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Radiofrequency Testing of Satellite Segment of Simulated 30/20-GHz Satellite Communications System

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SUMMARY

A laboratory communications system has been developed that can serve as a test bed for the evaluation of advanced microwave (30/20 GHz) components produced under NASA technology programs. The system will ultimately permit the transmission of a stream of high-rate (220 Mbps) digital data from the originating user, through a ground terminal, through a hardware-simulated satellite, to a receiving ground station, to the receiving user. This report contains the results of radiofrequency testing of the satellite portion of that system. Data presented include output spurious responses, attainable signal-to-noise ratios, a baseline power budget, usable frequency bands, phase and amplitude response data for each of the frequency bands, and the effects of power level variation.

INTRODUCTION

Six years ago the NASA Lewis Research Center began a major program to develop communications technology. This program has resulted in the design and fabrication of numerous communications system components critical to the implementation of advanced satellite communications systems in the 1990's. None of these components, however, was tested in a full-system environment during its development. Consequently Lewis is developing a facility to provide system test capability. A complete satellite communications system will be simulated within the laboratory, including data sources, a ground terminal, satellite portions, a receiving terminal, and a receiving "user."

This report deals specifically with radiofrequency (RF) testing of the satellite transponder segment of that system, including the 30-GHz receiver, the onboard intermediate-frequency (IF) switching, and the 20-GHz downlink transmitter. Although the initial system design was focused on specifications of components that have been completed or are under development, an attempt has been made to provide the flexibility required for testing more complex components.

TEST PROGRAM OBJECTIVES

In preparation for a planned series of data transmission tests, the RF characteristics of the system were tested extensively. A preliminary set of tests was followed by a final, more exhaustive set of tests. The objectives of the preliminary tests were to identify design deficiencies and to provide baseline data for design revisions. The objective of the final tests was to define the system capabilities and limitations (such as the attainable signal-to-noise ratio as a function of uplink frequency, downlink frequency, and power level). Also examined were system phase distortion, nonlinearities, intermodulation distortion, and saturation power levels at various points throughout the system.

INITIAL SYSTEM DESIGN

The RF portion of the initial system (fig. 1) was designed around a low noise receiver developed by LNR Communications (refs. 1 and 2), an IF switch matrix built by Ford Aerospace (refs. 3 and 4), and a downlink transmitter consisting of a solid-state GaAs field-effect transistor (FET) power amplifier designed and fabricated by Texas Instruments (ref. 5). The system was required to be capable of transmitting 220 Mbps of serial-minimum-shift-keyed SMSK-modulated data at bit error rates of 10^{-6} or better in an information bandwidth of 330 MHz.

INITIAL TESTS AND DESIGN MODIFICATIONS

Several tests were performed to determine the nominal transponder operating point and to identify any unanticipated problems. A number of power linearity measurements were made in developing a baseline power budget. The other initial measurements of interest are frequency source leveling, output spurious response, and initial output carrier-to-noise ratio.

Frequency Source Leveling

The frequency source chosen for transponder testing was the Wiltron Model 610D sweep generator with a Wiltron Model 6140D RF plug-in (SG1 in fig. 1). This unit produces 1 mW (0 dBm) of RF power over the frequency range 26.5 to 40.0 GHz. The source output was measured with an RF power meter, and the output level was recorded on an X-Y recorder as the source was swept from 27.5 to 30.0 GHz. The output was leveled externally with a crystal detector coupled to the signal via a 10-dB directional coupler. The results (fig. 2) indicate that the source was leveled to within 0.67 dB over the 2.5-GHz bandwidth.

Output Spurious Responses

A larger than expected number of spurious responses were observed on a spectrum analyzer connected to the transponder output (fig. 3). These were found to originate from the LNR 30-GHz low noise receiver. In the absence of an input RF signal, increasing the attenuation (attenuator AT1, fig. 1) decreased these spurious responses. It was concluded that the receiver's local oscillator was feeding through the RF input port, reflecting from the Wiltron 6140D (SG1 in fig. 1), and reentering the input port. A power meter measurement indicated that the local oscillator's signal level at the RF input port was -8.1 dBm.

The transponder design was modified at this point to include a 20-dB WR28 waveguide isolator (I1 in fig. 1) at the Wiltron 6140D output. Adding the isolator significantly reduced the number of spurious responses in the receiver output (fig. 4).

Output Carrier-to-Noise Ratio

The carrier-to-noise ratio (C/N) of the transponder output was measured with a spectrum analyzer. The spectrum analyzer produced a noise measurement normalized to a 1-Hz bandwidth. Adding 85.2 dB Hz to this normalized measurement gave the equivalent noise in a 330-MHz bandwidth. Comparing this result with the measured power level of a continuous-wave (CW) signal placed at the center of the 330-MHz band gave a carrier-to-noise ratio. This measurement was performed for five test bands (see the section Transponder Test Guidelines) with results ranging from 13.4 to 17.9 dB (table I).

An investigation of noise levels at various points in the transponder revealed that the major contributor of noise was the driver amplifier (A3 in fig. 1). This amplifier, a 1-W traveling-wave tube, produced a high level of broadband noise. The traveling-wave tube was replaced by a solid-state amplifier that produced 50 mW but had a lower noise output. Higher C/N's were measured after the solid-state driver amplifier was in place (table II). Future testing with modulated signals will require that C/N's of 18 to 20 dB be obtainable. Thus the replacement of the traveling-wave tube by the solid-state amplifier was made a permanent modification.

Baseline Power Budget Development

The baseline power budget was based on the desired input power levels for the transponder's proof-of-concept (POC) elements. These power levels are defined as follows:

(1) For the receiver an input power level of -30 dBm was chosen. Although this was a much higher level than would be expected in a real system, the presence of spurious responses in the receiver's output required that the input power level be high enough to reduce these responses to at least 30 dB below the output signal level. An input of -30 dBm accomplished this and was also well within the linear operating range of the receiver.

(2) For the matrix switch an input power level of -10 dBm was chosen. This was 20 dB below the maximum input power and corresponded approximately to the expected output power of the receiver. It was also within the linear operating range of the matrix switch.

(3) The GaAs FET high power amplifier was operated at the 1-dB compression point at 28.8 GHz (the center of test band 3). An input power of 5.0 dBm was required at that frequency.

