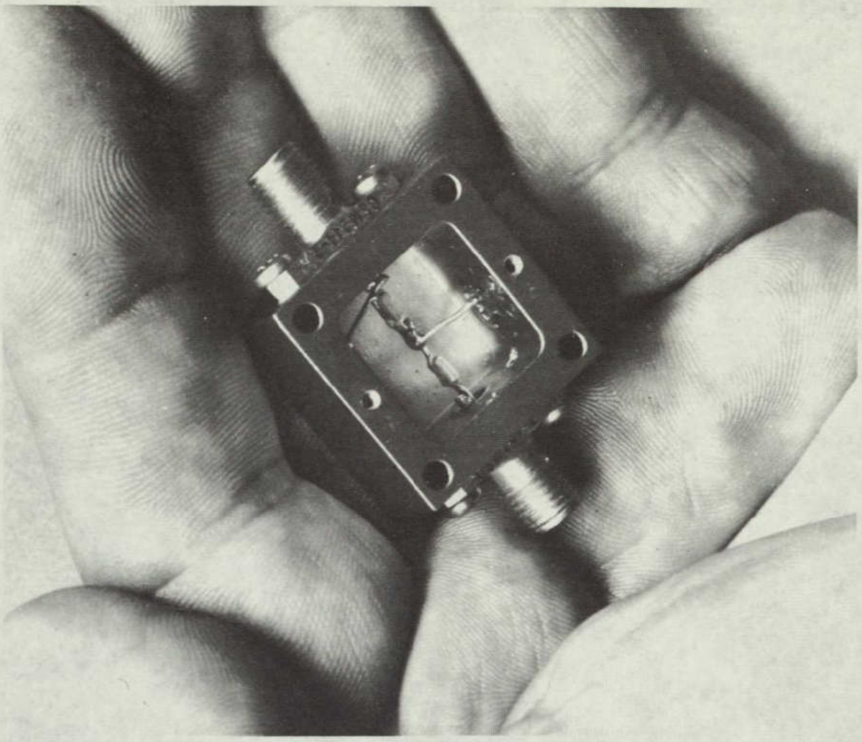

Figure 6. Preselector Module

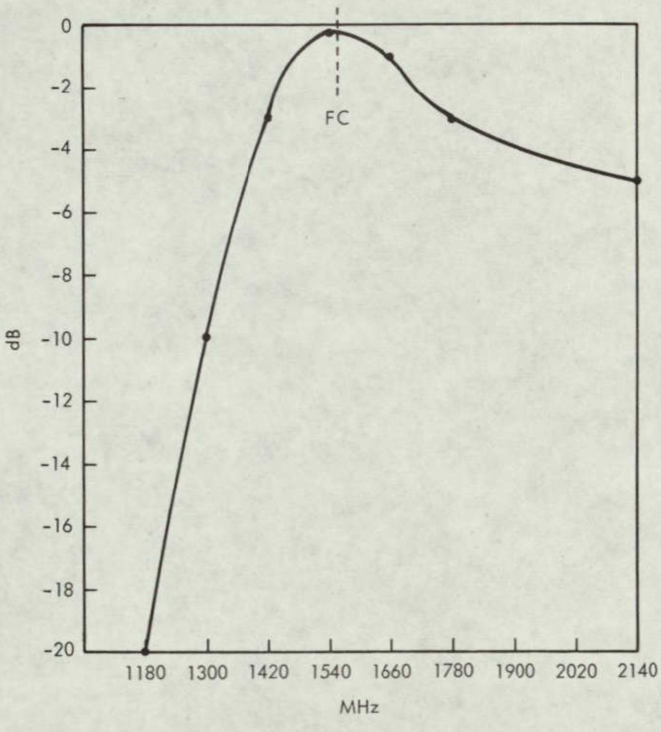

Figure 7. Preselector Response

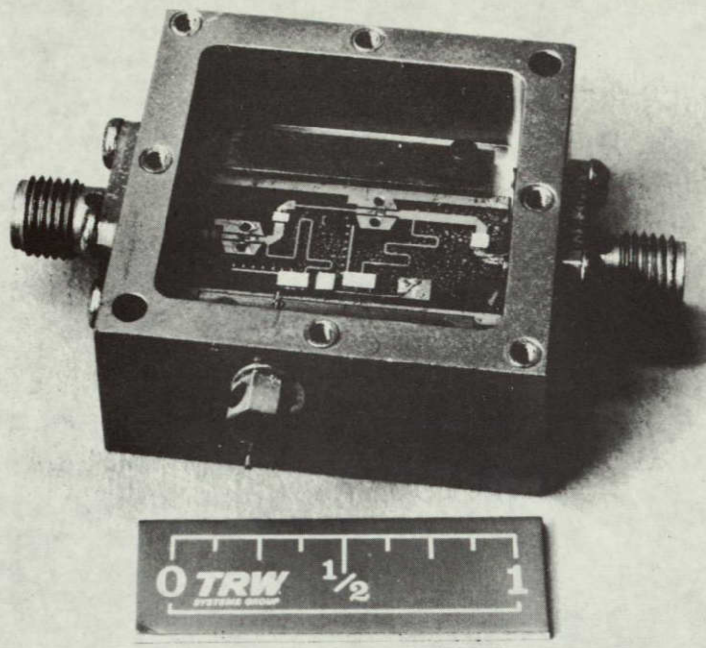

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Figure 8. Microwave Preamplifier

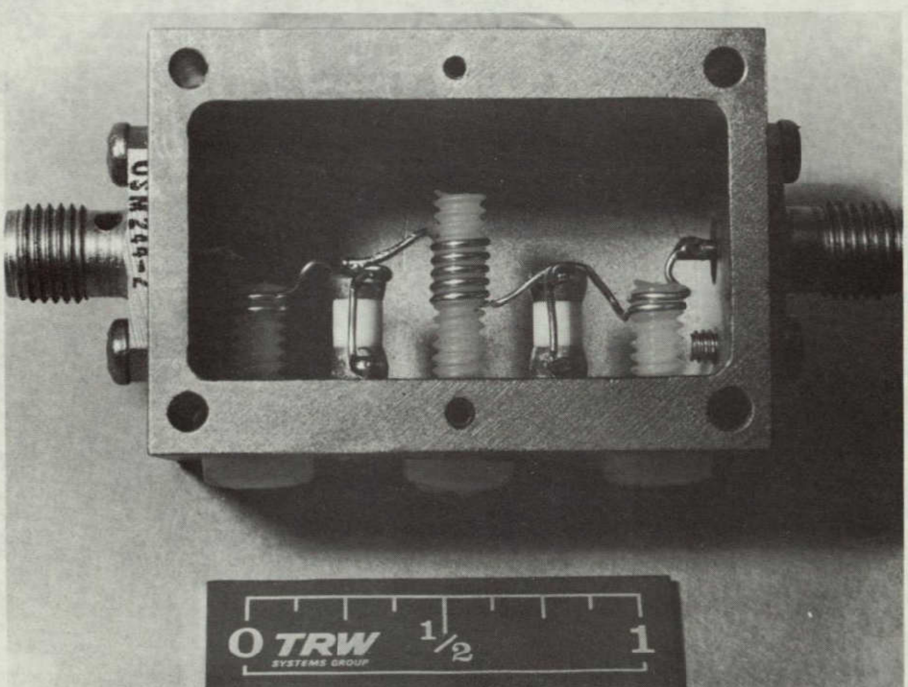

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Figure 9. Post Selector Module

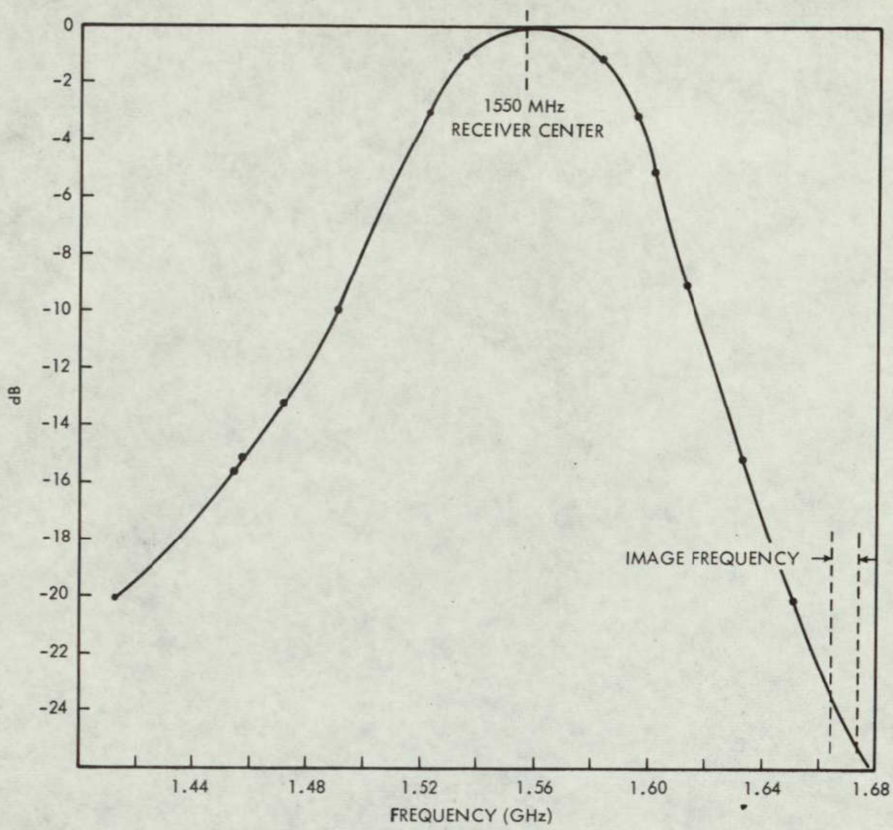

Figure 10. Post Selector Response

3.4 FIRST MIXER

This balanced microwave mixer is built on a sapphire substrate (Figure 11) and has the following characteristics:

Center frequency:	1.6 gHz
Bandwidth:	100 MHz
IF frequency:	60 ±4 MHz
Noise figure:	<9 dB

3.5 FIRST IF AMPLIFIER

The 62-MHz, first IF amplifier has 70 dB of gain and 40 dB of AGC. The large allocation of gain for this circuit is intentional to keep the gain in the 26.8 MHz, second IF amplifier down to 30 dB. The gain of the second IF stages is kept low so that the receiver will not lock onto itself.

The first IF circuit consists of three Philco PA 7600 broadband monolithic amplifiers and a two-pole bandpass filter inserted between the second

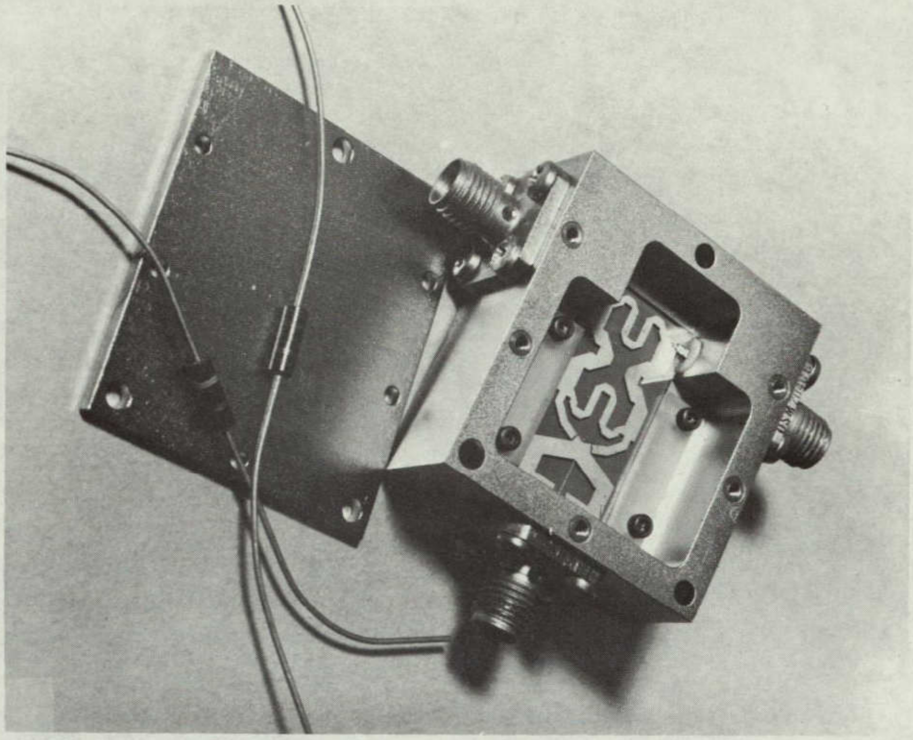

Figure 11. First Mixer Module

and third stages. The filter bandwidth is 6 MHz. AGC for the first IF is implemented by the combination of a pin diode, connected as a variable attenuator between the first and second stages, plus controlling the gain of all three stages simultaneously.

Figure 12 is a photograph of the amplifier, and Figure 13 illustrates the AGC characteristics.

3.6 SECOND MIXER AND SECOND IF AMPLIFIER

The second mixer and second IF amplifier are combined in one module. In the second mixer portion, the 62-MHz information signal is converted to 26.866666 MHz by proper interaction with the 88.866666 MHz reference oscillator. Figures 14 and 15 show the circuit diagram and the photograph of the second mixer. The mixer is a monolithic circuit that is manufactured by TRW and consists of a two-transistor device with the first transistor being the mixer and the second transistor being the impedance matching emitter follower stage. The 62-MHz signal is applied to the base of the first transistor while the 88.86 MHz reference oscillator

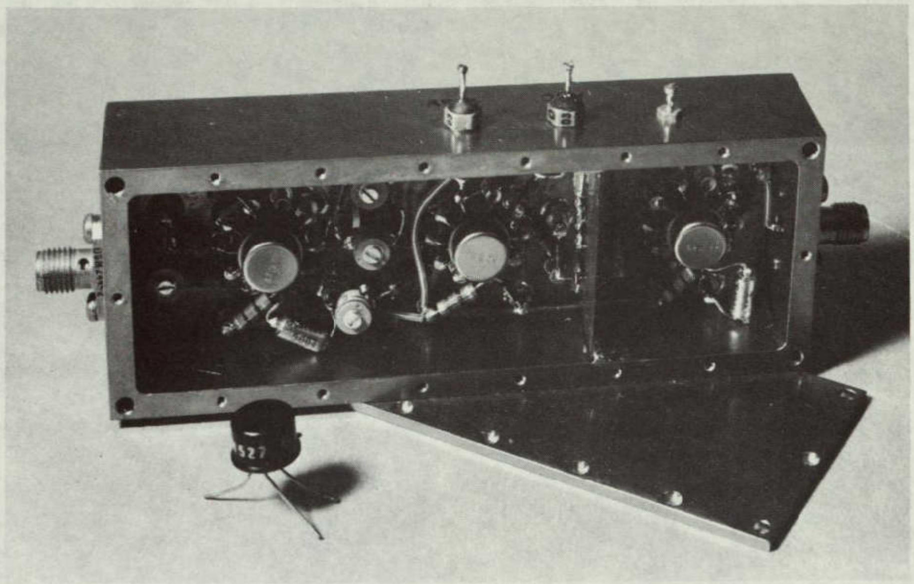

Figure 12. First IF Amplifier

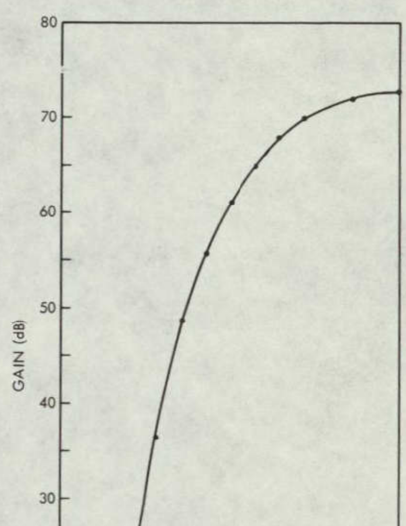

Figure 13. First IF AGC Characteristics

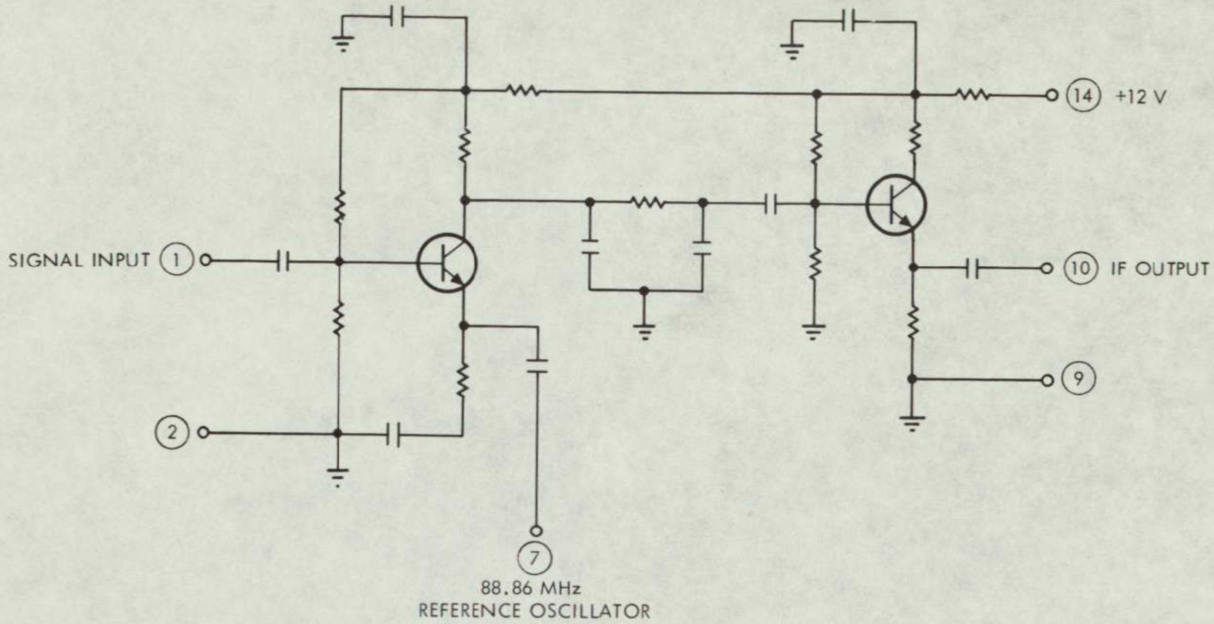

Figure 14. Monolithic Second Mixer Diagram

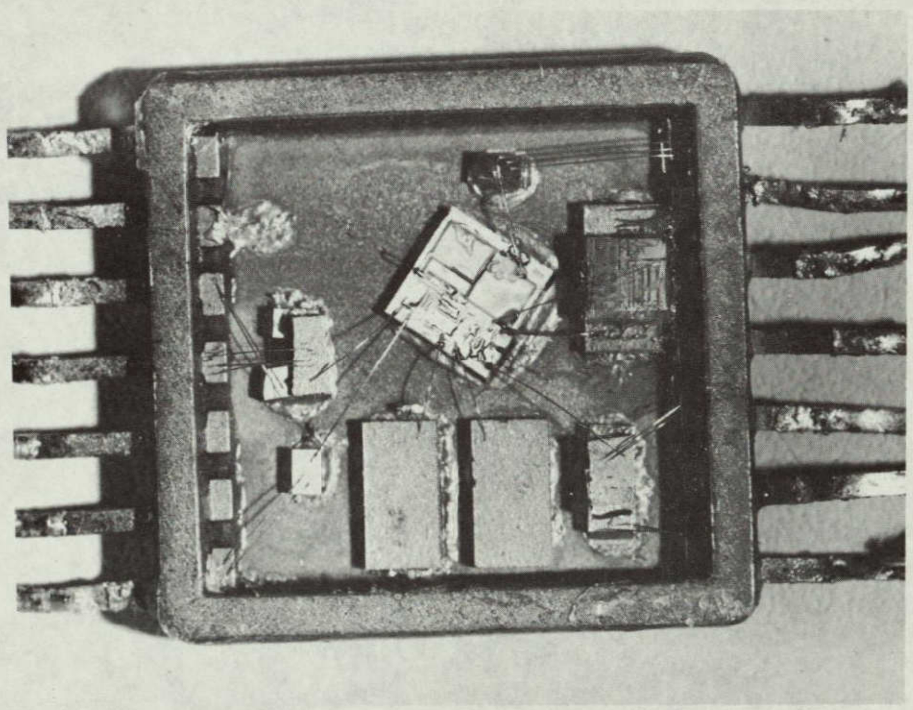

Figure 15. Second Mixer in Flatpack

signal is injected into the emitter. A resistor-capacitor, low-pass network is inserted between the two transistors to attenuate the local oscillator leakage signal.

