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Performance Measurements for a Laboratory-Simulated 30/20 GHz Communication Satellite Transponder

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PERFORMANCE MEASUREMENTS FOR A LABORATORY-SIMULATED 30/20 GHz COMMUNICATION SATELLITE TRANSPONDER

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Abstract

NASA has developed a digital satellite communications system simulator and test bed facility, known as the SITE (Systems Integration, Test and Evaluation) Project. The purpose of the facility is to evaluate satellite system components, develop and verify system concepts, and perform satellite system experiments. A recently completed set of experiments measured the performance of the 30/20 GHz satellite transponder portion of the system in terms of RF parameters and high rate digital data transmission. The results of these tests indicate the quality of data transmission which can be obtained under various transponder operating conditions, as well as the relative effects of degraded RF performance on the bit-error rate (BER) of transmitted data.

Introduction

The SITE Project at NASA's Lewis Research Center has focused on the development and testing of components, subsystems, and network architectures for future generation satellite communication systems. In the recently completed first phase of the project, a simplified satellite transponder, operating in the 30 GHz uplink/20 GHz downlink bands was developed and tested. The required ground terminal equipment, including up and down converter and digitally modulated transmit and receive circuits were also developed. The characteristics of the transponder allowed a number of operational modes to be tested, both with CW and modulated signals. The resulting test data is presented in the following sections.

Description of Transponder

The 30/20 GHz transponder was configured as shown in Fig. 1. It consists of three major elements, the low noise receiver, IF matrix switch, and high power amplifier. Power control sections and an upconverter (from satellite IF to downlink frequency) complete the functional design. The filtering in the transponder is minimal, allowing a single wideband communication signal to be placed anywhere within a 2.5 GHz bandwidth. At the completion of the testing described in this report, the transponder was reconfigured into a three channel satellite-switched TDMA network. Hence, the IF matrix switch was included in the first phase transponder tests to determine its effect on system performance even though no dynamic switching would occur.

The low noise receiver, developed under contract by LNR Communications, Inc., used an image-enhanced mixer front end, reflecting the technology available at the time of its development.[1,2] A local oscillator frequency of 23.8 GHz transformed the input frequency band of 27.5 to 30.0 GHz down to a satellite IF band of 3.7 to 6.2 GHz. Filtering and IF amplification resulted in an overall receiver gain of 21.8 dB, while the noise figure achieved was 5.8 dB.

The IF matrix switch, built by Ford Aerospace and Communications Corp., consisted of a partially-populated 20 input by 20 output hybrid coupled crossbar architecture, with two-stage dual gate GaAs FET switching elements.[3,4] The average insertion loss per crosspoint was 20.7 dB.

The transponder was evaluated with two different 20 GHz high power amplifiers (HPA) providing a 17.7 to 20.2 GHz downlink transmission. A solid state GaAsFET power amplifier, built by Texas Instruments, Inc., produced 2.6 W of output power at saturation.[5,6] The gain at 1 dB compression was 30 dB.

The second amplifier used was a helix type traveling wave tube (TWT) amplifier built by Hughes Aircraft Co.[7] The TWT was combined with a power processor unit (PPU) built by TRW, Inc. The TWT/PPU combination was unique in that three separate operating power modes were made possible by controlling the TWT anode voltage. The purpose of this design was to allow temporary increases in the satellite transmit power to be used to combat downlink rain attenuation. The TWT produce 5.1 W at saturation in the low power mode, 18.6 W in the medium power mode, and 34.7 W in the high power mode.

Testing of the Transponder

Two sets of tests were performed. RF data was accumulated using unmodulated CW signals. Digital transmission tests were then performed using a digitally modulated signal.