The baseline power budget was adjusted by using five variable attenuators and one variable amplifier and was monitored by six power meters. Although testing could have taken place anywhere in the 2.5-GHz band, the baseline power budget was set at the 28.8-GHz uplink frequency.

All transponder active devices (except the POC GaAs FET high power amplifier) were tested to determine if they were operating linearly. Several attenuator settings needed adjustment to obtain linear operation of amplifier A2 (fig. 1). After these adjustments were made, the final baseline power budget assured linear transponder operation up to the POC high power amplifier input. The final settings of the baseline power budget (table III) were valid after 1 hr of warmup but may vary by ±1 dB with variations in room temperature.

FINAL TEST RESULTS

Transponder Test Guidelines

The following guidelines for transponder parameters were established at the onset of testing.

Frequency. - Five frequency bands were chosen for testing. These bands were 330-MHz wide, corresponding to the bandwidth required for the 220-Mbps SMSK signal to be used in future testing. The major goal in determining the location of the five test bands in the 2.5-GHz overall transponder bandwith (fig. 5) was to avoid the major spurious responses occurring in the LNR receivers. The output spectrum from LNR low noise receiver S/N 001 (fig. 6, from ref. 3) had the fewest spurious responses. All of the LNR receivers had spurious responses grouped at 500-MHz intervals (fig. 6). Of the five test bands, band 3, at about the center of the 2.5-GHz transponder bandwidth, was chosen as the primary test band.

Power levels. - Transponder testing was conducted at the baseline power levels, as described in the Baseline Power Budget Development Section. There were two exceptions: the receiver and matrix switch power variation tests, and some C/N and carrier-to-interference ratio (C/I) tests.

Matrix switch crosspoints. - The Ford POC matrix switch contains 65 active crosspoints. From the data taken under the POC test program (ref. 4) crosspoint 7,6 (referring to the matrix switch input and output ports, respectively) was chosen as the primary test crosspoint on the basis of frequency response. In addition to the primary crosspoint a representative group of 16 crosspoints in a four-by-four matrix (table IV) was chosen to allow the observation of the effects of crosspoint variation on the transponder's RF response.

Transponder Frequency Response

Amplitude. - The transponder's amplitude/frequency response was recorded at the baseline power levels for the five transponder test bands. This measurement (fig. 7) was performed at the transponder output and at three other points within the transponder: the receiver output, the upconverter input, and the high power amplifier (HPA) input. A CW input signal from the signal generator was swept across the appropriate receiver input frequencies. The amplitude response was measured and displayed by the spectrum analyzer and recorded by the plotter via the control computer.

The best end-to-end transponder frequency response (table V; fig. 8), in terms of the smallest amplitude variation over the 330-MHz bandwidth, occurred in band 5; the worst, in band 4. The poor response of band 4 was due primarily to its position at the upper edge of the passbands of the matrix switch and the HPA (Texas Instruments' POC GaAs FET amplifier). The matrix switch (located between the low noise receiver and the upconverter, fig. 7) is the largest contributor to overall transponder amplitude variation. The HPA (fig. 7), operating at its 1-dB compression point, acts as a soft limiter to reduce the overall amplitude variation.

A second set of the transponder's amplitude/frequency response measurements (table VI) was taken for the 16 representative matrix switch crosspoints for band 3 only. These measurements were made in the same manner as the first set. The mean amplitude variation for the transponder using the 16 crosspoints was 1.96 dB. The range was 1.1 to 2.9 dB and the standard deviation was 0.48 dB.

Group delay. - Swept frequency, group delay response measurements were performed for the same conditions as the amplitude response measurements. That is, the measurements were made for the five transponder test bands at the transponder output and at three other transponder points; the receiver output, the upconverter input, and the HPA input. An automated group delay measurement system (fig. 9) was used for this measurement. The system input (CW) signal was amplitude modulated at a fixed frequency. The phase shift of the modulation envelope at the test point was measured by a vector voltmeter. This phase shift can be mathematically related to the group delay through the device being tested (ref. 6). The computer/controller interprets the phase shift from the output of the vector voltmeter via the digital multimeter and corrects the measurement by subtracting a previously stored calibration value (obtained with the transponder removed from the measurement setup). This procedure was performed in 10-MHz increments across the passband.

In terms of group delay variation across the passband (table VII; fig. 10), band 2 was the best band and band 3, the worst. As with the amplitude response measurements the matrix switch was the largest contributor to the transponder's overall group delay variation, and some improvement was obtained by operating the HPA in compression.

A second set of group delay measurements was made for the 16 matrix switch crosspoints for band 3 at the transponder output. The mean group delay variation for the 16 crosspoints was 1.73 ns (table VIII). The range was 1.27 to 2.32 ns and the standard deviation was 0.34 ns.

Power Variation Tests

Receiver. - The receiver's input power was varied from -10 to -75 dBm via attenuator AT1 (fig. 1). The transponder's output was recorded by sweeping the input signal from 27.5 to 30.0 GHz. The output was displayed on a spectrum analyzer and recorded on a plotter, as in figure 7. Over the entire range (-10 to -75 dBm) the transponder was able to compensate for the variation in input power by adjusting amplifier A1 and attenuator AT2 (fig. 1) to maintain baseline power levels at all other points in the transponder. The output response (fig. 11) was relatively constant over the input range -10 to -45 dBm. As the input power was further decreased, spurious responses, constant in amplitude, began to dominate the receiver's output signal. At this point transponder power meters were reading primarily the power of these spurious responses rather than the desired signal, and amplifier A1 and attenuator AT2 were adjusted to give proper power readings based on the spurious, rather than the desired, signals. This accounts for the lower level of the swept response at the output. Additional amplification would restore swept response at the transponder output to the baseline level (as for the higher inputs). However, the relative difference between the amplitude of the spurious responses and the swept signal would remain constant. It is probable, also, that the spurious responses would saturate the output amplifier before the desired signal could be amplified to baseline level.

Matrix switch. - The input power of the matrix switch was varied (via amplifier A1 and attenuator AT2) from 0 to -50 dBm, and the output of the transponder was recorded as in the power variation test for the receiver.

To maintain the baseline power levels attenuators AT3, AT4, and AT5 (fig. 1) were used to compensate for the power variation at the matrix switch output. This was possible for matrix switch input levels from 0 to -35 dBm. Below -35 dBm the transponder could not compensate for the power decrease (fig. 12). The output level fell, the HPA operated linearly, and the output frequency response degraded.