3.7 PHASE DETECTOR AND VIDEO AMPLIFIER (DATA CHANNEL)

The receiver uses three identical phase detectors: one for the data channel, the second for the loop filter, and the third for the coherent amplitude detector (CAD) of the signal presence circuitry. All of these three-phase detectors are monolithic (Type MC 1596G manufactured by Motorola). The circuit consists of an input differential amplifier driving a pair of synchronized, single-pole double-throw switches. The switches use transistor current mode gates with collectors cross-coupled in such a manner that a full-wave balanced multiplication results between an input voltage and the reference switching voltage.

Figure 16 shows the output scale factor at 26.8 MHz in millivolt/radians versus reference signal levels for input signals of -10 to -30 dBm.

The data channel phase detector is followed by a monolithic video amplifier (Type CA3028A manufactured by RCA). This circuit is a low-power differential amplifier that converts the differential output of the phase detector into a single-ended output. The frequency response of this module has been adjusted for a 3-MHz bandwidth into a 1000-ohm load. A complementary follower or other video power stage will be necessary if the receiver is to drive a 50-ohm line.

3.8 LOCAL OSCILLATOR MULTIPLIER

The local oscillator (L.O.) multiplier chain receives its 26.866-MHz input signal from the voltage-controlled crystal oscillator (VCXO) and multiplies it by a factor of 60. The 1.612-gHz output signal is then fed to the first mixer as the L.O. signal. The L.O. multiplier chain consists of three transistorized multipliers, with multiplication factors of 6, 5, and 2.

Each transistorized multiplier consists of two stages, the first one operated in Class A mode and the second one in Class B or C. Each multiplier is followed by a filter to eliminate the spurious responses.

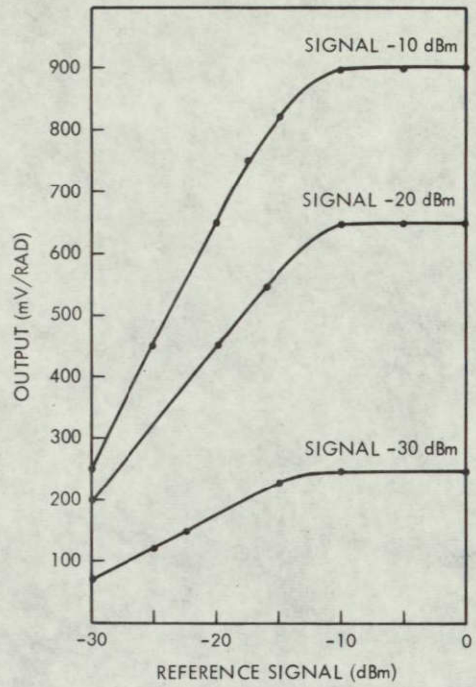

Figure 16. Phase Detector Performance

The entire circuit is made with discrete components with the exception of the X2 filter, which is a combline filter built on a sapphire substrate employing microminiature technology. The input and output impedance of each multiplier is approximately equal to 50 ohms; therefore, each unit may be aligned and tested independently. A photograph of the entire L.O. multiplier unit is shown in Figure 17.

3.9 VCXO AND BUFFER

The oscillator circuit is a Colpitt type with emitter feedback. A varicap is used as the voltage-tuned, frequency-determining element. The circuitry of the VCXO is a hybrid type packaged in a 3/8 x 3/8 flatpack (Figure 18). The measured VCXO characteristics are shown in Figure 19. Because of the X60 multiplier, the frequency variation required of the VCXO is only ±420 Hz from its center frequency of 26.866666 MHz. An emitter follower follows the VCXO, to supply four output signals of -11 dBm each for the various circuits of the receiver. The stability of the VCXO is better than ±5 ppm within the temperature range of 10°C to 40°C and the frequency range of interest.

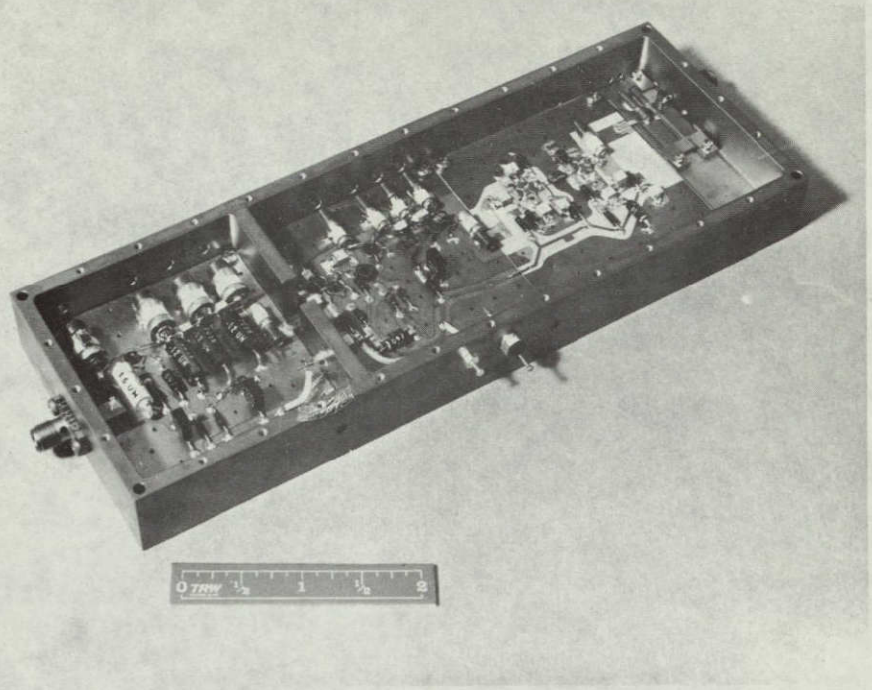

Figure 17. L.O. Multiplier Unit

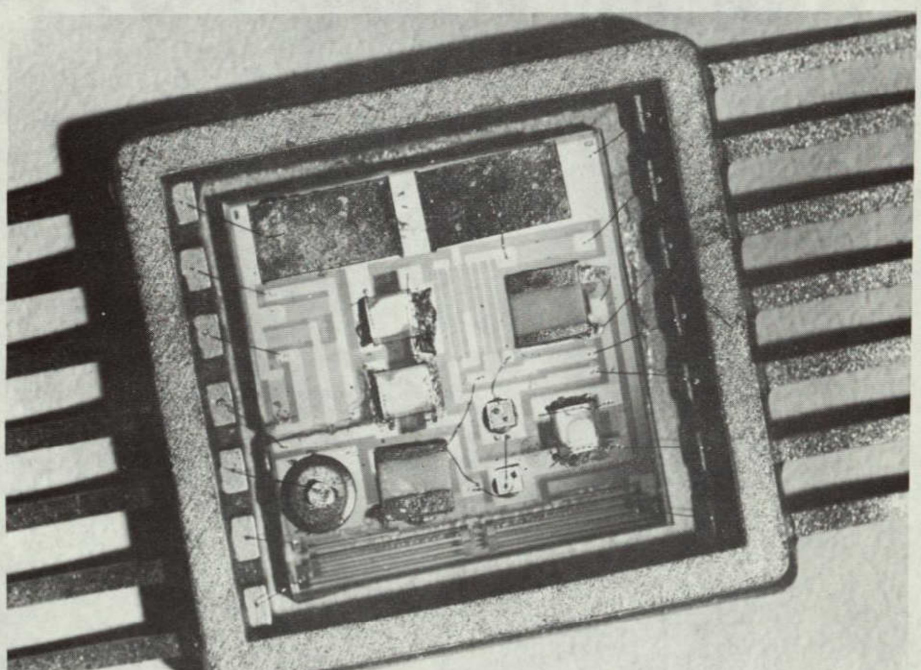

Figure 18. VCXO in Flatpack

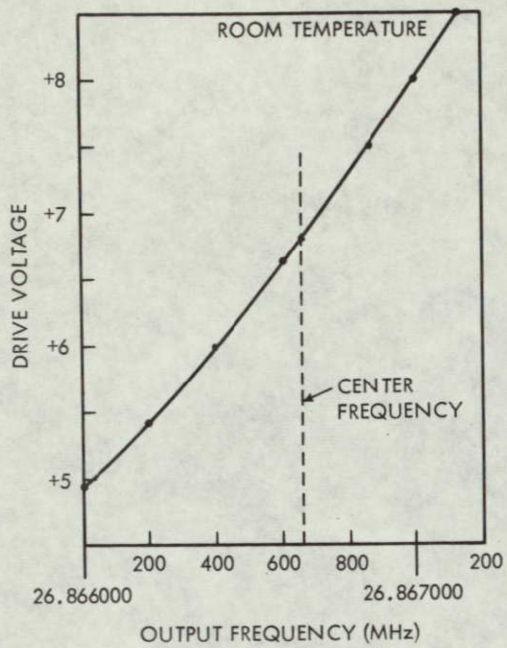

Figure 19. VCXO Characteristics

3.10 REFERENCE OSCILLATOR

The reference oscillator (XO) is also a Colpitt type. The same masks used in the manufacturing of the VCXO were used for the XO. The difference between the VCXO and the XO is in the tuning elements and crystal frequency. The XO generates an 88.866666-MHz signal with an output power of -5 dBm, and the stability is ±10 ppm within the specified temperature range. The stability of the reference oscillator is masked by the multiplier factor of the L. O. multiplier chain. Figure 20 shows the reference oscillator module.

3.11 BANDPASS FILTER AND AMPLIFIER

At threshold input, the S/N ratio at the second IF amplifier is -30 dB. To improve this condition and to avoid noise saturation of the phase detectors for the loop filter and AGC circuitry, a bandpass filter (BPF) is placed in the signal path. The bandwidth of the BPF is 500 kHz, resulting in an improvement of the S/N ratio of 10 dB.

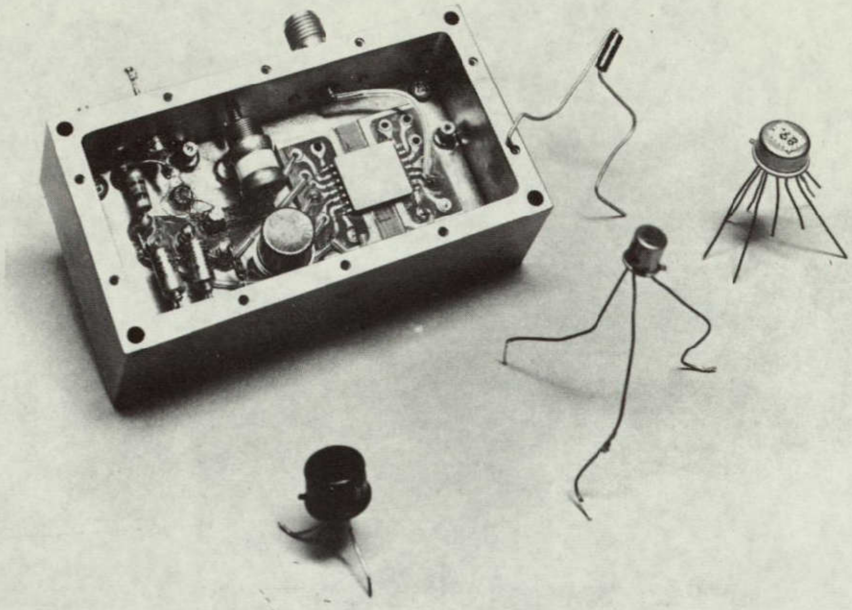

Figure 20. Reference Oscillator Module

The BPF is a three-pole filter centered at 26.866 MHz and followed by a two-stage IC amplifier to compensate for the losses in the filter. Figure 21 shows the BPF and amplifier module.

3.12 LOOP FILTER AND SWEEP CIRCUIT

A block diagram of the loop filter and sweep circuit module is shown in Figure 22. The inputs to this module are the 26.86 MHz IF signal from the bandpass filter module and the 26.86 MHz VCXO signal. The output of the phase detector is then filtered in the active loop filter and fed to the VCXO, closing the loop when coherency appears.

The loop noise bandwidths (2BL) are determined by the time constants associated with the active loop filter. Bandwidth switching is accomplished by changing the time constants with miniature relays. The relays are operated by the signal presence module.

Prior to acquisition, the VCXO is swept with a sawtooth waveform of 0.38 sec duration applied to the VCXO drive control voltage. The sawtooth waveform is generated in the active loop filter, acting as an integra-

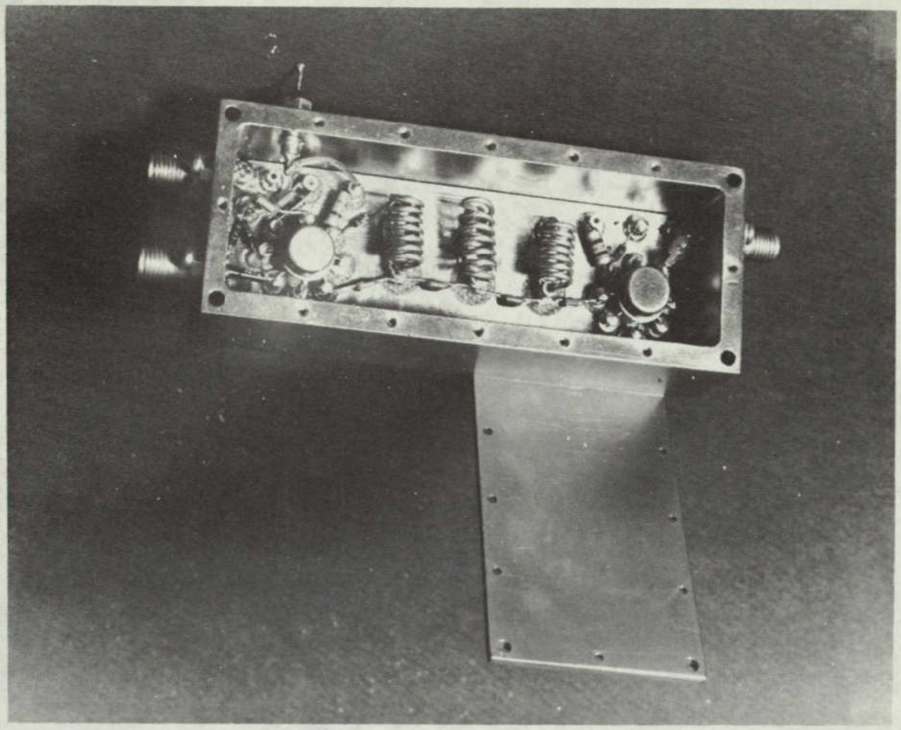

Figure 21. BPF and Amplifier Module

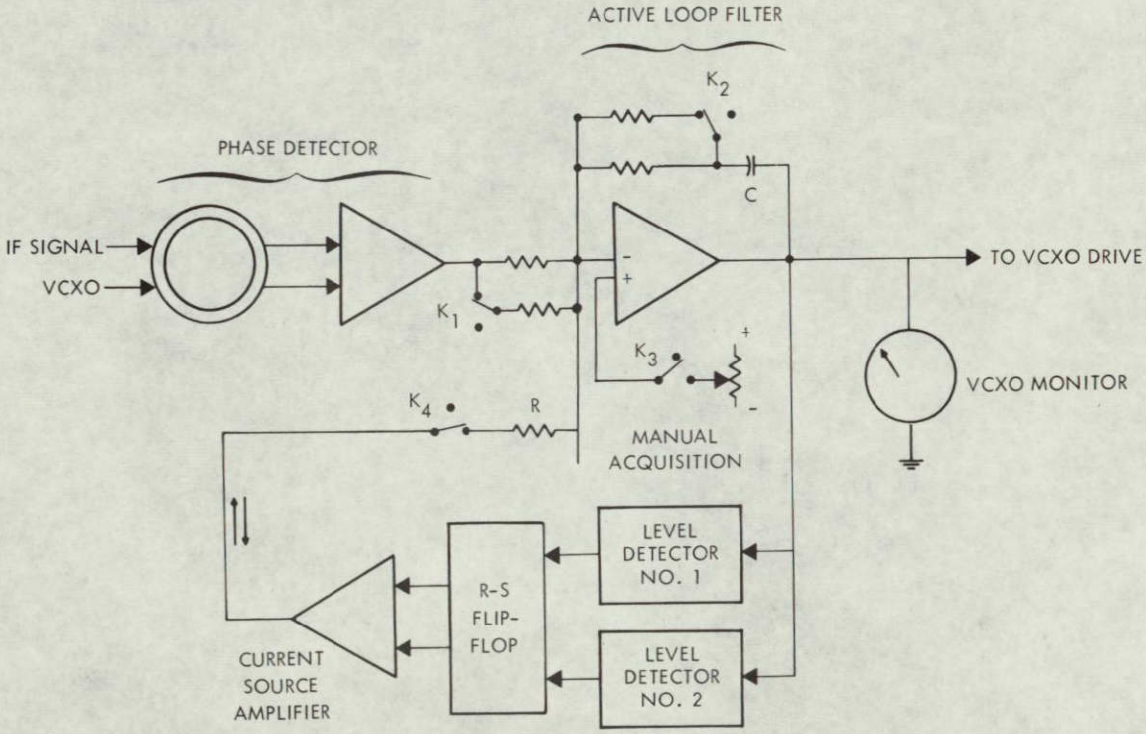

Figure 22. Loop Filter and Sweep Circuit Diagram

tor. The current source amplifier supplies either positive or negative current to the input of this integrator through resistor R. The period of oscillation is determined mainly by the product of R and C.

