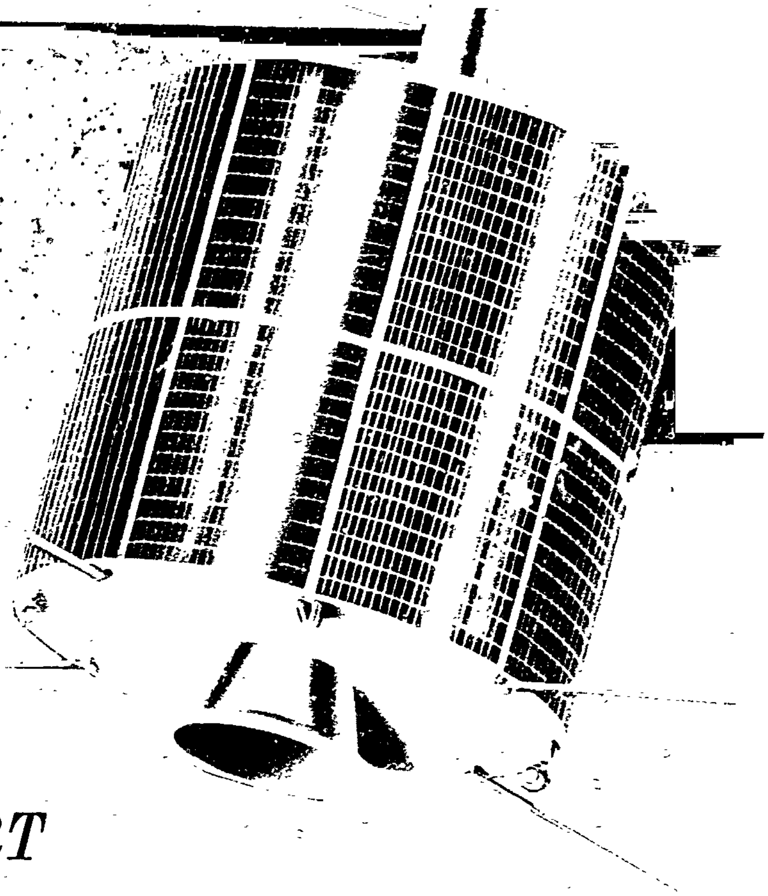
Advanced SYNCOM



31 October 1963

SUMMARY REPORT

•

Volume 6

•

Engineering Data on Transponder Control Items and Phased Array

•

Published 29 November 1963

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NASA Contract 5-2797

AEROSPACE GROUP
SPACE SYSTEMS DIVISION
HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA

HUGHES

SSD 31123R

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CONTENTS

1. INTRODUCTION

The use of communication satellites provides the practical solution to the need for greatly expanded global communications capability. A major effort of the United States Government and of industry has been in process since the late 1950s to develop a satellite relay system at the earliest possible time.

The National Aeronautics and Space Administration, having management responsibility for developing the space technology leading to a communication satellite system, has investigated nonsynchronous passive satellites and nonsynchronous active repeater satellites. The Goddard Space Flight Center Project Syncom is assigned the synchronous-orbit active repeater satellite investigations.

Under NASA Goddard Space Flight Center Contract NAS5-1560, Hughes developed and constructed three Syncom spacecraft for launch from the Atlantic Missile Range by Delta Launch vehicles for conduct of inclined synchronous-orbit communications experiments during 1963. The Syncom spacecraft have demonstrated a simple spin-stabilized, active repeater satellite design capable of being placed in a synchronous orbit. Similarly, it has been demonstrated that a simple pulsejet control system can provide the stationkeeping necessary to maintain a synchronous orbit.

The Advanced Syncom spacecraft, currently under study for feasibility and advanced technological development, will demonstrate the stationary, or equatorial, synchronous orbit with a vehicle providing a relatively large, adaptable payload capability, achievement of long life in orbit, an electronically steerable antenna beam, continuous wide-band communications, and new multiple-access communications. Scientific instruments will be carried to measure the radiation environment and to assess radiation damage occurring during the orbiting process and throughout satellite life in the synchronous, equatorial orbit.

The Advanced Syncom study program has included research and development of engineering models of a multielement phased array transmitting antenna and associated control circuits; a dual-mode communications transponder operating at 6-gc receiving frequency and 4-gc transmitting frequency and providing alternate modes of operation as a multi-channel SSB-PM multiple-access transponder or as a wide-band FM frequency translation transponder; a traveling-wave tube final power amplifier for the transponders; a spacecraft structure; and a bipropellant rocket jet control system.

In May 1963, the NASA expanded the advanced technology program to include design effort on all elements of the spacecraft and the communication system test equipment. Currently under way is the fabrication and testing of advanced engineering models of the communication transponders, transmitting and receiving antennas, and traveling-wave tube power amplifiers. Breadboard circuits of the telemetry encoders and command decoders are similarly in process. The system test equipment being developed will permit quantitative measurements of communication system performance to be obtained. The above activities will be completed by the end of October 1963.

This Summary Report covers the technical progress achieved during the contract period and details the system configuration and specifications resulting from system studies. The report is divided into seven volumes:

Volume 1: Advanced Syncom Summary Report

Volume 2: Major and Minor Control Item Test Plans and In-process Specifications

Volume 3: Interface Reports

Volume 4: System and Subsystem Performance Requirements

Volume 5: System Test Plans

Volume 6: Engineering Data on One Set of Transponder Control Items

Volume 7: T-1 Structural Vibration Test Report

2. SPACECRAFT SYSTEM SUMMARY

The Advanced Syncom satellites, as in the Delta-launched Syncom, will utilize spin stabilization for attitude stabilization. The spacecraft physical parameters are increased over those of Syncom to accommodate a large increase in communications capacity. In addition, the self-contained apogee injection stage removes approximately 29 degrees of inclination from the orbit while circularizing the elliptical transfer orbit at the synchronous radius. The parameters of an Advanced Syncom spacecraft are summarized in Table 2-1. Figures 2-1 and 2-2 illustrate the general arrangement, and the structural engineering model of the Advanced Syncom.

The communication capacity of each of the satellite transponders is 600 two-way telephone conversations. The design for each satellite contains four such transponders, providing a total system capacity through the satellite of 2400 two-way voice channels. Alternately, the system can accommodate television or other wide-bandwidth signals through each of the transponders.

Ground-station characteristics for which the full communications capacity is achieved would be as follows:

1) Transmitter (for each frequency assignment): saturated power, 10 kilowatts; frequency band, 6 gc; bandwidth, 25 mc; diplexer loss, -1 db; and frequency stability, 1 part in 10^{10} for short term and 1 part in 10^7 for long term.

2) Antenna: diameter, 85 feet; efficiency (transmitting and receiving), 54 percent.

3) Receiver noise temperature (all sources including antenna), 80°k.

Smaller stations can be used with a proportionate reduction in capacity. With 40-foot-diameter antennas and the same transmitters and receivers, the voice channel capacity is reduced to 120 two-way channels and the television signal noise level, and therefore picture quality, falls below CCIR standards.

The system has two alternate modes of operation possible in each assigned frequency band. The first mode accommodates a wide-band FM transmission to the spacecraft, which translates the signal-carrier frequency and repeats the signal with no conversion in modulation. This mode is used for television or other wide-band data originating from a single station. The spacecraft transponder mode for such signals is termed the "frequency-translation mode."

The second mode of operation involves the transmission, simultaneously from a large number of ground stations, of frequency division multiplexed, single-side-band, suppressed carrier voice channels. The signals are converted into phase modulation of a single carrier in the spacecraft, and are retransmitted back to all stations in this form. This mode permits simultaneous two-way interconnection of all combinations of the ground stations. The spacecraft transponder mode for these signals is termed the multiple-access mode.

TABLE 2-1. PARAMETERS OF ADVANCED SYNCOM

Physical Configuration	58-inch diameter cylinder
Weight	1500 pounds at launch 760 pounds in 24-hour, equatorial orbit
Apogee injection motor	Solid propellant, JPL
Control systems	Liquid bipropellant Fuel: monomethylhydrazine Oxidizer: nitrogen-tetroxide Two independent systems: capacity per system adequate for correcting initial errors and providing 3 years stationkeeping Self-contained spin rate control
Communications	Four independent dual-mode transponders Redundant 4.0-watt traveling-wave tube power amplifiers in each transponder 8-db collinear array receiving antenna 18-db phased array transmitting antenna 6.02 to 6.3 gc ground-to-spacecraft 3.99 to 4.18 gc spacecraft-to-ground
Telemetry	Four 1.25-watt transmitters in 136-mc band Four encoders; GSFC PFM standard
Command	Four receivers in 148-mc band Four decoders; GSFC FSK standard
Electrical power	147-watt, N-P solar cell array 650-watt-hour rechargeable nickel-cadmium energy storage system

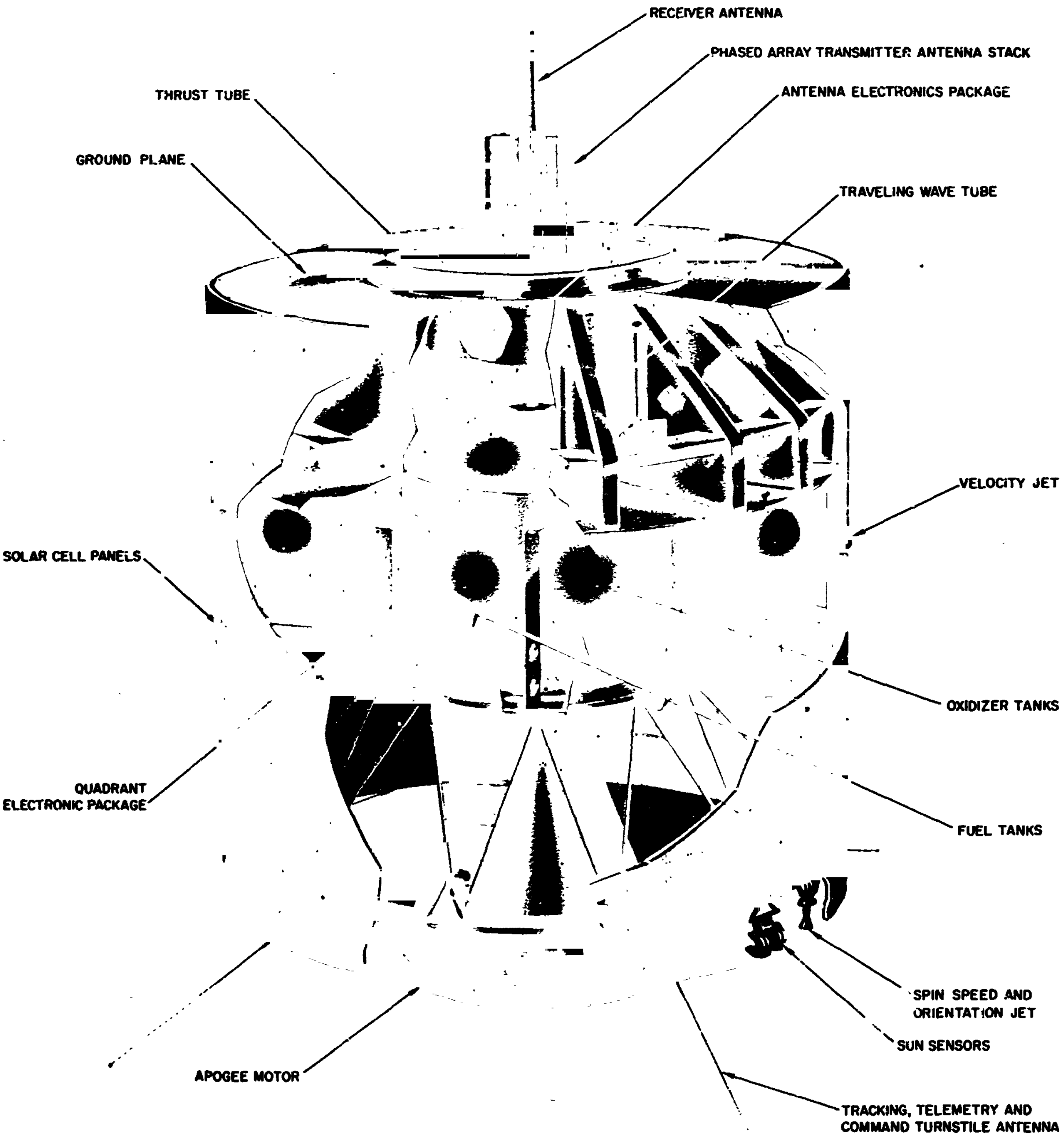

Figure 2-1. General Internal Arrangement of Advanced Syncom

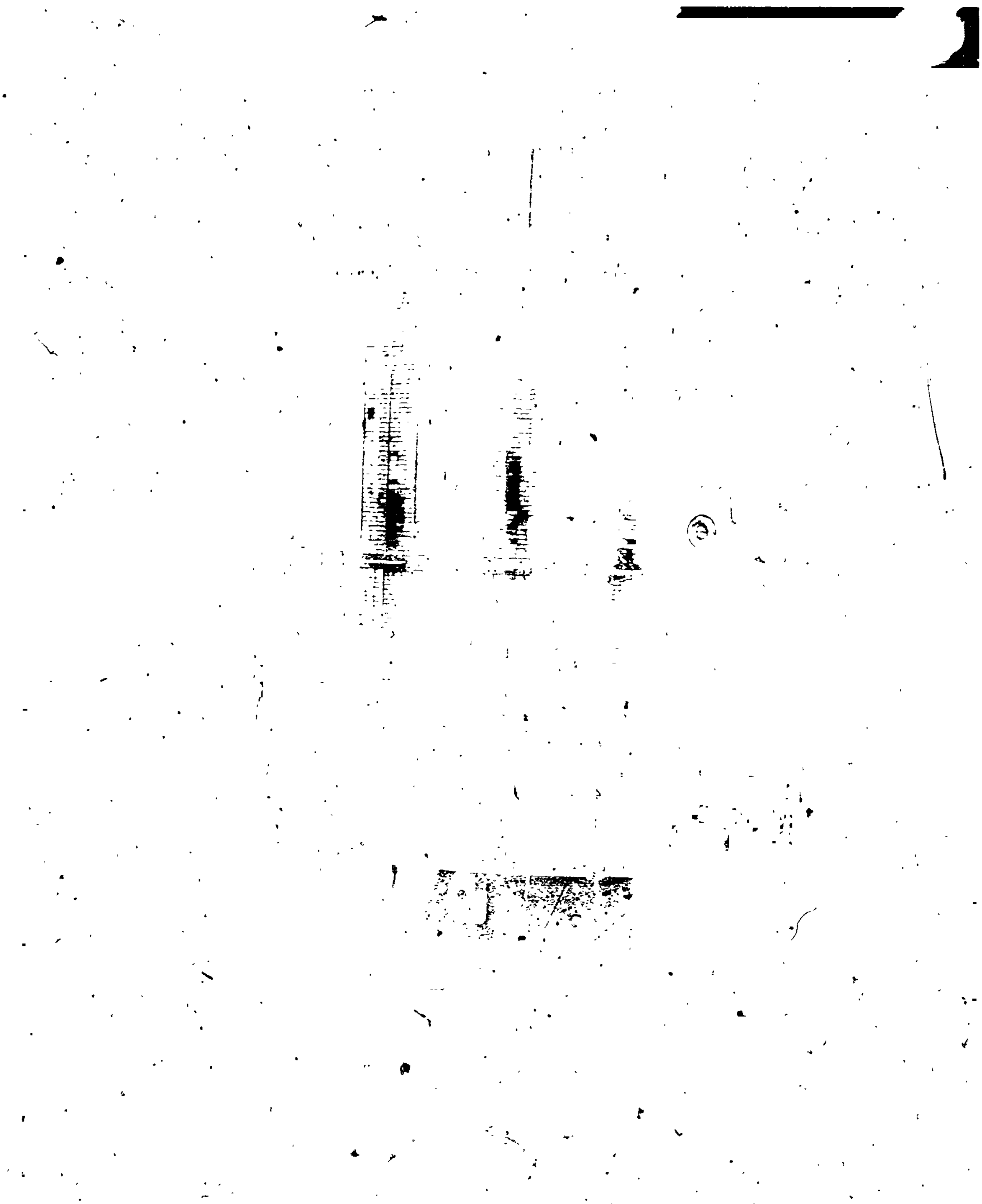

Figure 2-2. Structural Engineering Model of Advanced Syncom

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3. INTRODUCTION TO ENGINEERING DATA

SCOPE

This document contains the results of the tests conducted on the engineering model of the dual mode transponder of the Advanced Syncom spacecraft. Also included are the results of the major control item tests performed on the phased array antenna.

INTRODUCTION

The data presented in this document was obtained from the tests conducted in accordance with the various major and minor control item tests published as Volume II of the September 1963 Advanced Syncom Summary Report. This document is divided into sections as follows:

Sections 4 and 5 contain the major control item tests of the frequency translation and multiple access transponders respectively.

Section 6 contains the minor control item tests of the units used in common by both transponders.

Sections 7 and 8 contain the minor control item tests of frequency translation and multiple access transponders respectively.

Section 9 contains the phased array antenna test results.

SUMMARY OF TEST RESULTS

The results of these tests indicate the dual mode transponder performance is adequate. Results of all tests are essentially within design specifications. However, several packaging problems were uncovered during vibration testing. These include mounting of the multiple access master oscillator, the physical design of the X3 multiplier, and the mixers. A detailed discussion of these problems and the proposed solutions, are contained in the transponder sections.

Several operating characteristics of the transponders can be improved. For instance, the high level X32 multiplier temperature stability can be improved, and this unit also requires better stability as a function of input power. The multiple access master oscillator is slightly more noisy than desirable and further design effort will be advantageous.

The measurement of the intermodulation (noise loading tests) on the multiple access transponder is as yet an unresolved problem. It appears that the intermodulation of the transponder itself is adequate; however, the measurement technique is not precise enough to allow fine grain measurements. The problem is associated with translating the outputs of the noise loading test set to microwave frequencies and then retranslating it back to baseband. Further effort will be expended in developing this test technique.

4. FREQUENCY TRANSLATION TRANSPONDER

DESCRIPTION

The frequency translation transponder is designed primarily for television or other wideband usage in which one ground transmitter utilizes the complete channel. In addition, a beacon signal is provided for ground station tracking. In operation the received 6 kmc signal is mixed and converted to an intermediate frequency of approximately 60 mc, amplified and limited and then mixed again for conversion to the 4 kmc transmit frequency. The limiter serves the additional function of introducing the beacon signal and controlling its level. Wide-band circuitry is utilized throughout the signal chain so that the resulting usable bandwidth is 25 mc.

RESULTS OF FREQUENCY TRANSLATION TESTING (479159) AT 6212 MC

A summary of the data taken for Transponder Unit 479159, Serial Number 1, is shown in Table 4-1. This table contains all the data recorded on the data sheets for the various test conditions of the transponder.

In addition to the data shown in this table, measurements were taken on

1) Output power as a function of input power

2) Beacon level

3) Output variation over the passband

4) Half power bandwidth

These measurements were taken for both the 6212 mc and the 6108 mc transponder.

Phase delay distortion measurements were also taken for the 6212 mc frequency translation transponder.

TABLE 4-1. TEST DATA SUMMARY FOR ANTENNA ELECTRONICS SUBASSEMBLY NO. 471935 A-3, SERIAL NO. 1 AT 6212 MC

Frequency Translation Mode								
				Vacuum				
	Initial Test	Pre-vibration Test	Post Vibration Test	Pre-Thermal	at 70°F	at 120°F	at -20°F	Post Thermal
Local oscillator power, milliwatts	3.6[1]	3.0[2]	3.5[3]	3.6[1]	3.0[2]	3.0[2]	-	3.2[3]
Noise figure, decibels	9.5	-	-	9.8	-	-	-	-
Receiver sensitivity, dbm	-86	-85	-	-88	-88	-88	-	-88
Telemetry monitor voltage								
a) Limiting at 3 db below	-3.99	-	-	-	-	-	-	-
b) Limiting at 6 db below	-3.95	-	-	-	-	-	-	-
c) Limiting	-3.88	-	-	-	-	-	-	-
Output power with -73 dbm input, milliwatts	0.41	0.44	0.2	0.39	0.42	0.23		.78
Variation over the passband, decibels	0.51	0.7	-	0.5	0.5	0.6		0.5

Notes:

1) Power measured at local oscillator filter output in antenna box.
2) Power measured at local oscillator filter input in antenna box.
3) Power measured at quandrant output.
4) It was found at the beginning of the prethermal vacuum test that the polarity of the ferrite switch had been reversed. This affected the receiver sensitivity by about 3 db as can be seen in the above table.
5) Power measured at transponder output.

During these tests it was discovered that the telemetry signal strength monitor voltage was due mainly to noise. This circuit will be redesigned for a higher sensitivity.

Output Power as a Function of Input Level

Table 4-2 lists the output level as the input level is varied. The results are also shown in Figure 4-1.

TABLE 4-2. TRANSPONDER UNIT 471959, SERIAL NO. 1 AT 6212 MC

Input Level, dbm	Output Level, dbm	Analog Voltage
-63	-4	-
-73	-4	-4.03
-78*	-4	-
-86	-7	-3.99
-90	-10	-3.95
-95	-14	-3.89

Note: *This point is the limiting corner, i.e., the point at which there is no longer an increase in output with an increase in input.

Beacon Level

With a signal level of -73 dbm, the beacon level is 20 db below the signal output level; i.e. -24 dbm at the input to the traveling-wave tube. The beacon level remains the same when there is no input signal.

Output Variation Over the Passband

The gain variation over the passband was measured under two conditions; one at -73 dbm input which is well into limiting and the second at -86 dbm input which is the limiting threshold. The limiting threshold is defined as the input level required to give an output level which is 3 db below the fully limited output level. For a -73 dbm input, the gain variation is 0.5 db; for a -86 dbm input, it is 0.6 db.

Half-Power (3 db) Bandwidth

The half-power bandwidth was measured with various input levels and with 20 db of attenuation between the intermediate amplifier and the postamplifier to reduce the noise level at the limiter. The beacon was also removed for this test. Table 4-3 lists the results.

TABLE 4-3. HALF-POWER BANDWIDTH MEASUREMENT

Power Input, dbm	Power Output, dbm	Half-Power Bandwidth, mc
-43	-3.8	43
-53	-3.8	43
-58	-4.0	42
-63	-4.2	37
-73	-5.2	34
-78	-7.6	32
-83	-11.2	33

The half-power bandwidth, from the data shown, is 32 mc. The wider bandwidth measurements at the higher input levels are due to the limiting which would make the bandwidth appear wider. At the lowest input level the bandwidth readings appear to widen but this is because a portion of the power at the power meter is noise, and when the power output drops to one-half its midband level the actual signal must drop more than 3 db.

Due to the 20 db of attenuation, the signal as well as the noise is attenuated. This means that the signal input power in this setup is equivalent to a signal 20 db lower under normal operating conditions.

Measurement of Phase Delay Distortion

The phase delay distortion of the transponder was measured for various baseband frequencies and the results are tabulated in Table 4-4. The envelope distortion was also measured at a baseband of 1 mc; this measurement was 0.5 db.

TABLE 4-4. PHASE DELAY DISTORTION MEASUREMENT

Baseband Frequency, mc	Phase Delay, usec	Frequency Sweep, mc
0.5	25.5	25.0
1.0	24.0	25.0
2.0	20.0	25.0

RESULTS OF FREQUENCY TRANSLATION TESTING (471958) AT 6108 MC

Similar tests were performed on Transponder 471958, Serial No. 1, at 6108 mc.

Initial Test Data

Results of initial tests on this transponder for the antenna electronics package 471935A-Z, Serial No. 1, at 6108 mc, in the frequency translation mode are as follows:

Power measured at output of local oscillator filter	5.6 mw
Noise figure	10.5 db
Receiver sensitivity	-87 dbm
Output power with -73 dbm input	0.41 mw
Output variation over the passband	0.5 db

In the frequency translation mode of this transponder, the preamplifier was 5 db short on gain resulting in a 5 db displacement of the limiting corner as seen in Figure 4-1.

Output Power as Function of Input Power

The results of this test are shown in Table 4-5 and Figure 4-1.