Output Carrier-to-Noise Ratios

The C/N's at the transponder output were measured by introducing a CW signal to the transponder input and measuring the signal and noise powers at the transponder output on a spectrum analyzer. The CW signal was placed at the center of each of the five transponder bands; the resulting C/N's at baseline power levels are given in table IX.

The C/N's were also measured as a function of transponder input power. Two cases were observed: in one case transponder power levels were adjusted to maintain baseline power levels; in the other case the transponder power levels were allowed to vary with the input power. The results (fig. 13) show that at baseline power levels (-30-dBm input) the transponder was operating near its maximum C/N.

Interference and Intermodulation

Several tests were performed to observe various types of interference and intermodulation in the transponder.

Spurious responses at transponder output. Spurious responses at the transponder output were recorded on a plotter from a spectrum analyzer display. The five distinct responses with no RF input to the transponder (fig. 14(a)) were all directly traceable to the low noise receiver. The insertion of an RF input signal created additional spurious responses (fig. 14(b)) resulting from mixing the RF signal with the spurious responses at the low noise receiver output (fig. 4) and from harmonics of the RF signal. These mixing products and harmonics occurred in the upconverter mixer.

Carrier-to-interference ratio. - C/I was measured by applying a CW signal, at the center frequency of the band being tested, to the transponder input and observing the relative levels of the CW signal and the largest inband interferer on a spectrum analyzer at the transponder output. (An interferer, as used herein, is defined as any unwanted signal appearing in the transponder output spectrum.) This measurement, like the C/N measurement, was performed versus transponder input power for two cases, both for the five 330-MHz bands. In the first case (fig. 15(a)) the transponder power levels were adjusted to maintain baseline power levels. For the second case (fig. 15(b)) all transponder power levels were allowed to vary with the input power. Bands 4 and 5 were significantly degraded when the transponder power levels were not controlled.

Third-order intermodulation (between bands). - With a CW signal placed at the center of a desired band, a second "interfering" signal was placed at the center of another band. The signals resulting from intermodulation of the interfering signal with the desired signal, and with other transponder spurious signals that fall within the desired band, were measured on a spectrum analyzer. This was done for all combinations of desired and interfering bands.

The strongest interferer observed was in band 6 (due to a signal in band 5) at 34 dBc (table X). The level of interfering intermodulation signals was proportional to the proximity (in frequency) of the interfering signal to the desired signal.

Third-order intermodulation (inband). - For this test two CW signals, F_0 + 25 MHz and F_0 - 25 MHz, at baseline power levels were applied to the transponder (where F_0 is the center frequency of the band being tested). The levels of the resulting intermodulation products (relative to the two fundamental signals) that appeared within the 330-MHz band were measured with a spectrum analyzer. The relative levels of the intermodulation products indicate the amount of signal compression and phase distortion. The highest amount of compression occurred in band 2; the lowest amount, in band 4 (table XI).

SUMMARY OF SYSTEM CAPABILITIES

The transponder's capabilities are summarized in terms of frequency, power, noise, and interference.

Frequency Capability

The transponder operated in a fixed uplink frequency band of 27.5 to 30.0 GHz and a fixed downlink frequency band of 17.7 to 20.2 GHz. The intermediate frequency (IF) was dependent on the low noise receiver. For the LNR receiver the IF was 3.7 to 6.2 GHz. This required the upconverter local oscillator to be at a frequency of 14.0 GHz.

Power Levels

Because five variable attenuators and three amplifiers were used, a wide range of power levels (table XII) was available to the major components of the transponder.

Carrier-to-Noise Ratios

The transponder provides output carrier-to-noise ratios of 40 to 50 dB (fig. 13). This is far in excess of the 20 dB required for data transmission testing.

Carrier-to-Interference Ratios

The available carrier-to-interference ratios depend on the portion of the 2.5 GHz band being tested. Ratios of 43 to 54 dB were obtainable at the baseline power level (fig. 15).

FUTURE PLANS

Revisions

Subsequent testing of the transponder has indicated that the low noise receiver's internal local oscillator degrades with age in power and frequency stability. The frequency drift has been measured to be greater than 30 MHz. This frequency error would seriously impair an attempt to transmit data through the system. The problem could be controlled to some extent by adjusting the transponder upconverter's local oscillator to compensate for the receiver frequency drift; this is a temporary solution. A permanent solution would be to replace the receiver's internal local oscillator with a stable, external frequency source. Preliminary tests have shown that receiver and transponder performance would be significantly improved. An acceptable frequency source is being obtained to replace the receiver's local oscillator for future transponder operation.

Future Testing

Plans for further testing of the transponder include both RF and data transmission tests. The RF tests would involve replacing the solid-state, high power amplifier with a traveling-wave-tube amplifier and adding ground-terminal up-and-down converters. The data transmission tests would use 220-Mbps modulators and demodulators to transmit modulated signals through the transponder and the ground-terminal up-and-down converters. The bit error rate of the transmitted data would be measured as a function of the transponder RF parameters.

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2. Conroy, M.J.: Test Results for 27.5 to 30.0 GHz Communications Satellite Receivers. NASA TM-83662, 1984.

3. Ho, Pang T.; Coban, Eugene; and Pelose, J.: Spacecraft IF Switch for Wideband Service Applications in 30/20 GHz Communications Satellite Systems. NASA CR-168175, 1983.

4. Saunders, A.: 20 x 20 High Speed Microwave Matrix Switches. NASA TM-83775, 1984.

5. Saunier, P.; and Nelson, S.: 30/20 GHz Spacecraft GaAs FET Solid State Transmitter for Trunking and Customer-Premise-Service Application. (TI-08-83-42, Texas Instruments; NASA Contract NAS3-22504.) NASA CR-168276, 1983.

6. Swept Frequency Group Delay Measurements. Hewlett Packard Applications Note 77-4, Hewlett-Packard Co., Palo Alto, CA, Sept. 1968.