The level detectors, Nos. 1 and 2, sense the upper and lower levels of the sawtooth waveform and supply this information to the current source amplifier through the R-S flip-flop. Once either of the two levels has been reached, the flip-flop reverses the integrating current. A photograph of the loop filter and sweep circuit is shown in Figure 23.

3.13 SIGNAL PRESENCE AND AGC AMPLIFIER

The signal presence and AGC amplifier module performs the following tasks:

- Drives the signal presence light to indicate when the receiver has acquired and locked onto an incoming signal.
- Supplies a digital signal to the bandswitching relays to change bandwidth from 1650 Hz to 50 Hz when coherence is attained.

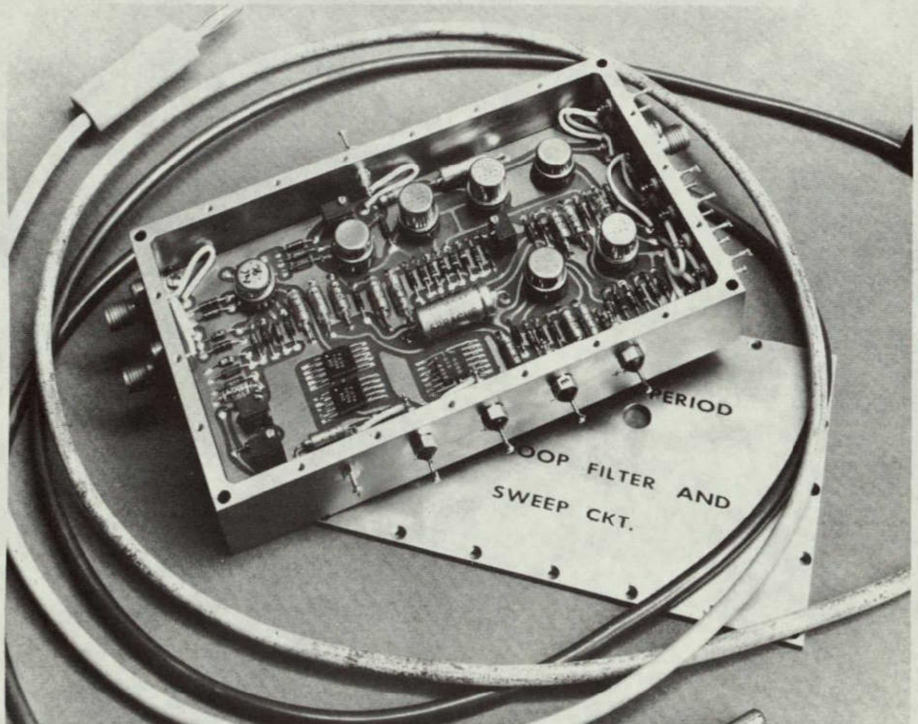

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Figure 23. Loop Filter and Sweep Circuit

- Supplies a coherent AGC voltage to control the gain of the first IF amplifier.

- Drives the signal strength meter to indicate input level at the receiver.

The input signals to this module are the 26.86 MHz IF signal and the 26.86 MHz VCXO signal. The circuitry consists of a phase detector connected as a coherent amplitude detector (CAD) followed by a threshold level detector (μA710) and digital drivers (SG132) for the signal presence light and bandswitching relays.

The CAD also drives the AGC amplifier (LH201, No. 2). The gain of the AGC amplifier is set to cause only a 3-dB change in the second IF output when the input signal to the receiver varies from -130 dBm to -90 dBm. Because of scale factor and polarity, a separate amplifier drives the signal strength meter. A block diagram of the signal presence and AGC circuitry is shown in Figure 24.

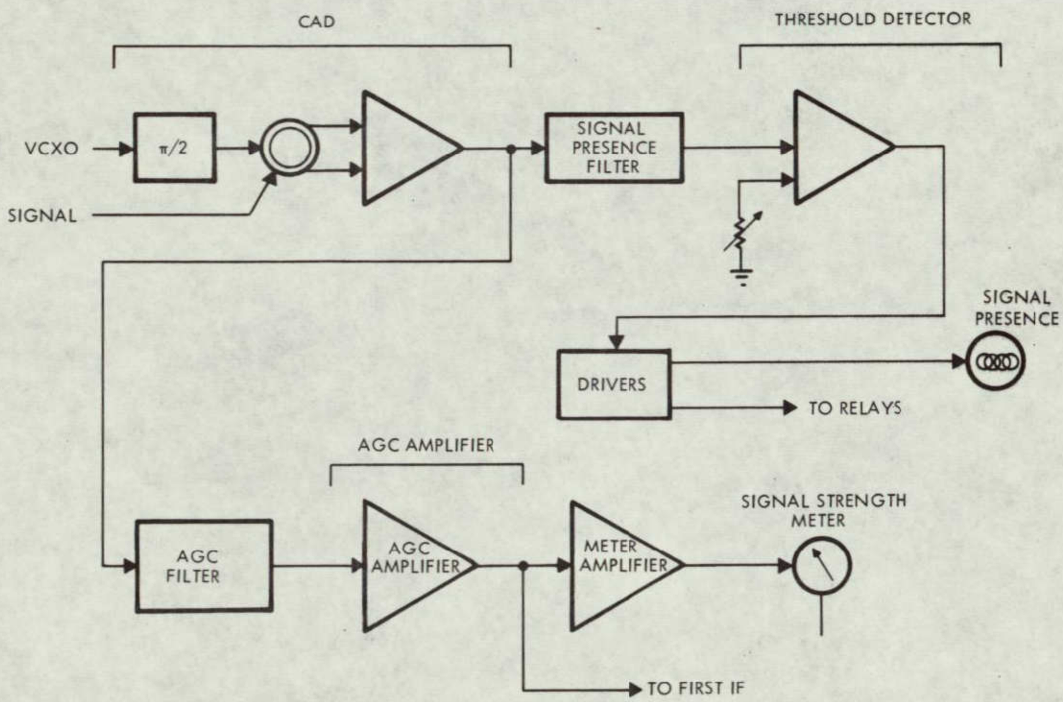


Figure 24. Signal Presence and AGC Block Diagram

3.14 POWER SUPPLY

The supply voltages required to operate the receiver are + 12, -12, + 6, and -6 V. Regulated power supplies are necessary to be able to track the negative output with the positive output since several operational amplifiers are used throughout the receiver. A dynage module (K 12/12-0.50/0.50 AKR) dual output, dc power supply was selected for the ±12 V with the following specifications:

Input:	105-125 Vac, 50 to 400 Hz
Output:	±12 V at 0.5 A each
Regulation, combined:	±0.05%
Ripple:	2 mV, rms
Tracking:	±0.005%/°C
Temperature, coefficient:	±0.03%/°C over range -20°C to +60°C
Temperature, operating:	-20°C to + 71°C

The + 6 and -6 V power supplies are derived from the ±12 V supply in a separate regulator card. The 6-V regulator consists of a temperature-compensated zener and an operational amplifier followed by a passing transistor.

4. RECEIVER TEST RESULTS

All the receiver parameters called out in Table I have been tested according to the test procedure described in Appendix A. Table II shows those parameters with their respective design goals and the measured values.

TABLE II.
RECEIVER TEST PARAMETERS

Test No.	Parameter	Design Goal	Measured Values
1	Carrier frequency	1550 gHz ±25 kHz	1550 gHz ±25 kHz
2	Carrier acquisition threshold	-130 dBm	-131 dBm
3	Carrier acquisition level	-125 dBm	-125 dBm
4	Carrier tracking level	-134 dBm	-135 dBm
5	Signal dynamic range	40 dB	40 dB
6	Receiver noise figure	6 dB	5.2 dB
7	IF bandwidth, D channel	5 MHz	5 MHz
8	VCXO stability (10^{o} to 40^{o}C)	±10 ppm	±2.2 ppm
9	VCXO sweep range	±416 Hz	±420 Hz
10	Sweep period	0.38 sec	0.38 sec ±0.02 sec
11	Probability of lock at -127 dBm one sweep	0.999	Not directly measured
12	Differential time delay	±15 msec	±9 nsec
13	Receiver operational temperature range	10^{o}C to 40^{o}C	10^{o}C to 40^{o}C
14	Acquisition loop bandwidth $2\ B_L$	1650 Hz	Approx 1780 Hz
15	Tracking loop bandwidth, $2\ B_L$	50 Hz	Approx 51 Hz

During the month allocated for testing and integration with the BINOR processor, it became evident that the following corrections were necessary:

a. AGC characteristics

b. Temperature compensation of the VCXO

c. Lower the output impedance of the video output.

Items a. and b. were corrected, but Item c. was not considered urgent, provided the cable connecting the video output of the receiver to the BINOR processor was kept short.

The following paragraphs clarify the test results for the signal dynamic range, VCXO, and loop bandwidth measurements.

4.1 SIGNAL DYNAMIC RANGE

The receiver has an input dynamic range of 40 dB. The gain of the AGC amplifier was adjusted to maintain the signal output from the second IF amplifier within 3 dB.

4.2 VCXO STABILITY

The VCXO stability required is ±10 ppm over the temperature range of 10° to $40^{\circ}C$. The uncompensated VCXO shows stabilities of ±14 ppm and is illustrated in Figure 25.

Thermistor-resistance stabilization was used, resulting in ±2.2 ppm over the temperature and frequency ranges. Figure 26 illustrates the compensated VCXO.

4.3 LOOP BANDWIDTH

The loop bandwidth of the receiver was measured with an input signal of -124 dBm, as described in the test procedure in Appendix A. Figure 27 shows the response for the 1650-Hz mode, and Figure 28 depicts the response for the 50-Hz mode.

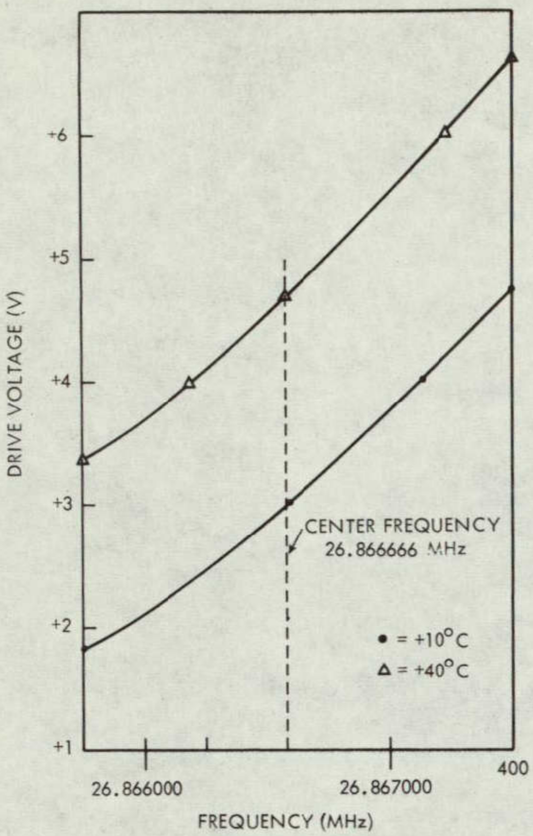


Figure 25. VCXO Performance Uncompensated

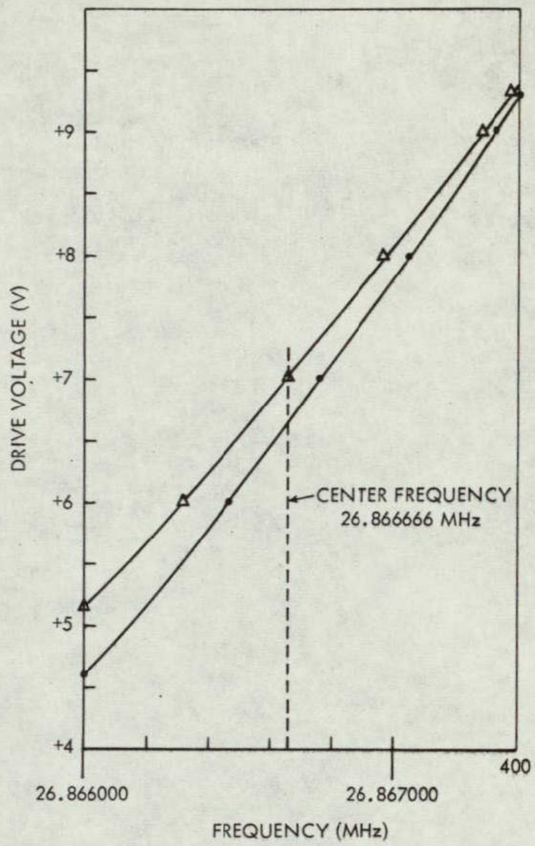


Figure 26. VCXO Performance Temperature Compensated

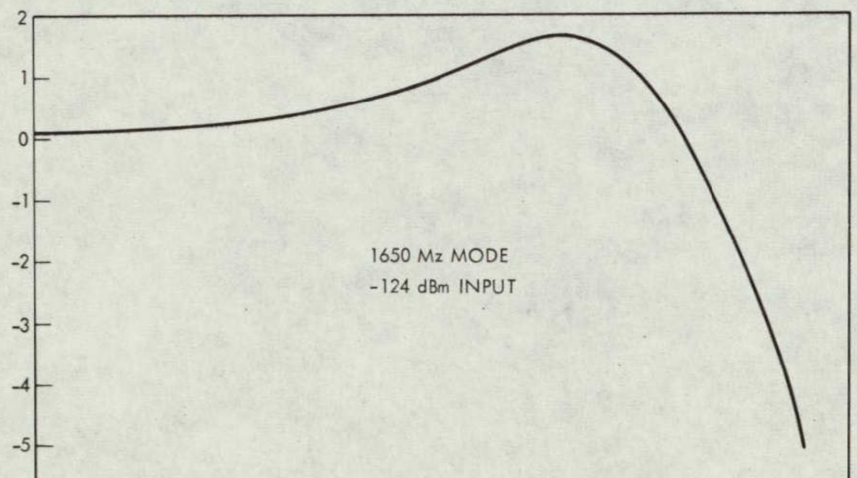


Figure 27. 1650 Hz Mode Response

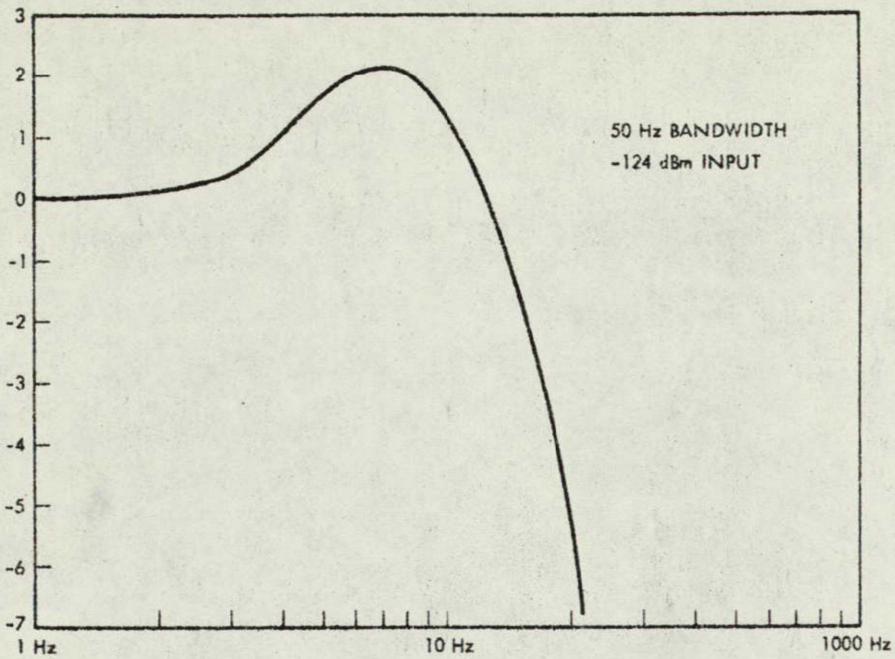


Figure 28. 50 Hz Mode Response

5. BINOR TEST RESULTS

The interface preliminary tests consisted of the L-band transmitter modulation with the BINOR code or the 312 kHz top tone; transmission to the receiver; and processing of the receiver output.

After the receiver AGC was adjusted, the signal level into the BINOR processor stayed within the acceptable limits for a wide range of receiver input levels. The receiver output coupling capacitor needed to be increased because of an inadequate correlation level on the lowest sub-frequency tone to the code processor.

The receiver-to-processor interface also required close proximity of the two units because of the high output impedance of the receiver, and may require receiver changes for impedance matching. Printout of the processor output indicated that the system concept and method is practical and feasible.

Figure 29 illustrates the output of the receiver with three different signal input levels. In comparison to the upper two waveforms, the signal in the bottom portion of the photograph was completely buried within the noise when adjusted for a minimum signal level, but lock-in and processing by the BINOR code processor were easily accomplished with no errors.

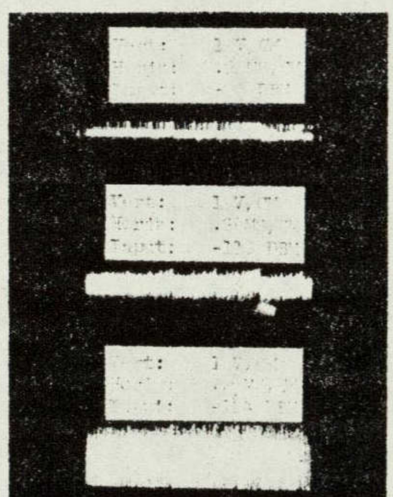


Figure 29. Video Output Waveforms

APPENDIX A

The test procedure for the L-band phase-lock receiver is included in this appendix. This procedure explains the tests performed for the fifteen parameters called out in the receiver specifications. The block diagram test setup, the test equipment required, and the test procedure are given for each parameter.

TEST PROCEDURE FOR THE L-BAND PHASE LOCK RECEIVER

Documentation required: 1) Schematic L-Band Receiver SK68137

2) L-Band Phaselock Receiver Modules Interconnections SK68138

1.0 Carrier Frequency. Figure A-1 shows one of the suggested RF source set-up configurations to test most of the receiver parameters.