The limiting corner is at -73 dbm. The difference in the limiting corner in this transponder compared to the 6212 mc transponder is due to the missing 5 db of gain in the preamplifier. This 5 db would change the limiting corner to -78 dbm which would fall at the same point of the other transponder. Note also that the analog voltage is down compared to the 6212 mc transponder, this is also due to the missing 5 db of gain.

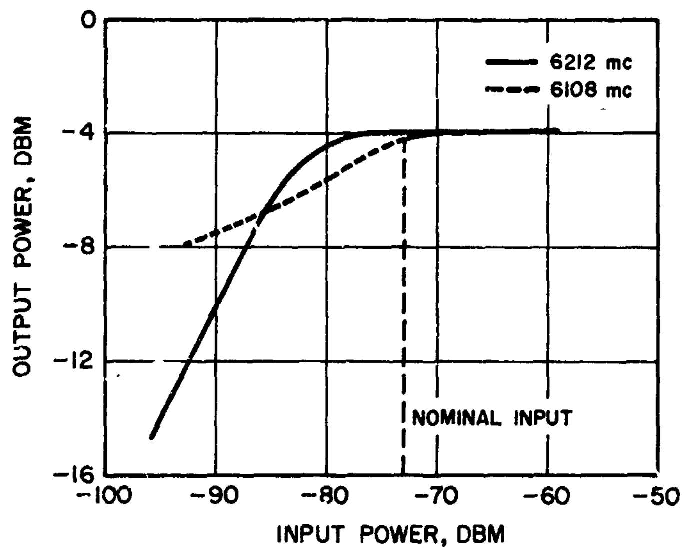


Figure 4-1. Output Power as a Function of Input Power in Frequency Translation Mode of Operation

TABLE 4-5. OUTPUT VERSUS INPUT POWER

Input Power, dbm	Output Power, dbm	Analog Voltage
-73	-4	-1.25
-87	-7	-0.5
-93	-8	-0.42

Beacon Level

With a signal level of -73 dbm, the beacon level is 21 db below the signal output level; i.e., -25 dbm at the input to the traveling-wave tube. When the signal is removed, the beacon increases 5 db to -20 dbm at the traveling-wave tube input. This 5 db increase in beacon level would not occur if the missing 5 db of gain were present in the preamplifier.

Output Variation Over Passband

The gain variation over the passband was measured under two conditions, one at -73 dbm input where the transponder limits and the second at -87 dbm input which is the limiting threshold, the results are listed as follows:

Power Input, dbm	Gain Variation, db
-73	0.5
-87	0.7

Half-Power (3 db) Bandwidth

The half-power bandwidth was measured with various input levels and with 20 db of attenuation between the intermediate amplifier and the postamplifier to reduce the noise level at the limiter. The beacon was also removed for this test. The results are shown in Table 4-6.

The true half-power bandwidth in this transponder is 29.0 mc. The wider bandwidth measurements at the higher input levels are due to the limiting which would make the bandwidth appear wider. At the lower input levels the bandwidth readings appear to widen but this is due to the fact that a portion of the power at the power meter is noise and when the power output drops to one-half its midband level the actual signal must drop more than 3 db. Due to the 20 db of attenuation, the signal as well as the noise is attenuated. This means that the signal input power in this setup is equivalent to a signal 20 db lower under normal operating conditions.

TABLE 4-6. HALF-POWER BANDWIDTH MEASUREMENT

Input Power, dbm	Output Power, dbm	Half-Power Bandwidth, mc
-53	-4	41
-58	-3.8	35
-63	-5.5	32.5
-68	-8	29.0
-73	-13	29.0
-78	-17.6	30.0
-83	-22	33.0

THERMAL VACUUM TESTS (6212 MC)

The 6212 mc frequency translation transponder was operated in a thermal vacuum at 70, 120°F, and at -20°F. The results of this test are listed in Table 4-7. At -20°F, the frequency translation mode of the local oscillator chain had no output at all, and therefore no data are shown in the table. The transponder operated at 70 and at 120°F in the vacuum. At about 20°F, an oscillation appeared in the local oscillator output and at about 0°F the output power dropped to zero.

TABLE 4-7. FREQUENCY TRANSLATION MODE IN THERMAL VACUUM

Temperature	70°F	120°F
Local oscillator power, mw	3.0	3.0
Receiver sensitivity, dbm	-88	-88
Output power, mw	0.42	0.23
Output variation over band, db	0.5	0.6

During the testing, the X32 multiplier was retuned three times and the X3 multiplier was retuned once because of oscillations. Further development of the X32, X3, and master oscillator units will substantially decrease this occurrence.

Vacuum level throughout the test was 2 x 10^{-6} Torr and the transponder temperature was stabilized at -20, 0, 70, and +120°F. When all thermocouples were within a ±5°F range of the desired temperature, the unit temperature was considered stable. The transponder was continually operated during the entire test. Total time in a vacuum environment was approximately 96 hours although not continuous. Figure 4-2 shows the location of the thermocouples.

VIBRATION TESTS

Vibration tests of the transponder were performed. During these tests the X3 multiplier began to oscillate due to a high conversion loss. The conversion loss was caused by the mechanical shifting of the input fitting which was not rigid. The input fitting is being redesigned for mechanical rigidity and the present multipliers modified.

The high level mixer also had high conversion loss due to the vibration testing. The tuning slugs in the unit were shaken loose during the test. These slugs are now spring-loaded so that this condition will not reoccur. The high level mixer is being redesigned in this area to shorten the physical dimensions.

Vibration Test Conditions

During the vibration tests, the quadrant was mounted on a flat fixture, as shown in Figure 4-3. Accelerometers shown are as mounted during the Transverse No. 2 plane. All accelerometers were repositioned to record in the plane of vibration as the test conditions changed except for the one on quadrant board No. 3 (X473501). Therefore in the longitudinal and transverse No. 2 planes, it recorded crosstalk.

The transponder qualification vibration levels were derived from data acquired during the Advanced Syncom model HSX-302-T-1 spacecraft structural vibration tests. These levels are published in Summary Report, Volume 7, Page 8-11 (SSD 31139R). However, these spectrum levels are unit responses to excitation at the spacecraft interface with the booster. Thus a modification was necessary to reference these responses to the Transponder mounting points.

Resultant input levels were determined by conducting a low level search before each sinusoidal test, and extrapolating the amplification to a high level input. Therefore actual inputs differ from the spectra referenced above, while the transponder responses are approximately the same. Any differences in the responses can be attributed to changes from the T-1 mockup quadrant and the actual item tested, and to inherent inaccuracies in extrapolations of this nature. Revised input specifications, based on the actual test data, are recommended as shown in Figure 4-4. Expected transponder responses to these inputs are shown in Figure 4-5.

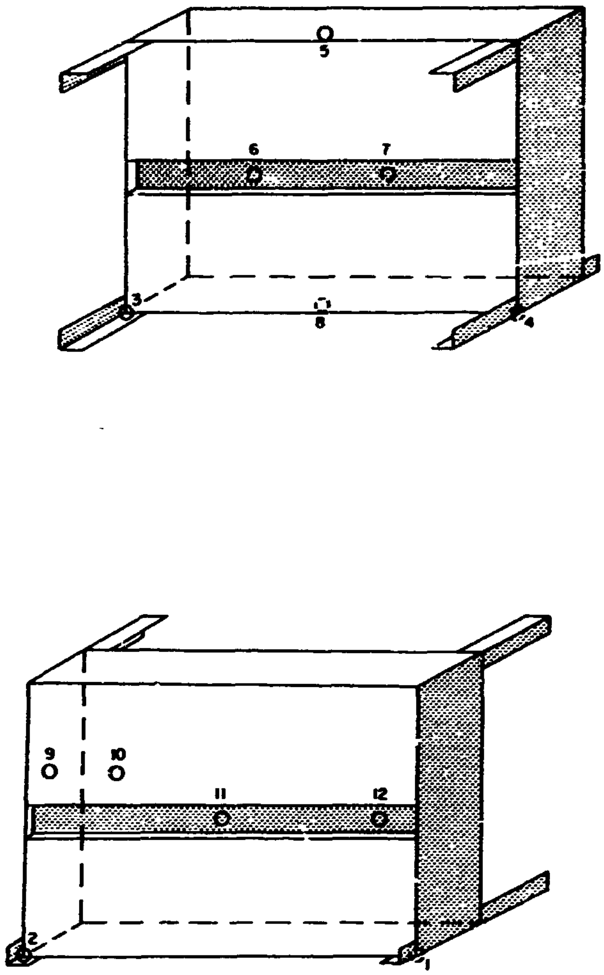


Figure 4-2. Transponder Thermal Vacuum—Thermocouple Locations

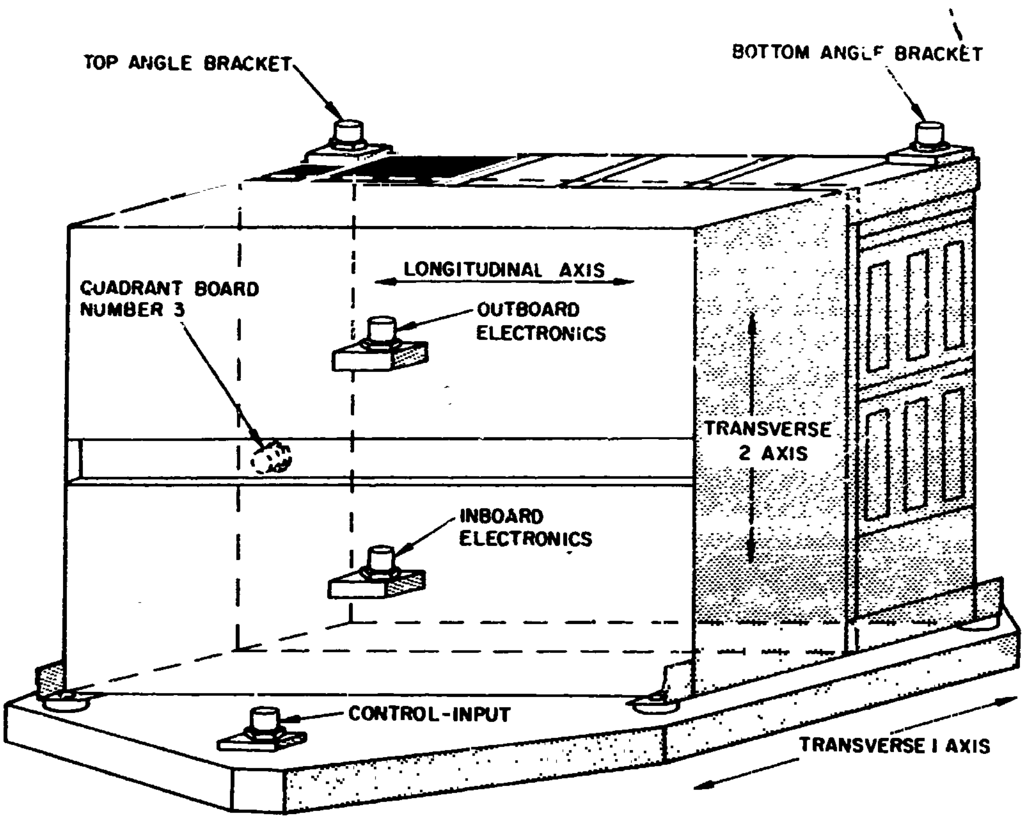
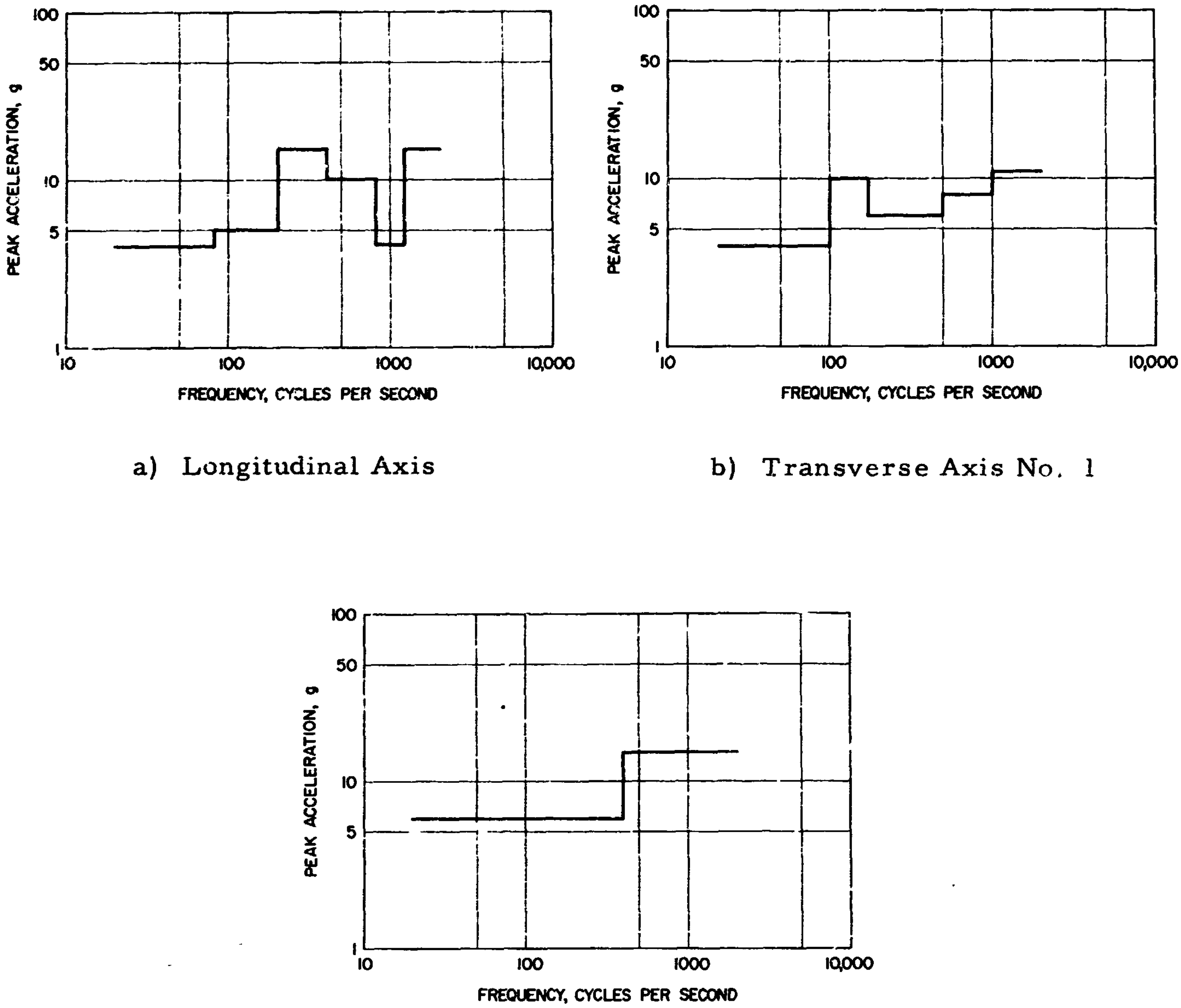


Figure 4-3. Transponder Accelerometer—Locations



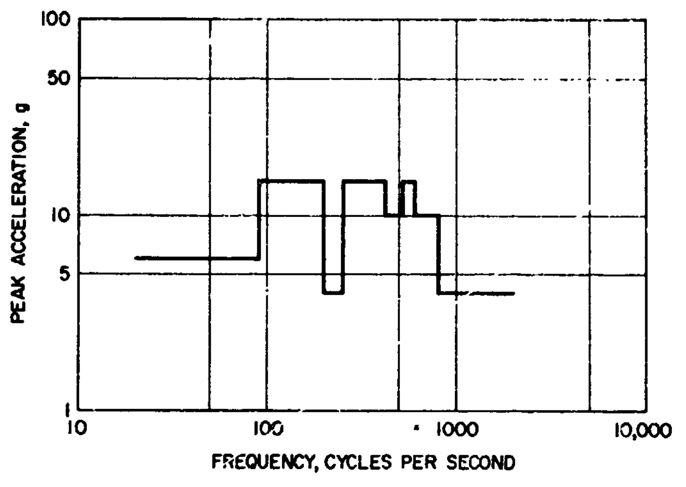
a) Longitudinal Axis

b) Transverse Axis No. 1

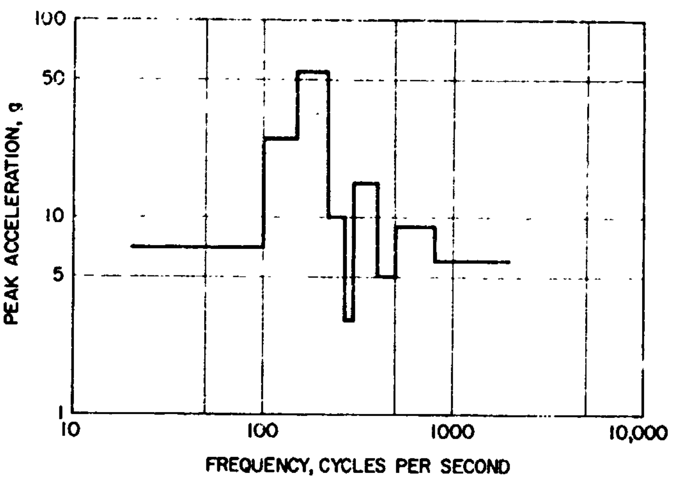
c) Transverse Axis No. 2

Figure 4-4. Transponder Qualification Test Level—Sinusoidal Vibration

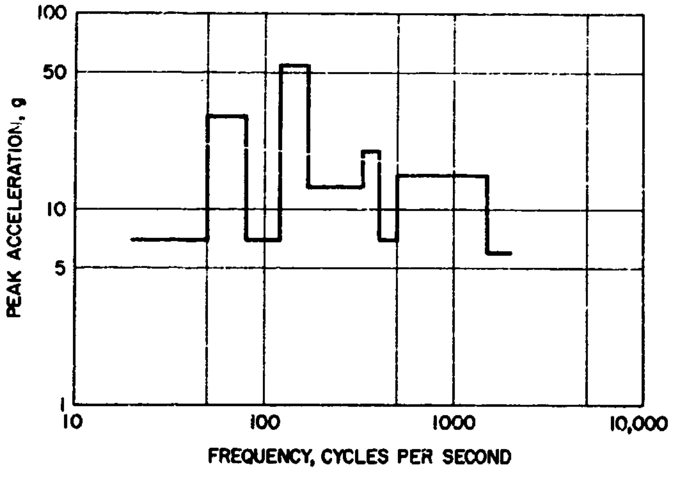
Test duration = 3.66 minutes



a) Longitudinal Axis



b) Transverse Axis No. 1



c) Transverse Axis No. 2

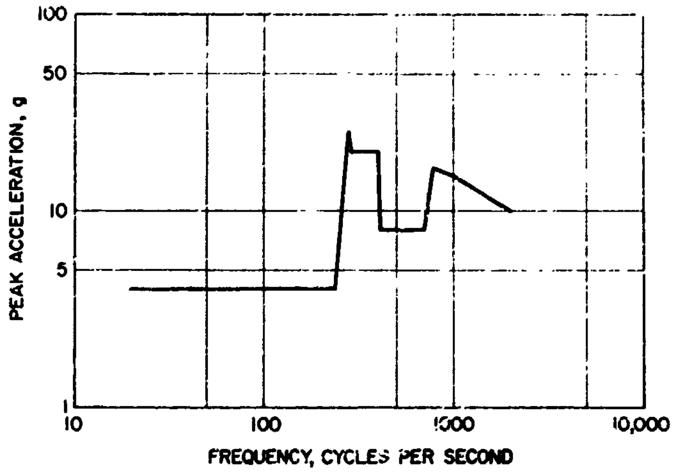
Figure 4-5. Transponder Response to Sinusoidal Vibration

Two different planes of lateral vibration are required because the quadrant mass inertia characteristics about the longitudinal axis are not symmetrical. Rate of sweep during the sinusoidal vibration remains at 2 octaves per minute or 3.66 minutes from 20 to 2000 cps.

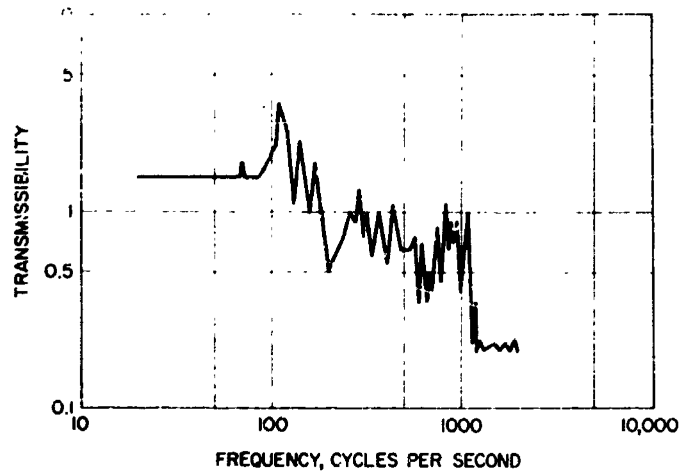
Results of the sinusoidal vibration tests are presented in Figure 4-6 as transmissibility versus frequency curves. Longitudinal resonances were observed to occur at 70, 110, 450, and 1200 cps; lateral resonances (Transverse No. 1) were found at 60, 160, 350, 550, 750, and 1600 cps; lateral resonances (Transverse No. 2) were found at 65, 135, 170, 300, 400, 530, 930, and 1500 cps. Clearly, not all points monitored resonate at all these frequencies as shown by the individual graph for exact frequencies in Figures 4-7, 4-8, and 4-9.

The random vibration spectrum was also determined by first performing a low level (1/100 of full level) search before each plane of vibration. However, the random correlation of low level to high level spectrum was not as good as the sinusoidal extrapolation. Equipment limitations, high spectral density required, and an apparent 60 cps pickup inhibited good results.

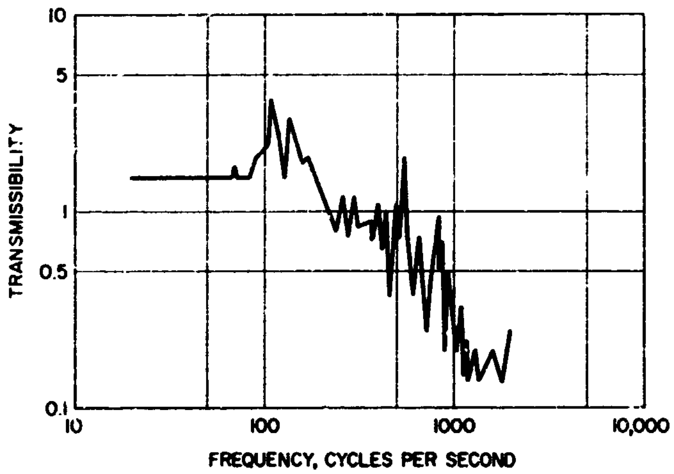
After each vibration plane the quadrant was disassembled in part and inspected for any damage that may have resulted to the structure or components. No damage was discovered until after the last plane of random vibration (Transverse No. 1). Figures 4-10 through 4-13 show the damage.