TABLE I. - INITIAL CARRIER-TO-NOISE RATIOS

Band	Carrier-to-noise ratio, C/N, dB
2	17.9
3	17.1
4	14.1
5	15.4
6	13.4

TABLE II. - CARRIER-TO-NOISE RATIOS AFTER REPLACEMENT OF TRAVELING-WAVE-TUBE DRIVER AMPLIFIER

Band	Carrier-to-noise ratio, C/N, dB
2	44.3
3	41.5
4	35.1
5	42.3
6	36.6

TABLE III. - BASELINE POWER BUDGET

Transponder element	Figure 1 designation	Setting, dB	Meter reading, dBm
Source-output power meter	PM1	---	-10
Receiver-input attenuator	AT1	30	---
Adjustable amplifier	A1	14	---
Matrix-switch input attenuator	AT1	14	---
Matrix-switch input power meter	PM2	---	-20
Matrix-switch output power meter	PM3	---	-45
Upconverter-input attenuator	AT3	9	---
Upconverter-input power meter	PM4	---	-19
Driver-amplifier input attenuator	AT4	14	---
HPA-input attenuator	AT5	10	---
HPA-input power meter	PM5	---	-15
Transponder-output power meter	PM6	---	4

TABLE IV. - FORD POC MATRIX-SWITCH CROSSPOINTS USED IN TRANSPONDER TESTING

Crosspoint	Input port	Output port	Comments
29	7	6	Primary test crosspoint
1	3	3	Part of four-by-four matrix
2	4	3	
3	5	3	
4	6	3	
19	3	5	
20	4	5	
21	5	5	
22	6	5	
25	3	6	
26	4	6	
27	5	6	
28	6	6	
31	3	7	
32	4	7	
33	5	7	
34	6	7	

TABLE V. - TRANSPONDER AMPLITUDE VARIATION (HIGHEST TO LOWEST POINT IN 330 MHz) FOR FIVE BANDS

Band	Receiver output, dB	Upconverter input, dB	HPA input, dB	Transponder output, dB
2	7.3	9.0	9.5	6.3
3	2.5	7.8	4.6	3.5
4	1.0	6.0	9.0	11.1
5	1.7	3.4	3.7	2.0
6	1.7	3.5	5.5	2.6
Mean	2.8	5.9	6.5	5.1
Standard deviation	2.3	2.2	2.4	3.3

TABLE VI. - TRANSPONDER AMPLITUDE VARIATION FOR 16 CROSSPOINTS, BAND 3

Crosspoint (input, output)	Amplitude variation, dB
3,3	1.1
4,3	2.9
5,3	2.3
6,3	1.7
3,5	2.2
4,5	2.7
5,5	1.8
6,5	2.1
3,6	1.8
4,6	2.2
5,6	1.5
6,6	1.5
3,7	1.6
4,7	2.6
5,7	1.5
6,7	1.9
Mean	1.96
Standard deviation	.48

TABLE VII. - TRANSPONDER GROUP DELAY VARIATION (HIGHEST TO LOWEST POINT IN 330 MHz) FOR FIVE BANDS

Band	Receiver output, ns	Upconverter input, ns	HPA input, ns	Transponder output, ns
2	2.97	4.63	5.44	4.33
3	.49	2.25	1.86	1.27
4	.62	2.99	4.23	4.09
5	.96	2.43	2.17	1.51
6	.33	3.01	3.09	2.49
Mean	1.07	3.06	3.36	2.74
Standard deviation	.97	.84	1.33	1.27

TABLE VIII. - TRANSPONDER GROUP DELAY VARIATION FOR 16 CROSSPOINTS, BAND 3

Crosspoint (input, output)	Group delay variation, ns
3,3	1.37
4,3	1.41
5,3	1.27
6,3	1.83
3,5	2.15
4,5	2.32
5,5	1.50
6,5	2.28
3,6	1.53
4,6	1.71
5,6	1.38
6,6	2.06
3,7	1.83
4,7	1.84
5,7	1.27
6,7	1.86
Mean	1.73
Standard deviation	.34

TABLE IX. - TRANSPONDER OUTPUT CARRIER-TO-NOISE RATIOS AT BASELINE POWER LEVELS

Band	Carrier-to-noise ratio, CN, dB
2	44.3
3	41.5
4	35.1
5	42.3
6	36.6
Mean	40.0
Standard deviation	3.51

TABLE X. - INTERFERENCE RESULTING FROM INTERMODULATION WITH OUT-OF-BAND CONTINUOUS WAVE SIGNAL

Desired signal	Interfering signal				
	Band 2	Band 3	Band 4	Band 5	Band 6
	Relative level of observed interferer, dBc				
Band 2		48	60	62	58
Band 3	50		56	[a]48	[a]55
Band 4	46	48		49	51
Band 5	59	[a]39	54		36
Band 6	48	[a]43	55	34	

[a]Bands 3 and 5 overlap and bands 3 and 6 overlap.

TABLE XI. - RELATIVES LEVELS OF INBAND INTERMODULATION PRODUCTS

Band	3rd-order product	5th-order product	7th-order product
	Relative level of intermodulation product, dBc		
2	13	21	28
3	13	24	37
4	22	47	---
5	15	27	42
6	14	31	43

TABLE XII. - TRANSPONDER AVAILABLE POWER LEVELS

Frequency	Transponder point	Available power levels, dBm
Uplink	Receiver input	0 to -70
Intermediate frequency	Matrix-switch input	30 to -100
Intermediate frequency	Upconverter input	15 to -80
Downlink	Driver amplifier input	0 to -100
Downlink	Power amplifier input	15 to -110