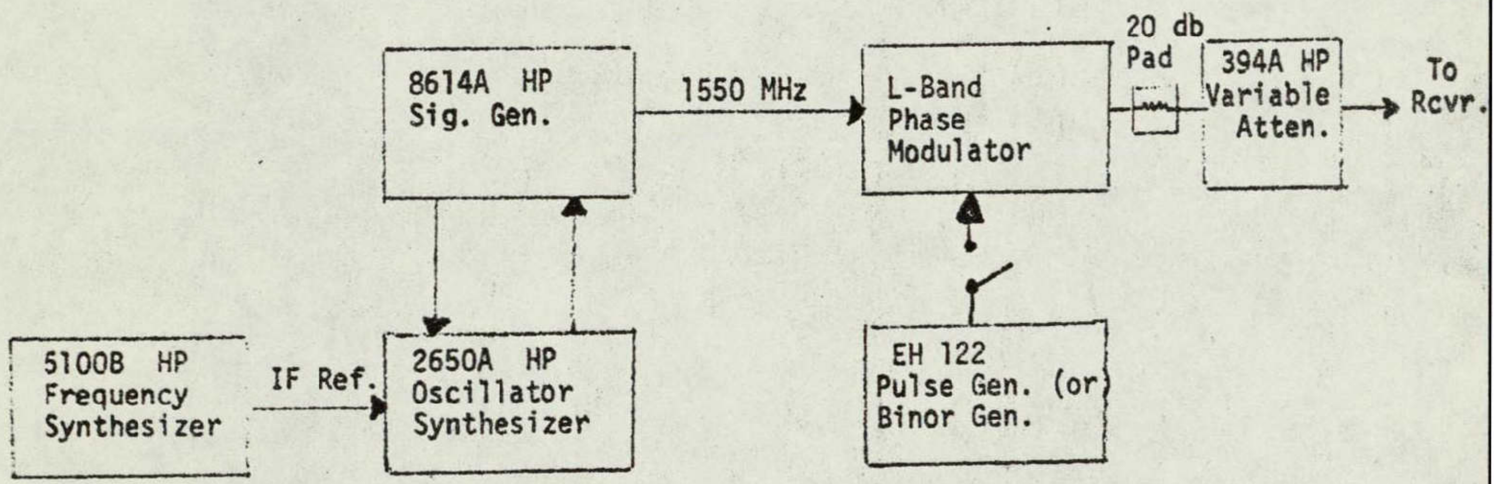


Figure A-1

1.1 Test Equipment Required

- Frequency Synthesizer, HP 5100B
- Oscillator Synchronizer, HP 2650A
- Signal Generator, HP 8014A
- Pulse Generator, EH 122
- Binor Code Generator (TRW)
- L-Band Phase Modulator (TRW)
- Calibrated Variable Attenuator, HP 394A

1.2 Test Procedure

- Measure the frequency of the 8614A Signal Generator with 5245-L Electronic Counter, Hp or equivalent.
- Make necessary adjustment to the IF reference frequency, so as to read a frequency of 1550 MHz from the Signal Generator.
- Record frequency reading on test data sheet.

2.0 CARRIER ACQUISITION THRESHOLD

2.1 Test Equipment Required

- RF Test source of Figure A-1.
- Power meter, HP 431C

2.2 Test Procedure

- Measure RF power available at the input of the receiver with 431C Power Meter HP.
- Add sufficient attenuation following the signal generator so as to decrease the available power at the output of the coaxial calibrated attenuator to -81 dbm when the dial is reading 6 db.
- Turn the Mode Selector switch of the receiver to 1650/50 Hz mode, and set the calibrated coaxial attenuator to -145 dbm output.
- Increase the RF power to the receiver from -145 dbm until the receiver shows signs of threshold locking.
- Record carrier acquisition threshold level on data sheet.

3.0 CARRIER ACQUISITION LEVEL

3.1 Test Equipment Required

- RF Test source of Figure A-1.

3.2 Test Procedure

- Increase the RF power to the receiver to -125 dbm. Receiver should remain locked.

4.0 CARRIER TRACKING LEVEL

4.1 Test Equipment Required

- RF Test source of Figure A-1.

4.2 Test Procedure

- Decrease the RF power to the receiver from -125 dbm to -134 dbm. Receiver should continue in locked condition.

5.0 SIGNAL DYNAMIC RANGE

5.1 Test Equipment Required

- RF Test source of Figure A-1.
- Spectrum analyzer, HP 851B/8551B.

5.2 Test Procedure

- Connect spectrum analyzer to the 2nd IF amplifier output pin 5.
- Set the RF test source to feed -130 dbm signal to the input of the receiver.
- Set the spectrum analyzer in a narrow IF bandwidth to observe the carrier signal.
- Increase the input signal to the receiver by 40 db. Output signal observed in the spectrum analyzer should remain constant within 4 db.

6.0 RECEIVER NOISE FIGURE

6.1 Test Equipment Required

- Noise figure meter, HP 342A.
- UHF Noise Source, HP 349A.
- 10 db Pad.

6.2 Test Procedure

- Set up equipment as shown in Figure A-2.

Notice that the UHF Noise Source has a 10 db pad following, removal of this pad will damage the receiver Pre-amplifier.

6.2 Test Procedure (continued)

- Adjust the zero and infinity adjustments of the noise figure meter before taking a reading. Noise figure should read between 5 to 6 db. Record measurement on data sheet.

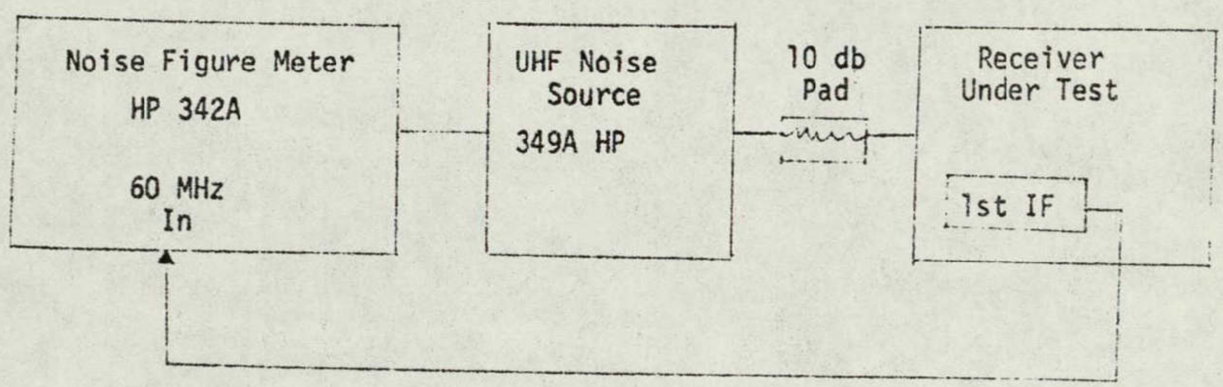


Figure A-2

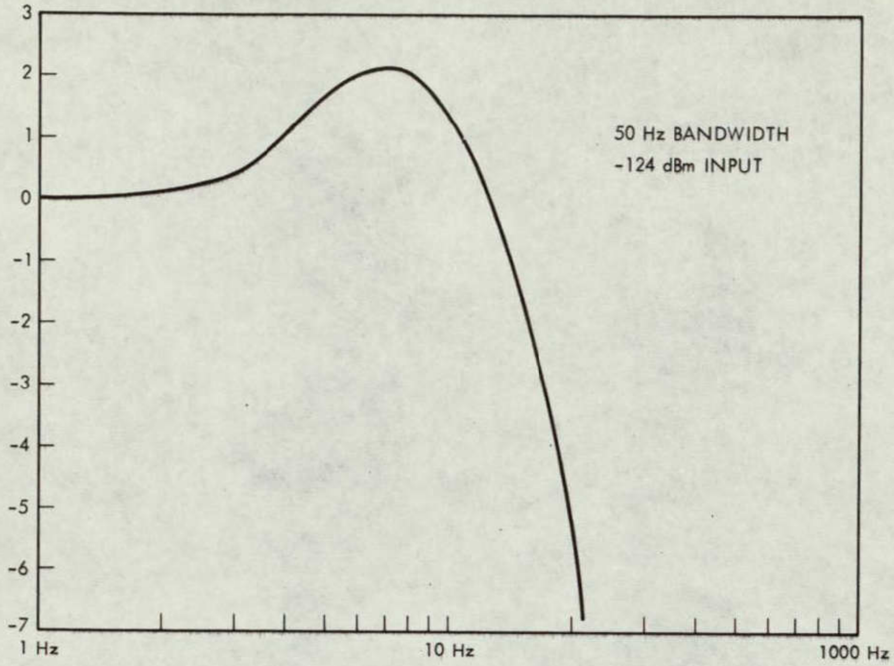


Figure 28. 50 Hz Mode Response

5. BINOR TEST RESULTS

The interface preliminary tests consisted of the L-band transmitter modulation with the BINOR code or the 312 kHz top tone; transmission to the receiver; and processing of the receiver output.

After the receiver AGC was adjusted, the signal level into the BINOR processor stayed within the acceptable limits for a wide range of receiver input levels. The receiver output coupling capacitor needed to be increased because of an inadequate correlation level on the lowest sub-frequency tone to the code processor.

The receiver-to-processor interface also required close proximity of the two units because of the high output impedance of the receiver, and may require receiver changes for impedance matching. Printout of the processor output indicated that the system concept and method is practical and feasible.

Figure 29 illustrates the output of the receiver with three different signal input levels. In comparison to the upper two waveforms, the signal in the bottom portion of the photograph was completely buried within the noise when adjusted for a minimum signal level, but lock-in and processing by the BINOR code processor were easily accomplished with no errors.

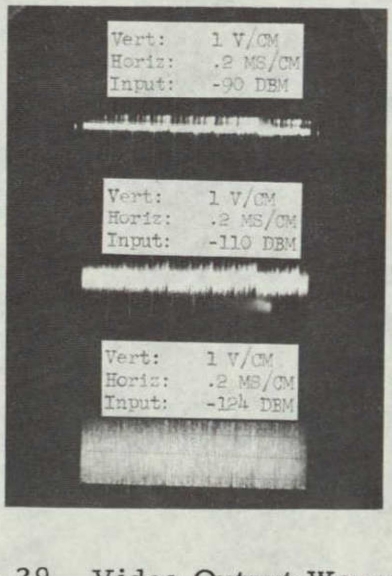


Figure 29. Video Output Waveforms

APPENDIX A

The test procedure for the L-band phase-lock receiver is included in this appendix. This procedure explains the tests performed for the fifteen parameters called out in the receiver specifications. The block diagram test setup, the test equipment required, and the test procedure are given for each parameter.

TEST PROCEDURE FOR THE L-BAND PHASE LOCK RECEIVER

Documentation required: 1) Schematic L-Band Receiver SK68137

2) L-Band Phaselock Receiver Modules Interconnections SK68138

1.0 Carrier Frequency. Figure A-1 shows one of the suggested RF source set-up configurations to test most of the receiver parameters.

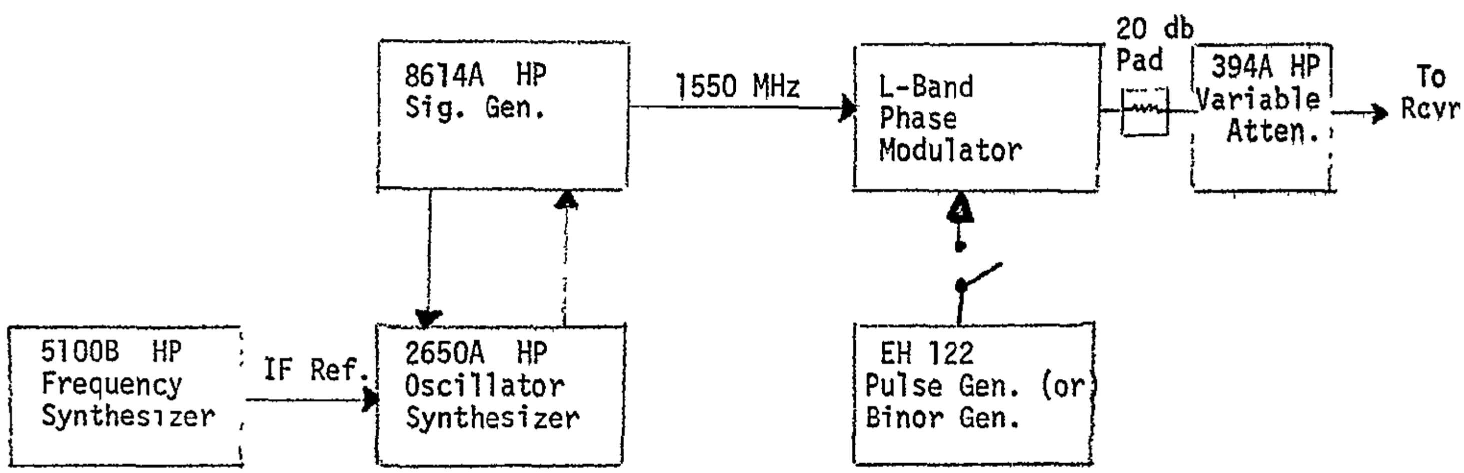


Figure A-1

1.1 Test Equipment Required

- Frequency Synthesizer, HP 5100B
- Oscillator Synchronizer, HP 2650A
- Signal Generator, HP 8014A
- Pulse Generator, EH 122
- Binor Code Generator (TRW)
- L-Band Phase Modulator (TRW)
- Calibrated Variable Attenuator, HP 394A

1.2 Test Procedure

- Measure the frequency of the 8614A Signal Generator with 5245-L Electronic Counter, Hp or equivalent.
- Make necessary adjustment to the IF reference frequency, so as to read a frequency of 1550 MHz from the Signal Generator.
- Record frequency reading on test data sheet.

2.0 CARRIER ACQUISITION THRESHOLD

2.1 Test Equipment Required

- RF Test source of Figure A-1.
- Power meter, HP 431C

2.2 Test Procedure

- Measure RF power available at the input of the receiver with 431C Power Meter HP.
- Add sufficient attenuation following the signal generator so as to decrease the available power at the output of the coaxial calibrated attenuator to -81 dbm when the dial is reading 6 db.
- Turn the Mode Selector switch of the receiver to 1650/50 Hz mode, and set the calibrated coaxial attenuator to -145 dbm output.
- Increase the RF power to the receiver from -145 dbm until the receiver shows signs of threshold locking.
- Record carrier acquisition threshold level on data sheet.

3.0 CARRIER ACQUISITION LEVEL

3.1 Test Equipment Required

- RF Test source of Figure A-1.

3.2 Test Procedure

- Increase the RF power to the receiver to -125 dbm. Receiver should remain locked.

4.0 CARRIER TRACKING LEVEL

4.1 Test Equipment Required

- RF Test source of Figure A-1.

4.2 Test Procedure

- Decrease the RF power to the receiver from -125 dbm to -134 dbm. Receiver should continue in locked condition.

5.0 SIGNAL DYNAMIC RANGE

5.1 Test Equipment Required

- RF Test source of Figure A-1.
- Spectrum analyzer, HP 851B/8551B.

5.2 Test Procedure

- Connect spectrum analyzer to the 2nd IF amplifier output pin 5.
- Set the RF test source to feed -130 dbm signal to the input of the receiver.
- Set the spectrum analyzer in a narrow IF bandwidth to observe the carrier signal.
- Increase the input signal to the receiver by 40 db. Output signal observed in the spectrum analyzer should remain constant within 4 db.

6.0 RECEIVER NOISE FIGURE

6.1 Test Equipment Required

- Noise figure meter, HP 342A.
- UHF Noise Source, HP 349A.
- 10 db Pad.

6.2 Test Procedure

- Set up equipment as shown in Figure A-2.

Notice that the UHF Noise Source has a 10 db pad following, removal of this pad will damage the receiver Pre-amplifier.

6.2 Test Procedure (continued)

- Adjust the zero and infinity adjustments of the noise figure meter before taking a reading. Noise figure should read between 5 to 6 db. Record measurement on data sheet.

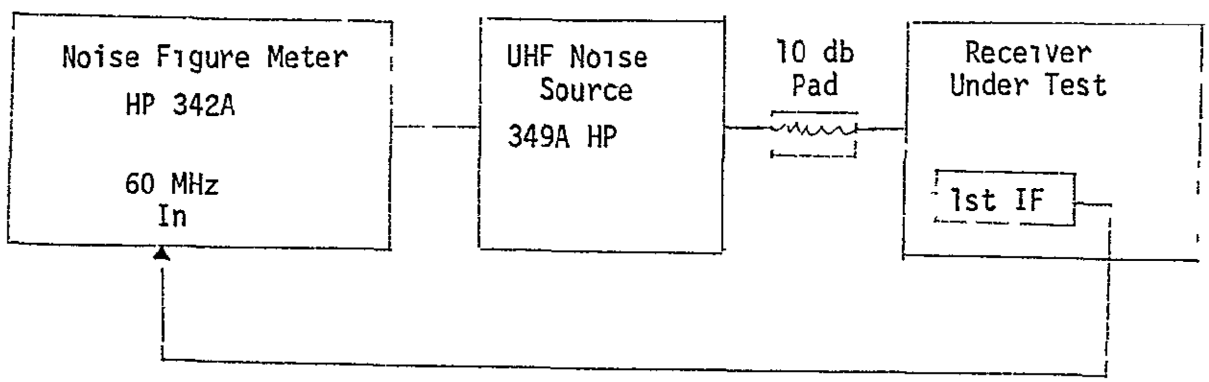


Figure A-2

7.0 IF BANDWIDTH, DATA CHANNEL

7.1 Test Equipment Required

- Power Meter, HP 431C
- Signal Generator, HP 606C.

7.2 Test Procedure

- Reconnect the equipment as shown in Figure A-3.
- Sweep manually the input frequency to the 1st IF and record upper and lower frequencies resulting in 3 db drop from the 62 MHz center frequency.
- The difference between the two readings is the bandwidth of the IF data channel. Record the bandwidth on data sheet.