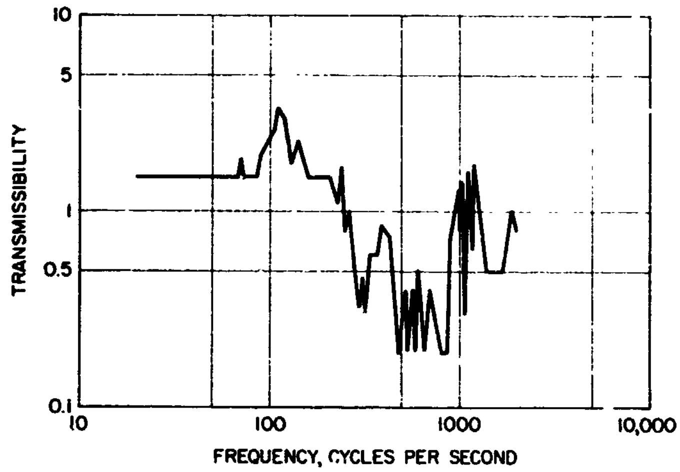
a) Longitudinal Axis



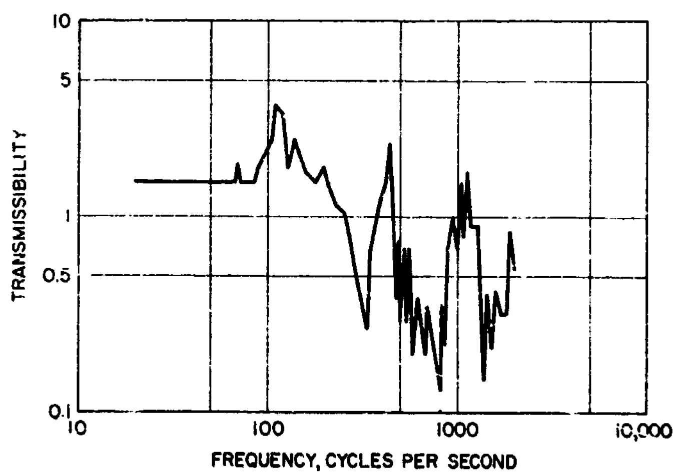
b) Longitudinal Axis—
Inboard Electronics



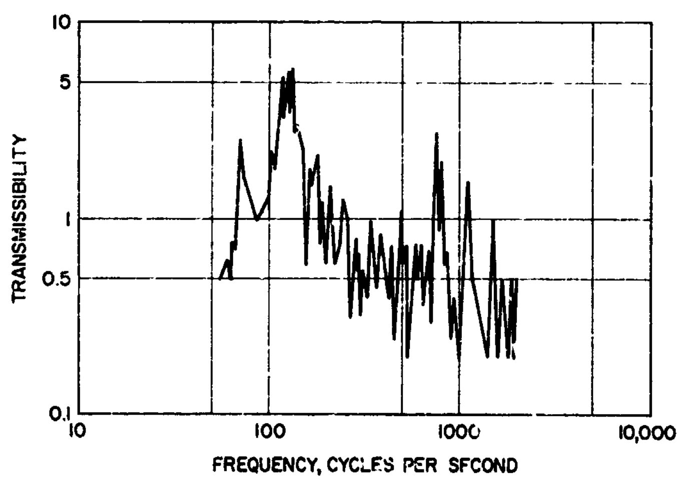
c) Longitudinal Axis -
Outboard Electronics



d) Longitudinal Axis—
Top Angle Bracket

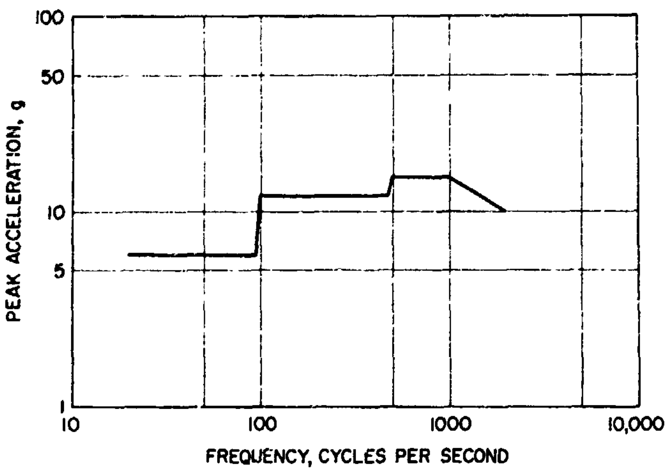


e) Longitudinal Axis—Bottom
Angle Bracket

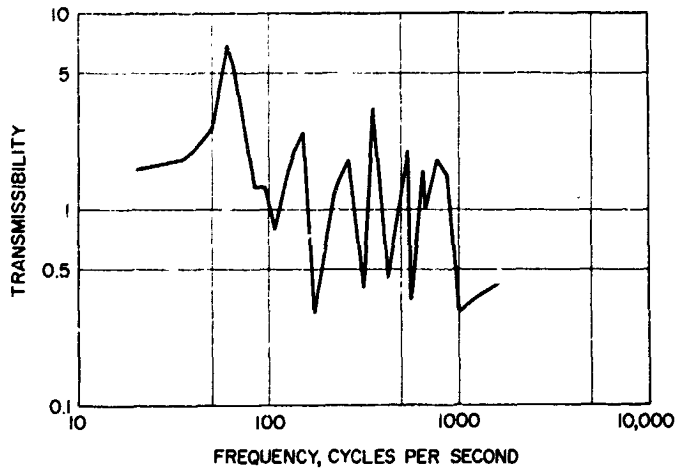


f) Longitudinal Axis—Quadrant Board
No. 3 Crosstalk Transmissibility

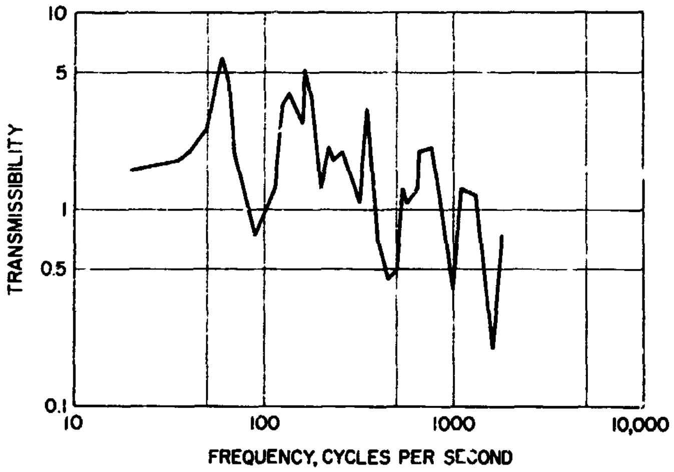
Figure 4-6. Transponder Qualification Test Results—Sinusoidal Vibration
Test duration = 3.66 minutes



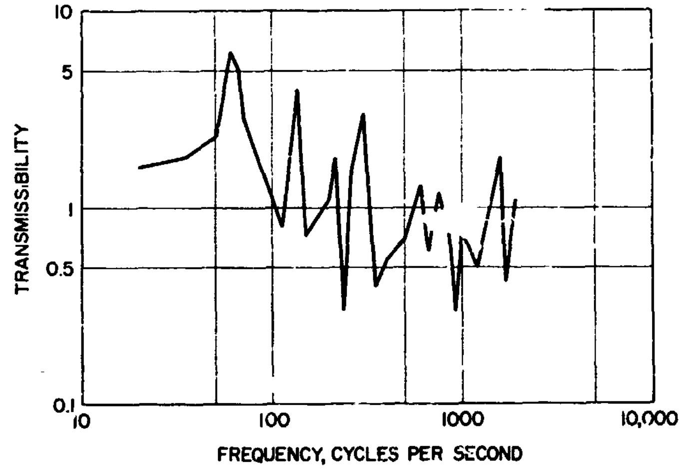
g) Transverse Axis No. 1



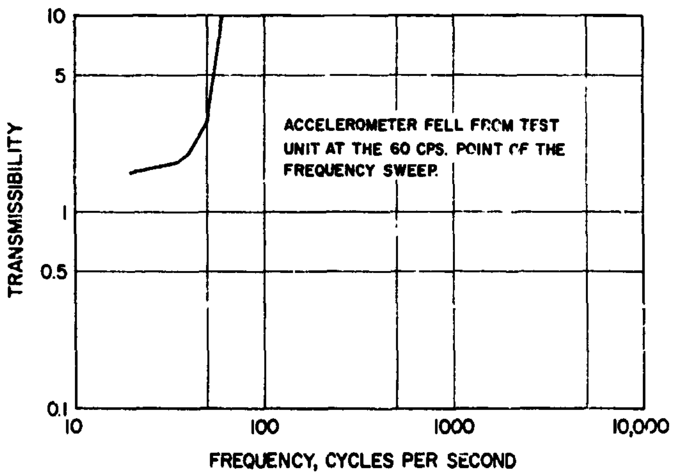
h) Transverse Axis No. 1—
Inboard Electronics



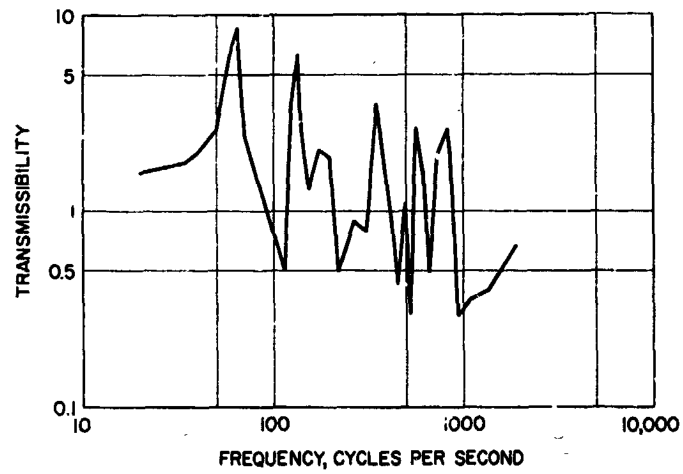
i) Transverse Axis No. 1—
Outboard Electronics



j) Transverse Axis No. 1
Top Angle Bracket

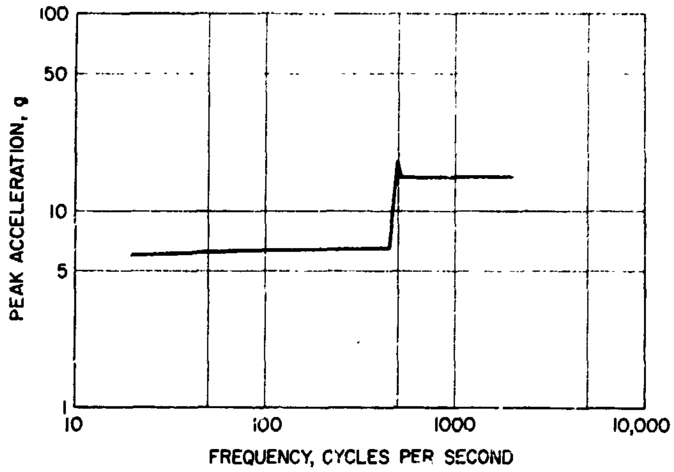


k) Transverse Axis No. 1—
Bottom Angle Bracket

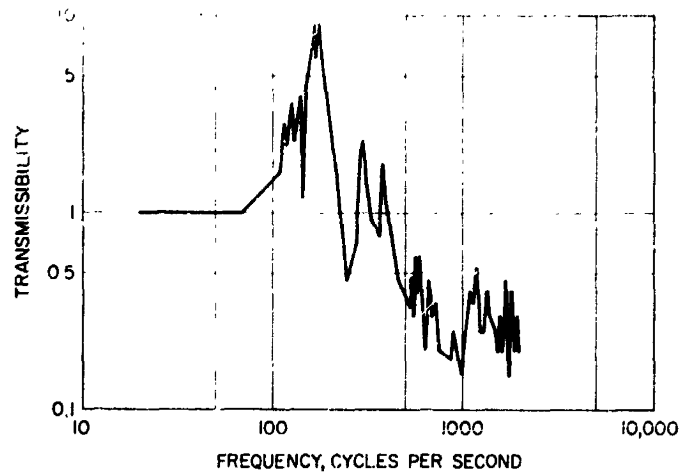


l) Transverse Axis No. 1—
Quadrant Board No. 3

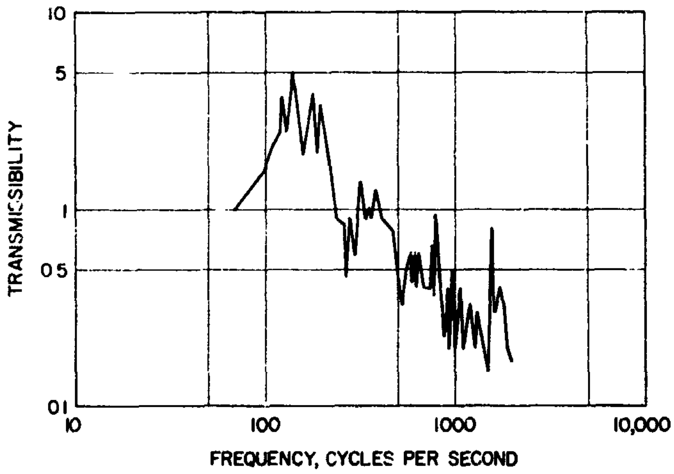
Figure 4-6 (continued)



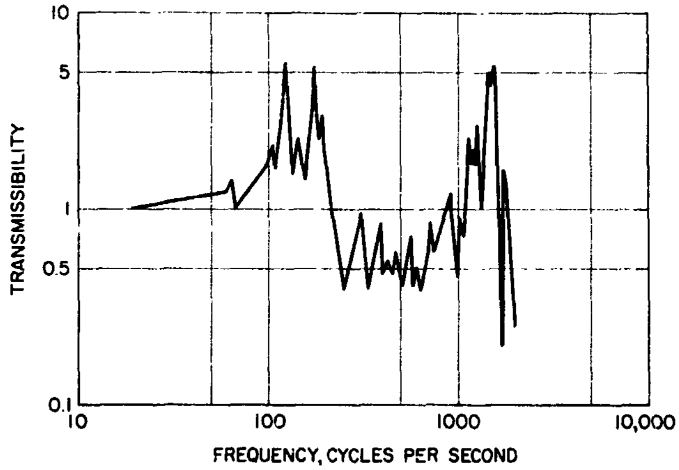
m) Transverse Axis No. 2



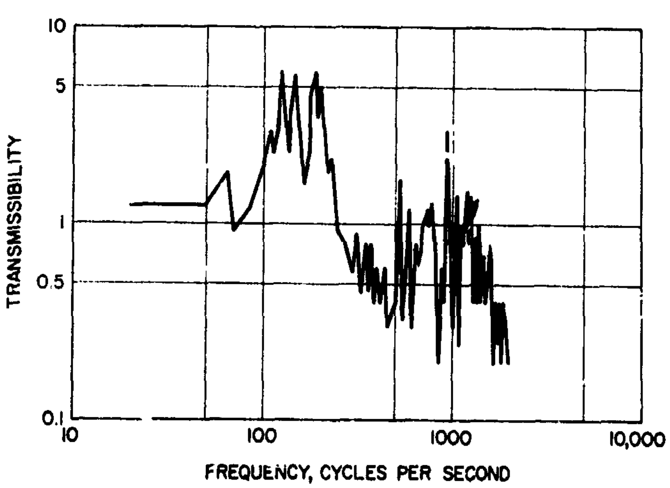
n) Transverse Axis No. 2—
Inboard Electronics



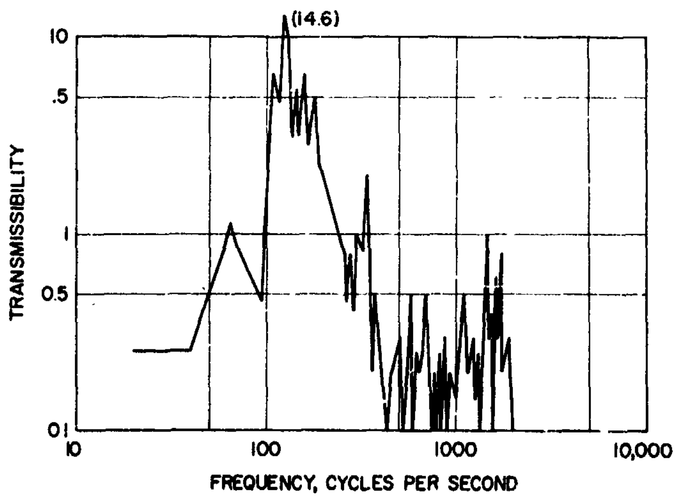
o) Transverse Axis No. 2—
Outboard Electronics



p) Lateral Axis No. 2—
Top Angle Bracket

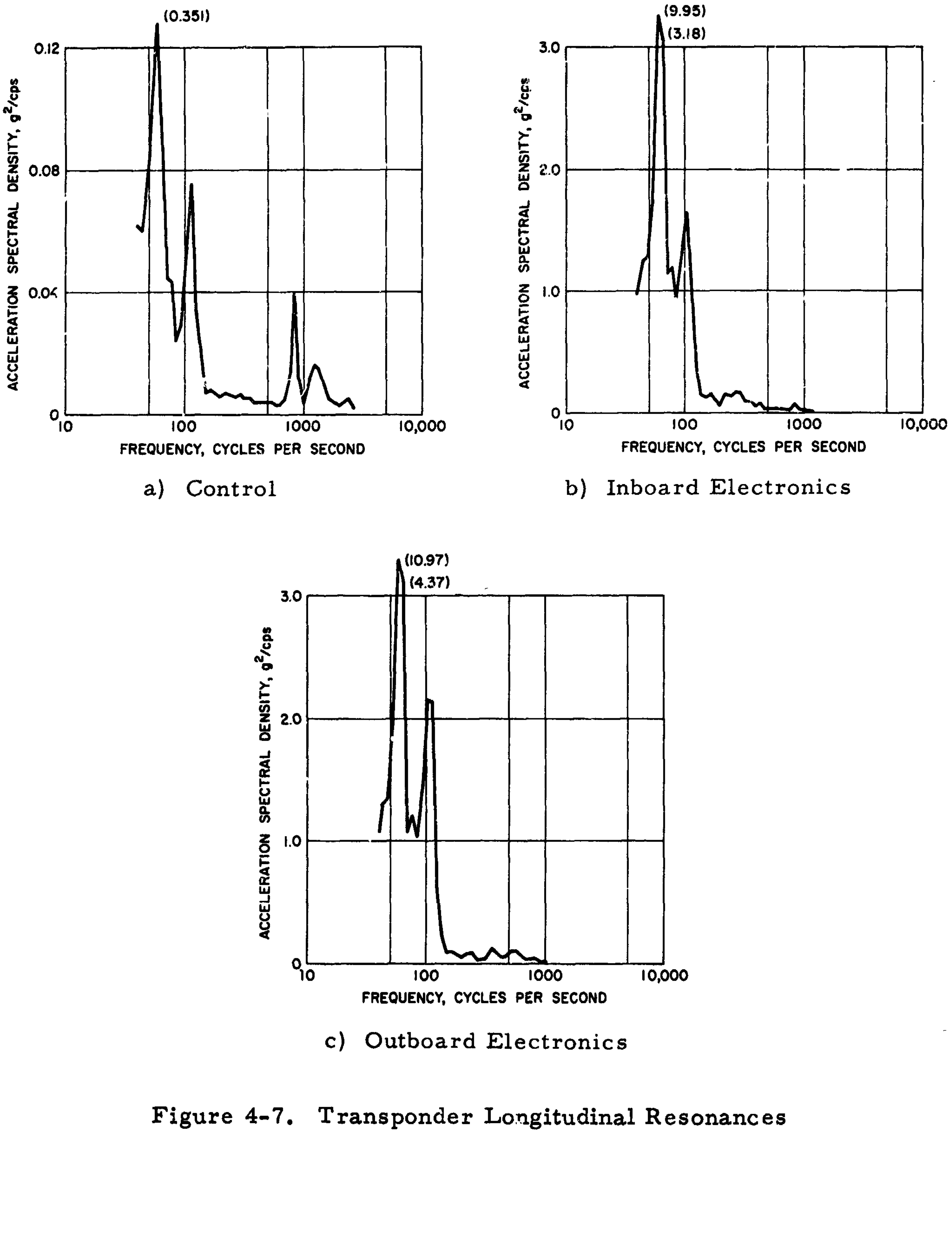


q) Transverse Axis No. 2—
Bottom Angle Bracket



r) Transverse Axis No. 2—
Quadrant Board No. 3—
Crosstalk Transmissibility

Figure 4-6 (continued)

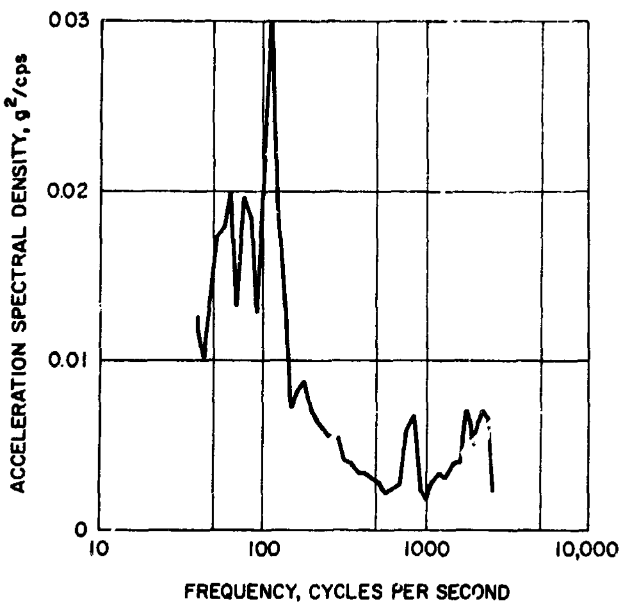


a) Control

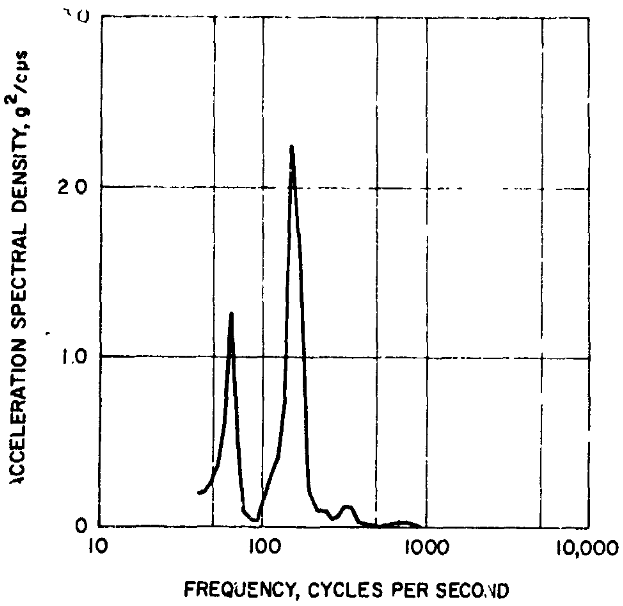
b) Inboard Electronics

c) Outboard Electronics

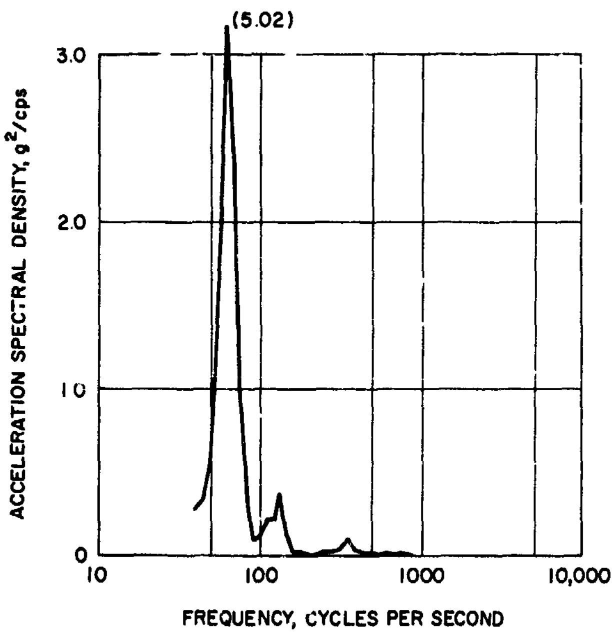
Figure 4-7. Transponder Longitudinal Resonances