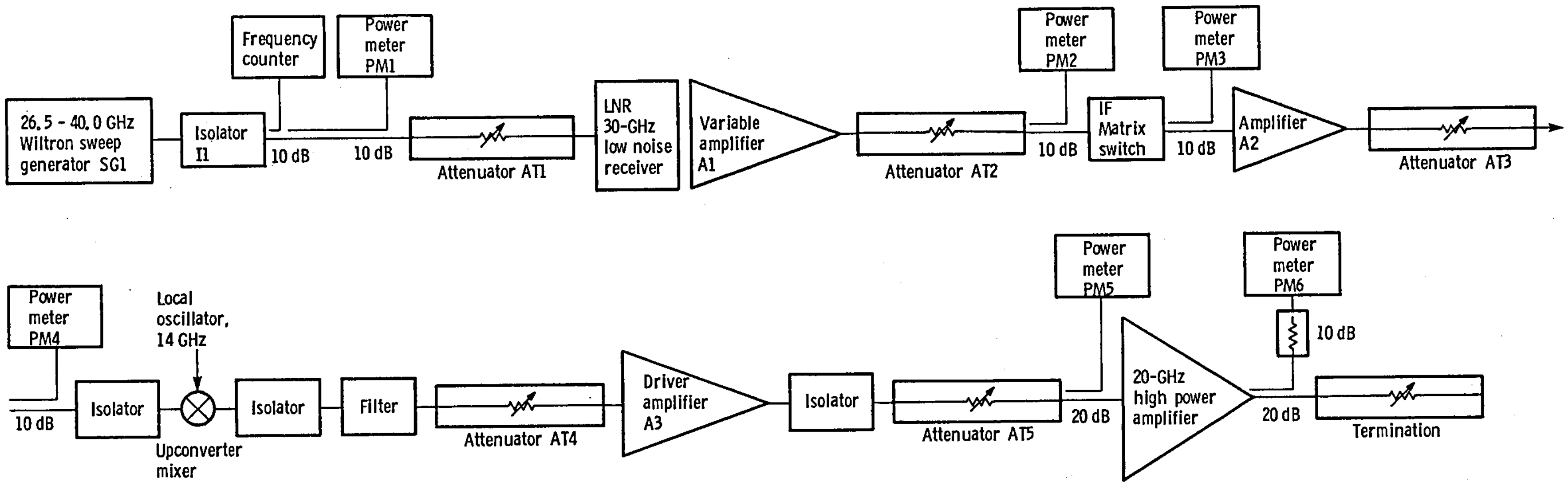


Figure 1. - Transponder block diagram.

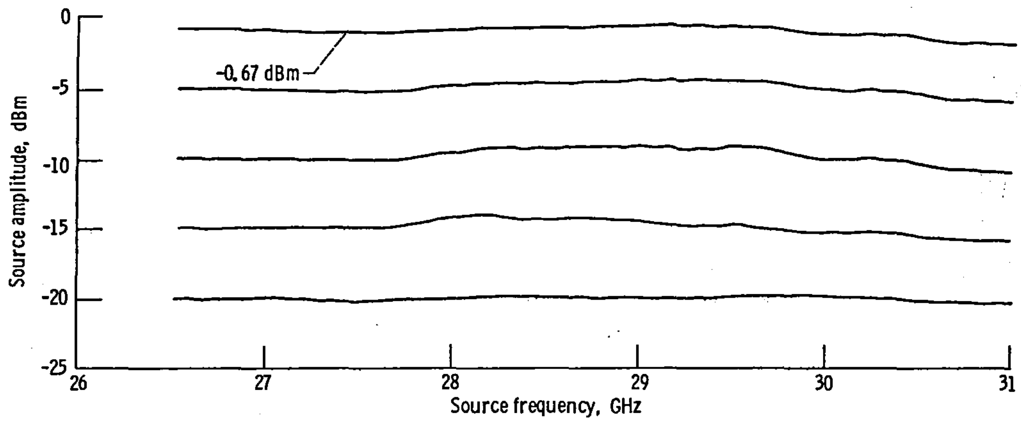


Figure 2. - Wiltron sweeper output leveling.

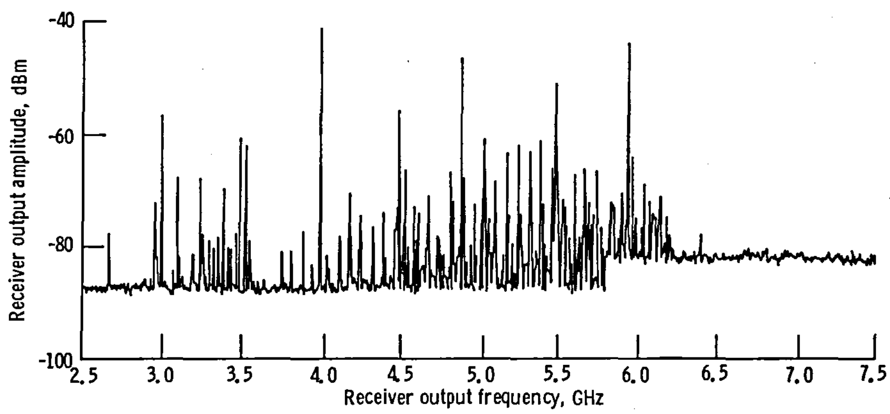


Figure 3. - Low noise receiver output with no input isolation. Input attenuation, 30 dB; resolution bandwidth, 10 kHz.

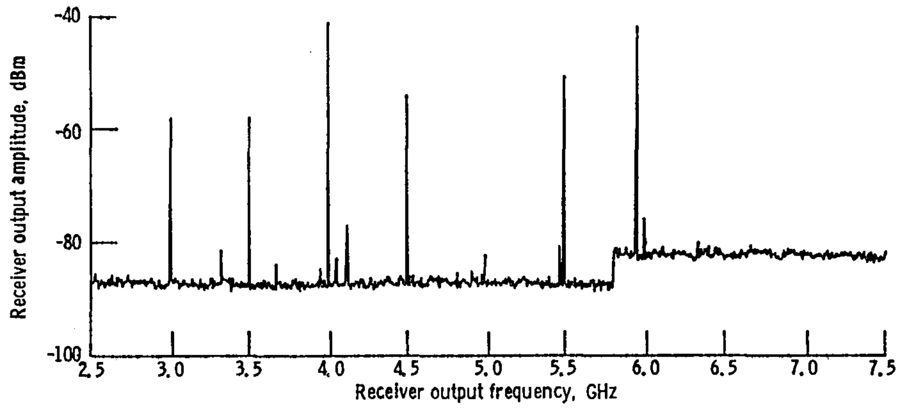


Figure 4. - Low noise receiver output after addition of input isolater. Input attenuation, 30 dB; resolution bandwidth, 10 kHz.

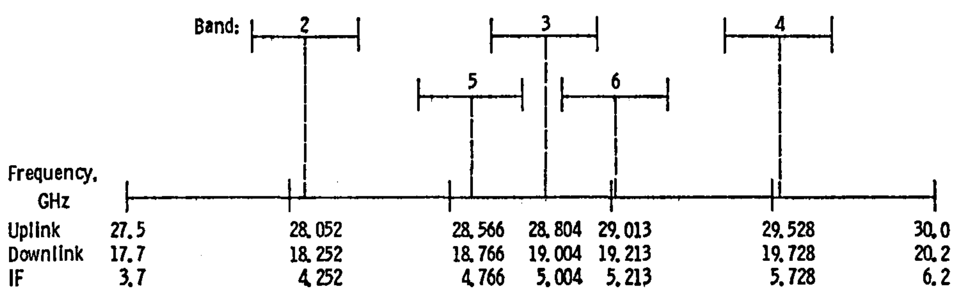


Figure 5. - Transponder test bands.