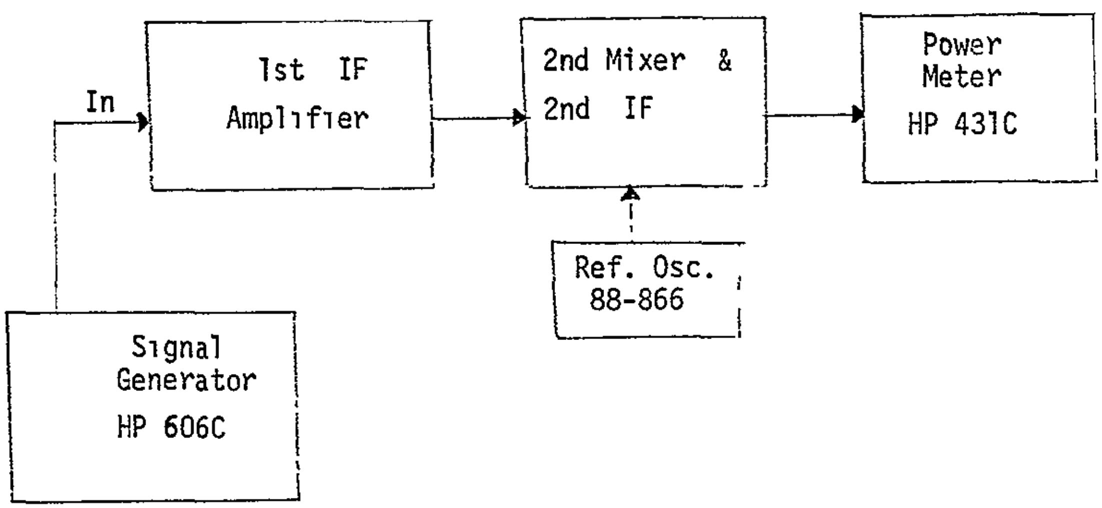


Figure A-3

8.0 VCXO STABILITY (10° to 40°C)

Data on this test is available in Engineering Notebook No. 8904. Examination of this data can be used to determine the VCXO stability in lieu of an actual test.

8.1 Test Equipment Required

- Test oven.
- Frequency counter, HP5245L
- Precision power supply, EPCO model

8.2 Test Procedures

- Connect equipment as shown in Figure A-4.

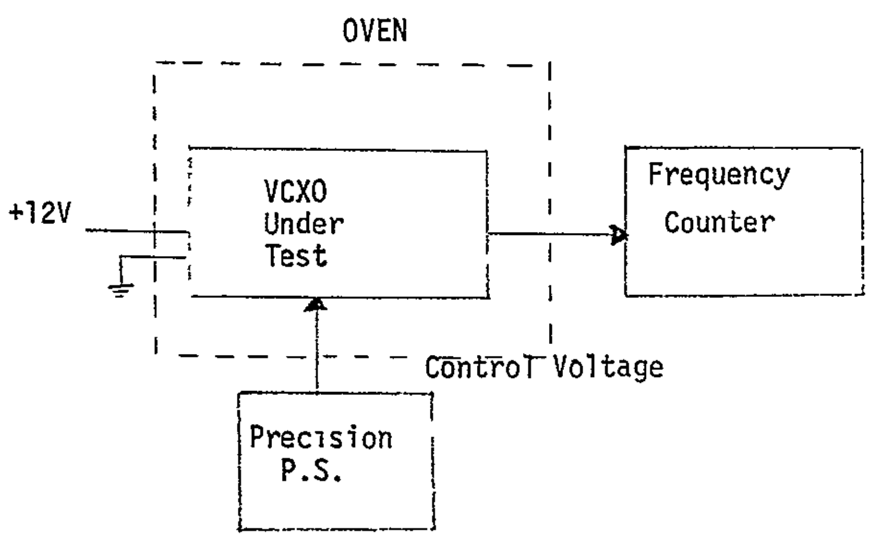


Figure A-4

- Vary the temperature of the oven from 0°C to 50°C in 10 degree intervals.
- For each temperature setting, vary the control voltage from +1 to +7 in steps of 1 volt.
- Record and tabulate the data.

9.0 VCXO SWEEP RANGE

The receiver has been designed with a sweep range of ± 25 kHz.
The VCXO preceeds a times 60 multiplier chain, therefore the actual deviation of the VCXO is 1/60 of ± 25 kHz or ± 416 Hz.
From the data taken in paragraph 8, the scaling factor (approximately 416 Hz/volts) can be obtained. The amplitude of the sawtooth waveform sweeping the VCXO determines the sweep range.

9.1 Test Equipment Required

° Osci-loscope, Tektronix 585.

9.2 Test Procedure

° Connect oscilloscope to test point marked "TP" on the Loop Filter and Sweep Circuit module.
° Measure peak-to-peak amplitude of the sawtooth waveform.
° Calculate and record the sweep range..

10.0 SWEEP PERIOD

10.1 Test Equipment Required

° Oscilloscope, Tektronix 585.

10.2 Test Procedure

° Connect oscilloscope to test point "TP" of the loop filter and sweep circuit.
° Measure and record the sweep period.

11.0 PROBABILITY OF LOCK (-127 dbm) on one sweep

A direct measurement of probability of lock requires several thousands locking operations and a correlation of the compiled data into a single number.
Probability of lock of 0.999 becomes very difficult to measure and beyond the scope and capabilities of this program, therefore this test cannot be performed at this time.

It is important to notice that the probability of acquisition is a function of several parameters such as signal to noise ratio, threshold sensitivity, damping factor, sweep rate, loop bandwidth, etc.

It has been demonstrated (*) that the smaller the ratio of sweep rate and loop noise bandwidth, the greater is the probability of lock for a given signal to noise ratio and damping factor.
The ratio just mentioned is 0.046 for this receiver and it is obtained as follows:

$$\text{ratio} = \frac{R}{(Bno)^2} = \frac{25x10^3/0.2}{(1650)^2} = 0.046$$

Figure 3 of the referenced paper shows that the probability of lock for a 10 db S/N and damping factor of 0.7 is 95% when this ratio is 0.12. Therefore, the 0.046 ratio is an assurance that the probability of lock is better than 95%.

12.0 DIFFERENTIAL TIME DELAY

12.1 Test Equipment Required

- AD-YU 202 Vectorlyzer
- Binor Code Generator
- Binor Processor

12.2 Test Procedure

- Connect the system as shown in Figure A-5.

* J.P. Frazier and J. Page, "Phase Lock Acquisition Study", IRE Trans. on Space Electronics and Telemetry page 211, figure 3, September 1962.

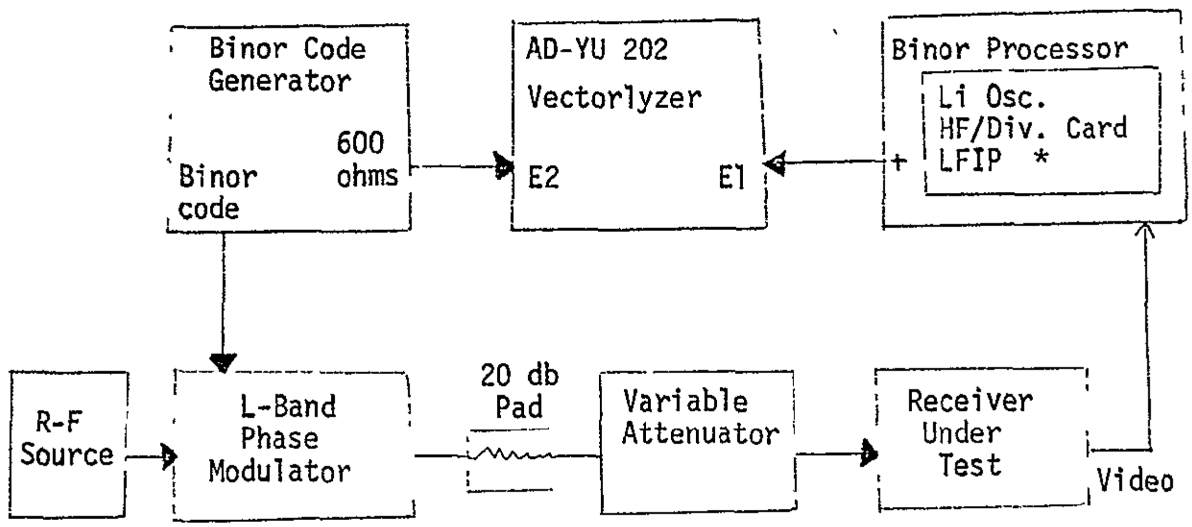


Figure A-5

12.2 Test Procedure (Continued)

- Set the Binor Code Generator switches as follows:

Mode Switch	to	CW
Clock Switch	to	RUN
OUT Switch	to	NORM
Osc/Sel Switch	to	INT
Gate Switch	to	INT
AC Power Switch	to	ON

- Adjust the Vectorlyzer per manufacturer procedure on the 0-180° scale.

* LFIP supplies a 300 kHz signal from the binor processor oscillator which is phase locked to the fundamental of the video output of the receiver, providing a noise-free signal for use in the differential time delay measurement.

12.2 Test Procedure (Continued)

- Set the RF attenuator for -121 dbm signal to the input of the receiver and note the phase difference.
- Increase signal to the receiver to -81 dbm. Note the maximum phase deviation from step above.
- Multiply maximum phase deviation observed in step above by 9.25 nsec per degree. The resulting value is the absolute value of differential time delay.

13.0 RECEIVER OPERATING TEMPERATURE RANGE TEST

13.1 Test Equipment Required

- Test oven for 10°C to 40°.
- Frequency source set-up as per Figure A-1.

13.2 Test Procedure

- Place receiver in the oven and set temperature to 10°C. After 20 minutes at that temperature, check carrier acquisition threshold.
- Repeat above step for temperature of 20, 30, and 40°C.
- All the preceeding tests should show a -130 dbm carrier acquisition threshold or better. Record test in data sheet.

14.0 ACQUISITION LOOP BANDWIDTH ($2B_L$, 1650 Hz)

14.1 Test Equipment Required

- Signal Generator, HP 8614A
- Oscillator Syncronizer, HP 2650A
- Frequency Synthesizer, HP 5100B
- Synthesizer Driver, HP 5110B
- Dual DC Power Supply, HP/Harrison 6205B
- Pin Diode Switch Modulator
- Waveteck III Voltage Controlled Generator
- DC Power Supply, HP 721A
- Oscilloscope, Tektronix 453
- Variable Attenuator, HP 394A
- 20 db Pad
- Wave Analyzer, HP 302A
- AC Transistor Voltmeter, HP 403A
- Oscilloscope, Tektronix 585

14.1 Test Equipment Required (Continued)

Transmitter Assembly Test Set-up

- Connect the transmitter assembly as shown in Figure A-6.
- Set the following switches to the indicated position.
  - Tektronix 453 Oscilloscope:
    - Power switch to ON
    - Vertical : 2 V/cm DC
  - Waveteck III V.C. Generator:
    - Power switch to X1
    - Output selector to Sine wave
  - HP 721A Power Supply :
    - Power switch to ON
    - Voltage adjust pot to -5.5 VDC (seen on the 453 oscilloscope)
  - Harrison 6205B Dual Power Supply:
    - Power switch to ON (Modulator power switch should be OFF)
    - Both Voltage pots to 20 volts DC. Wiring should be set up to provide both +20V and -20 volts to the modulator.
  - Modulator:
    - Power switch to ON
  - HP 8614 Signal Generator:
    - Line switch to ON
    - RF switch to ON
    - ALC switch to ON
    - Ext FM switch to ON
    - DBM meter to 0
    - Attenuation dial to -045 db
    - Frequency dial to 1554 MHz
  - HP 5100B / HP 5110B Synthesizer
    - Power switch to operate (both 5100B and 5110B)
    - Frequency standard switch to INT.
    - Frequency selection switch to Local Keyboard
    - Frequency Keyboard switch to 30010050.00 Hz
    - Search control switch to Remote

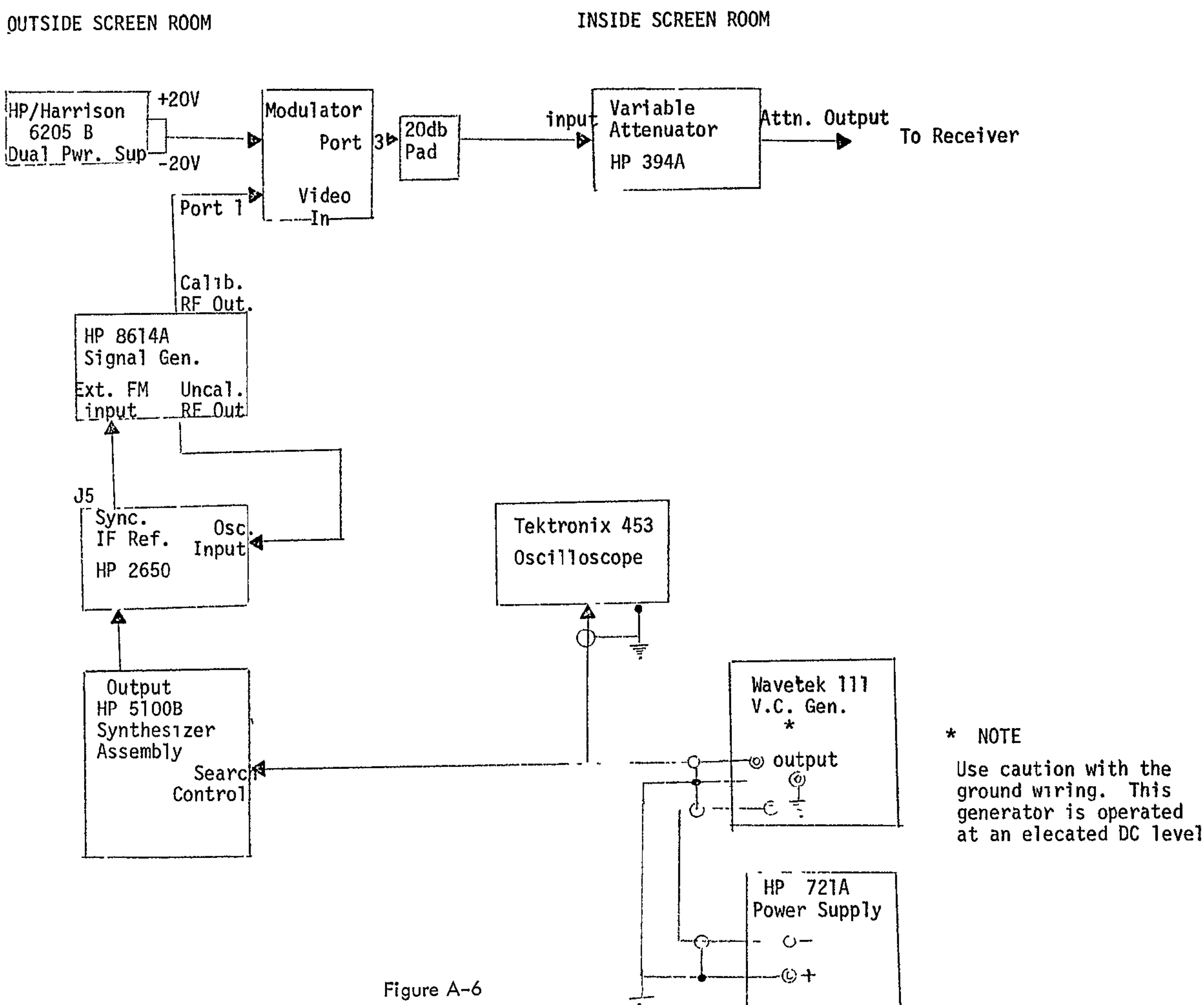

OUTSIDE SCREEN ROOM
INSIDE SCREEN ROOM
HP/Harrison
6205 B
Dual Pwr. Sup
+20V
-20V
Modulator
Port
3
Port 1
Video
In
20db
Pad
input
Variable
Attenuator
HP 394A
Attn. Output
To Receiver
Calib.
RF Out.
HP 8614A
Signal Gen.
Ext. FM
input
Uncal.
RF Out
J5
Sync.
IF Ref.
HP 2650
Osc.
Input
Tektronix 453
Oscilloscope
Output
HP 5100B
Synthesizer
Assembly
Search
Control
Wavetek 111
V.C. Gen.
*
output
HP 721A
Power Supply
* NOTE
Use caution with the
ground wiring. This
generator is operated
at an elecated DC level

Figure A-6

14.1 Test Equipment Required (Continued)

- HP 2650A Synchronizer:
  - Power switch to ON
  - IF Mode switch to EXT.
  - APC switch to ON
  - Search light should be OFF
  - Phase meter should be slightly off center. This is accomplished by adjusting the HP 8614A signal generator frequency.
- HP 394A Variable Attenuator:
  - Set the variable attenuator control dial to read 49 db of attenuation. (This provides a power into the receiver of -124 dbm).

Allow a 30 minute warm up period before conducting test.

Receiver Test Set-up

- Connect the receiver assembly as shown in Figure A-7.
- Set the following switches to the indicated positions:
  - HP 403A AC Transistorized Voltmeter:
    - Range switch to 0 db (1 V RMS full scale)
    - Function switch to 1 cps - 1 Mc
  - Tektronix 585 Oscilloscope:
    - Power switch to ON
    - Vertical to 1 V/cm DC
  - HP 302A Wave Analyzer:
    - Power switch to ON
    - Scale Value switch to Absolute
    - Mode selector switch to Normal
  - L-Band Phase Lock Receiver (Unit under Test)
    - Power switch to ON

Allow a 30 minute warm-up period before conducting tests.

14.2 Test Procedure, 1650 Hz Noise bandwidth

- The HP 302A Wave Analyzer should be connected to point (A) in figure 7. The Mode Selector switch on the receiver should be in the 1650 Hz AUTO position. Set the frequency of the Wavetek 111 oscillator to 250 Hz.