a) Control

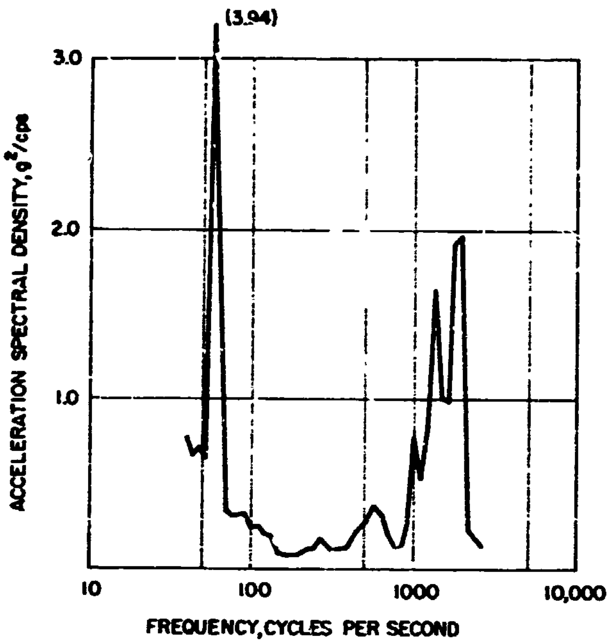


b) Inboard Electronics

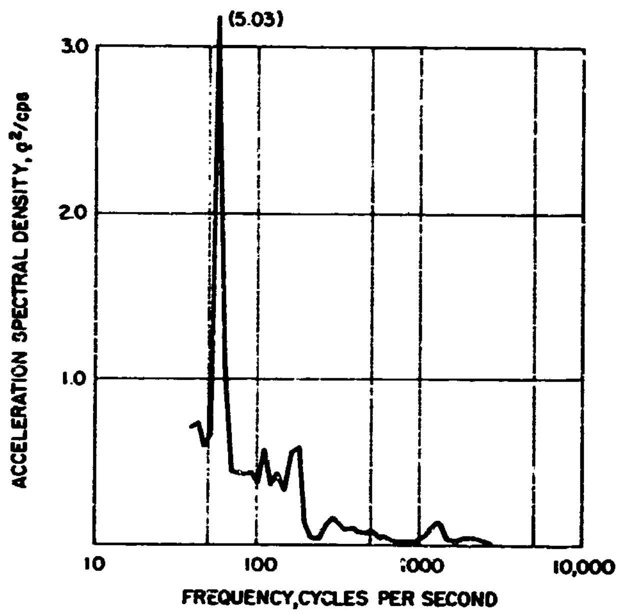


c) Outboard Electronics

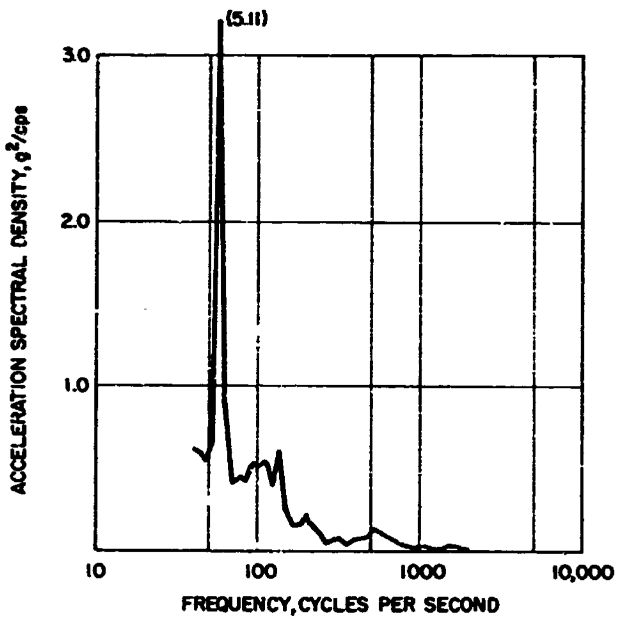
Figure 4-8. Transponder Transverse No. 1 Resonances



a) Control



b) Inboard Electronics



c) Outboard Electronics

Figure 4-9. Transponder Transverse No. 2 Resonances

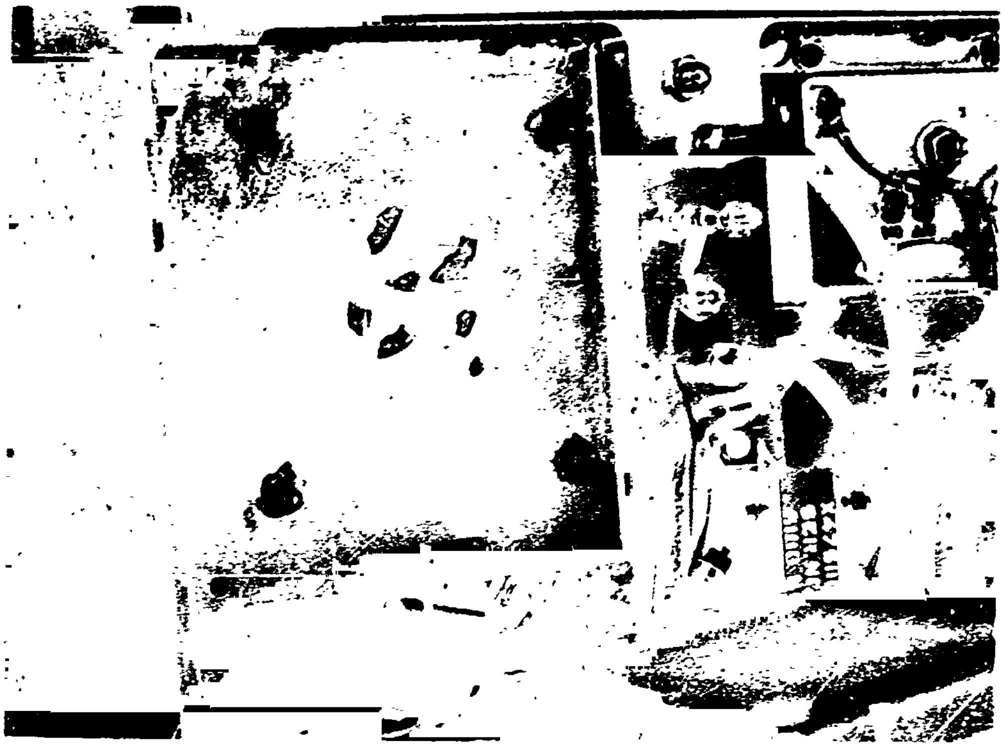


Figure 4-11. Master Oscillator Quadrant Mount

Figure 4-10. Master Oscillator Mount

Figure 4-12. Master Oscillator Cracked Foam

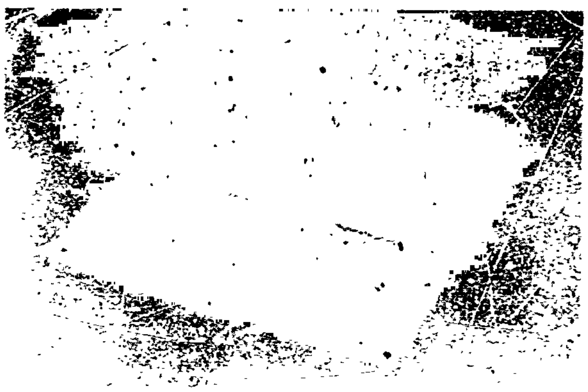


Figure 4-13. X32 Multiplier

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5. MULTIPLE ACCESS TRANSPONDER TEST RESULTS

DESCRIPTION

The multiple access transponder is designed to receive frequency multiplexed single sideband signals at 6 gc, translate them to IF, amplify and then convert them to a composite modulated carrier for retransmission at 4 gc. The conversion from single sideband to phase modulation is accomplished without detection.

The bandpass of the multiple access transponder is wide enough to handle 1200 voice modulated channels. The single sideband signals may be originated from one or more ground stations simultaneously.

The transponder has a noise figure of 10 db, a received bandwidth of 5 mc, transmitter power of 4 watts, and transmit bandwidth of 25 mc.

TEST RESULTS (6212 MC MULTIPLE ACCESS TRANSPONDER)

Table 5-1 summarizes the test results.

Additional Testing

Output Variation Over the Passband

For each input frequency the input power was varied to produce a modulation index of 1.435 radians peak. The signal frequency in terms of its position with respect to the inserted carrier, is listed as follows:

Signal Frequency	Power Input
.25 mc	-71 dbm
.50 mc	-72 dbm
1.00 mc	-72 dbm
1.50 mc	-72 dbm
2.00 mc	-73 dbm
2.50 mc	-74 dbm

TABLE 5-1. MULTIPLE ACCESS MODE

	Initial Test	Pre-Vibration Test	Post Vibration Test	Pre Thermal Vacuum Test	Vacuum 70°F	Vacuum +120°F	Vacuum -20°F	Post Thermal Vacuum Test
Local Oscillator Power, milliwatts	4.1[1]	4.8[2]	5.5[3]	4.2[1]	5.0[2]	5.0[2]	4.7[2]	6.0[3]
Noise Figure, decibels	9.0	---	---	9.5	---	---	---	---
Receiver Sensitivity, dbm	-74	-72	---	-76	-76	-76	-75	-78
Output Variation over Passband, decibels	4	4	---	3	2.5	5.5	1	2
Output Power, milliwatts	1.1	0.96	0.0	1.13	1.0	0.88	0.95	2.6[4]

Notes:

1) Power measured at local oscillator filter output in antenna box.
2) Power measured at local oscillator filter input in antenna box.
3) Power measured at quadrant output.
4) Power output measured at the transponder output.

Signal Frequency	Power Input
2.90 mc	-74 dbm
3.00 mc	-74 dbm
3.50 mc	-74 dbm
4.00 mc	-74 dbm
4.50 mc	-73 dbm
5.00 mc	-73 dbm
5.30 mc	-70 dbm
5.50 mc	-70 dbm
6.00 mc	-64 dbm

Figure 5-1 is a plot of the bandpass characteristics of this transponder.

Environmental Test Results

Section 4 contains a detailed description of the environmental test procedures and conditions.

Vibration

A number of problems were found as a result of the vibration test. These are listed as follows as well as the steps being taken to eliminate these problems.

1) The multiple access master oscillator, 475122-102 Serial Number 1 came loose from the quadrant frame. The metal around the four captive nuts which hold the master oscillator frame to the quadrant frame fatigued and fractured. The foam is cracked but has not deteriorated. The master oscillator frame is being redesigned to make it stronger in the problem area.

2) The multiple access X32 multiplier, 475114-110 Serial Number 1 gave no output with normal input. Examination showed the first doubler deck had not been properly foamed allowing the input coil to flex which fractured the input RF wire connection. The present inspection procedure will be changed to see that this does not reoccur.

3) The multiple access X3 multiplier, 475116-107, Serial Number 1 oscillated. The input tuning had to be readjusted. The input fitting is not mechanically rigid. The input fitting is being redesigned for mechanical rigidity and the present multipliers modified.

Thermal Vacuum

The multiple access mode transponder operated over the complete range of temperatures in vacuum. Data was taken in vacuum with the

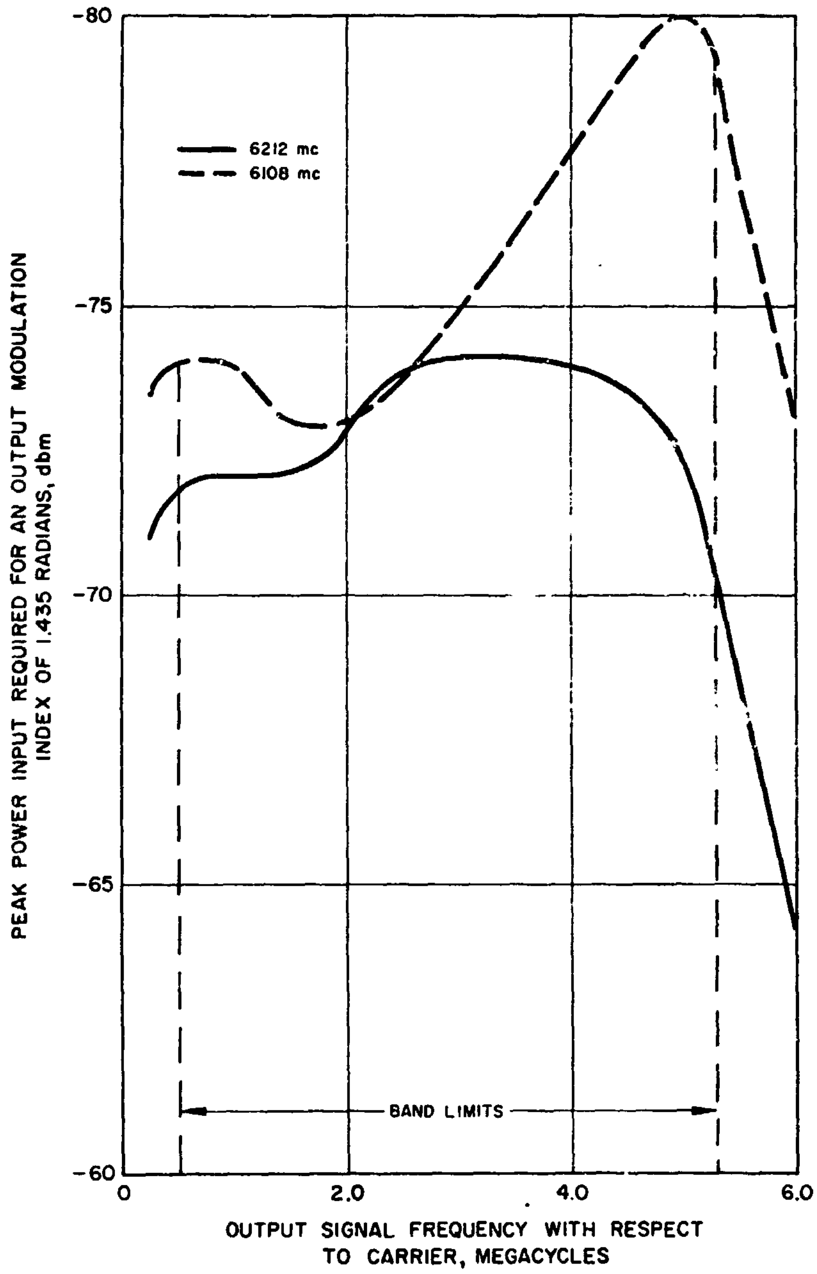

Figure 5-1. Output Variation over the Passband in the Multiple Access Mode of Operation

transponder at -20, 70, and 120°F. Table 5-2 is a summary of the results obtained from these tests.

TABLE 5-2. MULTIPLE ACCESS MODE IN THERMAL VACUUM

Temperature	-20°F	70°F	120°F
Local Oscillator Power, milliwatts	4.7	5.0	5.0
Receiver Sensitivity, dbm	-75	-76	-76
Output Power, milliwatts	0.95	1.0	0.88
Output Variation Over Passband, db	4	2.5	5.5

Figure 5-2 is a plot of the band characteristics of multiple access transponder at various temperatures when in a vacuum.

TEST RESULTS (6108 MC MULTIPLE ACCESS TRANSPONDER)

Following is a summary of the results of tests conducted on the 6108 mc multiple access transponder, Serial No. 1.

Local oscillator power, milliwatts	4.2 (measured at output of local oscillator filter)
Noise figure, decibels	10.0
Receiver sensitivity, dbm	-75
Output variation over the passband, decibels	7
Output power, milliwatts	1.4

Figure 5-1 is a plot of the bandpass characteristics of this transponder.

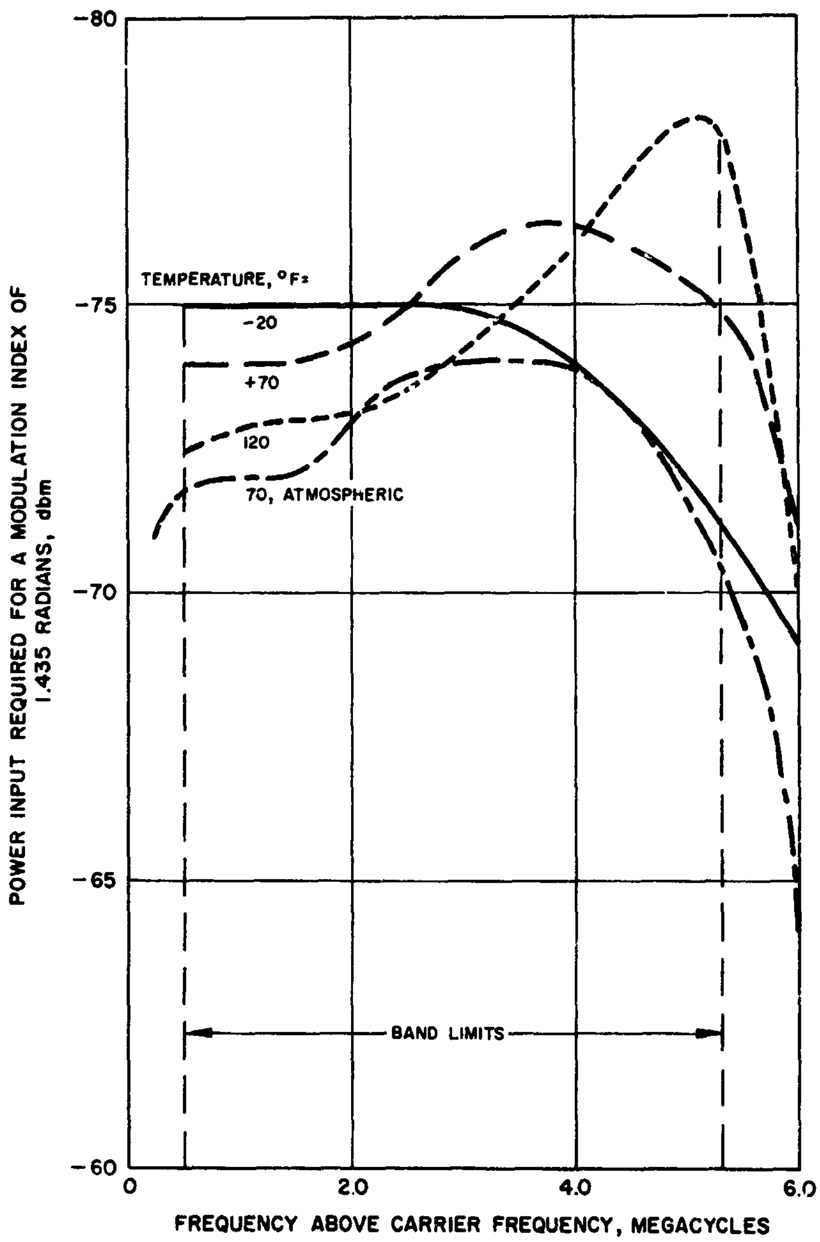

Figure 5-2. Bandpass Characteristics of Multiple Access Mode in Thermal Vacuum Environmental Test

6. UNITS COMMON TO BOTH FREQUENCY TRANSLATION AND MULTIPLE ACCESS TRANSPONDERS

TRANSMITTER FERRITE SWITCH (475173)

Discussion of Test

The ferrite switch routes the selected traveling-wave tube output power to the antenna. It is operated by drive circuits within the traveling-wave regulator converters. The units were tested for insertion loss and input isolation.

Performance Summary

Both units produced met preliminary test specifications. Average insertion loss was 0.17 db with a maximum of 0.2 db. Minimum input-input isolation was 23.7 db. The weight was 4 ounces.

RECEIVER FERRITE SWITCH (475176)

Discussion of Tests

The ferrite switch routes the received signal to the selected type transponder, multiple access or frequency translation. It is operated by drive circuits within the transponder receiver regulators. The units were tested for insertion loss and input isolation.

Performance Summary

Both units produced met preliminary test specifications. Average insertion loss was about 0.15 db with a maximum of 0.23 db. Minimum input-input isolation was 25 db. Weight was 4 ounces.

TELEMETRY MONITOR DUAL COUPLER-DETECTOR (475172)

Description of Tests

The dual coupler-detector samples the traveling-wave tube output. One output is used to provide a direct power measurement, while the other output is rectified by the detector for a telemetry input.

Both units produced were tested for insertion loss, coupling, input voltage standing wave ratio, and detector conversion.

Performance Summary

As shown in Table 6-1, the measured performance met preliminary test specifications.

The maximum insertion loss was 0.2 db. The coupling was about 20.8 and 24 db. The maximum input VSWR was 1.18:1. Detector output for 40 milliwatts input was approximately -2.7 volts.

Temperature tests were not made. The finished weight of each unit is about 1.9 ounces. No changes in design are contemplated.

TABLE 6-1. PERFORMANCE TEST RESULTS - TELEMETRY MONITOR (475172-100)

Test	Design Standard		Unit Serial Number	
	Minimum	Maximum	1	2
Insertion loss, decibels		0.25	0.20	0.17
Coupling attenuation, decibels				
TWT to telemetry	18.5	21.5	20.8	20.8
Test to multiplex	21.5	24.5	23.8	24.1
Voltage standing wave ratio (VSWR)		1.30:1	1.18:1	1.13:1
Detector output with input of 40 mw, volts dc	-3.5	-2.0	-2.8	-2.5

RECEIVER DIRECTIONAL COUPLER (475103)

Description of Tests

The receiver directional coupler provides an input to the transponder receivers for test purposes. Both units produced were tested for insertion loss, input voltage standing wave ratio, and coupling.

Performance Summary

As shown in Table 6-2, the measured performance met preliminary test specifications. The maximum insertion loss was 0.25 db. Maximum voltage standing wave ratio was 1.18:1. The coupling was about 21.9 db.

Temperature tests were not made. The finished weight of each unit is about 0.95 ounce. No changes in design are contemplated.

TABLE 6-2. PERFORMANCE TEST RESULTS - RECEIVER COUPLER (475103-100)

Test	Design Standard		Unit Serial Number	
	Minimum	Maximum	1	2
Insertion loss (2.2), decibels		0.25	0.10	0.25
Voltage standing wave ratio		1.30:1	1.13:1	1.18:1
Coupling attenuation, decibels				
At 6020 mc	17.0	23.0		
At 6110 mc	17.0	23.0	21.8	21.7
At 6210 mc	17.0	23.0	22.2	21.9
At 6300 mc	17.0	23.0		

LOCAL OSCILLATOR FILTER (475118)

Discussion of Test

The local oscillator filter allows the desired harmonic of the master oscillator to supply local oscillator power to the input mixer while attenuating other harmonics. The units were tested for insertion loss, VSWR, and 120 mc bandwidth attenuation.

Performance Summary

The four units produced met the preliminary test specifications as shown in Table 6-3. Average insertion loss was about 0.5 db. Average VSWR was about 1.16 with a maximum of 1.2. The 120 mc bandwidth attenuation was greater than 40 db. Unit weight is about 3.1 ounces. No temperature tests were made. No unit changes are anticipated.

TABLE 6-3. PERFORMANCE TEST RESULTS - LOCAL OSCILLATOR FILTER (475118)

	Design Standard		Unit			
Test	Minimum	Maximum	475118-101	476118-102	475118-105	475118-106
Insertion loss, decibels	-	0.7	0.5	0.4	0.5	0.5
Spurious frequency attenuation, decibels	40.0	-	>40	>40	>40	>40
Voltage standing wave ratio (VSWR)	-	1.5:1	1.2:1	1.14:1	1.1:1	1.2:1
Weight, ounces			3.12	3.04	3.12	3.09

3 DB HYBRID (475171)

Description of Test

The 3 db hybrid is a four-part power splitter with isolated input ports and approximately equal power at the output ports.

Each of the units produced was tested for port to port insertion loss and input isolation at two frequencies corresponding to band edges.

Performance Summary

As shown in Table 6-4, the measured performance of the three units met preliminary test specifications.

The actual insertion loss was less than the minimum recorded by instruments and is estimated to be about 0.1 db. Maximum output port unbalance was approximately 0.6 db.

Input isolation was 20.2 to 34 db at the two frequencies. Temperature tests were not made. The finished weight of each unit was about 1 ounce. No changes are contemplated.

TABLE 6-4. PERFORMANCE TEST RESULTS - 3 DB HYBRID (475171-100)

Test	Design Standard		Unit Serial Number		
	Minimum	Maximum	1	2	3
Insertion loss, decibels					
Input port 1 to output 1 at 3980 mc	2.50	3.50	2.65	2.60	2.65
Input port 1 to output 2 at 3980 mc	2.50	3.50	3.20	3.20	3.20
Input port 1 to output 1 at 4200 mc	2.50	3.50	2.80	2.70	2.80
Input port 1 to output 2 at 4200 mc	2.50	3.50	3.20	3.20	3.20
Input port 2 to output 1 at 3980 mc	2.50	3.50	3.25	3.20	3.20
Input port 2 to output 2 at 3980 mc	2.50	3.50	2.65	2.65	2.65
Input port 2 to output 1 at 4200 mc	2.50	3.50	3.20	3.20	3.20
Input port 2 to output 2 at 4200 mc	2.50	3.50	2.80	2.70	2.80
Isolation, decibels					
Between input ports at 3980 mc	20.0	-	34.0	30.8	33.0
Between input ports at 4200 mc	20.0	-	21.0	20.8	20.2
Between output ports at 3980 mc	20.0	-	30.0	31.2	32.5
Between output ports at 4200 mc	20.0	-	20.2	21.0	20.4

INPUT MIXER (475100)

Description of Test

The input mixer is a ring hybrid microwave frequency converter using semiconductor diodes.