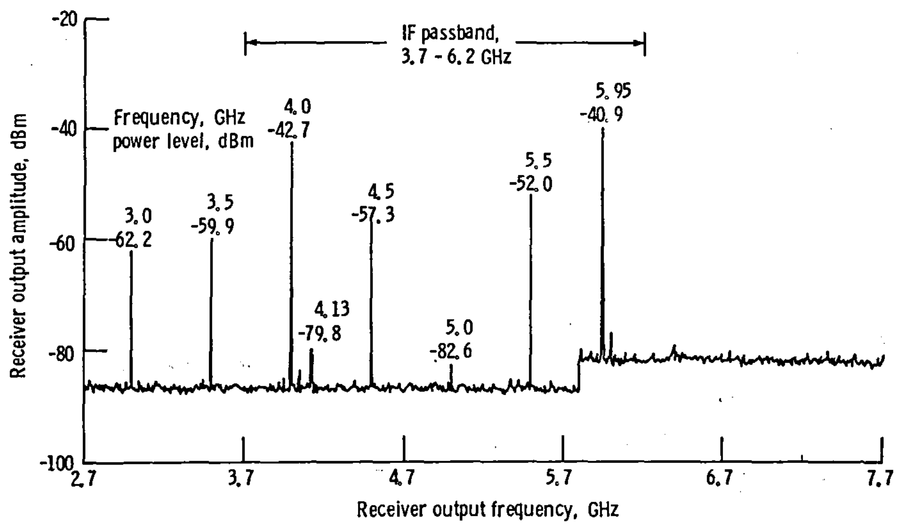


Figure 6. - LNR-1 low noise receiver output spectrum. Resolution bandwidth, 10 kHz. (From ref. 2.)

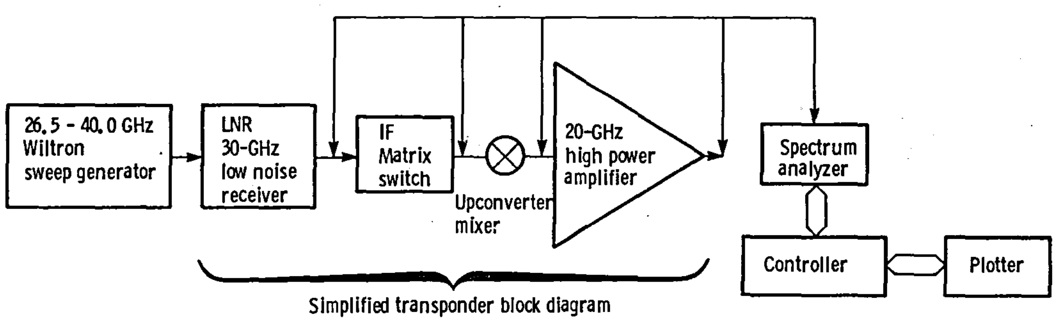


Figure 7. - Amplitude/frequency response test setup.

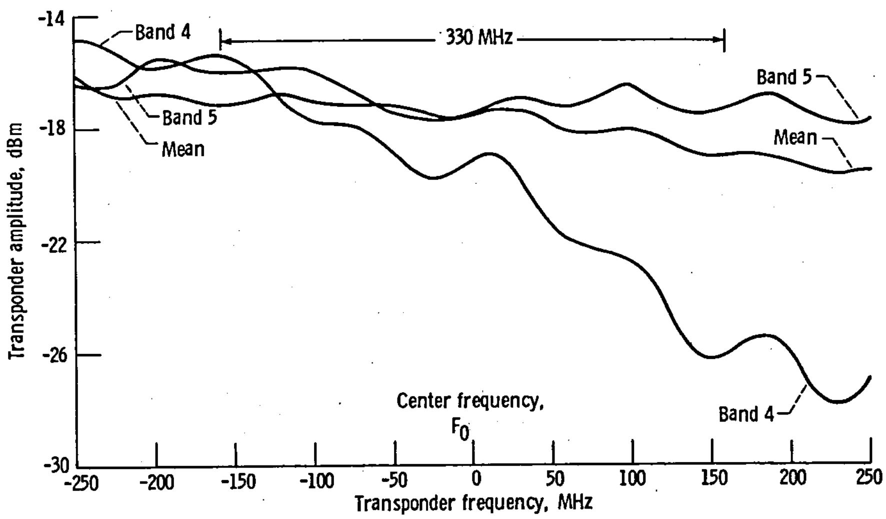


Figure 8. - Transponder frequency response for 330-MHz bands, normalized with respect to center frequency. Resolution bandwidth, 10 kHz.

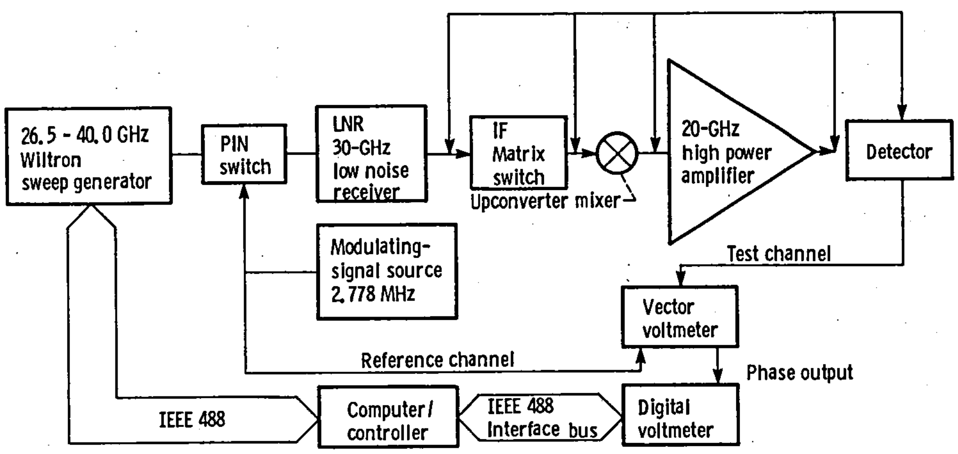


Figure 9. - Group delay response test setup.