All tests were performed using the ground terminal, as shown in Fig. 1. The ground terminal up and down converter included variable local oscillators, allowing the ground terminal IF of 3.373 GHz to be transmitted and received anywhere within the 2.5 GHz bandwidth. The digital portion of the ground terminal allowed digital data transmission using pseudo-random data.[8] Computer controlled noise insertion, calibration, and bit error rate (BER) measurement allowed complete BER curves to be measured as a function of energy-per-bit to noise power density ratio (E_b/N_o) for the system.[9]

The modulation format used for digital transmission tests was serial minimum shift keying (SMSK). Modems operating at 220 Mbps, built by Motorola, were the source of the digitally modulated signal.[10] The SMSK format has a relatively low percentage of power in its sidelobes, allowing QPSK-quality performance to be achieved with the transmission of the main lobe of the modulated

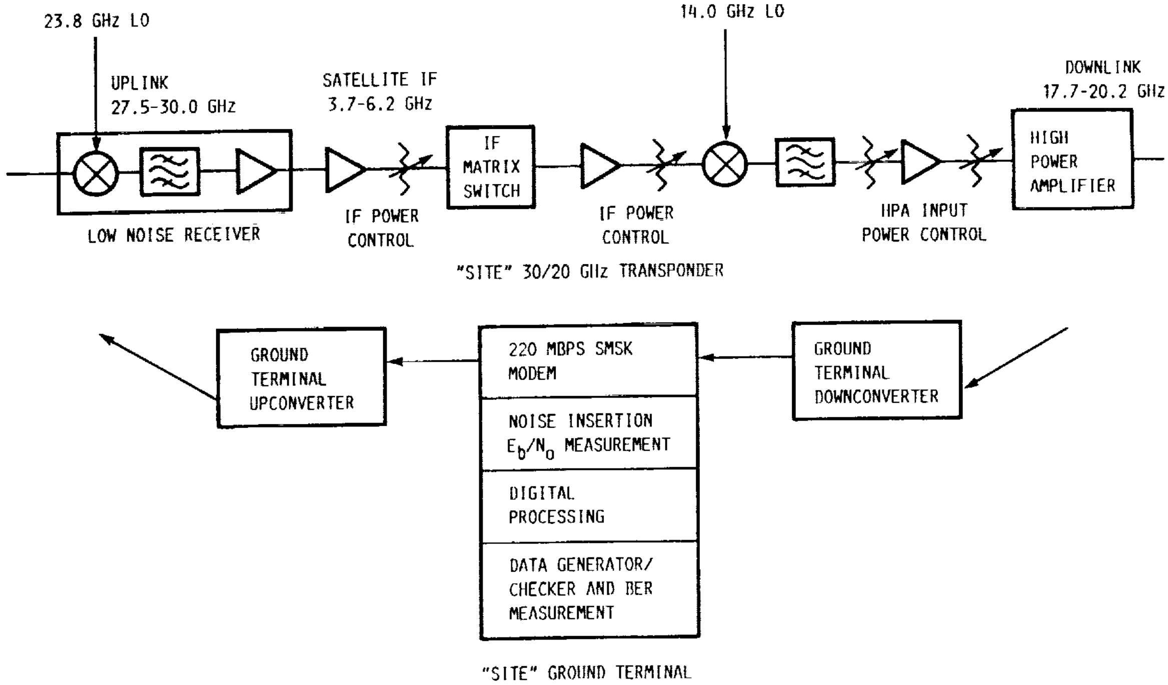

FIGURE 1. - "SITE" 30/20 GHz TRANSPONDER AND GROUND TERMINAL TEST HARDWARE.

spectrum. Transmission of this main lobe requires a channel bandwidth of 1.5 times the data rate. Thus, a 330 MHz channel was necessary for transmission of the 220 Mbps signal. All swept RF measurements were therefore also made over a 330 MHz bandwidth.

Transponder Operating Conditions

Several operating parameters of the transponder were varied during testing. These were test frequency band, matrix switch crosspoint, HPA and HPA power mode, and HPA operating point.