Each of the seven units produced was tested for local oscillator isolation, VSWR, and noise figure at two frequencies representing band edges.

Performance Summary

As shown in Table 6-5, the measured performance met modified preliminary test specifications. Figure 6-1 shows the noise figure versus temperature and frequency.

Minimum local oscillator isolation was 27 db. The maximum VSWR at the signal input port was 1.9:1 with an average of about 1.5:1. The maximum VSWR at the local oscillator input port was 2.3:1 with an average of about 1.8:1. Average noise figure was 8.4 db. Maximum measured noise figure was 10.2 db at the two local oscillator frequencies corresponding to the band edges. The IF preamplifier noise figure was about 3.8 db.

Additional tests of the input mixer noise figure were performed as a function of temperature and frequency on one unit. The local oscillator input level was varied from 0.5 to 3.0 mw causing less than 3 db change in noise figure.

The finished weight of each unit was about 3.4 ounces.

One of the present mixers produced will be lightened and, in addition, a new mixer will be developed with pressed metal ground planes to facilitate production and reduce weight. Its shape will be longer and narrower to provide better VSWR by proper matching.

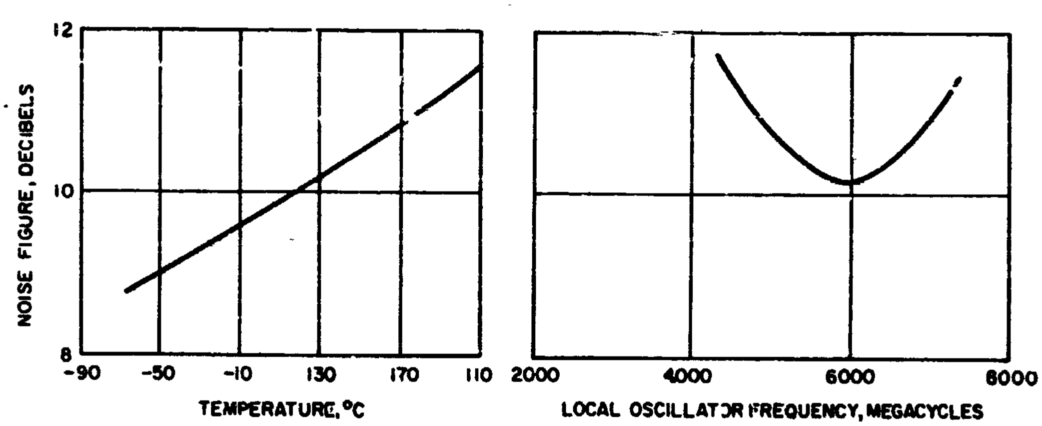

Figure 6-1. Noise Figure versus Temperature

TABLE 6-5. PERFORMANCE TEST RESULTS - INPUT MIXER (475100-100)

Test	Design Standards		Unit Serial Number						
	Minimum	Maximum	1	2	3	4	5	6	7
Isolation, decibels									
At 5988 mc	20.0		28.0	28.0	31.5	28.0	35.0	34.0	29.0
At 6366 mc	20.0		30.0	27.0	30.0	>30.0	35.0	27.0	32.0
Input VSWR									
At 6019 mc		2.0:1	1.65:1	1.76:1	1.16:1	1.60:1	1.67:1	1.45:1	1.46:1
At 6301 mc		2.0:1	1.70:1	1.58:1	1.26:1	1.22:1	1.16:1	1.70:1	1.90:1
Local oscillator VSWR									
At 5988 mc		2.5:1	2.20:1	1.90:1	1.68:1	1.75:1	1.36:1	1.95:1	2.20:1
At 6366 mc		2.5:1	2.30:1	1.96:1	1.56:1	1.80:1	1.30:1	1.90:1	1.78:1
Noise figure, decibels									
At 5988 mc		10.5	8.0	10.2	9.0	8.2	9.5	8.8	8.5
At 6366 mc		10.5	8.0	8.0	8.5	8.0	8.5	8.7	9.0

IF ATTENUATOR (475124)

Discussion of Test

The attenuator is an intermediate frequency pi pad used for adjustment of overall system levels. Seven db attenuators happened to be used in the transponders produced. All six of the attenuators produced were tested for proper attenuation.

Performance Summary

The units produced met the preliminary test specifications as shown in Table 6-6. No temperature tests were made. No changes on this unit are contemplated.

TABLE 6-6. PERFORMANCE TEST RESULTS - IF ATTENUATOR (475124)

Test	Design Standard		Unit Serial Number					
	Minimum	Maximum	1	2	3	4	5	6
Attenuation, decibels								
475124-100	2.7	3.3						
475124-101	3.6	4.4						
475124-102	4.5	5.5						
475124-103	5.5	6.5						
475124-104	6.5	7.5	7.0	7.0	6.9	6.9	6.8	6.9
475124-105	7.4	8.6						
475124-109	11.5	12.5	12.0					

2 KMC ISOLATOR (475115)

Description of Test

The 2 kmc isolator is a unilateral coupler in which the attenuation in one direction is much greater than the opposite direction. The isolators have stripline Y junctions with a magnetized ferrite disc at the center to provide circulation. Each of the units produced were tested for insertion loss at the center frequency and for isolation at the center frequency and 35 mc from the center frequency.

Performance Summary

As shown in Tables 6-7, 6-8, and 6-9, the measured performance of all 23 units met the preliminary test specifications.

The average measured insertion loss was about 0. 2 db. Minimum and maximum insertion loss was 0. 12 and 0. 3 db respectively. The measured isolation at center frequency was 35. 7 db to greater than 40 db.

The measured isolation 35 mc from the center frequency was 25. 2 db to 33. 8 db. Temperature tests were made on one unit. The results are also shown in the performance tables. The finished weight of each unit was about 3. 5 ounces. No changes are contemplated.

TABLE 6-7. PERFORMANCE TEST RESULTS - 2 KMC ISOLATOR (475115-100)

Test	Design Standard		Unit Serial Number						Serial Number			
									TS 2071		TS 2036	
	Minimum	Maximum	1	2	3	4	5	6	1	2	1	2
Insertion loss at F_1, decibels		0.50	0.20	0.14	0.15	0.15	0.27	0.15	0.3	0.26	0.2	0.29
Isolation at F_1, decibels	30.0		40.0+	36.5	37.0	40.0	37.5	39.0	>40	>40	35.7	>40
Isolation at F_1 +35 mc, decibels	20.0		27.0	27.6	30.8	26.0	29.8	25.2	29	27	28.6	29.8
Isolation at F_1 - 35 mc, decibels	20.0		29.0	28.0	26.6	31.4	26.5	33.8	27.2	27	26	27.2

TABLE 6-8. PERFORMANCE TEST RESULTS - 2 KMC ISOLATOR (475115-101)

Test	Design Standards		Unit Serial Number											
	Minimum	Maximum	1	2	#3 at 50°F	#3 at 75°F	#3 at 115°F	4	5	6	7	8	9	10
Insertion loss at F_1, decibels	-	0.50	0.15	0.20	0.12	0.20	0.26	0.18	0.20	0.13	0.20	0.15	0.27	0.13
Isolation at F_1, decibels	30.0	-	40.0+	36.0	31	40	29	39.0	38.4	39.0	37.5	35.8	40.0+	40.0+
Isolation at F_1 + 35 mc, decibels	20.0	-	27.8	28.0	27.5	27	24.5	27.0	25.5	28.5	25.5	28.0	[illegible]1.2	28.3
Isolation at F_1 -35 mc, decibels	20.0	-	28.0	26.3	26.2	28.7	28.7	27.7	33.2	27.5	32.2	27.0	26.5	28.5

TABLE 6-9. PERFORMANCE TEST RESULTS - 2 KMC ISOLATOR (475115-102)

Test	Design Standard		Unit Serial Number			
	Minimum	Maximum	1	2	3	4
Insertion loss at F_1, decibels	--	0.50	0.20	0.28	0.20	0.12
Isolation at F_1, decibels	30.0	--	40.0	40.0	38.0	36.5
Isolation at F_1 + 35 mc, decibels	20.0	--	28.4	27.5	29.0	27.0
Isolation at F_1 - 35 mc, decibels	20.0	--	28.5	29.0	27.0	26.6

4 KMC ISOLATOR (475126)

Description of Test

The 4 kmc isolator is a unilateral coupler in which the attenuation in one direction is much greater than the opposite direction.

The isolators have stripline Y junctions with a magnetized ferrite disc at the center to provide circulation. Each of the units produced was tested for insertion loss at the center frequency and for isolation at the center frequency and 35 mc from the center frequency.

Performance Summary

As shown in Table -10, the measured performance of all 11 units met the preliminary test specifications.

The average measured insertion loss was about 0.1 db. Minimum and maximum insertion loss was 0.05 db and 0.15 db respectively. The measured isolation at center frequency was 26.1 db to greater than 40 db.

Temperature tests were not made. The furnished weight of each unit was about 2 ounces. No changes are contemplated.

TABLE 6-10. PERFORMANCE TEST RESULTS -
4 KMC ISOLATOR (475126-100)

Test	Design Standards		Unit Serial Number				
	Minimum	Maximum	1	3	4	5	6
Insertion, loss decibels	-	0.50	0.10	0.10	0.10	0.10	0.15
Isolation at 4120 mc, decibels	20.0	-	33.0	37.7	36.2	33.0	28.0
Isolation at 3955 mc, decibels	20.0	-	30.3	30.4	25.8	28.0	26.5
Isolation at 4279 mc, decibels	20.0	-	28.5	33.2	28.2	27.0	26.6

Test	Design Standards		Unit Serial Number					
	Minimum	Maximum	2	7	8	9	10	11
Insertion loss, decibels	-	0.50	0.05	0.10	0.12	0.10	0.15	0.10
Isolation at 4120 mc, decibels	20.0	-	31.8	30.0	33.1	35.9	26.1	40.0^{+}
Isolation at 397[illegible] mc, decibels	20.0	-	32.8	37.0	35.0	40.0^{+}	27.5	33.8
Isolation at 4321 mc, decibels	20.0	-	28.0	34.0	32.4	26.8	25.2	40.0^{+}

X32 MULTIPLIER (475114)

Discussion of Test

The X32 multiplier consists of five doubler stages, each stage an unbalanced-balanced dual varactor doubler. It is used for 64 mc to 2 kmc multiplication. The frequency translation multiplier is a high power single frequency unit which supplies local oscillator power to the input mixer and high level mixer. The multiple access local oscillator X32 multiplier is a medium power single frequency device while the multiple access transmitter multiplier is a low power wide band unit.

The six units produced were tested for conversion loss, output power with specified input power, and stability. Wideband tests were made using a chain of operating units in a separate test.

Performance of Units

The units met revised preliminary test specifications after foaming as shown in Table 6-11. Average conversion losses were about 6.1db, 6.8 db, and 7.3 db for the high power, medium power, and low power units respectively. Maximum variation was 0.8 db (two unit samples).

The curves in Figures 6-2 and 6-3 show power output versus temperature and input voltage as measured. Maximum bias voltages were 38 volts (absolute).

Effort will continue to improve the stability of this unit from spurious output and variations in power output with environmental changes. In addition, a study is being made of the phase linearity and bandwidth characteristics of the wideband multiplier, which is the most difficult to adjust because of the additional requirements.

The presently designed multiplier has an output power range limitation of about 20 to perhaps 120 milliwatts because of tuning and stability as used with the high output impedance transistor driver circuits. It has been found that the stability can be improved somewhat with a low impedance source. A newly designed fourth and fifth multiplier deck also appears to improve stability.

TABLE 6-11. PERFORMANCE TEST RESULTS - X32 MULTIPLIER (475114)

Test	Design Standard		Unit (All Serial No. 1)				
	Minimum	Maximum	475114-101	475114-105	475114-106	475114-109	475114-110
Conversion loss, decibels							
475114-100 through -103		-7.0	-6.1				
475114-104 through -107		-8.4		-7.2	-6.4		
475114-108 through -111		-9.6				-7.0	-7.6
Output power, milliwatts							
475114-100 through -103	80	126	96				
475114-104 through -107	26	42		29.5	32		
475114-108 through -111	12	19				24.6	18.0
Spurious response, decibels							
with -24 volt dc input		-40	None	None	None	None	None
with -22 volt dc input		-40	None	None	None	None	None
with -26 volt dc input		-40	None	None	None	None	None
Weight, ounces					9.02		9.15

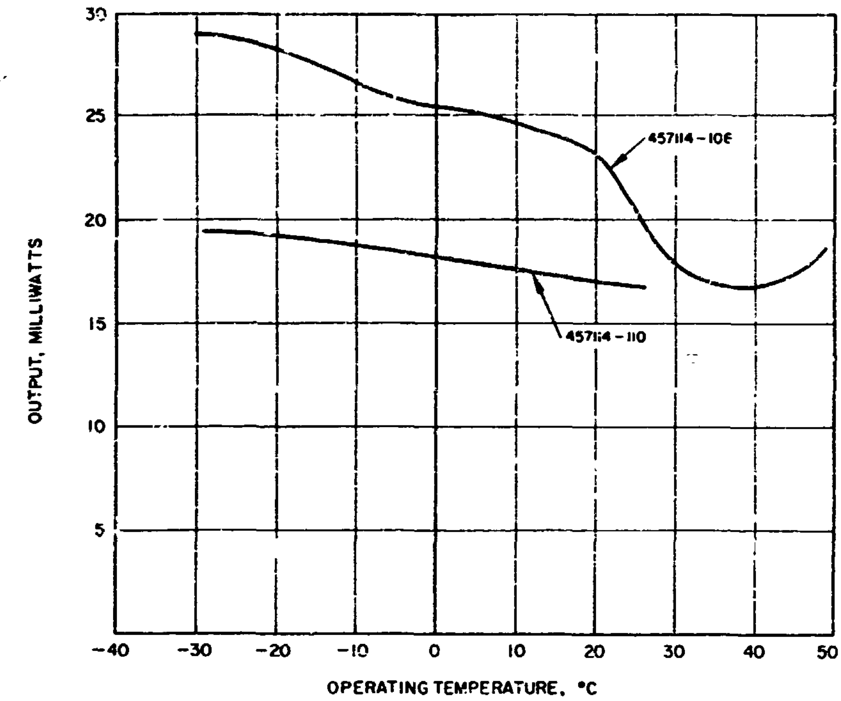

Figure 6-2. X32 Multiplier Environmental Temperature Test Results

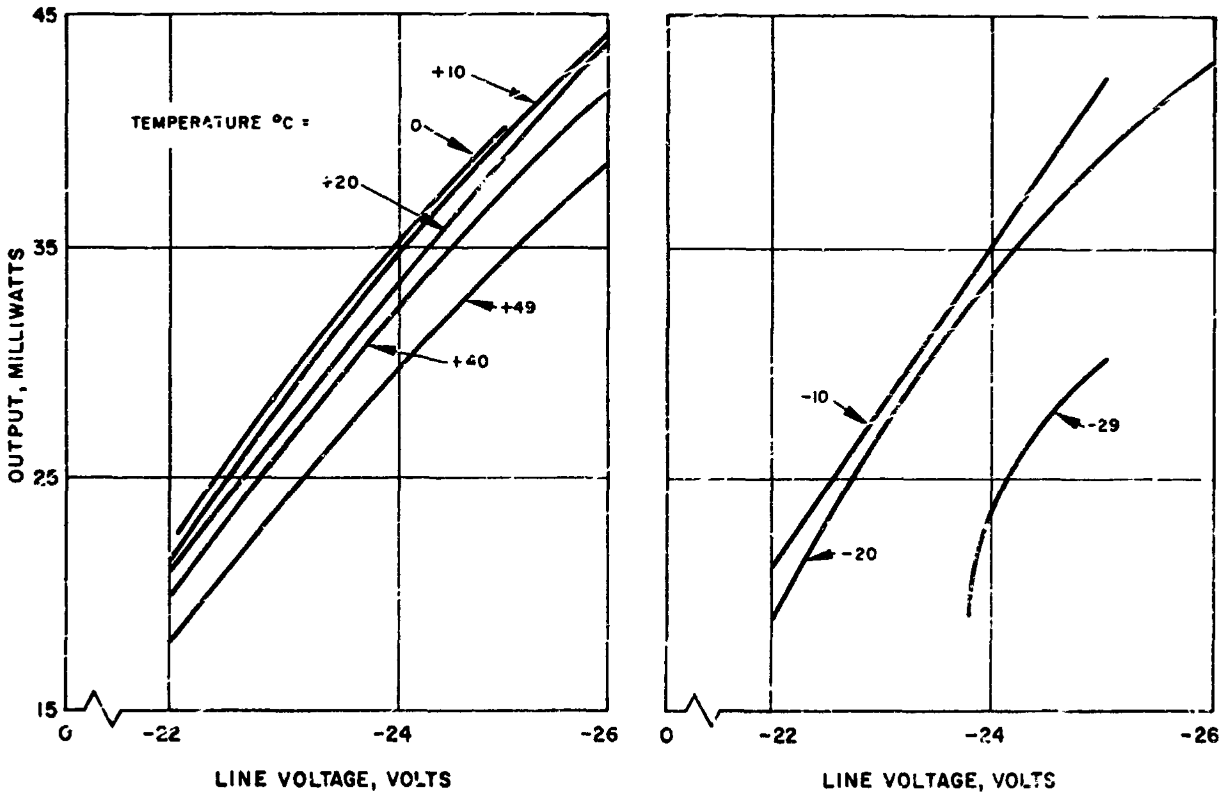

Figure 6-3. X32 Multiplier Environmental Voltage Temperature Results

X2 MULTIPLIER (475117)

Discussion of Test

The X2 multiplier is used for 2 kmc multiplication to 4 kmc. The multiple access multiplier is a low power wideband device compared to the frequency translation multiplier which has a higher power single frequency input. A dual varactor unbalanced-balanced doubler is used. The units were tested for proper bias voltage, power output with desired input power, spurious response and VSWR. Input RF power was 24 and 7.2 milliwatts.

Performance of Units

The four units produced met the preliminary test specifications as shown in Table 6-12. Average conversion loss was 3.55 db for the high power unit and 3.25 db for the low power unit. Maximum input VSWR was 1.4:1.

No temperature tests were made. Average weight was about 3.41 ounces. No changes are expected at this time. All bias voltages were less than 1.55 volt (absolute).

TABLE 6-12. PERFORMANCE TEST RESULTS - X2 MULTIPLIER (475117)

Test	Design Standard		Unit (All Serial No. 1)			
	Minimum	Maximum	475117-101	475117-102	475117-105	475117-106
Output power, milliwatts						
475117-100 through 475117-103	9.0		10.8	10.4		
475117-104 through 475117-107	1.9				3.4	3.4
Spurious response, decibels		-40	<-40	<-40	<-40	<-40
Voltage standing wave ratio		1.5:1	1.2:1	1.2:1	1.4:1	1.2:1

X3 MULTIPLIER (475116)

Discussion of Test

The X3 multiplier is used for 2 to 6 kmc multiplication. The single frequency multipliers supply local oscillator power to the input mixers. A single varactor cavity multiplier is used.

The units were tested for proper bias voltage, power output with 24 milliwatts input, and spurious response.

Performance of Units

The four units produced met the preliminary test specifications as shown in Table 6-13. Average conversion loss was 3.8 db with a maximum of 4 db. All bias voltages were less than 0.75 volt. The temperature test results are shown on the curve of Figure 6-4.

A mechanical problem found during vibration will be corrected on future units produced. In addition, a split ring will be added to the RF input fitting to correct the units now installed in the quadrants. Average weight was about 2.8 ounces.

TABLE 6-13. PERFORMANCE TEST RESULTS - X3 MULTIPLIER (475116)

Test	Design Standard		Unit			
	Maximum	Minimum	101	102	105	106
Output power, milliwatts	3.9	-	10.0	10	10	9.6
Spurious response, decibels	-	-40	<-40	<-40	<-40	<-40

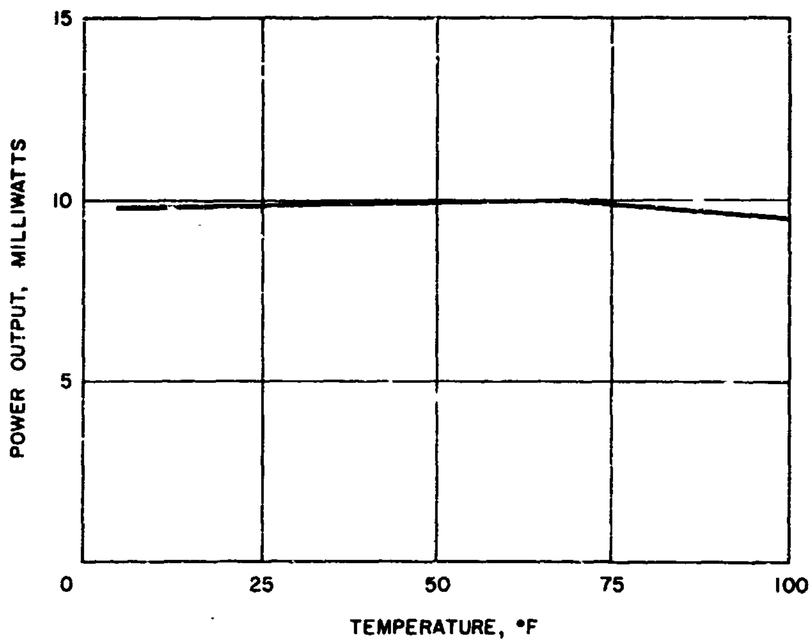

Figure 6-4. X3 Multiplier Temperature Test Results

TRAVELING-WAVE TUBE POWER SUPPLY (475174)

Discussion of Test

The power requirements of each traveling-wave tube are supplied by a dc to dc converter and a dc to ac inverter. The input power to the converter and inverter is supplied by a series regulator. The inverter supplies filament power, while the converter supplies power to the tube cathode, anode, and collector. Both the inverter and converter are saturable core square wave oscillators. The converter has rectified outputs and the inverter supplies approximately constant power to the tube filament.

The unit was tested at ambient, +100°F, and 0°F for all of its appropriate parameters. The results are listed in Table 6-14.

Performance of Unit

The high voltage dc-dc converter performed satisfactorily over this temperature range, but the helix-collector voltage was 1 percent out of specification at 0°F. The voltage-temperature regulation was satisfactory. The out-of-specification condition was caused by manufacturing tolerances associated with the transformer. Some difficulty was experienced with the constant power filament supply. The power regulation was ±4 percent at room temperature, and dropped to approximately 50 percent of rated power at 0°F.