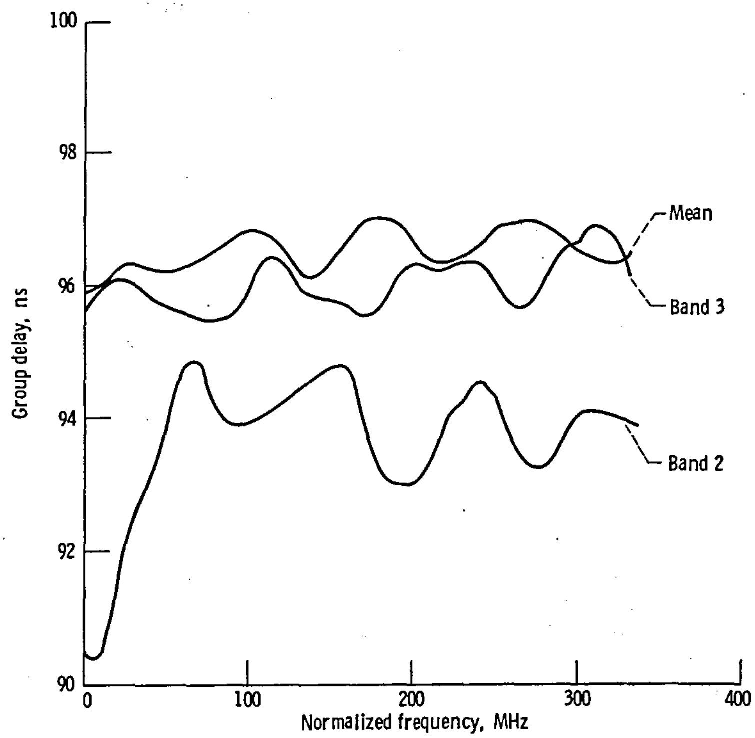


Figure 10. - Transponder group delay response for 330-MHz bands.

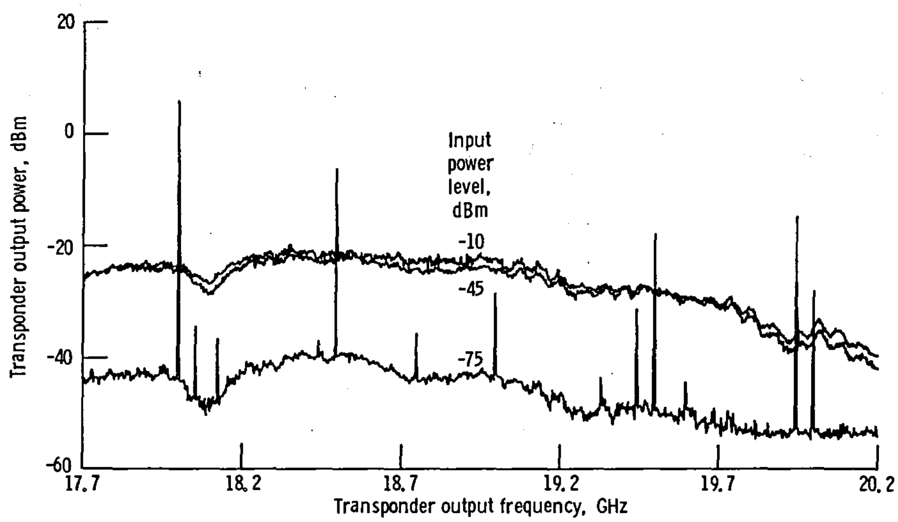


Figure 11. - Transponder output power variation. Resolution bandwidth, 10 kHz.