Three test frequency bands were chosen. Referred to as bands A, B, and C, they were centered at uplink frequencies of 28.050, 28.800, and 29.525 GHz, respectively. These bands were chosen to provide a variety of transmission characteristics. Band B, due to its location at the center of the 2.5 GHz bandwidth, provided the least distorted transmission characteristics. Band A, at the lower edge of the 2.5 GHz bandwidth, was slightly more distorted, while band C, at the upper edge, was significantly distorted.

Seventeen matrix switch crosspoints were used during testing. The design of the matrix switch resulted in varying frequency responses between crosspoints, thus adding additional variation of transmission characteristics.

Both the GaAs FET and TWT HPA's were used, with the TWT being exercised in all three power modes. In addition, three operating points (linear, 1 dB compression, and saturation) were tested. It should also be pointed out that the HPA was the only transponder element operating nonlinearly.

Using various combinations of the above transponder operating parameters, a total of 468 different transponder configurations were tested. For RF parameters, amplitude response, group delay response, AM-to-PM conversion, and output carrier-to-noise ratio (C/N) were measured for all nearly all cases. A two-tone third order intermodulation test was performed for one matrix switch crosspoint only. A BER curve was measured for all 468 cases.

RF Test Results

The results of all of the RF and BER measurements are summarized in Table 1. The values listed are the means of all crosspoints tested for the conditions as stated in the table. For amplitude and group delay, the value listed is the maximum variation (peak to peak) measured within the 330 MHz test bandwidth. The third order intermodulation figure is the relative difference in amplitude between the lowest fundamental signal and highest third order intermodulation product, measured at the system output.

The system amplitude response was found to vary significantly with frequency band, HPA, HPA operating point and matrix switch crosspoint. Band B had the flattest response, while band C was the most severely distorted. A comparison of typical frequency responses for each test band is shown in Fig. 2. The average variation of amplitude response over the 330 MHz test band was 1.0 dB lower when the GaAsFET was the system HPA than when the TWT was used. The standard deviation of the amplitude variation as a function of matrix switch crosspoint varied from 0.5 dB for band A to 1.25 dB in band C. The most significant result of the amplitude response measurements was the fact that significant improvement in amplitude flatness was obtained when the HPA was driven into the compressive, nonlinear region.

The group delay response of the system was found to vary with frequency band, matrix switch crosspoint, and HPA. Band B had the flattest group delay response over the 330 MHz band, while

TABLE I—SUMMARY OF RESULTS FOR SINGLE CHANNEL RF AND BER MEASUREMENTS
(MEAN VALUE FOR ALL MATRIX SWITCH CROSSPOINTS TESTED ARE GIVEN.)