TABLE 6-14. TRAVELING-WAVE TUBE POWER SUPPLY

Test	Minimum	Maximum	77°F	100°F	0°F
On/off drivers turn-on transient, volts					
No. 1		SS+4	0	0	0
No. 2		SS+4	0	0	0
No. 3		SS+4	0	0	0
No. 4		SS+4	0	0	0
Ferrite switch drive					
Pulse amplitude, volts	22		22.2	22.5	22.8
Pulse width at 90 percent amplitude, microseconds	4	40	19	23	14
Overcurrent limit					
Lowline -26 volts dc	1.0a	1.6a	1.20	1.14	1.37
Highline -34 volts dc	1.0a	1.6a	1.23	1.17	1.41
Dc-dc converter high voltage outputs					
Lowline -26 volts dc					
Anode-helix voltage (V_{AH} ± 3 percent)	261.9	278.1	273.0	271.8	276.6
PARD, volts		2*	0.59	0.7	0.6
Power, watts			0.037	0.037	0.0382
Helix collector voltage (V_{HC} ± 3 percent)	679.0	721.0	718.3	714.8	727
PARD, millivolts		500*	200	250	220
Power, watts			0.849	0.841	0.870
Collector cathode voltage (V_{CK} ± 3 percent)	566.5	601.5	570.9	567.8	580.8
PARD, millivolts		500*	110	150	120
Power, watts			11.52	11.39	11.91
Helix-cathode voltage (V_{HK} ± 3 percent)	1245.5	1322.5	1289.2	1282.6	1307.8
PARD, millivolts		500*	280	350	300
Total output power, watts			13.52	12.27	12.82

TABLE 6-14 (continued)

Test	Minimum	Maximum	77°F	100°F	0°F
Highline -34 volts dc					
Anode-helix voltage	261.[illegible]	278.1	273.	271.8	276.7
PARD, volts		2*	0.59	0.7	0.6
Power, watts			0.037	0.037	0.0382
Helix-collector voltage	679.0	721.0	718.4	714.9	727.4
PARD, millivolts		500*	200	250	220
Power, watts			0.849	0.841	0.871
Collector-cathode voltage	566.5	601.5	571.0	567.9	531.1
PARD, millivolts		500*	110	150	120
Power, watts			11.52	11.39	11.92
Helix-cathode voltage	1245.5	1322.5	1289.4	1282.8	1308.5
PARD, millivolts		500*	280	350	300
Total output power, watts			13.52	12.27	12.83
Filament inverter output power					
Lowline -26 volts dc					
Hot filament, watts					
1.0 per unit resistance (P_F ± 3 percent)	1.11	1 18	1.19	1.17	1.15
0.8 per unit resistance (P_F ± 3 percent)	1.11	1.18	1.10	1.14	0.625
Cold filament, milliamperes		400	245	250	220
Variable load (P_F ± 3 percent), watts	1.11	1.18	1.19	1.17	1.15
Highline -34 volts dc					
Hot filament, watts					
1.0 per unit resistance	1.11	1.18	1.19	1.17	1.15
0.8 per unit resistance	1.11	1.18	1.10	1.14	0.825
Cold filament, milliamperes		400	245	250	220
Variable load (P_F ± 3 percent), watts	1.11	1.18	1.19	1.17	1.15
Power supply efficiency					
Lowline -26 volts dc	70 percent		77.5	71.1	73.6
Highline -34 volts dc	50 percent		59.3	54.2	56.1

*Peak-to-peak

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7. FREQUENCY TRANSLATION UNITS

FREQUENCY TRANSLATION DUAL FILTER HYBRID (FS222)

Discussion of Test

The dual filter with symmetrical power split hybrid allows the desired harmonic of the master oscillator to supply power to the X2 and X3 multipliers while maintaining isolation between the two outputs to avoid feedback. The units were tested for VSWR, insertion loss, power split, hybrid directivity, and 80 mc bandwidth attenuation and isolation.

Performance of Units

The five units received from Rantec Corp. met the revised preliminary test specifications as shown in Table 7-1.

Average insertion loss was 1 db. The maximum output to output power ratio showing uneven power split was 0. 6 db. The minimum 80 mc bandwidth attenuation was 47 db. The 80 mc bandwidth isolation between outputs was greater than 90 db in all units.

Average weight was 5. 66 ounces. No thermal tests were made on the units. No changes are anticipated.

TABLE 7-1. PERFORMANCE TEST RESULTS - DUAL FILTER HYBRID (FS 222)

Serial Number	VSWR Terms A, B, D	Insertion Loss, A to B and A to D, db	Total Insertion Loss, db	Output to Output Ratio, db	Hybrid Directivity, db	Rejection Input to Output, db B D	Rejection Input to Output, db B D	Isolation between Outputs, db	Isolation between Outputs, db	Weight, ounces
	f_o	f_o	f_o	f_o	f_o	f_o -40	f_o +40	f_o -40	f_o +40	
Specification Value	1.20	-	1.25	1.0	20	40	40	90	90	8.5
0-1	A 1.15 B 1.09 D 1.07	A-B 4.4 A-D 3.8	1.1	0.6	23	B 49 D 48	B 48 D 48	> 90	> 90	5.65
0-2	A 1.12 B 1.07 D 1.05	A-B 4.2 A-D 3.8	1.0	0.4	30	B 49 D 48	B 48 D 48	> 90	> 90	5.68
1-1	A 1.07 B 1.07 D 1.04	A-B 4.1 A-D 3.8	0.9	0.3	30	B 49 D 48	B 50 D 47	> 90	> 90	5.62
1-2	A 1.14 B 1.06 D 1.05	A-B 4.3 A-D 3.8	1.0	0.5	31	B 48 D 48	B 48 D 48	> 90	> 90	5.68
1-3	A 1.17 B 1.05 D 1.03	A-B 4.3 A-D 3.7	1.0	0.6	27	B 49 D 48	B 49 D 48	> 90	> 90	5.68

4 KMC BANDPASS FILTER (FC 207)

Discussion of Test

In the multiple access transponder, the filter allows the desired harmonic of the master oscillator and its phase modulation sidebands to supply power to the traveling-wave tubes while attenuating other harmonics. The frequency translation transponder filter allows the desired sidebands of the high level mixer to supply power to the traveling-wave tube while attenuating the high level mixer local oscillator signal and image sidebands. The units were tested for VSWR, insertion loss, and attenuation 64 mc above center frequency.

Performance of Units

The eight units received from Rantec Corp. met the preliminary test specifications as shown in Table 7-2. Average insertion loss was about 0.5 db, with a maximum of 0.8 db. Average input VSWR was 1.07. The minimum center frequency plus 64 mc was 26 db.

Average weight was 2.69 ounces. No temperature tests were made. No changes are anticipated.

TABLE 7-2. PERFORMANCE TEST RESULTS - 4 KMC BANDPASS FILTER (FC 207)

Serial Number	VSWR			Insertion Loss, db			Rejection db	Weight, ounces
	f_o -12	f_o	f_o +12	f_o -12	f_o	f_o +12	f_o +64	
Specification value:	1. 20	1. 20	1. 20	1.0	1.0	1.0	25	3 0
0-1	1.08	1.06	1.08	0. 4	0. 4	0. 4	26. 3	2. 69
0-2	1.05	1. 11	1. 12	0. 4	0. 5	0. 3	27. 5	2. 69
0-3	1. 13	1.03	1.07	0. 7	0. 8	0. 5	26. 0	2. 69
0-4	1.07	1.03	1. 18	0. 5	0. 6	0. 5	26. 5	2. 69
1-1	1. 11	1.07	1. 13	0. 5	0. 4	0. 4	27. 5	2. 69
1-2	1.08	1.09	1.07	0. 6	0. 5	0. 6	27. 5	2. 69
1-3	1.07	1.08	1. 13	0. 5	0. 4	0. 3	26. 7	2. 69
1-4	1. 15	1.06	1.06	0. 8	0. 6	0. 7	28. 2	2. 67

FREQUENCY TRANSLATION MASTER OSCILLATOR (475113)

Discussion of Test

The 16 mc crystal oscillator provides a 48 mc beacon signal and a 64 mc output for generation of the input mixer local oscillator signal and high level mixer local oscillator signal after multiplication. The units were tested for output power and frequency.

Performance of Units

The two units produced met modified preliminary test specifications as shown in Table 7-3. System tests showed that one of the units allowed beat modulation of the 64 mc output through the signal present at the beacon channel output due to the limiter connection. Investigation indicates that faulty internal finger stock connection is allowing unit output to output feed-through. This problem will be rectified on this and future units produced.

Initial problems in obtaining the required oscillator frequency have been traced to out-of-specification crystals. The reason will be investigated and new crystals ordered. The substitute crystals presently installed will be replaced and a low noise oscillator circuit incorporated for standardization. In addition, circuit changes to improve the X32 stability and power output change versus temperature may be incorporated.

The unit was tested for temperature and voltage as shown in Figure 7-1. Unit efficiency was about 30 percent.

TABLE 7-3. PERFORMANCE TEST RESULTS - FREQUENCY TRANSLATION MASTER OSCILLATOR (475113)

Test	Design Standards		Unit	
	Minimum	Maximum	101 Serial No. 2	102 Serial No. 1
65 mc output power, milliwatts	325	375	370	340
48 mc output power, milliwatts	4.5	5.5	5.2	5.3
Output frequency, megacycles	47.512328 48.214466 49.033899 49.736085	47.514232 48.216394 49.035861 49.737975	48.215862	49.035024
65 mc spurious response, decibels	-	-50	None	None
48 mc spurious response, decibels	-	-50	None	None
Input power, watts	-	1.46	1.175	1.18
Weight, ounces				5.85

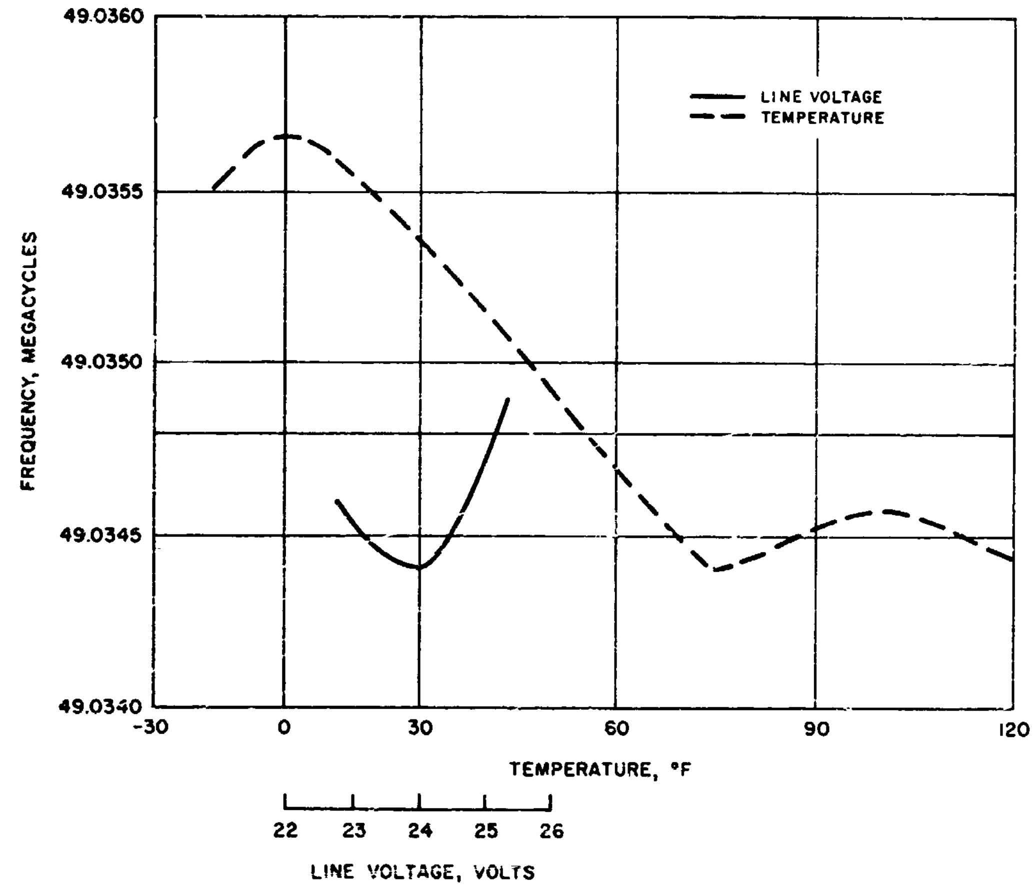

Figure 7-1. Master Oscillator Temperature and Voltage Test Results

FREQUENCY TRANSLATION PREAMPLIFIER (475110), INTERMEDIATE AMPLIFIER (475104), AND POSTAMPLIFIER (475111)

Discussion of Tests

The IF amplifier chain determines frequency translation system bandwidth and about 90 db of signal gain. The units were individually tested for gain, gain variation over a 25 mc passband, and noise figure (preamplifier only). In addition, the IF chain was tested.

Performance of Units

The two sets of units met the preliminary test specifications as shown in Tables 7-4, 7-5, and 7-6 and the curves of Figure 7-2. One preamplifier has a different type of transistor in the input stage, resulting in a 0.6 db improvement for a noise figure of 3.3 db. The gain of all amplifiers is about 30 db.

No circuit changes are contemplated. Preamplifier input matching may be investigated for a small improvement in noise figure.

TABLE 7-4. PERFORMANCE TEST RESULTS - IF PREAMPLIFIER (475110)

Test	Design Standard		Unit	
	Minimum	Maximum	101 Serial No. 1	102 Serial No. 2
Gain, decibels	27	33	31	30.5
Gain variation over 25 mc passband at ambient temperature, decibels		1.0	0.5	0.5
Noise figure, decibels		4.5	3.3	3.9
Input power, milliwatts		200	168	168
Weight, ounces			2.58	2.7

TABLE 7-5. PERFORMANCE TEST RESULTS - IF AMPLIFIER (475104)

Test	Design Standard		Unit	
	Minimum	Maximum	101 Serial No. 1	102 Serial No. 2
Gain, decibels	27	33	30.0	30.5
Gain variation over 25 mc passband at ambient temperature, decibels		1.0	0.5	0.5
Input power, milliwatts		200	168	170
Weight, ounces			2.45	2.45

TABLE 7-6. PERFORMANCE TEST RESULTS - IF POSTAMPLIFIER (475111)

Test	Design Standard		Unit	
	Minimum	Maximum	101 Serial No. 1	102 Serial No. 2
Gain, decibels	27	33	30	30
Gain variation over 25 mc passband at ambient temperature, decibels		1.0	0.7	0.7
Input power, milliwatts		250	208	204
Weight, ounces			2.19	2.2

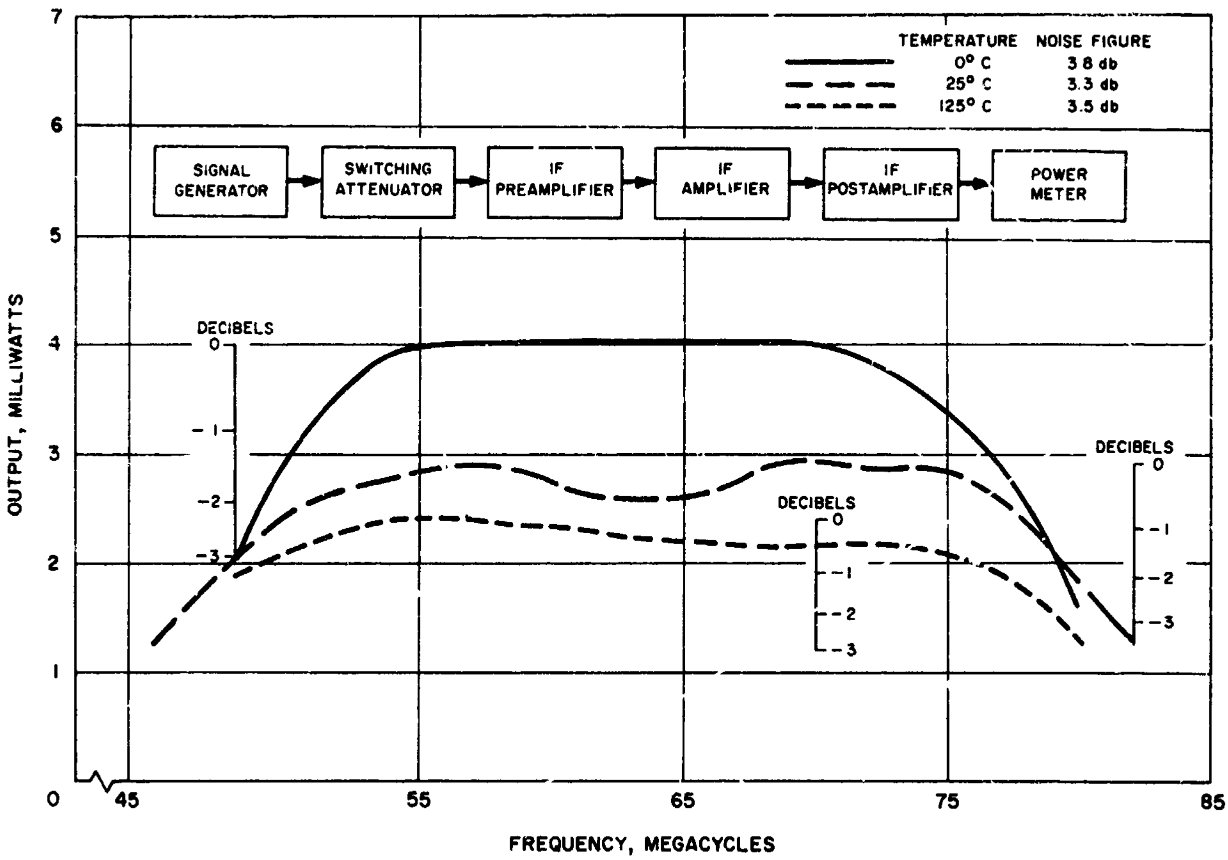

Figure 7-2. IF Amplifier Chain Group Test

Signal-to-noise ratio = 1
Input signal = -86 dbm

FREQUENCY TRANSLATION LIMITER (475109)

Discussion of Test

The limiter provides a limited amplitude 64 mc signal to the high level mixer by symmetrical clipping of the input signal waveform. The unit was tested for output variation over the passband, limiting threshold, and monitor voltage using a high level mixer as a load and viewing the signal at the beacon port with a spectrum analyzer. The input impedance of the high level mixer is highly reactive and not a constant over the passband, which should be considered when evaluating the test results. The unit was aligned using the high level mixer 4 kmc output.

Performance of Units

The two units produced met the preliminary test specifications except for output variation over the passband. Pending completion of system tests, it would appear that the specification should be changed. Test data is shown in Table 7-7.

Unit weight was 2.67 ounces. No temperature tests were made on the final circuit configuration.

Circuit changes simplifying dc supply decoupling will be incorporated to improve transistor bypassing and to decrease component density facilitating toroid coil adjustment since no tuning capacitors are provided in the circuit.

System tests show the present signal level monitor circuit to be inadequate because the output voltage changes only a few tenths of a volt between normal signal and no signal with the present 18 db limiting threshold. The limiter is operating on noise with no signal present in the existing design. The high level mixer is also operating as a limiter since it adds 5 db to the limiting threshold as shown in the high level mixer discussion.

TABLE 7-7. PERFORMANCE TEST RESULTS - IF LIMITER (475109)

Test	Design Standard		Unit Serial No.	
	Minimum	Maximum	1	2
Output variation over passband, decibels		2.0	2.2	2.2
Limiting action (attenuation required to produce 3 db decrease in output), decibels	10.0		18.0	19.0
DC monitor voltage, volts	-4.5	-3.5	-4.04	-4.03
Input power, milliwatts		547	451	444

FREQUENCY TRANSLATION HIGH LEVEL MIXER (475112)

Discussion of Test

The high level mixer converts 64 mc IF signals to 4 kmc by mixing and filtering. The mixer uses a 4 kmc hybrid and two varactor diodes.

The units were tested for output power from the single sideband filter with 8 milliwatts 4 kmc input and 65 mw IF input to the high level mixer. This test is an initial performance test and excludes the frequency translation limiter unit. It is readjusted during the frequency translation transmitter group test.

Performance of Unit

The two units produced met the preliminary test specification as shown in Table 7-8.

Unit weight was 4.9 ounces.

The high level mixer was not thermally tested. The bandpass characteristics of the high level mixer are shown in Figure 7-3.

The mixer detuned during vibration. Cause was skewing of the shorting bars used for tuning. The units will be modified by adding threads to the tuning screw, allowing full engagement with the shorting bar and probably spring-loading the combination. In addition, the overall length of the high level mixer will be decreased approximately 1-1/2 inches by reducing the tuning screw length. Two new units are being modified at present.

TABLE 7-8. PERFORMANCE TEST RESULTS - HIGH LEVEL MIXER (475112)

Test	Design Standard		Unit	
	Minimum	Maximum	101 Serial No 1	102 Serial No. 2
Output power (measured through isolator and filter), milliwatts	1.4		1.47	1.67
Output variation over passband, decibels		2.0	0.5	1.0
Weight, ounces			4.9	4.9
Tested with following units:				
Isolators 475126-100			4 and 5	2 and 6
Rantec filter			207-0 No. 1	207-1 No. 1

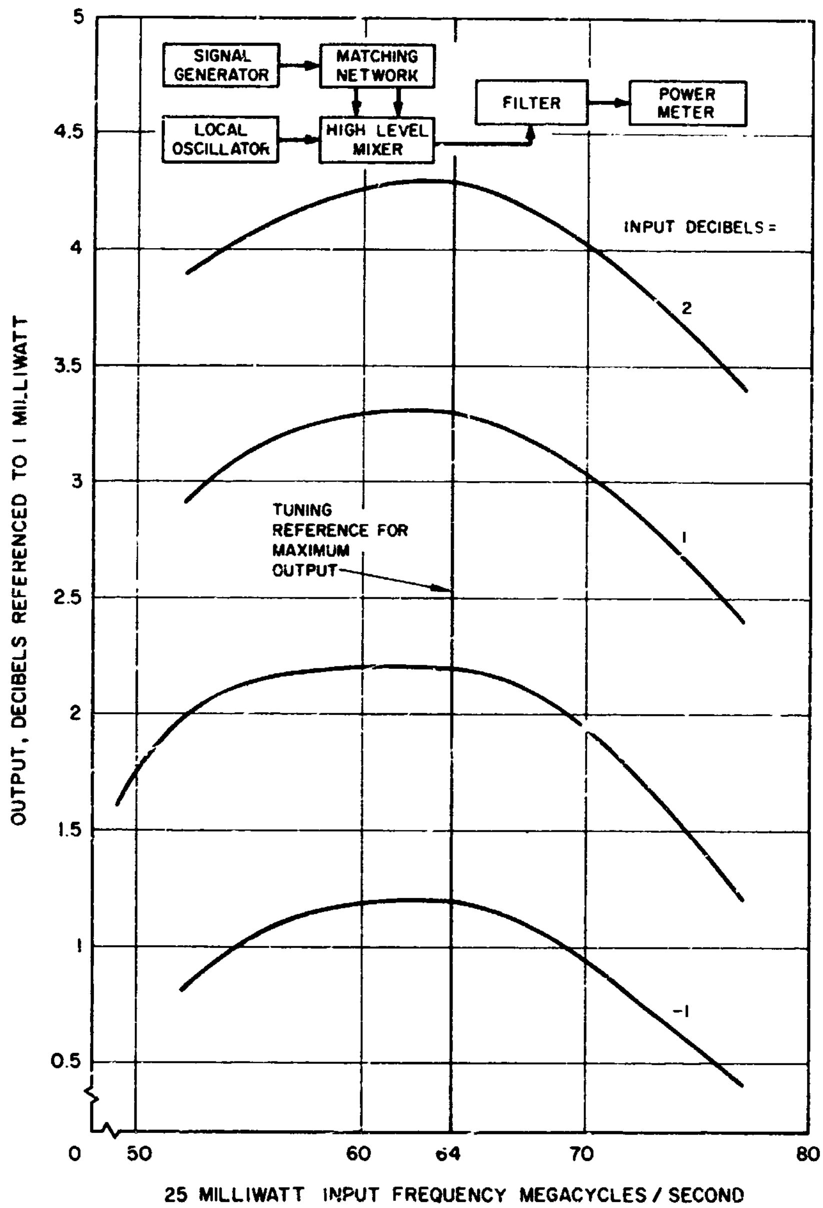

Figure 7-3. High Level Mixer Bandpass Characteristics

9.3 mw at 4184 mc

FREQUENCY TRANSLATION TRANSMITTING GROUP

Discussion of Test

The frequency translation transmitting group consists of the limiter, high level mixer, single sideband filter, and two 4 kmc isolators.

It was tested for output power, output power variation over the passband, beacon output, and limiting threshold with 9.3 mw RF input and +3 dbm IF input. The beacon attenuator was selected at this time and local oscillator leakage measured.

Performance of Units

The two groups tested met revised preliminary test specifications as shown in Table 7-9.

Overall conversion loss was about 8.1 db. Beacon power was set for 20 db below the carrier with a normal signal. Limiting threshold averaged 23 db below normal IF signal input.

Output variation over the passband was 0.45 db on the first limiter foamed. Refinement of the adjustment technique provided essentially zero output variation over the passband on the second limiter foamed with normal input levels.

Output power as a function of frequency with various input levels is shown in Figure 7-4.

Changes are discussed for the individual units.