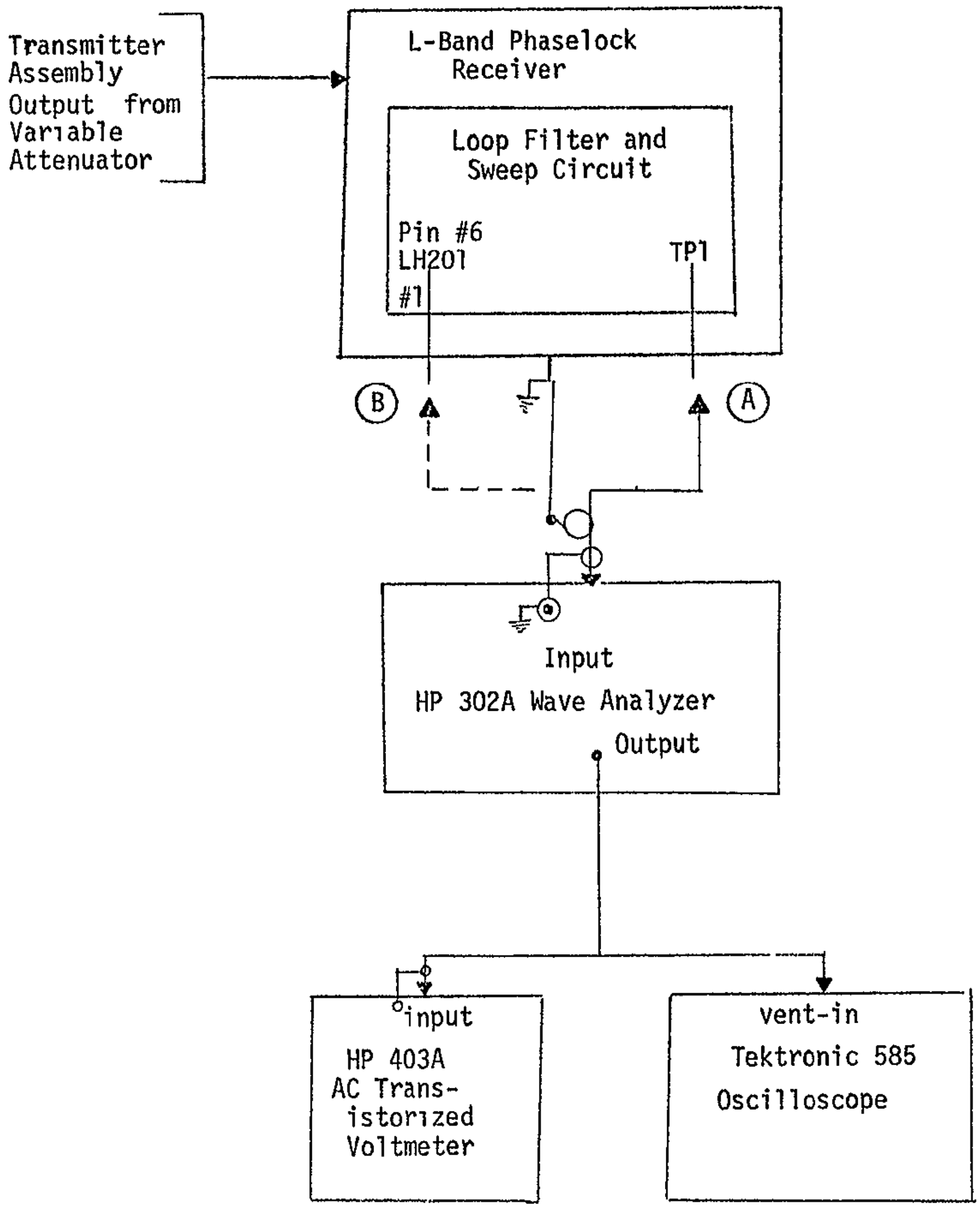

Transmitter
Assembly
Output from
Variable
Attenuator
L-Band Phaselock
Receiver
Loop Filter and
Sweep Circuit
Pin #6
LH201
#1
TP1
B
A
Input
HP 302A Wave Analyzer
Output
input
HP 403A
AC Trans-
istorized
Voltmeter
vent-in
Tektronic 585
Oscilloscope

Figure A-7

- Vary the ATTEN control on the Wavetek111 oscillator and the FREQ. Keyboard setting of the HP 5100B FREQ. Synthesizer until a reading of -40 db is observed on the HP 302A wave analyzer meter. (The Frequency control on the Wave Analyzer will need to be adjusted for a peak at 250 Hz and the MODE Selector set to AFC). The proper setting of the FREQ. Keyboard will be one of the following settings:
  - 3 0 0 1 0 0 0 5.0 0 Hz
  - 3 0 0 1 0 0 5 0.0 0 Hz
  - 3 0 0 1 0 5 0 0.0 0 Hz
  - 3 0 0 1 5 0 0 0.0 0 Hz
- Note the signal level in db for various frequencies ranging from 10 Hz to 2 kHz. The procedure for this is to set the frequency of the Wavetek 111 oscillator to the desired setting. Set the MODE selector on the wave analyzer to NORMAL. Adjust the Wave Analyzer Frequency control until a peak is observed, then replace the MODE Selector to AFC. Read the signal in db directly from the Wave Analyzer meter. Compare this data with figure 3-3 in reference No. 1 in order to determine the damping factor and the loop resonate frequency.

15.0 TRACKING LOOP BANDWIDTH, (2 B_L, 50 Hz)

15.1 Test Equipment Required

- Same as paragraph 14.1

Transmitter Assembly Test Set Up

- Same as paragraph 14.1

Receiver Test Set Up

- Same as paragraph 14.1

15.2 Test Procedures, 50 Hz Noise Bandwidth

- The HP 302A wave analyzer should be connected to point (B) in figure 7. The mode selector switch on the receiver should be in the 1650/50 Hz AUTO position. Set the frequency of the Wavetek 111 oscillator to 10 Hz.

15.2 Test Procedures, 50 Hz Noise Bandwidth (Continued)

- Using the procedure of paragraph 14.2, second item, obtain a meter reading of -10 db at a frequency of 10 Hz. Adjust the OUTPUT AMP pot on the Wave Analyzer until the HP 403A AC transistorized voltmeter reads 0 db.

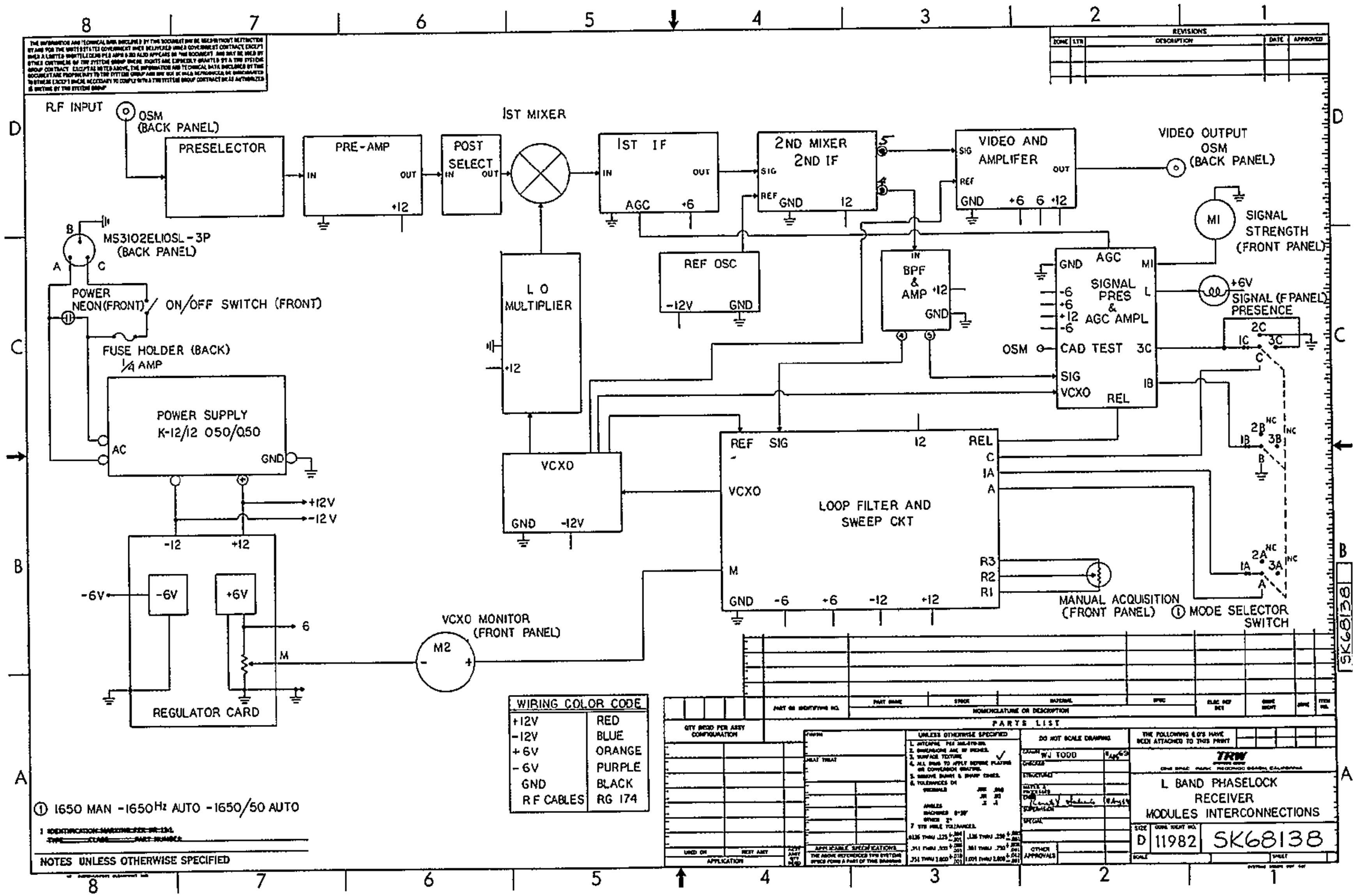
Note: The range of this meter is now identical to the range of the Wave Analyzer. This setup may be used down to the frequency of 3 Hz. It should not be used below 3 Hz and at this frequency 1 db should be added to the meter reading. At 4 Hz and above the meter may be read directly.

- Using the procedure of paragraph 14.2, third item, obtain the signal level for various frequencies ranging from 3 to 30 Hz The signal should be read in db from the HP 403A voltmeter. The Tektronix 585 scope is provided to aid in the peaking of the signal. Compare this data with figure 5-1 in reference No. 1 in order to determine the loop resonate frequency.
- The HP 302A Wave Analyzer should be connected to point (A) in figure 7. The Mode Selector switch on the receiver should be in the 1650/50 Hz AUTO position. Set the frequency of the Wavetek 111 oscillator to 10 Hz.
- Using the procedure of paragraph 14.2, second item, obtain a meter reading of -70 db at a frequency of 10 Hz. Using the procedure of paragraph 15.2, second item, calibrate the HP 403A Voltmeter.
- Using the procedure of paragraph 14.2 and 15.2, third items, obtain the signal level for various frequencies ranging from 3 Hz to 100 Hz. Compare this data with figure 3-3 of reference No. 1 to obtain the damping factor.

Reference No. 1: Theory of Phaselock Techniques as applied to Aerospace Transponders, Floyd M. Garner and Steven S. Kent. Contract No. NAS8-11509, Marshall Space Flight Center, NASA, Huntsville, Alabama.

APPENDIX B

The modules interconnections diagram is included to serve as an aid in receiver maintenance. All cabling is coaxial with the exception of the color-coded power supply wiring, meters, and selector switches.


RF INPUT
OSM (BACK PANEL)
PRESELECTOR
PRE-AMP
IN OUT +12
POST SELECT
1ST MIXER
1ST IF
AGC +6
2ND MIXER 2ND IF
SIG REF GND 12
VIDEO AND AMPLIFER
GND +6 6 +12
VIDEO OUTPUT OSM (BACK PANEL)
M1
SIGNAL STRENGTH (FRONT PANEL)
MS3102EL10SL-3P (BACK PANEL)
POWER NEON (FRONT)
ON/OFF SWITCH (FRONT)
FUSE HOLDER (BACK) 1/4 AMP
L O MULTIPLIER
REF OSC
-12V GND
BPF & AMP
GND AGC M1
SIGNAL PRES & AGC AMPL
+6V SIGNAL (F PANEL) PRESENCE
OSM CAD TEST 3C
SIG VCXO REL 1B
POWER SUPPLY K-12/12 050/050
AC GND
+12V
-12 V
VCXO
GND -12V
REF SIG 12 REL
C 1A A
LOOP FILTER AND SWEEP CKT
R3 R2 R1
M
GND -6 +6 -12 +12
MANUAL ACQUISITION (FRONT PANEL)
① MODE SELECTOR SWITCH
REGULATOR CARD
-6V +6V
VCXO MONITOR (FRONT PANEL)
M2
WIRING COLOR CODE
+12V RED
-12V BLUE
+6V ORANGE
-6V PURPLE
GND BLACK
RF CABLES RG 174
① 1650 MAN -1650Hz AUTO -1650/50 AUTO
NOTES UNLESS OTHERWISE SPECIFIED
PARTS LIST
TRW
L BAND PHASELOCK RECEIVER MODULES INTERCONNECTIONS
D 11982 SK68138

APPENDIX C

ALIGNMENT PROCEDURE

REQUIRED TEST EQUIPMENT AND TYPICAL TEST SET UP

The following test equipment or its equivalent should be on hand for performing these tests.

Sweep Generator	Jerrold model 900C HP 8690A with 8691A plug-in
CW Generator:	HP 606 50 kHz to 65 MHz HP 608 10 MHz to 480 MHz HP 612 450 MHz to 1230 MHz HP 8614A 800 MHz to 2400 MHz
Oscilloscope:	Tektronix 453 Tektronix 585 with (CA type plug-in)
Attenuator:	OSM model 20510-3 (3 db) fixed OSM model 20510-6 (6 db) fixed OSM model 20510-10 (10 db) fixed HP 394A (6-140 db) variable HP 8491A - 20 db (20 db) fixed HP 8491A - 10 db (10 db) fixed
Spectrum Analyzer:	HP 851B/8551B
Power Meter:	HP 431C with 478A thermistor
RF Detector:	HP 423A
Synchronizer	HP 2650A with 105.3333 MHz crystal
Synthesizer	HP 5100B/5110B
Modulator:	TRW Bi phase
Power Supply:	HP/Harrison 6205B (dual) (3 each) EPSCO VRS 611 HP 721A
Loads:	50 ohm 0SM 20140P (4 each)
DC Milliamp Meter:	Simpson model 269
Pulse Generator	EH 122 TRW Binor code generator

Voltage Controlled Generator·	Wavetek model 111
Frequency Counter:	HP 5245L with 5253 and 5254 plug-in
Voltmeter:	HP 3430A
Noise Figure Meter:	HP 342A with the HP 349A UHF Noise Source.
AC Voltmeter.	HP 403A (no equivalent)
Wave Analyzer	HP 302A (no equivalent)

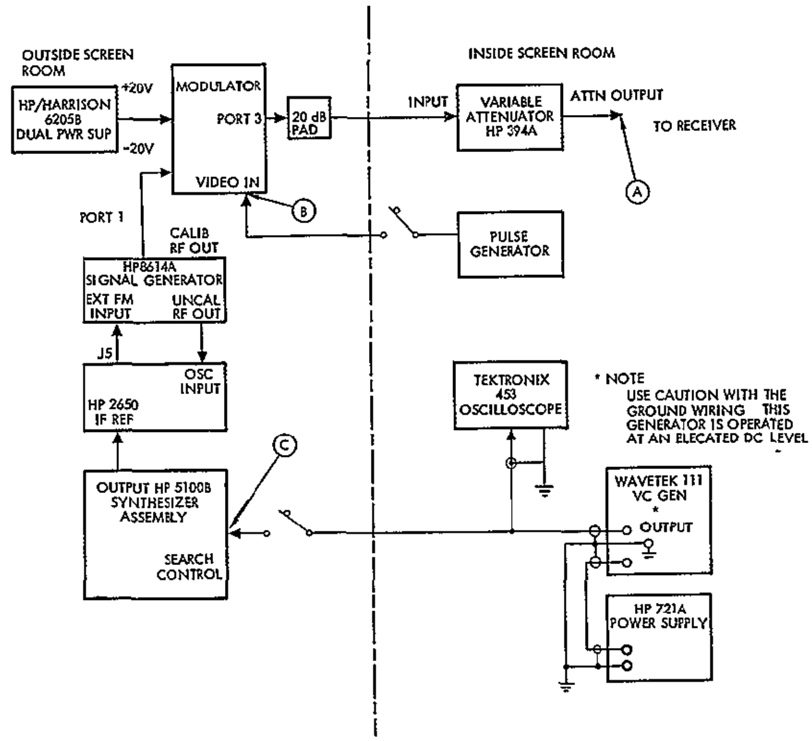


Figure 1. Transmitter Assembly Test Set-Up

The following test set-ups will be referenced frequently throughout this procedure.

1.1 RF Test Set-Up

The RF Test Set-Up is illustrated in Figure 1. This set-up will be used for the following modules:

- Pre-selector
- Pre-amplifier
- Post selector
- First IF amplifier
- Second mixer and second IF amplifier
- Narrowband filter
- L. O. multiplier

Each section of this test procedure will specify the connections used (Ⓐ through Ⓕ) or not used, and the frequencies and power levels associated with each connection. From this the test equipment may be easily selected from the provided list.

In all sections of this test procedure the RF connections on the test unit must be terminated into 50 ohms. It is recommended that an attenuator (3 to 10 db) or a 50 ohm load be placed on all connectors in order to insure the proper load impedance and reduce cable effects. It is also recommended that all cables be kept as short as practical.

It will be noted that when swept measurements are made then the sweep generator, the RF detector and the oscilloscope are used. When a CW measurement is made the CW generator is used in conjunction with either the spectrum analyzer or the power meter. Allow a 30 minute warm up before conducting tests.

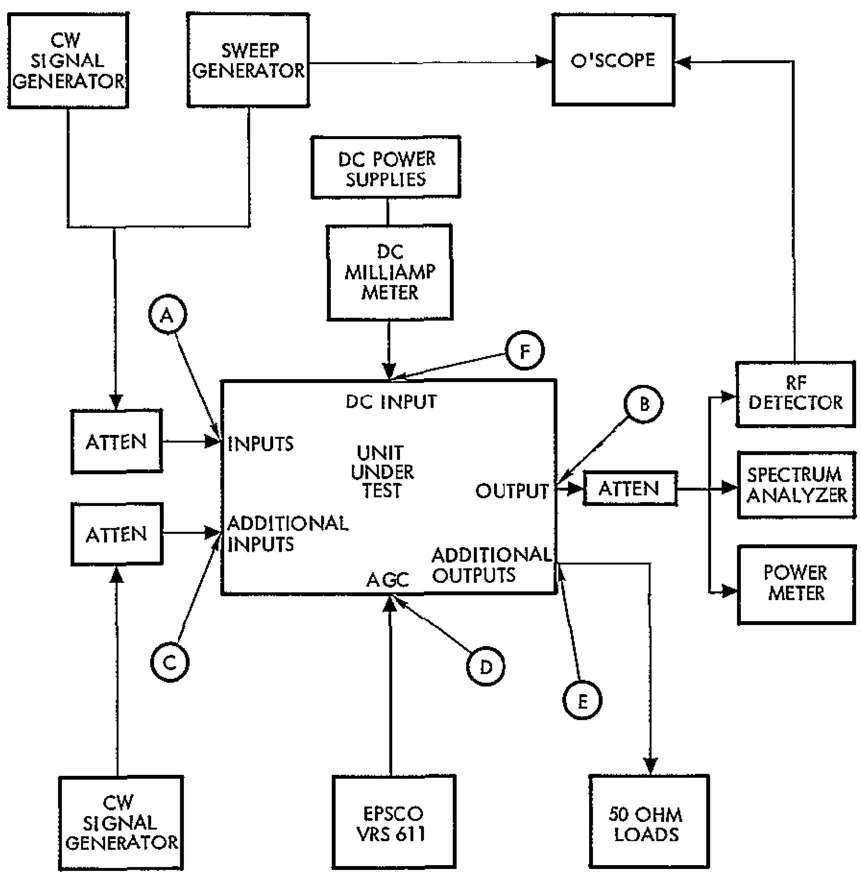


Figure 2. RF Test Set-Up

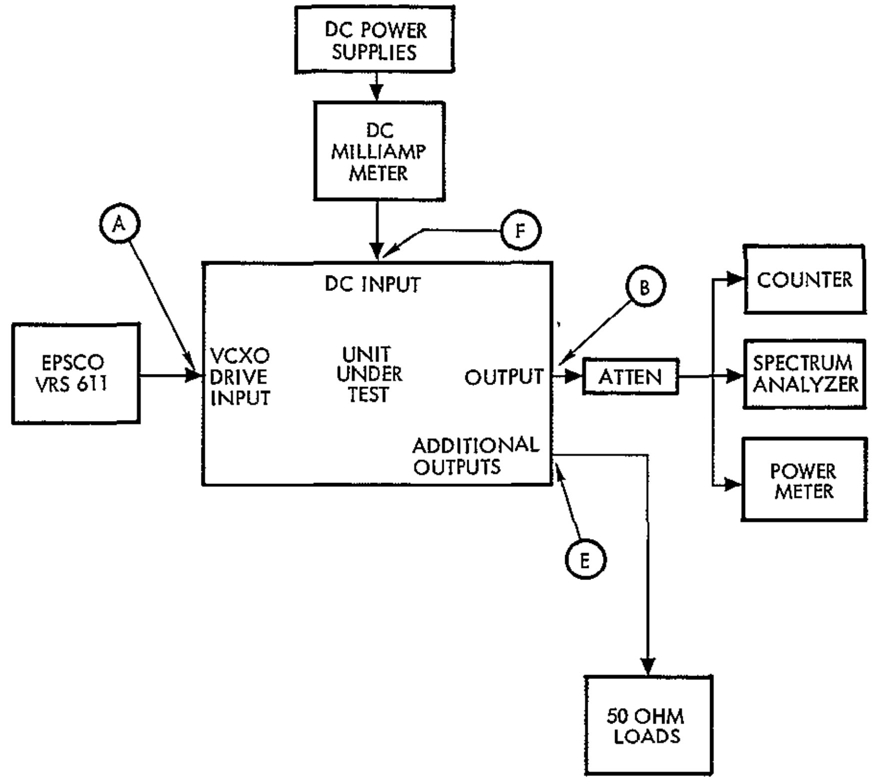


Figure 3. Oscillator Test Set-Up

1.2 <u>Oscillator Test Set-Up</u>

The Oscillator Test set-up is illustrated in Figure 3. This set-up will be used for the following modules

Reference Oscillator
VCXO and Buffer

Each section of this test procedure will specify the connections used ((A) through (F)) or not used, and the frequencies and power levels associated with each connection. From this the test equipment may be easily selected from the provided list.