HIGH POWER AMPLIFIER	OPERATING POINT	BAND	AMPLITUDE VARIATION, (DB)	GROUP DELAY VARIATION, (NSEC)	AM/PM CONV. DEG/DB	OUTPUT C/N (DB)	*3RD ORD. IMOD (DBC)	Eb/No AT BER = 10^{-6} (DB)
TWT LOW MODE	LINEAR	A	2.09	1.44	1.15	22.55	25.10	1.09
		B	3.47	1.86	1.29	21.34	23.00	1.25
		C	9.37	7.20	3.95	23.76	28.90	5.14
		ALL	4.98	3.50	2.13	22.55	25.67	2.50
	1DB COMP.	A	2.06	2.29	3.01	16.42	16.60	0.99
		B	2.86	2.24	3.50	15.68	13.70	1.07
		C	7.06	3.17	2.32	16.13	9.70	3.75
		ALL	4.00	2.57	2.94	16.08	13.33	1.94
	SAT.	A	1.78	7.03	4.75	14.80	6.60	0.98
		B	1.46	4.25	4.13	13.84	8.30	0.90
		C	5.72	8.94	3.74	14.81	9.10	2.86
		ALL	2.98	6.74	4.20	14.48	8.00	1.58
	ALL	ALL	3.68	4.51	3.39	16.21	15.67	1.85
TWT MEDIUM MODE	LINEAR	A	3.24	1.83	1.35	22.06	20.80	2.55
		B	3.24	1.83	0.78	21.12	26.10	2.18
		C	8.47	6.73	3.84	23.48	20.90	6.15
		ALL	4.99	3.47	1.99	22.22	22.60	3.63
	1DB COMP.	A	4.38	1.80	3.58	16.66	14.50	1.41
		B	2.36	2.35	4.18	16.17	12.30	1.27
		C	6.83	7.36	2.20	16.36	10.80	5.67
		ALL	4.52	3.83	3.32	16.39	12.53	2.79
	SAT.	A	2.88	2.44	4.02	11.00	8.40	1.08
		B	2.17	2.42	4.19	14.20	5.90	0.92
		C	2.32	3.54	2.39	14.41	1.50	2.32
		ALL	2.46	2.80	3.53	12.98	5.27	1.44
	ALL	ALL	3.68	3.33	3.24	15.65	13.47	2.31
TWT HIGH MODE	LINEAR	A	5.34	2.26	0.88	22.12	22.40	2.80
		B	3.26	2.47	0.61	20.84	27.40	1.95
		C	8.41	4.97	3.81	23.73	24.00	2.10
		ALL	5.67	3.23	1.77	22.23	24.60	2.28
	1DB COMP.	A	2.43	4.57	2.18	16.25	15.70	3.37
		B	2.11	2.71	3.30	16.48	13.40	1.60
		C	7.01	4.98	2.00	16.43	12.10	3.86
		ALL	3.85	4.09	2.49	16.38	13.73	2.94
	SAT.	A	3.54	5.26	4.91	14.14	8.70	2.25
		B	1.74	4.00	3.96	11.66	7.40	1.44
		C	3.42	3.98	2.44	14.38	−0.90	1.90
		ALL	2.90	4.41	3.77	13.39	5.07	1.87
	ALL	ALL	3.67	4.12	2.96	15.83	14.47	2.39

TABLE I—CONCLUDED.

HIGH POWER AMPLIFIER	OPERATING POINT	BAND	AMPLITUDE VARIATION, [DB]	GROUP DELAY VARIATION, [NSEC]	AM/PM CONV. DEG/DB	OUTPUT C/N DB	*3RD ORD. IMOD DBC	Eb/No AT BER = 10^{-6} DB
TWT	LINEAR	ALL	5.21	3.48	1.96	22.33	24.29	2.80
	1DB	ALL	4.12	3.50	2.92	16.28	13.20	2.56
	SAT.	ALL	2.78	4.64	3.83	13.62	6.11	1.63
	ALL	ALL	3.68	3.99	3.20	15.90	14.54	2.18
Ti GaAsFET	LINEAR	A	2.60	1.76	—	—	—	1.21
		B	3.81	2.05	—	—	—	1.01
		C	9.23	8.86	—	—	—	4.09
		ALL	5.21	4.22	—	—	—	2.10
	1DB COMP.	A	1.59	1.25	3.88	17.68	12.30	1.08
		B	2.98	1.70	3.71	18.07	12.20	0.89
		C	8.12	3.53	2.04	19.46	13.70	3.36
		ALL	4.23	3.16	3.21	18.40	12.73	1.78
	SAT.	A	1.42	2.91	4.48	17.80	8.00	0.82
		B	1.48	3.02	3.91	17.63	8.00	0.83
		C	2.89	4.34	3.03	18.33	2.80	1.93
		ALL	1.93	3.42	3.81	17.92	6.27	1.23
	ALL	ALL	2.69	3.41	3.51	18.16	9.50	1.58
TWT & GaAsFET	ALL	A	2.61	3.23	3.58	16.25	14.46	1.53
	ALL	B	2.31	2.74	3.57	16.07	14.30	1.21
	ALL	C	5.86	5.23	2.65	16.98	12.05	3.36
	ALL	ALL	3.59	3.73	3.27	16.43	13.60	2.03

FOR LINEAR OPERATING POINT, FIVE CROSSPOINTS WERE TESTED. FOR 1dB COMPRESSION AND SATURATED OPERATING POINTS, 17 CROSSPOINTS WERE TESTED.
*Only one crosspoint tested.