TABLE 7-9. PERFORMANCE TEST RESULTS - FREQUENCY TRANSLATION TRANSMITING GROUP (475025-605)

Test	Design Standard		Groups of Units	
			Channel 2	Channel 3
	Mini- mum	Maxi- mum	475109-101 #2 475112-101 #1 475126-100 #5 475126-100 #4 FC 207-0 #1	475109-102 #1 475112-102 #2 475126-100 #2 475126-100 #6 FC 207-1 #1
Output power, milliwatts	1.35		1.38	1.50
Output variation over passband, decibels		1.0	0.0	0.45
Beacon power (with respect to carrier), decibels	-23	-17	-20	-20
Spurious response, decibels		-40	<-40	<-40
Local oscillator leakage, decibels		-30	<-30	<-30
Limiting threshold (amount of input attenuation to obtain 3 db output decrease, decibels	10		23.5	22.5
Test frequencies Local oscillator IF Beacon Beacon attenuator			 4114 mc 63.3 48.2 7.0 db	 4184 mc 64.4 mc 49.0 mc 7.0

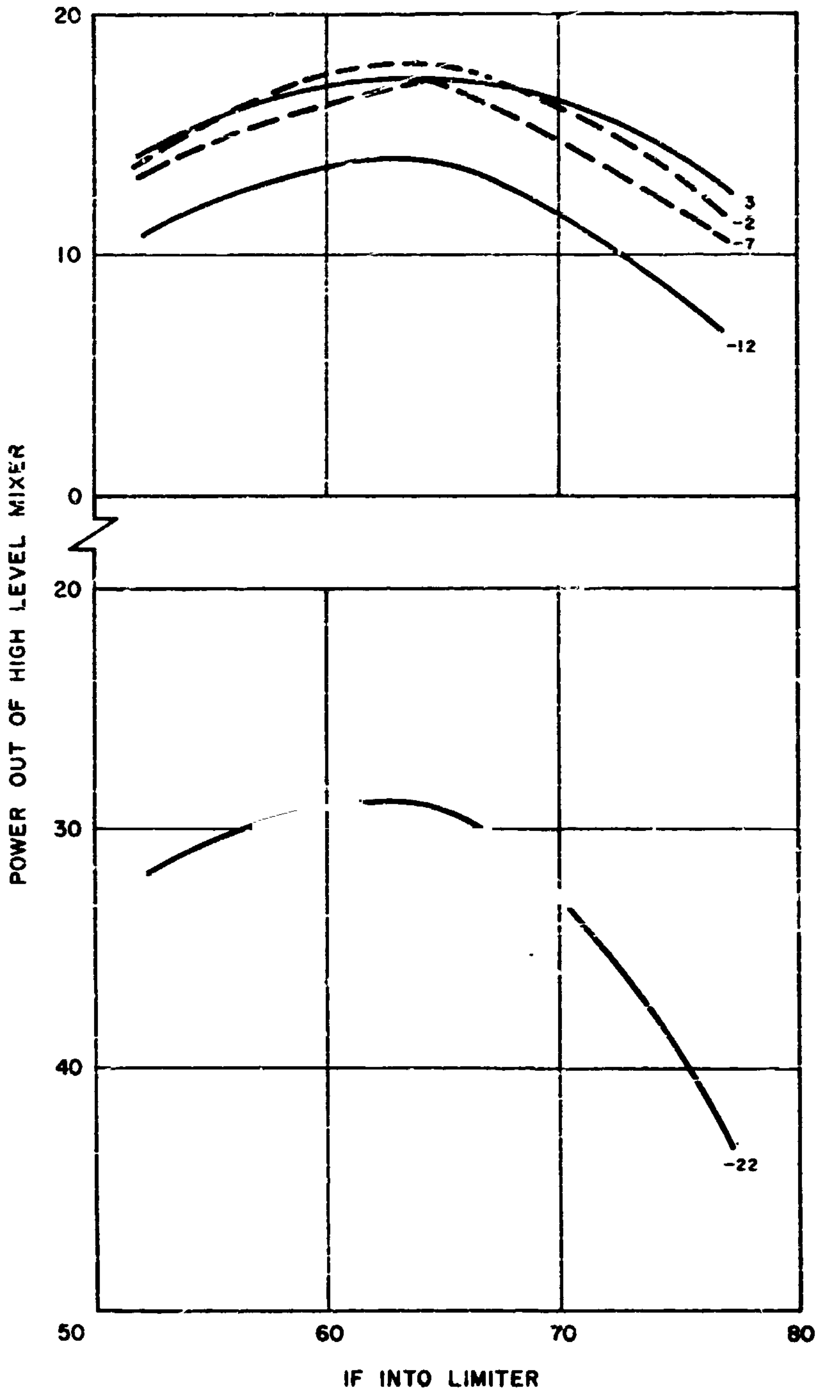

Figure 7-4 Transmitting Group Frequency Characteristics

FREQUENCY TRANSLATION MODE REGULATOR (475102)

Discussion of Test

The frequency translation mode regulator is a series regulator supplying -24 volts from the -31 ±5 volt unregulated bus. The output voltage tolerance is ±3 percent for load, line, temperature, and initial adjustment. Full load is 110 milliamperes. For testing convenience, full load has been defined in the test specification as a 200 ohm resistor. The regulator may be turned on and off by command.

The unit was tested for load, line, and temperature regulation.

Performance of Unit

The two units tested have met or exceeded all of the test specifications. The results of these tests are listed in Table 7-10.

The requirement to supply a one ampere pulse for 10 milliseconds to the ferrite switch has resulted in very good load and line regulation of the units. A Darlington connection was utilized as the control element of the series regulator in order to handle the current load. The extra loop gain resulting from this additional transistor stage substantially improved the load and line regulation.

The temperature regulation requirements of the 102 unit are not severe. For this reason, an uncompensated zener reference was chosen. Test data indicates that a 2 percent change in output voltage may occur for a temperature change between 0 and 100°F. There is insufficient data to establish whether this approaches a worst case condition or not. A zener diode was chosen whose typical positive temperature coefficient cancelled the effect of the first stage transistor emitter-base junction typical negative temperature coefficient. This constitutes a simple form of temperature compensation. It has the advantage of simplicity over the 101 unit reference and comparison circuit. The disadvantage of the 102 unit circuit is the uncertainty in zener diode and transistor temperature coefficients. These quantities are not specification controlled at this time, and the manufacturers have been reluctant to accept such a requirement. If an unfavorable tolerance accumulation in an individual unit should cause excessive voltage variation with temperature, it will be necessary to change the zener diode and/or first stage transistor to obtain a more favorable combination.

Except for the temperature compensation feature discussed above, the 101 and 102 units are identical. All comments in the 101 unit discussion relative to the ferrite switch drive and the voltage and current loop stability are equally applicable to the 102 unit.

TABLE 7-10. PERFORMANCE TEST RESULTS - FREQUENCY TRANSLATION MODE REGULATOR (475102)

$E_{in} = -26$ $R_L = 200$

Test	Design Standard		+75°F		+30°F		+120°F	
	Minimum	Maximum	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2
Load regulation, volts dc	23.3	24.7	24.002	24.000	24.214	24.058	23.788	23.895
Line regulation, volts dc	23.3	24.7	24.004	24.001	24.216	24.059	23.790	23.895
Overcurrent limit, milliamperes	150	300	177	181	180	194	170	175
Ferrite switch driver								
Pulse amplitude, volts	22		22.1	23	22.2	23.8	22.2	23.8
Pulse width, milliseconds	5	100	15	18	14	17	15	18
PARD, millivolts peak-to-peak		50	8	5	5	2	9	6

8. MULTIPLE ACCESS UNITS

MULTIPLE ACCESS 2 KMC 6MC BANDPASS FILTER (FS 218)

Discussion of Test

The filter allows the desired harmonic of the master oscillator to supply power to the X3 multiplier while attenuating other harmonics. The units were tested for insertion loss, VSWR, and 132 mc bandwidth attenuation.

Performance of Units

The seven units received from Rantec Corp. met the preliminary test specifications as shown in Table 8-1. Average insertion loss was 0. 8 db. Average VSWR was about 1. 08 with a maximum of 1. 11. The minimum 132 mc bandwidth attenuation was 54 db.

Average weight was 2. 39 ounces. No temperature tests were made. No unit changes are expected.

TABLE 8-1. PERFORMANCE TEST RESULTS – 2 KMC 6MC BANDPASS FILTER (FS 218)

Serial Number	VSWR			Insertion Loss, db			Rejection, db		Weight, ounces
	f_o-3	f_o	f_o+3	f_o-3	f_o	f_o+3	f_o-66	f_o+66	
Specification Value	1.20	1.20	1.20	1.25	1.25	1.25	50 (min)	50 (min)	2.5
1-1	1.05	1.10	1.07	0.8	0.8	0.8	57	57	2.37
1-2	1.11	1.11	1.13	0.8	0.8	0.9	57	58	2.37
1-3	1.11	1.09	1.06	0.9	0.9	1.0	58	59	2.37
1-4	1.06	1.02	1.09	0.9	0.8	1.0	59	59	2.43
2-1	1.09	1.04	1.07	0.8	0.8	0.8	56	58	2.37
2-2	1.12	1.10	1.06	0.9	0.8	0.9	57	60	2.39
2-3	1.11	1.06	1.02	0.8	0.7	0.7	54	58	2.39

MULTIPLE ACCESS 2 KMC 16MC BANDPASS FILTER (FS 217)

Discussion of Test

The filter allows the desired harmonic of the master oscillator and its phase modulation sidebands to supply power to the X2 multiplier while attenuating other harmonics. The units were tested for insertion loss, VSWR, and 110 mc bandwidth attenuation.

Performance of Units

The seven units received from Rantec Corp. met the preliminary test specifications as shown in Table 8-2. Average insertion loss was about 0.43 db. Average input VSWR was about 1.06 with a maximum of 1.09. The minimum 110 mc bandwidth attenuation was 32 db.

Average weight was 2.33 ounces. No temperature tests were made. No unit changes are contemplated at this time.

TABLE 8-2. PERFORMANCE TEST RESULTS
2 KMC 16MC BANDPASS FILTER (FS 217)

Serial Number	VSWR			Insertion Loss, db			Rejection, db		Weight, ounces
	f_o-8	f_o	f_o+8	f_o-8	f_o	f_o+8	f_o-55	f_o+55	
Specification Value	1.20	1.20	1.20	0.75	0.75	0.75	25 (min)	25 (min)	2.5
1-1	1.06	1.07	1.15	0.5	0.4	0.5	32	34	2.30
1-2	1.13	1.09	1.06	0.6	0.5	0.5	32	34	2.33
1-3	1.17	1.04	1.09	0.5	0.4	0.5	34	33	2.37
2-1	1.08	1.06	1.25	0.5	0.4	0.6	32.5	33.5	2.30
2-2	1.12	1.05	1.13	0.4	0.4	0.5	32.7	33.8	2.33
3-1	1.11	1.09	1.14	0.5	0.5	0.5	34	33	2.36
4-1	1.05	1.04	1.18	0.4	0.4	0.4	32	33	2.34

MULTIPLE ACCESS MASTER OSCILLATOR (475122)

Discussion of Test

The oscillator provides a 32 mc crystal-controlled signal for generation of the input mixer local oscillator signal and the phase-modulated transmitter signal. The units were tested for output power and frequency.

Performance of Units

The two units produced met the preliminary test specifications as shown in Table 8-3.

System tests indicate that the original oscillator circuit produces noise sidebands about 300 kc wide and peaked 30 db below the carrier at the 6 kmc multiplier chain output. Revision of the oscillator circuit to reduce the effect of feedback paths other than the series resonant crystal has decreased the noise sideband level. The new oscillator circuit will be incorporated in the transponder oscillators.

Initial problems in obtaining the required oscillator frequency have been traced to out-of-specification crystals. New crystals will be ordered.

The unit was tested for temperature and voltage variation as shown in Figure 8-1. Foamed unit weight is about 28 ounces.

Vibration tests showed stiffener plates are required under the captive nuts fastening the unit to the quadrant frame. Vibration caused the metal to fatigue, allowing the unit to break loose near the end of the vibration period. The foam was cracked but did not allow the inner stainless steel block to become loose.

TABLE 8-3. PERFORMANCE TEST RESULTS—
MULTIPLE ACCESS MASTER OSCILLATOR (475122)

Test	Design Standard		Unit Serial Number	
	Minimum	Maximum	102 Serial No. 1	101 Serial No. 2
Output power, milliwatts	6.3	7.7	7.0	7.2
Output frequency, megacycles				
475122-100	31.18752	31.188828		
475122-101	31.648567	31.649733		31.649369
475122-102	32.186363	32.187637	32.186596	
475122-103	32.647247	32.648553		
Spurious response, decibels		-50	None	None
Input power, milliwatts		94	89	83
Weight, ounces			27.65	

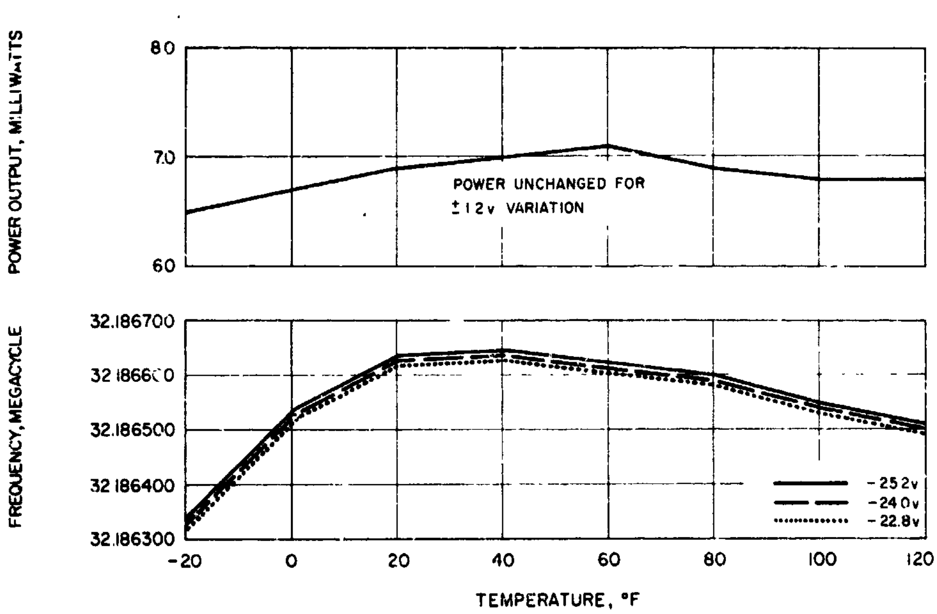

Figure 8-1. Multiple Access Master Oscillator
Temperature and Voltage Characteristics

MULTIPLE ACCESS MASTER OSCILLATOR AMPLIFIER (475123)

Discussion of Test

The master oscillator amplifier receives a 32 mc signal from the master oscillator and provides a 32 mc output to the phase modulator and a 64 mc output to the local oscillator X32 multiplier. Both units produced were adjusted and tested for proper output RF levels.

Performance of Units

As shown in Table 8-4, the units met the preliminary test specifications. The unit power efficiency is about 15 percent. The units were temperature and input voltage tested as shown in Figure 8-2.

Circuit improvement to increase efficiency and improve output power stability with temperature change is desirable.

TABLE 8-1. PERFORMANCE TEST RESULTS—
MULTIPLE ACCESS MASTER OSCILLATOR AMPLIFIER (475123)

Test	Design Standard		Unit	
	Minimum	Maximum	475123-101 Serial No. 2	475123-102 Serial No. 1
32 mc output power, milliwatts	0.45	0.55	0.49	0.45
64 mc output power, milliwatts	119	147	130	125
64 mc spurious response, decibels	-	-50	None	None
Input power, milliwatts		1074	865	815
Weight, ounces				2.53

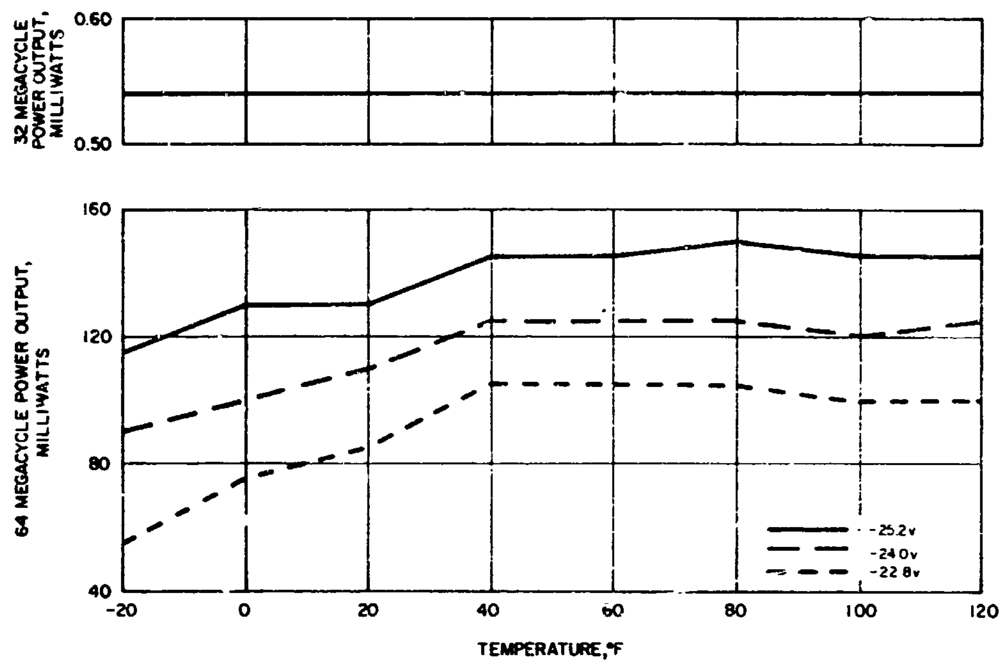

Figure 8-2. Multiple Access Master Oscillator Amplifier Temperature and Voltage Characteristics

MULTIPLE ACCESS DOUBLER AMPLIFIER (475132)

Discussion of Tests

The doubler amplifier supplies drive to the wideband X32. Its input is a 32 mc low index phase-modulated signal.

The two units were tested for output power, modulation index, and modulation index variation over the passband as measured with the phase modulator unit.

Performance of Units

The units produced met the modified preliminary specifications except for modulation index variation over the passband as shown in Table 8-5.

Unit efficiency was about 11 percent. The curves of Figures 8-3 and 8-4 show unit performance as a function of temperature and input voltage.

Examination of the test results indicate that the first sideband-carrier ratio increases by greater than 6 db, as expected, due to doubling. Detection and remodulation is one probable cause. In addition, the extremely steep passband skirts may introduce nonlinear phase shift. The passband is not as flat as is desirable. Circuit and test procedure revision is probably necessary in conjunction with the wideband X32 multiplier.

TABLE 8-5. PERFORMANCE TEST RESULTS—
MULTIPLE ACCESS DOUBLER AMPLIFIER (475132)

Test	Minimum	Maximum	Unit	
			101 Serial No. 2	102 Serial No. 1
Output power, millivolts	90	110	110	105
Modulation index, decibels				
At 34.5 mc	-34	-29	-29	--
At 35.1 mc	-34	-29	--	--
Output bandwidth variation, decibels				
32.1 to 36.9 mc		1.0	1.0	--
32.7 to 37.5 mc		1.0	--	2.0
Input power, milliwatts		1200	935	1005
Weight, ounces			--	2.66

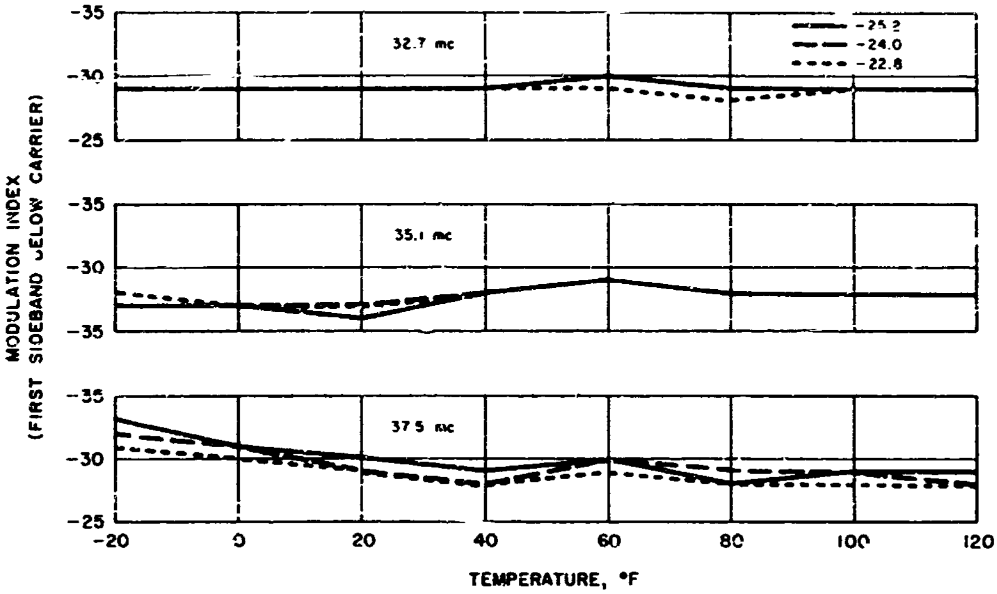

Figure 8-3. Multiple Access Doubler Amplifier Modulation Characteristics

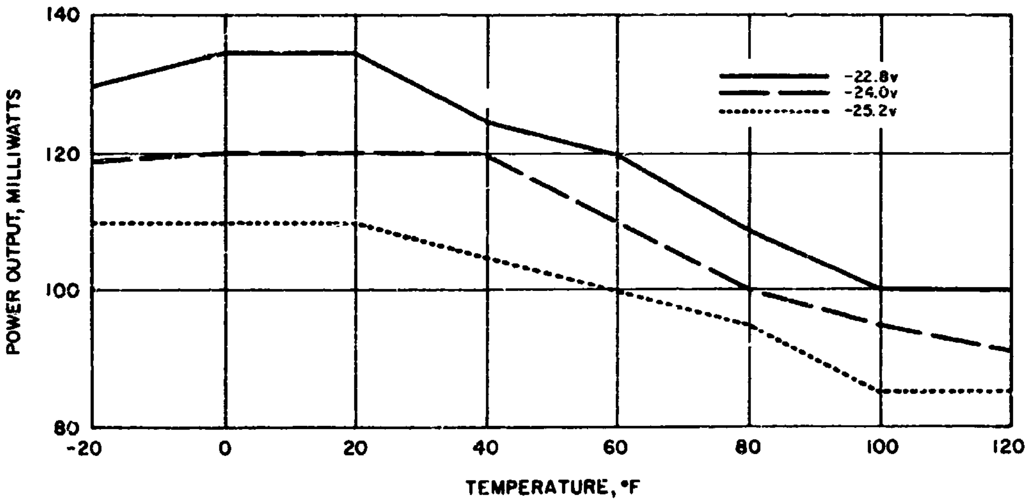

Figure 8-4. Multiple Access Doubler Amplifier Voltage and Temperature Characteristics

MULTIPLE ACCESS PHASE MODULATION (475131)

Discussion of Test

The phase modulator converts single sideband modulated signals to a phase-modulated output. The units were tested for output power, output modulation index, and output modulation index variation over the passband.

Performance of Units

The two units produced met the preliminary test specifications. Temperature and voltage tests were made and are shown in the curves of Figure 8-5. Unit weight was 4.75 ounces.

Effort will be made to reduce dc power consumption. Over 1/2 watt is presently required for a 2 milliwatt output. System tests indicate spurious noise. Sidebands are being generated in the multiple access transmitter chain producing a 25 mc nonflat noise spectrum on each side of the carrier at the 4 kmc output, independent of IF noise. Their exact cause and method of elimination will be investigated.