In all sections of this test procedure the RF connectors on the test unit must be terminated into 50 ohms. It is recommended that an attenuator (3 to 10 db) or a 50 ohm load be placed on all connectors in order to insure the proper load impedance and reduce cable effects. It is also recommended that all cables be kept as short as practical.

Allow a 30 minute warm up before conducting tests.

1.3 Transmitter Assembly Test Set-Up

Connect the transmitter assembly as shown in Figure 1.

1.3.1

Set the following switches to the indicated position.

- Tektronix 453 Oscilloscope*

  Power switch to ON

  Vertical: 2 V/cm DC

- Waveteck III V.C. Generator*

  Power switch to X1

  Output selector to Sine wave

- HP 721A Power Supply*

  Power switch to ON

  Voltage adjust pot to -5.5 VDC
  (Seen on the 453 oscilloscope)

- Harrison 6205B Dual Power Supply·

  Power switch to ON (Modulator power switch should be OFF)

  Both voltage pots to 20 volts DC. Wiring should be set up to provide both +20V and -20V to the modulator.

- Modulator.

  Power switch to ON

- HP 8614 Signal Generator

  Line switch to ON

  RF switch to ON

  ALC switch to ON

  Ext FM switch to ON

  DBM meter to 0

  Attenuation dial to -045 dB

  Frequency dial to 1554 MHz

*This equipment is used for specific tests only it will be called for in the procedure if required.

- HP 5100B/HP 5110B Synthesizer

  Power switch to operate (both 5100B and 5110B)

  Frequency standard switch to INT.

  Frequency selection switch to Local Keyboard

  Frequency Keyboard switch to 30010000. 00 Hz

  Search control switch to Local

- Pulse Generator*

  Power Switch to ON

- HP 2650A Synchronizer

  Power switch to ON

  IF Mode switch to EXT.

  APC switch to ON

  Switch light should be OFF

  Phase meter should be slightly off center. This is accomplished by adjusting the HP 8614A signal generator frequency.

- HP 394A Variable Attenuator

  Set the variable attenuator control dial to read 49 dB of attenuation. (This provides a power into the receiver of -124 dBm).

Allow a 30 minute warm up period before conducting test.

1.3.2 Transmitter Frequency Adjustment

Connect the counter to the output of the HP 8614A and adjust the HP 5100B synthesizer frequency until the counter reads 1550. 000 MHz. Reconnect the signal generator output to port 1 of the modulator.

1.3.3 Power Calibration Procedure

- Temporarily remove the 20 dB pad and set the variable attenuator to -10 dB.

- Connect the HP 431C power meter to point (A) (Figure 1).

*This equipment is used for specific tests only it will be called for in the procedure if required.

- Adjust the variable attenuator on the HP 8614 (oscillator) until -25 dBm is observed on the power meter.
- Replace the 20 dB pad and add 40 dB to the HP 8614 (oscillator) variable attenuator.

The system is now calibrated so that the power input in -dBm to the receiver is the sum of the HP 394A attenuator reading plus 75.

2. SUBASSEMBLY ALIGNMENT PROCEDURES

Ten modules of the L-Band receiver require bench alignment prior to receiver system test. The remaining modules are tested and aligned utilizing the receiver noise.

2.1 Pre-Selector Test Procedure

Utilize the RF test set up of paragraph 1.1 and Figure 2.

Connections	Approximate requirements
(A) input	1.55 GHz at -10 dBm
(B) output	1.55 GHz at -10 dBm
(C) (D) (E) and (F)	un-used

This is a high pass filter. It should have an insertion loss of less than .4 dB and greater than 60 dB loss at 400 MHz. The only adjustment possible in this module is to replace the capacitors or change the length of the inductors.

2.2 Pre-Amplifier Test Procedure

Utilize the RF test set up of paragraph 1.1 and Figure 2.

Connections	Approximate requirements
(A) input	1.55 GHz at -50 dBm
(B) output	1.55 GHz at -30 dBm
(C) (D) and (E)	un-used
(F) DC power	+12.0 VDC at 10 ma

There is no provision for adjustment of this module. It is a wide-band preamplifier with only the requirements that the gain at 1550 MHz be greater than 15 dB, that the 3 dB bandwidth be greater than 20 MHz (+ and -10 MHz), and that the noise figure be equal to or less than 5 dB.

The gain and bandwidth may be tested on this set up, however the noise figure will be tested during the receiver front end alignment (section 3.2).

CAUTION: The preamp contains open circuitry and transistors. Do not touch the substrate or any part in this box.

2.3 Post Selector Test Procedure

Utilize the RF test set up of paragraph 1.1 and Figure 2.

Connections	Approximate requirements
(A) input	1.55 GHz at -10 dBm
(B) output	1.55 GHz at -10 dBm
(C) (D) (E) (F)	un-used

This is a bandpass filter that has an insertion loss of 2 dB or less and a bandwidth greater than 20 MHz (+ and -10 MHz) at the 3 dB points. The image frequency range (1.665 to 1.675 GHz) must be greater than 20 dB down.

The two capacitors should be adjusted with the unit set up in the swept mode, and the CW mode should be used to check the specifications.

2.4 1st IF Amplifier Test Procedure

Utilize the RF Test set up of paragraph 1.1 and Figure 2.

Connections	Approximate requirements
(A) input	62 MHz at -80 dBm
(B) output	62 MHz at -10 dBm
(C) and (E)	un-used
(D) AGC input	0 VDC (min. gain) to 1.8 VDC (maximum)
(F) DC input	+6V at 55 ma

This high gain amplifier should have a gain of approximately 70 dB at the center frequency of 62 MHz and a 3 dB bandwidth of 6 MHz (+3 and -3 MHz). The AGC should have control over a dynamic range of 40 dB

The capacitor (C10 and C11) should be adjusted with the unit in the swept mode with the AGC voltage set to approximately 1.5 VDC. It may be necessary to select C-19, the coupling capacitor (between C-10 and C-11) for the proper bandwidth (a larger capacitance causes a narrower bandpass).

With the unit in the CW mode, apply 26.8 MHz at about -40 dBm to the input and adjust C-9 and C-16 for a null of the 26.8 MHz signal at the output. Reset the input signal to 62 MHz at -80 dBm and adjust the AGC voltage for maximum gain. Repeat these adjustments until satisfaction is achieved.

Make a plot of gain versus AGC voltage to insure that the AGC voltage has a 40 db dynamic range. Connect the spectrum analyzer to the IF output. Insure that there is no spurious oscillation while varying the AGC voltage from 0 to 2.0 volts.

2.5 2nd Mixer and 2nd IF Amplifier Test Procedure

Untilize the RF Test set-up of paragraph 1.1 and Figure 2.

	Connection	Approximate requirement
(A)	signal input	62 MHz at -50 dBm
(B)	output 4	26.8 MHz at -14 5 dBm (35 dB gain)
(C)	reference oscillator input	88.86 MHz at -5 dBm
(D)		unused
(E)	output 5	26.8 MHz at -19 dBm (31 dB gain)
(F)	DC power	+12.0 VDC at 20 ma +6.0 VDC at 2.4 ma

This unit should have a gain of approximately 35 db at output #4 and 31 db at output #5. The bandwidth should be 5 MHz at the 3 db points (+2.5 MHz and -2.5 MHz) centered at 26.8 MHz.

Set up the approximate bandwidth first by removing the reference oscillator input (point (C)) and setting up the sweep generator at 26.8 MHz. Adjust C-4 and C-8 for the approximate bandpass. Now reconnect the reference oscillator and set the sweep generator to 62 MHz. Adjust C-4 and C-8 until the desired bandpass is achieved. It may be necessary to select C-5 for the proper bandwidth (a larger capacitance causes a narrower bandpass).

With the test set-up in the CW mode and the spectrum analyzer on the output (4 or 5) insure that the proper gain is achieved at 26.8 MHz. If the conversion efficiency is bad it will be seen by a relatively low signal at 26.8 MHz and a relatively high signal at 62 MHz. If this efficiency is poor it may be required to change the two resistors on pin 5 of the MC 1550G (mixer). Also verify that there are no spurious oscillations observed on the spectrum analyzer.

2.6 Narrowband Filter Alignment

Utilize the RF test set-up of paragraph 1.1 and Figure 2.

Connection		Approximate requirements
(A)	input	26.8 MHz at -24 dBm *
(B)	output #4	26.8 MHz at -24 dBm *
(C) (D)		unused
(E)	output #5	26.8 MHz at -29 dBm
(F)	DC power	+12.0 VDC at 20 ma

This narrowband amplifier should have a gain of 0 dB at output #4 and a loss of 5 dB at output #5. The bandwidth should be 500 kHz (+250 kHz and -250 kHz) at the 3 dB points centered at 26.8 MHz.

*For swept measurements it may be necessary to increase this power to about -10 dBm in order to have an observable signal. However the bandwidth should be set such that it is correct for a CW test that is performed at -24 dBm.

Connect the test set up in the swept mode and adjust the bandpass of the filter. Adjustments are made by squeezing or separating the turn of L-3, L-4, and L-5. Next connect the test set-up in the CW mode and verify the bandpass and gain. Also verify that there are no spurious oscillations seen on the spectrum analyzer.

2.7 Reference Oscillator Alignment

Utilize the oscillator test set-up of paragraph 1.2 and Figure 3.

Connections			Approximate requirements
(A) (E)			unused
(B)	output	unit #1	88.866666 MHz at -5 dBm
		unit #2 & #3	88.861666 MHz at -5 dBm
(F)	DC power		-12.0 VDC at 3 ma

Adjust C-3 for the proper frequency as observed on the counter. Monitor the output on the power meter and observe the -5 dBm on the power meter. It may be necessary to add a resistor (15K or greater) from pin 10 of the flatpack to ground in order to increase the output power. Monitor the output on the spectrum analyzer and verify that there are no spurious oscillations.

Repeat the above tests with the unit in an environmental temperature chamber. Over the temperature range of +10°C to +40°C the frequency change should be less than 10 PPM (886 Hz).

2.8 VCXO and Buffer Alignment

Utilize the oscillator test set-up of paragraph 1.2 and Figure 3.

Connections		Approximate requirements
(A)	VCXO drive	3 VDC to 9 VDC nominal to 6 VDC
(B) and (E)	outputs	26.866666 MHz at -11 dBm
(F)	DC power	-12.0 VDC at 16 ma

NOTE All tests on this device are performed with the oscillator output (OUT) connector connected to the buffer input (IN) connector through a short piece of coaxial cable. Any one of the buffer outputs (output 1 thru 4) are then measured.

Select R-11 to the 9 05 K ohms.

Set the VCXO drive voltage to 6.0 VDC and adjust C-3 until the proper frequency (26.866666 MHz) is observed on the counter. Monitor the outputs (1 thru 4) with the power meter and verify that they are at -11 dBm. It may be necessary to add a resistor (15 K or greater) from pin 10 of the flatpack to ground in order to increase the output power. Make a graph of the frequency versus VCXO drive voltage of 3.0V to 9 0V. Verify that the slope of this curve (VCXO scale factor) is about 400 Hz/volt. Connect the output to the spectrum analyzer and verify that there are no spurious oscillations

Repeat the above tests with the unit in an environmental temperature chamber. Select R-11 until the change in frequency between the temperature of 10^{o}C and 40^{o}C at any VCXO drive voltage (3.0V, 6 0V, or 9.0V) is less 10 PPM (268 Hz).

Repeat the above tests until the satisfaction is achieved.

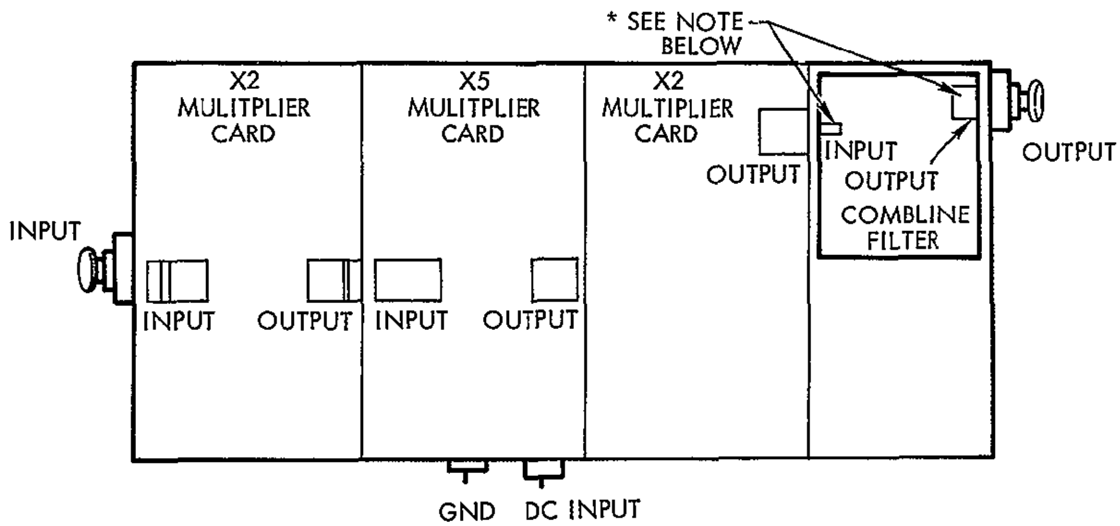
2.9 L O. Multiplier (X 60) Alignment

CAUTION: Due to the non-linear elements and the high frequencies associated with frequency multipliers it is not recommended that this adjustment be performed outside of the factory. Should this procedure be attempted it is essential that it be performed under laboratory conditions, utilizing the proper test equipment, and personnel that have extensive knowledge of RF techniques and experience with Varactor multiplier adjustment. This document is written as a guide to the qualified technician, not as an absolute step-by-step procedure.

2.9.1 Preliminary Set Up Considerations

The multiplier should be energized with +12.0 volts DC (the case is ground) The typical DC current for the whole unit is about 30 ma therefore a current limited supply at about 50 ma should be used

The unit is composed of 4 parts, 3 RF cards and one comb-line filter (see Figure 4) Preliminary adjustments on each of the 3 cards should be made individually. These adjustments are discussed in sections 2 9 2, 2.9 3, and 2.9.4. The set-up for each of these sections is to solder on a coaxial cable to the input and output of the card, having removed the original connection and terminate these cables into 50 ohm impedance It is recommended that each coax be kept short and that a 50 ohm attenuator (3 to 10 db) be placed as close to the card as possible.



* NOTE DO NOT SOLDER TO THE COMB-LINE (MICRO-STRIP) FILTER. CONDUCTIVE EPOXY MUST BE USED HERE

Figure 4 Multiplier Configuration

Final adjustment of the unit must be accomplished with the unit completely assembled, * and that the input and output connectors be terminated into 50 ohms It is recommended that an attenuator (3 to 10 db) be placed on the input and output connector in order to insure proper impedance matching and reduce cable effects.

*NOTE. <u>DO NOT</u> solder to the comb-line (micro-strip) filter. Conductive epoxy must be used here.

The typical test set up is illustrated in paragraph 1.1 and Figure 2. This set-up should be used whether the test unit is only one card or the entire multiplier unit The only precaution necessary is that the test equipment will supply the required input frequencies and power levels, and that the test equipment is linear at the output frequencies and power levels. These data are given in Table 1.

Table 1. Input/Output Requirements

	Input at Connection (A)		Output at Connection (B)	
Unit	Frequency MHz	Power at PT (A) dbm (50 ohm)	Frequency MHz	Power at PT (B) dBm (50 ohm)
X6	26.9	-10	161	-9.5
X5	161	-9.5	806	0
X2	806	0	1612	+10.0
X60	26.9	-10	1612	+10.0

Connection	Approximate Requirements
(C) (D) (E) (F)	Unused
DC Power	+12.0 VDC at 30 ma

.2.9.2 X6 Multiplier Card Adjustment

The test set-up should be connected in the CW mode utilizing the spectrum analyzer as an indicator. Tune C5, C8, C10, C12, and C11 for a maximum signal at 161 MHz. Be sure that the signals at 133 MHz (X5 mode) and 187 MHz (X7 mode) are as low as possible.

The test set-up should now be changed to the swept mode and the same capacitors adjusted until a pleasant band pass is observed that is about 7 MHz wide at the 3 dB points (relative to output frequency)

Repeat the previous two paragraphs until a satisfactory bandpass is achieved and all spurs and harmonics noted in the first paragraph are about 60 dB below the carrier.