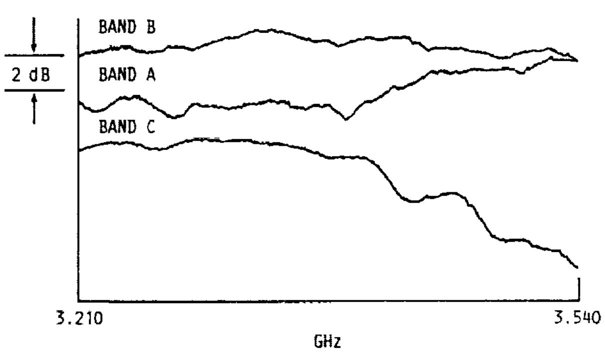

FIGURE 2. - TYPICAL TRANSPONDER FREQUENCY RESPONSES FOR BAND A, B, AND C, AS MEASURED FROM GROUND TERMINAL UPCONVERTER INPUT TO DOWNCONVERTER OUTPUT.

band C had the most distorted response. The standard deviation as a function of matrix switch crosspoint ranged from 0.54 nsec for band B to 1.89 nsec in band C. The average group delay variation was about 0.5 nsec less for the GaAsFET data than for the TWT data. No consistent variation of data was noted as the HPA operating point was varied.

The AM-PM measurements yielded no unexpected results. The AM-PM coefficient was found to be primarily a function of HPA operating point. Only slight variations existed as a function of HPA or matrix switch crosspoint. For frequency band C, the average AM-PM coefficient was 1 deg/dB lower than bands A and B. The average AM-PM conversion coefficient varied with HPA operating point. In the linear region, the average AM-PM coefficient measured less than 2.0 deg/dB, at the 1 dB compression point it was 3.0 deg/dB at 1 dB compression, and at saturation it was 3.8 deg/db.

For the C/N measurements, the only significant variations were noted for the TWT data, as a function of operating point. The measured C/N varied from 22.3 dB to 16.3 dB to 13.6 dB as the HPA operating point moved from linear to 1 dB compression to saturation.

Third order intermodulation level measurements showed only slight variations as a function of HPA. In terms of frequency band, variations were noted but were not consistent between the various HPA's and power modes. Although the third order intermodulation level varied between HPA's and power modes at a given operating point, the data indicated significant compression was occurring at the 1 dB compression and saturated power levels. The average third order level was 23.5 dB in the linear region, 13.1 dB at 1 dB compression, and 5.7 dB at saturation.

The interrelationships between the five RF parameters were analyzed by plotting each pair of parameters against each other and performing and graphing a linear regression. We observed that the amplitude variation, AM-PM conversion and C/N were relatively strong functions of third order intermodulation level, while the group delay was a very weak function. Group delay correlated well to the amplitude data; increasing amplitude data corresponded to increasing group delay variation. The effect was more pronounced for the GaAsFET cases than for the TWT cases. Finally, amplitude variation proved to be a function of AM-PM conversion, while group delay showed no such relationship.

BER Test Results

The number used to represent the results of each BER measurement is the BER degradation at BER = 10^{-6}, which is derived by measuring the difference in E_b/N_o between the measured curve and the theoretical curve at a BER = 10^{-6}. The BER results for the 468 cases tested are summarized in Table I. It should be noted here that the BER degradation measured with the modulator and demodulator operated back-to-back is 0.75 dB. This case represents the undistorted communication transmission channel, in which all degradation from the theoretical curve results from implementation losses occurring in the modulator and demodulator. All additional degradation measured when using the SITE 30/20 GHz transponder results from distortions created by the transponder itself. Distortions created by the ground terminal up and down converter, measured by replacing the transponder with a single downconverter translating the uplink frequency directly to the downlink frequency showed negligible contribution in BER by the up and down converter.