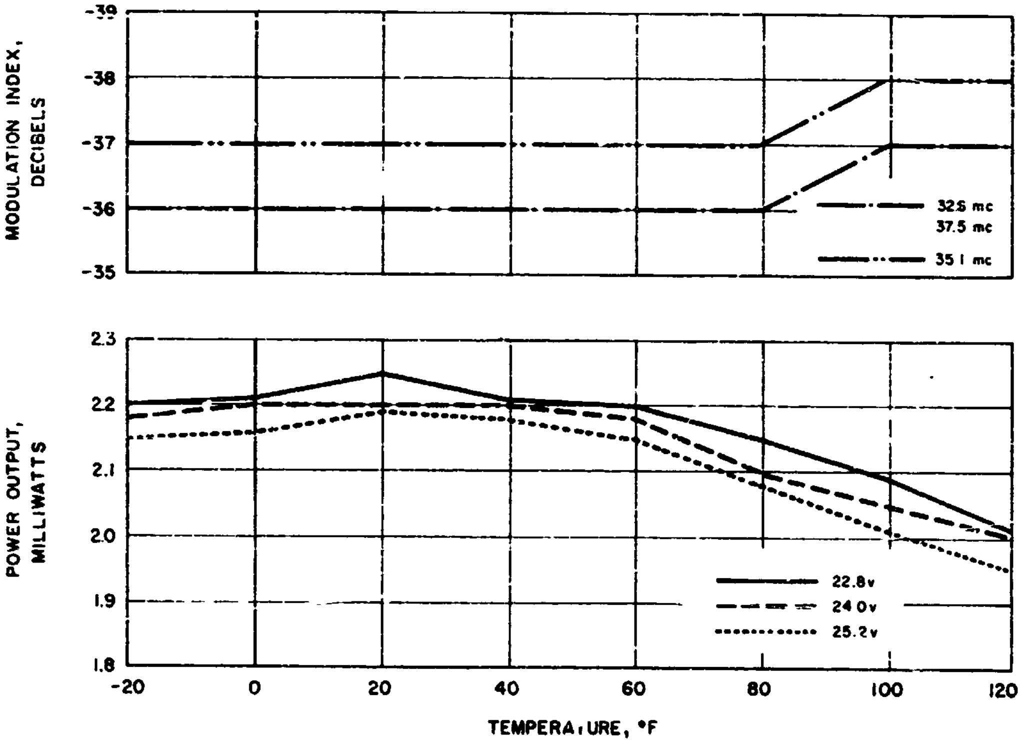

Figure 8-5. Multiple Access Phase Modulator Temperature and Voltage Characteristics

MULTIPLE ACCESS PREAMPLIFIER (475130)

Discussion of Tests

The multiple access preamplifier provides IF gain in the multiple access mode. Both units produced were tested for gain, noise figure, passband flatness, and bandwidth.

Performance of Units

As shown in Table 8-6, the units produced met modified preliminary test specifications. Gain variation over the 4.8 mc passband was 0.5 db. The 3 db bandwidth was about 6.55 mc. Gain was about 37 db. Noise figure was about 3.3 db.

The unit curves of Figure 8-6 show the effect of supply voltage and temperature variation on gain. No changes are contemplated at this time. Input matching may be investigated for a slight improvement in noise figure.

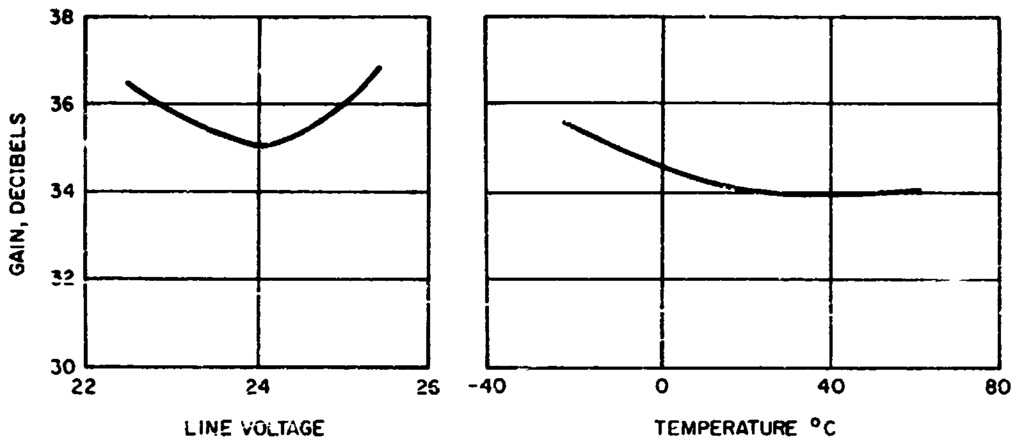

Figure 8-6. Multiple Access Preamplifier Voltage and Temperature Characteristics

TABLE 8-6. PERFORMANCE TEST RESULTS–
MULTIPLE ACCESS PREAMPLIER (475130)

Test	Design Standards		Unit Serial Numbers	
	Minimum	Maximum	1	2
Bandpass				
Signal variation over passband, decibels		1.0	0.5	0.5
Half power points of passband, mc				
475130-100, Low frequency	30.7	--		
High frequency	--	37.5		
475130-101, Low frequency	31.1	--		31.3
High frequency	--	37.9		37.8
475130-102, Low frequency	31.7	--	31.8	
High frequency	--	38.5	38.4	
475130-103, Low frequency	32.1	--		
High frequency	--	38.9		
Stability, decibels				
Bias at -3 volts d-c		3.0	0.5	0.7
Bias at -5 volts d-c		3.0	1.5	1.8
Gain, decibels	33	39	37.5	36.5
Noise figure, decibels		4.5	3.4	3.3
Input power, milliwatts		100	79.68	78.96

MULTIPLE ACCESS IF FILTER AMPLIFIER (475141)

Discussion of Tests

The IF filter amplifier provides gain and rejection filtering allowing only IF signals greater in frequency than the master oscillator carrier to phase modulate the carrier. Both units produced were tested for gain, gain variation over the 4.8 mc passband, and rejection filtering.

Performance of Units

The units passed the modified preliminary test specifications as shown in Table 8-7. Gain was about 13.3 db, and gain variation was 0.5 db. Minimum rejection over the rejection band was 16 db.

No circuit changes are expected to be required. The curves of Figure 8-7 show the measured gain variation with changes in -4 and -24 volt supplies.

TABLE 8-7. PERFORMANCE TEST SUMMARY— IF FILTER AMPLIFIER (475141)

Test	Design Standards		Unit Serial Numbers	
	Minimum	Maximum	1	2
Bandpass				
Signal variation over passband, decibels		1.0	0.5	0.5
Rejection, decibels				
Signal attenuation at low end of passband minus 1 mc				
475141-100 at 30.7 mc	15			
475141-101 at 31.1 mc	15			20.1
475141-102 at 31.7 mc	15		23.7	
475141-103 at 32.1 mc	15			
Minimum rejection over reject range, decibels	15		16.0	16.0
Gain, decibels	11.0	17.0	13.0	13.6
Input power, milliwatts		100	64.3	67.2

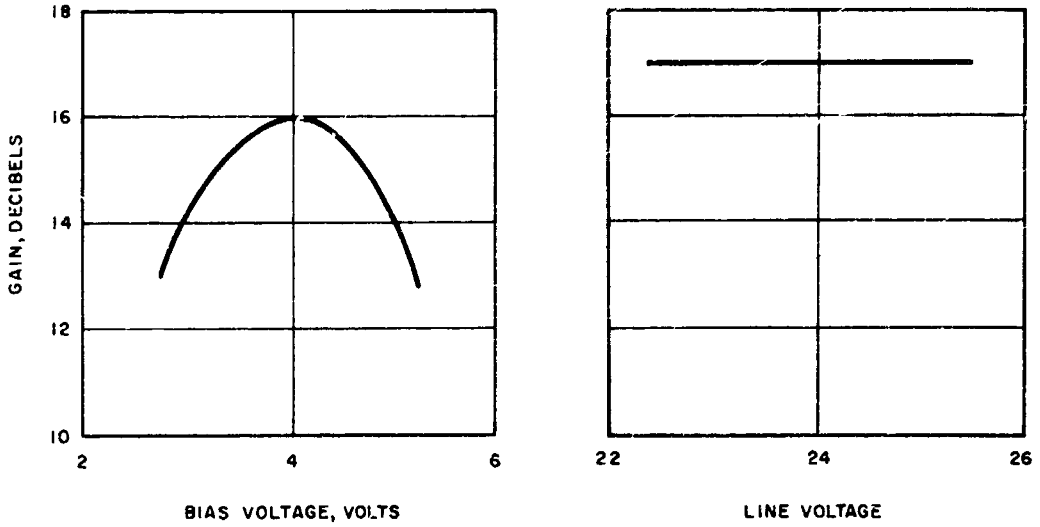

Figure 8-7. Multiple Access Filter Amplifier Line and Bias Voltage Characteristics

MULTIPLE ACCESS MODE REGULATOR (475101)

Discussion of Test

The multiple access mode regulator is a series regulator supplying -24 volts from the -31±5 volt unregulated bus. The output voltage tolerance is ±2 percent for load, line, temperature, and initial adjustment. Full load is 126 milliamperes. For testing convenience, full load has been defined in the test specification as a 200 ohm resistor. The regulator may be turned on and off by command.

The unit was tested for load, line, and temperature regulation.

Performance of Unit

The two units tested have met or exceeded all of the test specifications. The results of these tests are listed in Table 8-8.

A Darlington connection was utilized as the control element of the series regulator in order to supply a 1-ampere pulse for 10 milliseconds to the ferrite switch. The extra loop gain resulting from this additional transistor stage substantially improved the load and line regulation.

The requirement of rate of change of voltage not to exceed 0.52 millivolt per second, during temperature change of the spacecraft due to an eclipse, has resulted in a temperature compensated zener reference which exceeds the temperature regulation requirements.

Additional Tests

In addition to the test plan specifications, tests were performed on:

1) Ferrite switch compatibility

2) Overcurrent limit loop stability

3) Regulated voltage loop stability

Test Results

Ferrite Switch Compatibility. A small subsystem was established, consisting of a multiple access mode regulator (101 unit), frequency translation mode regulator (102 unit), and the receiver ferrite switch (176 unit). The 101 and 102 unit control circuits were connected such that one regulator turned on when the other turned off. This energized one side or the other of the ferrite switch center tapped coil, resulting in the required switching operation. By rectifying the CW signal passed through the switch and viewing its waveform with a memoscope, satisfactory operation of the system was confirmed. The RF rise time was on the order of 4 milliseconds, and the voltage pulse to operate the switch had a 17 millisecond width, when measured between the 90 percent amplitude points. This indicates a safety factor of over 4:1 to allow for manufacturing tolerances. The ferrite switch driver output pulse has been described in terms of current amplitude and pulsewidth. However, the RF has been observed to start switching when the current reaches approximately 50 percent amplitude and complete switching before 80 percent amplitude is reached. The current waveshape is quite irregular during the switching operation. It would have a reasonably rectangular leading edge with a 1 millisecond risetime, except for the back-voltage generated by the coil during the reorientation of the ferrite magnetic domains. Because of this current irregularity, the ferrite switch driver output will be specified in terms of voltage amplitude and 90 percent amplitude pulsewidth.

It is anticipated that the receiver ferrite switch (176 unit) will be removed from the final transponder configuration. In this event, the 101 and 102 unit regulators will be simplified by removing the ferrite switch drivers and the Darlington control element. However, the transmitter ferrite switch (173 unit) operated by the traveling-wave tube power supply (174 unit) will probably be retained. From the standpoint of ferrite switch driver requirements, there is no significant difference between the receiver and transmitter ferrite switches. Therefore, the above results are equally applicable to the 174 unit ferrite switch drive.

Overcurrent Limit Loop Stability. An oscillatory condition has been observed at the crossover between regulated voltage loop control and overcurrent loop control. It has been determined that each loop is stable by itself, but instability occurs when the two systems battle for control. A lead network in the reference voltage divider and a 2:1 reduction of differential amplifier collector load resistance appear to have solved the problem. However, further analysis will be necessary to determine the stability margin of this multiloop system if the ferrite switches are retained. If the ferrite switches are not retained, a simplified overcurrent limit circuit will probably be substituted. This simplified circuit is a passive network, which should eliminate the stability problem.

Regulated Voltage Loop Stability. The regulated voltage loop stability has been verified by observing its transient response. A memoscope was used to view the voltage recovery transient for a step function change in load. When full load was abruptly applied, the voltage magnitude dropped 150 millivolts, and a well damped recovery occurred in less than 60 milliseconds. When full load was suddenly removed, the voltage magnitude rose 150 millivolts, and a well damped recovery occurred in less than 300 microseconds.

There is yet some work to be accomplished on the 101 unit design. A more thorough investigation of the regulator loop should be made to ensure sufficient stability margin for a worst case tolerance accumulation.

TABLE 8-8. MULTIPLE ACCESS MODE REGULATOR PERFORMANCE

Regulation	Conditions	Measured ΔV			
		Serial No. 1		Serial No. 2	
		Millivolts	Percent of 24	Millivolts	Percent of 24
Load	$200 < R < \infty$ ohms V_{in} = -26 volts T = +75°F	21	0.0875	18	0.07500
Line	R = 200 ohms $-36 < V_{in} < -26$ volts T = +75°F	3	0.0125	2	0.00833
Temperature	R = 200 ohms V_{in} = -26 volts $+30 < T < 120$°F	63	0.2625	2	0.00833
Total	$200 < R < \infty$ ohms $-36 < V_{in} < -26$ volts	87	0.3625	22	0.9167
Pard	$150 < R < \infty$ ohms $-36 < V_{in} < -26$ volts $+30 < T < +120$°F	10 mv peak-to-peak		10 mv peak-to-peak	
Voltage temperature coefficient, ppm/°F		+29.2		+0.925	

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9. PHASED ARRAY

DESCRIPTION

The phased array antenna system is composed of a power splitter which divides the transmitter output signal into eight equal amplitude, equal phase parts. The outputs from the splitter are applied to eight phase shifters, each consisting of eight input couplers, ferrite sections, and output couplers. The ferrite sections consist of a tube of ferrite in a circular waveguide inside a four-pole, two-phase electromagnetic field coil. The output couplers convert the RF output of the ferrite sections into two equal amplitude signals with different phase shifts and feed the signals to diametrically opposite antenna elements. Sixteen antenna elements are symmetrically arranged about the spin axis on a circle of one wavelength radius. All of the elements are continuously driven, but are individually phased by the phase shifters in such a way that the radiation tends to reinforce in a given direction.

EXISTING TEST DATA

The majority of measurements made on the phased array have been of the overall system, and relatively little data has been taken on the individual phase shifters and stripline circuits. The results of measurements on the overall phased array system are reported in SSD 31079R, "Phased Array Antenna System."

As the measured gain of the array was slightly lower than expected, more specific tests are now being run to evaluate various losses. The theory of the phase shifter operation is also being examined, as to the effect of phase errors.

CURRENT TESTS AND MEASUREMENTS

Tests have been conducted to measure the mutual coupling between elements of the array. Equal length cables were inserted between the stripline output coupler and the antennas, except for one in which a directional coupler was inserted, and the cable length reduced accordingly. The array can thus be operated normally, while forward and reflected amplitudes and phases can be measured. By measuring reflected power alone, the power lost due to mismatch and mutual coupling can be determined. The antennas were matched individually but were somewhat mismatched when inserted in the array. The reflection loss measured on Antenna No. 5 came to 0.8 db averaged over 32 beam positions. No. 11 came to 0.75 db, but when the latter was matched in the array, the reflection loss was reduced to 0.5 db. The relative phase of the reflected signal to the forward signal was also measured for the two conditions. As the forward power to an antenna does not necessarily stay constant with beam position (because of unbalances in the phase shifters), the apparent magnitude of reflection coefficient is subject to error. The phase, however, should be fairly accurate. The interesting thing about the data is that the relative phase of the mutually coupled signal with respect to the incident signal does not stay constant as some previous graphical analysis seemed to indicate. Thus, the proposed method of reducing the coupling by a matching technique in each antenna does not appear to be applicable.

The phase of the forward signal to Antenna No. 1 with respect to the input signal to the array was measured as a function of programmed beam direction. The difference between the measured phase shift and the theoretical phase shift was calculated and the results plotted in Figure 9-1. The vertical scale is plotted with respect to the average phase shift, that is the phase shift about which the errors average to zero. Note that phase error is always less than about 10 degrees. The phase shift to each of the 16 antenna terminals was also measured, with no current in the field coils. The resultant phase variations are plotted in Figure 9-2.

To repeat with current on would require taking data for a number of beam directions, and averaging the results to get the average phase shift for each. This will be done in the near future. The phase error from the average never exceeded 15 degrees.

The receiving antenna and its fiberglass structure were installed on top of the array, with the feed line passing up through the center of the array. A quick check showed that the receiving antenna and feed worked properly at 6200 mc. Measurements were then made of the power coupled to the receiving antenna when the array was excited at 4100 mc. When the array was operated omnidirectionally, the power at the bottom of the receiver feed was 45 db below the input power to the array. When a beam was formed the power dropped to 55 db below the input. Most of the coupling seemed to be due to the near field, since the motion of various objects near the antennas caused no change in the readings. When the receiving antenna was replaced with a load, there was no measurable coupled power. Magnetic fields in the vicinity of the phase shifter field windings were measured. Using a gaussmeter whose smallest scale division was 1 gauss, no field could be measured anywhere around the windings on the array. On an extra winding, the gaussmeter probe had to be inserted into the coil and close to the poles, where a reading of 100 gauss was obtained. Apparently the field is well contained inside the winding.

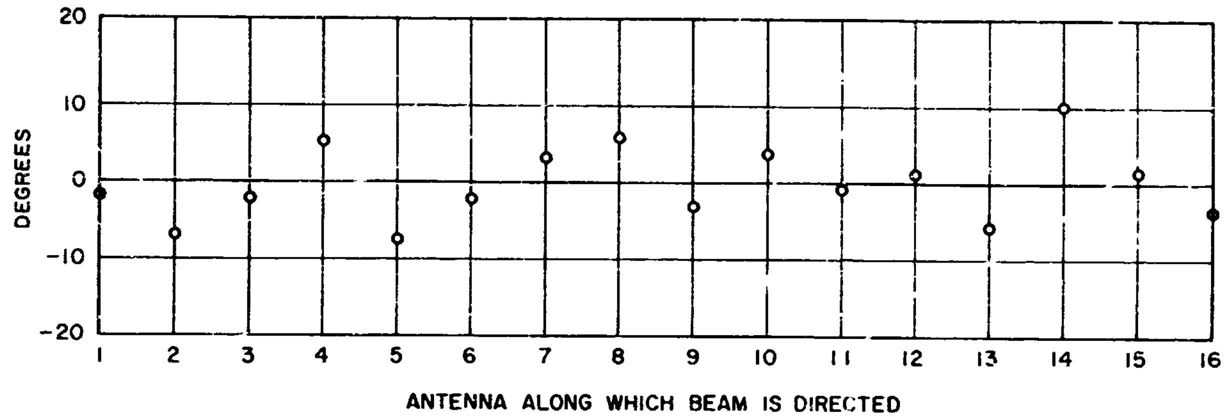

Figure 9-1. Phase Error versus B... Direction for Antenna

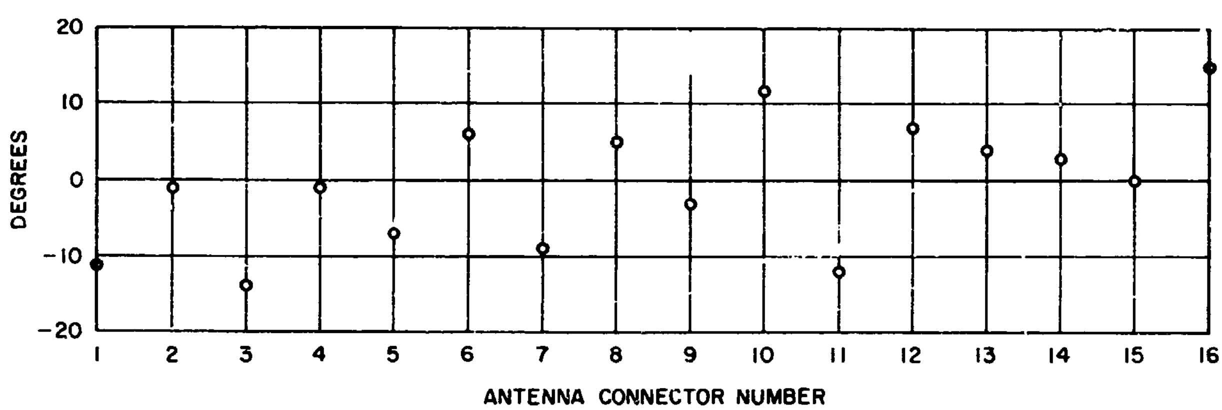

Figure 9-2. Relative Phase Shift Through Stripline and Phase Shifters

ERRATA

Advanced Syncom Summary Report, Volume 1

SSD 31118R

31 October 1963

Page 3-18, Table 3-10:

Title of second column from left should be followed by an asterisk: "Signal Sample Points*".

Page 3-20, Table 3-20:

In the fifth column, the entry for frequency translation mode under Power Level, dbm, should be 8.75, not 14.9.

Page 4-10, Equation 4-12:

Change unit vector i to $\bar{i}$.

Page 4-23, Figure 4-13:

The B's should be changed to betas.

Page 4-23, second column, Equation 4-48:

The first portion of the equation should be changed from

$$\frac{\Delta a}{\Delta d}$$

to

$$\frac{\Delta a}{2\Delta d}$$

Page 4-24, Equation 4-50:

The term within the last brackets should be changed from

$$\left[1 - e^{-\tau 4s}\right]$$

to

$$\left[1 - e^{-\tau_4 s}\right]$$

Page 5-5, Figure 5-2:

The numerical designations of the transponder traveling-wave tubes should be changed from 348H to 384H.

Page 5-11, first column, second paragraph:

In the second line, 2.47 watts should be changed to 4.10 watts; in the third line, 4.11 watts should be changed to 2.96 watts.

Page 5-20, Table 5-6:

Under voltages and currents (typical valves), the cathode voltage should be changed from 1290 to -1290.

Page 5-21, second column, second paragraph:

In the fifth and sixth lines, "mi" should be changed to "mc".

Page 5-44, Figure 5-55:

The top photograph is upside down, and should have the subtitle "a) Complete Unit"; the lower photograph should have the subtitle "b) Stripline Circuit".

Page 5-45, Figure 5-56:

The a) and b) subtitles should be reversed.

Page 5-60, Figure 5-79:

The function "A" Gate values should be changed from

$$\overline{8.9} + \overline{9.8}$$

to

$$8.\overline{9} + 9.\overline{8}\ .$$

The callout on Figure 5-79 should be changed from "Output Voltage of Second Analog-to-Digital Converter" to "Output Voltage of Second Digital-to-Analog Converter".

Page 5-62, first column:

Last portion of the equation should be changed from

$$\tan \frac{-1B}{A}$$

to

$$\tan^{-1} \frac{B}{A}$$

Page 5-86, Figure 5-105:

Title should be changed from "Transmitter Telemetry" to "Telemetry Transmitter".

Page 5-87:

In the first column, the value opposite "Carrier frequency" in the list of command receiver characteristics should be changed from 148 mc to 148.260 mc.

In the right column, last line, "standard" should be changed to "modified".

Page 5-106, Table 5-19:

Totals in extreme right-hand column should be changed from 107.0 and 117.5 to 1070 and 1175.

Page 5-107, Table 5-20:

Total in left-hand column should be changed from 832 to 834.

Page 5-107:

Just below Table 5-20, the following prefatory statement should be inserted:

> In the Advanced Syncom command system, the command execute tone is coherently transponded by the telemetry transmitter. It is desirable to impose discrete modulation levels on the transponded tone in order to identify the particular commands verified. This section investigates three systems which appear minimal relative to additional spacecraft complexity, coherent PSK, FSK, and AM modulation of the subcarrier tone.

Page 5-110, second column, first paragraph:

Figure 5-31 should be changed to Figure 5-131.

Page 5-147, Table 5-25:

In the column headed "Maximum Number of Units operating per Bus, the numbers 1, 2 should be changed to 1/2.

Page 5-148, Table 5-26:

The words "See Figure 5.7-3" should be changed to "See Figure 5-173".

Page 5-159, first column:

The first equation should be changed from

$$\left[\left(\frac{I_{so}}{I_s}\right)^2 - 1\right] = \Delta$$

to

$$\left[\left(\frac{I_{sco}}{I_{sc}}\right)^2 - 1\right] = \Delta$$

Page 5-217, Table 5-50:

Opposite the first entry in the first column, "Total impulse, pound-seconds, the number 37,100 should be inserted under the column headed "Initial Specification" and the number 30,600 under the column headed "Engineering Model" the numbers 33,300 and 30,600 opposite the second entry, "Thrust, pounds" should be deleted.

Page 8-15, Figure 8-8:

The designation "multipal access (SSB)" in the upper right portion of the diagram should be changed to "multiple access SSB".