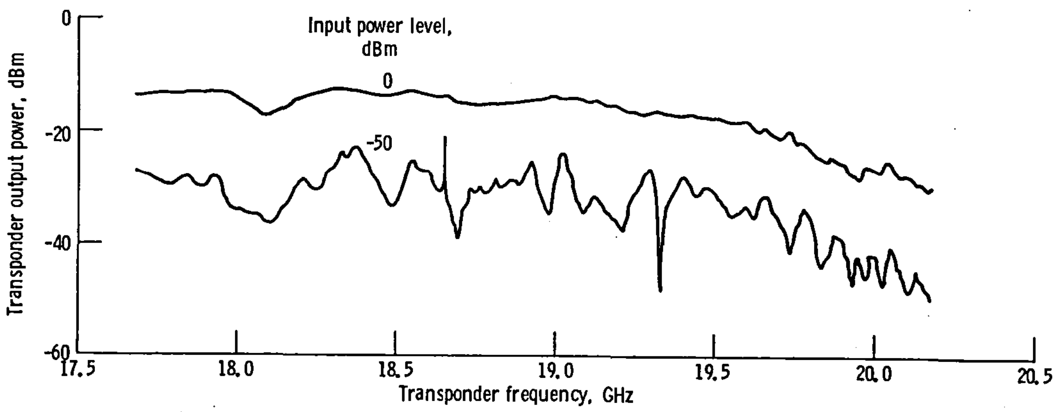
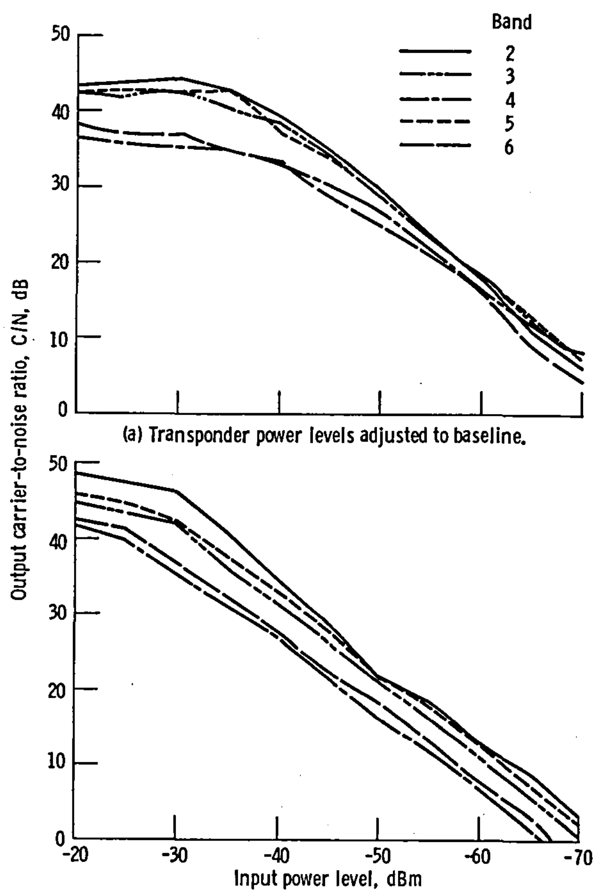
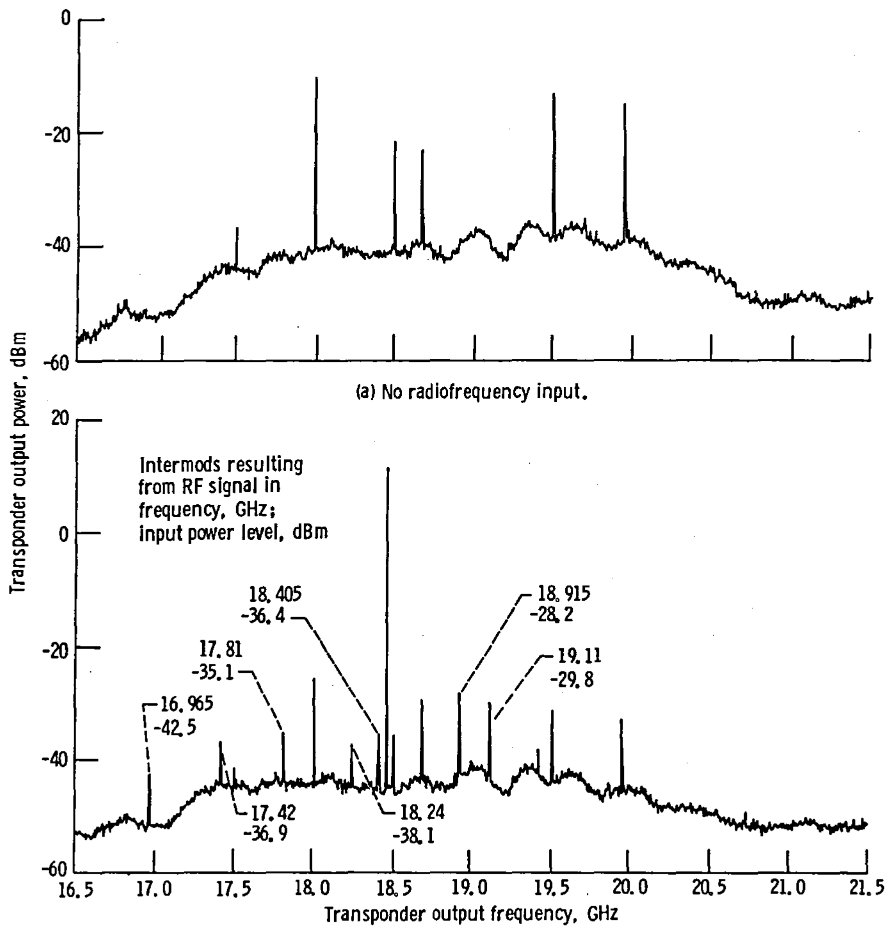


Figure 12. - Matrix switch input power variation. Resolution bandwidth, 30 kHz.



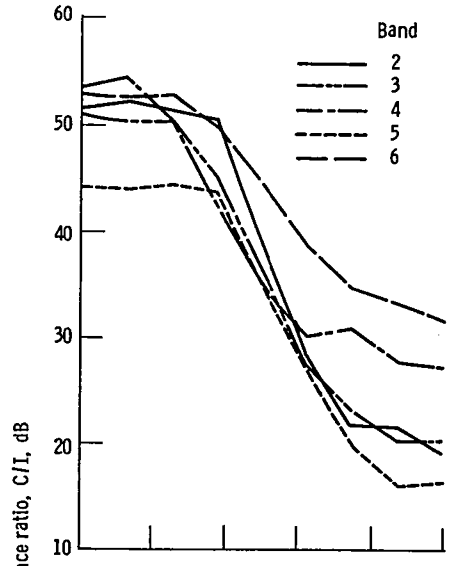
(b) Transponder power levels varied with input power.

Figure 13. - Output carrier-to-noise ratio as function of input power.

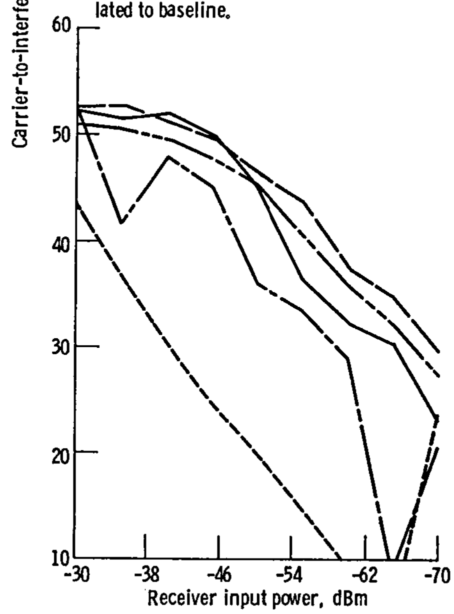


(b) Baseline input signal, 28.25 GHz.

Figure 14. - Transponder output. Resolution bandwidth, 10 kHz.



(a) Test 5.1; transponder power levels regulated to baseline.



(b) Transponder test 5.2; transponder power levels varied with input power.

Figure 15. - Output carrier-to-interference ratio as function of input power.

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15. Supplementary Notes

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16. Abstract

A laboratory communications system has been developed that can serve as a test bed for the evaluation of advanced microwave (30/20 GHz) components produced under NASA technology programs. The system will ultimately permit the transmission of a stream of high-rate (220 Mbps) digital data from the originating user, through a ground terminal, through a hardware-simulated satellite, to a receiving ground station, to the receiving user. This report contains the results of radiofrequency testing of the satellite portion of that system. Data presented include output spurious responses, attainable signal-to-noise ratios, a baseline power budget, usable frequency bands, phase and amplitude response data for each of the frequency bands, and the effects of power level variation.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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