Next connect the test set-up in the CW mode with the power meter as an indicator. The power out should be -10 dBm If this is not satisfactory adjust R2, or R1 until satisfaction is achieved.

Again repeat all previous paragraphs of this section until satisfaction is achieved.

It should be noted that C5 adjusts the resonance of the input circuit whereas C8, C10, and C12 each adjust the resonance of one pole of the 3 pole filter in the output circuit Adjustment of C11 changes the impedance loading that the filter sees and thus it adjusts the filters coupling and shape. Adjustment of R2 and R1 change the transistors bias voltage so that the transistor Q1 will be operating at its most optimum point (class B) for multiplication.

2.9.3 X5 Multiplier Card Adjustment

The test set-up should be connected in the CW mode utilizing the spectrum analyzer as an indicator. Tune C18, C21, C25, C27, and C26 for a maximum signal at 806 MHz. Be sure that the signals at 644 MHz (X4 mode) and 965 MHz (X6 mode) are as low as possible.

The test set-up should now be changed to the swept mode and the same capacitors adjusted until a pleasant bandpass is observed that is about 35 MHz wide at the 3 dB points (relative to output frequency).

Repeat the previous two paragraphs until a satisfactory bandpass is achieved and all spurs and harmonics noted in the first paragraph are about -47 dB below the carrier.

Next connect the test set-up in the CW mode with the power meter as an indicator. The power out should be at 0 dBm. If this is not satisfactory adjust R4 or R7 and R9 or R8 until satisfaction is achieved.

Again repeat all previous paragraphs of this section until satisfaction is achieved.

It should be noted that C18 adjusts the resonance of the output circuit of the input (161 MHz) amplifier, Q2. R4 and R7 adjust the bias voltage of this class A amplifier and thus adjusts its gain. R9 and R10 adjust the bias voltage of the multiplying transistor Q3 so that it will be operating at its most optimum point (class B) for multiplication. C21, C25, and C27 each adjust the resonance of one pole of the 3 pole filter in the output circuit. C26 adjusts the loading impedance seen by the filter, thus adjusting the filters coupling and shape.

2.9.4 X2 Multiplier Card Adjustment

The test set-up should be connected in the CW mode utilizing the spectrum analyzer as an indicator Tune L9 and C36 for a maximum signal at 1612 MHz. Be sure that the signals at 806 MHz (X1 mode) and 2418 MHz (X3 mode) are as low as possible.

L9 is adjusted by changing the length of the coil This usually involves unsoldering the coil changing it then resoldering it back in place, repeated soldering may damage the circuit board, therefore this procedure should be done as few times as possible.

The test set-up should now be changed to the swept mode and the same elements adjusted until a pleasant bandpass is observed that is about 140 MHz wide at the 3 db points (relative to output frequency).

Repeat the previous two paragraphs until a satisfactory bandpass is achieved and all spurs and harmonics noted in the first paragraph are about 27 db below the carrier.

Next connect the test set-up in the CW mode with the power meter as an indicator. The power out should be equal to or greater than +10 dbm. If this is not satisfactory adjust R13 or R12 and R16 or R17 until satisfaction is achieved.

Again repeat all previous paragraphs of this section until satisfaction is achieved

It should be noted here the L9 adjusts the resonant point of the output circuit of the input (806 MHz) amplifier Q4, whereas R13 and R12 adjust the bias voltage of this amplifier (class A) R16 and R17 adjust the bias voltage for the multiplying transistor Q5 such that it is operating at its optimum point (class B) for multiplication. C35 adjust the output tank of this circuit.

2.9.5 Total Multiplier Alignment

It is essential that the technician follow three basic principles when adjusting the total unit:

First: Always understand exactly what he is adjusting in terms of circuit element, electrical element and expected response, i.e., C10 adjusts the center pole of the 160 MHz filter and should cause the response to increase in amplitude and become flat when properly adjusted.

Second: Only make very small changes at any one time. A large change could cause an erroneous indication, i.e., a large change in C21 could cause the X5 multiplier to operate better as a X4 and the swept bandpass look improved however, the change in output frequency would go un-noticed.

Third: Always use proper RF techniques

The unit should be set up in the swept mode and the following adjustments performed while looking for the highest-most pleasant looking bandpass.

1. Adjust the two capacitors of the comb line (microstrip) filter along with C36. This is to align the output filter and the output tank of the X2 multiplier card.

2. Next adjust the input tank C5 to insure input impedance matching.

3. Next adjust C27, C25, and C21 to insure the alignment o of the 800 MHz filter.

4. Next adjust C12, C10, and C8 to insure the alignment of the 160 MHz filter

5. Then adjust C18 to insure the alignment of the 160 MHz amplifier.

6. Steps 1 through 5 should be repeated.

7. Then adjust coupling capacitor C26 to flatten out and widen up the response. C27 will need to be adjusted to bring the filter pole back to its proper position.

8. Then adjust coupling capacitor C11 to flatten out and widen up the response. C12 will need to be re-adjusted to bring the filter pole back to its proper position

9. Again repeat steps 1 through 5.

This procedure should be repeated until a satisfactory response is noted.

The test set-up should then be set up in the CW mode utilizing the spectrum analyzer as an indicator Insure that the spurs and harmonic frequencies are all about 45 dB below the carrier. The 806 MHz harmonic may be only about 30 dB below the carrier - for this frequency this is an acceptable level

The test set-up should then be set up in the CW mode utilizing the power meter as indicator. The power out must be equal to +10 dBm. If these last two requirements are not satisfactory then all steps of this section should be repeated until satisfaction is achieved

It should be noted that between the output of the X6 multiplier card and the input of the X5 multiplier as well as on the input of the X2 multiplier card are provisions for the installation of a resistive π type attenuator. The application of the attenuator is left to the judgement of the technician. Should an attenuator be placed at either of these points then it should be calculated for a characteristic impedance of 50 ohms

2.10 <u>6V Regulator Alignment</u>

Connect +12.0 volts and -12.0 volts to the regulator card. Load the +6 volt and -6 volt output with 120 ohm 1/2 watt resistor. This will give a current of approximately 50 ma. Connect the DC voltmeter to +6 volt output and adjust R-9 for 6 000 VDC Connect the DC voltmeter to the -6 volt output and adjust R-2 for -6.000 VDC

3. SYSTEM TESTS

It is assumed that all of the modules have been previously tested as illustrated in section 2 of this procedure, that the receiver has been assembled per drawings SK 68137 (Receiver Schematic) and SK 68138 (Receiver Modules Interconnections), the Power switch is ON, the Mode

Selector switch is to 1650 Hz manual, and that the system has had a 30 minute warm up period.

3.1 Power Supply and Regulator Adjustment

Connect the voltmeter to the +12 volt input to the regulator card. Adjust the power supply for +12.00 volts.

Connect the voltmeter to the -12 volt input to the regulator card. Verify that this voltage is -12.00 ±.06 volts

Connect the voltmeter to the -6 volt output of the regulator card. Adjust R-2 for -6.000 VDC.

Connect the voltmeter to the +6 volt output of the regulator card. Adjust R-9 for +6 000 VDC.

Adjust R-15 until the VCXO monitor meter swings about mid range.

Adjust R-16 until the signal strength meter reads 0

3.2 Receiver Front End (RF) Alignment

Connect a power meter through a 10 dB attenuator to the output of the L. O. multiplier. Adjust the input capacitor (C-5) of the multiplier for maximum power out. Reconnect the L. O. output to the 1st mixer

Set up equipment as shown in Figure 5 Notice that the UHF noise source is connected to the receiver through a 10 dB pad, removal of this pad will damage the receiver pre-amplifier.

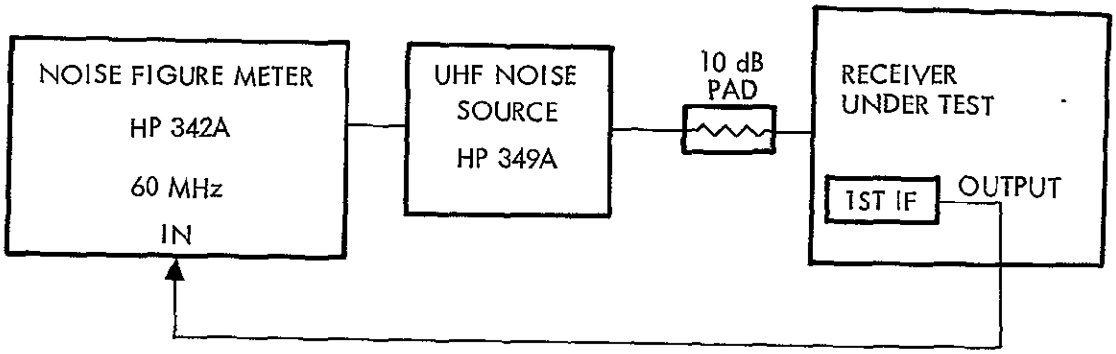


Figure 5. Front End Alignment

Adjust the zero and infinity adjustments of the noise figure meter before taking a reading.

Adjust the following items for minimum noise figure:

- The output (Bandpass) filter of the L O. multiplier.
- The length of cable between preselector and pre-amp.
- The length of cable between pre-amp and post selector.
- The length of cable between post selector and 1st mixer.

The final noise figure should be less than 6 dB. Return the system to its normal configuration (paragraph 3. 0)

3. 3 System Alignment

3. 3. 1 Reference Oscillator Adjustment

Connect the counter to the output of the reference oscillator. Adjust C-3 for a frequency of 88. 866666 MHz.

Return the system to its normal configuration.

3. 3. 2 Video Amplifier Gain Adjustment

Connect the oscilloscope to the video output. Adjust R13 of the phase detector and video amplifier for maximum noise signal.

3. 3. 3 VCXO Sweep Adjustment

Connect the oscilloscope to TP-1 on the loop filter and sweep circuit. Adjust the following controls on the loop filter and sweep circuit until the wave form conforms to Figure 6.

R13 - Symmetry Control

R16 - Lower Voltage Control (+5. 5V)

R17 - Upper Voltage Control (+8. 3V)

R31 - Period Control (76 ±. 04 Sec)

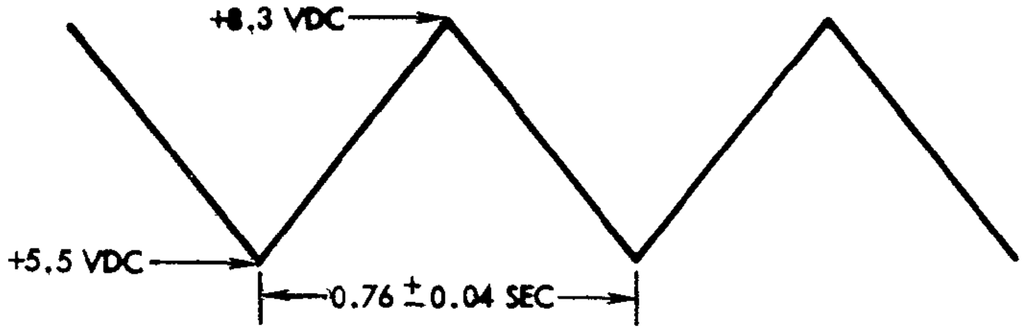


Figure 6   VCXO Drive Waveform on TP 1

3.3.4 AGC Adjustment

Insure that there is no RF input to the receiver. On the signal presence and AGC amplifier, connect the voltmeter to the CAD Test connector and adjust R-11, CAD zero, for zero volts. Next connect the voltmeter to the AGC output of this amplifier and adjust R-27, AGC level, for a DC voltage of 1.80 VDC. Next connect the voltmeter to pin 6 of the LH 201 #3 in this amplifier and adjust R-35, AGC meter, for zero volts.

3.3.5 Threshold Adjustment

Connect the transmitter assembly of paragraph 1.3 and Figure 3 to the receiver input. The power at point (A) (Figure 3) should be set to -120 dBm and the connections at points (B) and (C) should be open.

On the signal presence and AGC amplifier, connect the voltmeter to the CAD test connector. Increase the variable attenuator until the receiver locks up. Adjust C1 of the Signal Presence and AGC Amplifier until a maximum positive voltage is observed. Remove the voltmeter.

Adjust the variable attenuator until there is -130 dBm at the input to the receiver.

On the signal presence and AGC amplifier, adjust R-18, threshold, until acquisition just occurs at -130 dBm input level

Repeated adjustment of the attenuator and adjustment of R-18 will be required. Repeat this until satisfaction is achieved

With the receiver locked up at 130 dBm input level, adjust R-16 of the 6 volt voltage regulator until the signal strength meter reads -130 dBm

Verify that step 1.3.2 of this procedure has been performed.

Adjust R-15 of the 6 volt voltage regulator until the VCXO monitor meter reads center scale.

3.3.6 Loop Bandwidth Measurements

Set Up

Connect the transmitter assembly of paragraph 1.3 and Figure 3 to the receiver input. The power at point A (Figure 3) should be set to -124 dBm. The connection at point B should be open, and the connection at point C should have the Wavetek III voltage controlled generator and the HP 721A power supply with the Tektronix 453 oscilloscope monitoring this input.

Receiver Test Set-Up

Connect the receiver assembly as shown in Figure 7.

Set the following switches to the indicated positions

HP 403A AC Transistorized Voltmeter·
Range switch to 0 dB (1 V RMS full scale)
Function switch to 1 Hz - 1 Hz

Tektronix 585 Oscilloscope·
Power switch to ON
Vertical to 1 V/cm DC

HP 302A Wave Analyzer·
Power switch to ON
Scale Value switch to Absolute
Mode selector switch to Normal

Allow a 30 minute warm-up period before conducting tests.

1650 Hz Noise Bandwidth

The HP 302A Wave Analyzer should be connected to point (A) in Figure 7. The Mode Selector switch on the receiver should be in the 1650 Hz AUTO position. Set the frequency of the Wavetek III oscillator to 250 Hz.

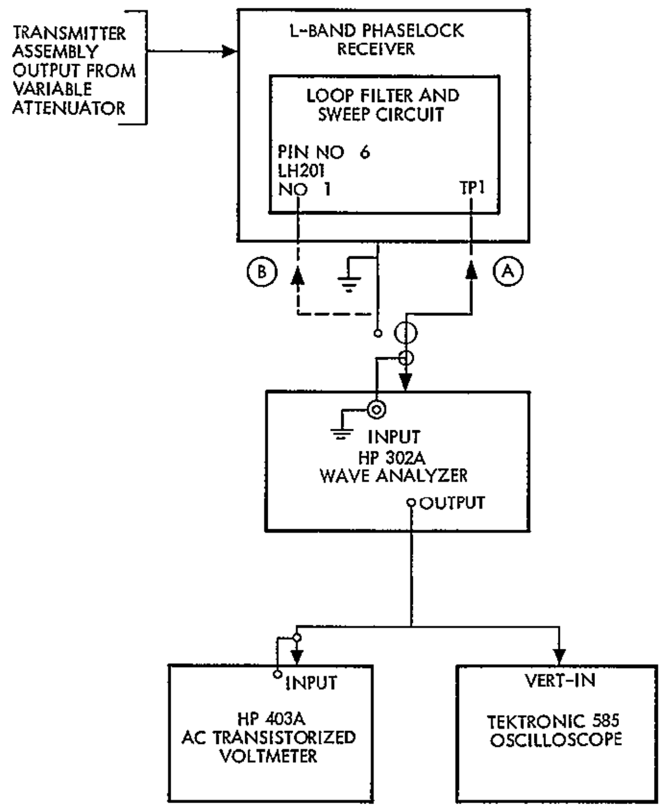


Figure 7. Noise Bandwidth Set-Up

Vary the ATTEN control on the Wavetek III oscillator and the FREQ. keyboard setting of the HP 5100B FREQ Synthesizer until a reading of -40 db is observed on the HP 302A wave analyzer meter (The Frequenc control on the Wave Analyzer will need to be adjusted for a peak at 250 Hz and the MODE Selector set to AGC) The proper setting of the FREQ. keyboard will be one of the following settings.

3 0 0 1 0 0 0 S. 0 0 Hz

3 0 0 1 0 0 S 0 0 0 Hz

3 0 0 1 0 S 0 0. 0 0 Hz

3 0 0 1 S 0 0 0. 0 0 Hz

The HP 302A Wave Analyzer should be connected to point (A) in Figure 7. The Mode Selector switch on the receiver should be in the 1650/50 Hz AUTO position. Set the frequency of the Wavetek III oscillator to 10 Hz

Using the procedure of 1650 Hz noise bandwidth, obtain a meter reading of -70 dB at a frequency of 10 Hz. Using the procedure of paragraph 3.3.6.3.2, calibrate the HP 403A voltmeter.

Using the procedure of 1650 Hz noise bandwidth, obtain the signal level for various frequencies ranging from 3 Hz to 100 Hz Compare this data with Figure 3-3 of reference No. 1 to obtain the damping factor. If the loop resonant frequency or the damping factor are unsatisfactory then R21 and R24 must be changed. These resistors, in conjunction with C11, determine the loop bandwidth of the receiver.

Reference No. 1: Theory of Phaselock Techniques as applied to Aerospace Transponders, Floyd M. Garner and Steven S. Kent. Contract No. NAS8-11509, Marshall Space Flight Center, NASA, Huntsville, Alabama.

Note the signal level in db for various frequencies ranging from 10 Hz to 2 kHz. The procedure for this is to set the frequency of the Wavetek III oscillator to the desired setting. Set the MODE selector on the wave analyzer to NORMAL Adjust the Wave Analyzer Frequency Control until a peak is observed, then replace the MODE Selector to AFC. Read the signal in dB directly from the Wave Analyzer meter. Compare this data with Figure 3-3 in reference No. 1 in order to determine the damping factor and the loop resonant frequency. If these are unsatisfactory R22 and R23 must be changed. These resistors, in conjunction with C-11, set up the time constants that determine the loop bandwidth of the receiver.

<u>50 Hz Noise Bandwidth</u>

The HP 302A wave analyzer should be connected to point (B) in Figure 7. The mode selector switch on the receiver should be in the 1650/50 Hz AUTO position. Set the frequency of the Wavetek III oscillator to 10 Hz. Using the set-up procedure indicated above, obtain a meter readings of -10 dB at a frequency of 10 Hz.

Adjust the OUTPUT AMP pot on the Wave Analyzer until the HP 403A AC transistorized voltmeter reads 0 dB

NOTE The range of this meter is now identical to the range of the Wave Analyzer This set-up may be used down to the frequency of 3 Hz. It should not be used below 3 Hz and at this frequency 1 dB should be added to the meter reading. At 4 Hz and above the meter may be read directly.

Using the procedure of the 1650 Hz noise bandwidth, obtain the signal level for various frequencies ranging from 3 to 30 Hz. The signal should be read in dB from the HP 403A voltmeter. The Tektronix 585 scope is provided to aid in the peaking of the signal. Compare this data with Figure 5-1 in reference No 1 in order to determine the loop resonant frequency.