The system BER performance proved to be a strong function of operating frequency. Test band B, which is at the center of the system 2.5 GHz bandwidth and has the best response in terms of RF parameters, produces the least BER degradation, averaging 1.21 dB. Band A is slightly more degraded, with an average of 1.53 dB of degradation. Band C, exhibiting the poorest RF characteristics, also showed significantly degraded BER performance, averaging 3.23 dB of degradation. A plot of typical BER performance as a function of frequency band is shown in Fig. 3.

Performance variation also occurs as a function of matrix switch crosspoint, due to the varying crosspoint characteristics. The standard deviation of the BER degradation, while reasonably low for band B data (0.3 dB), is approximately 1 dB over all data. This is a considerable variation in BER performance caused by changing matrix switch crosspoint.

In terms of HPA and HPA operating point, significant differences in performance were measured. Table II summarizes these results. Significantly better BER performance was obtained when the HPA was operated at saturation compared to the 1 dB compression or linear operating points. The TWT high mode provided the best TWT linear performance, low mode was the best at the 1 dB compression point, and medium mode was the best at saturation. Therefore, no TWT mode clearly outperformed the others. The GaAs FET HPA provided significantly better performance than the TWT, particularly at the linear and 1 dB compression points.

Overall, the SITE transponder proved capable of transmitting digitally modulated data with acceptable amounts of degradation. In 16 percent of the cases tested, the measured degradation from theoretical was $\leq$ 0.90 dB. Since 0.75 dB of degradation was due to modem implementation losses, the transmission channel actually contributed 0.15 dB or less of degradation in these cases, which indicates nearly distortionless performance. In over

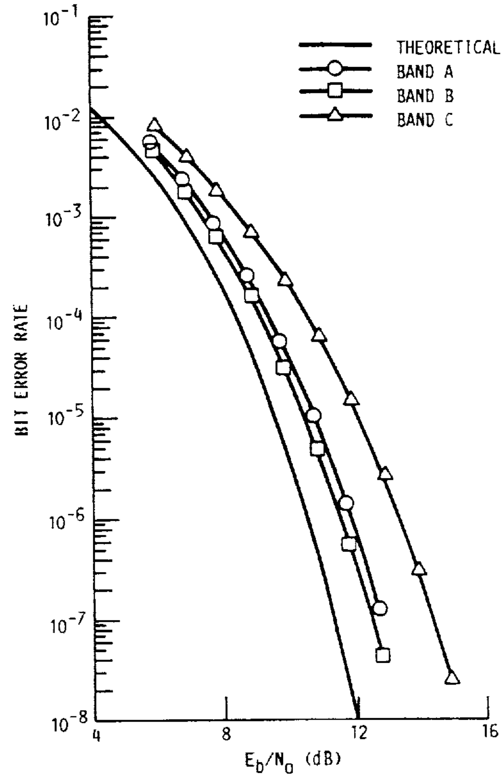

FIGURE 3. - COMPARISON OF TYPICAL BER CURVES FOR TEST BANDS A, B, AND C. THESE CURVES WERE MEASURED WITH THE GaAsFET HPA AT THE 1 dB COMPRESSION POINT USING MATRIX SWITCH CROSSPOINT 7, 6.

TABLE II

BER DEGRADATION [dB] AS A FUNCTION OF HPA AND HPA OPERATING POINT

HPA/ MODE	LINEAR	1 dB COMP.	SATURATION
TWT LOW	2.50	1.94	1.58
TWT MED	3.63	2.79	1.44
TWT HIGH	2.28	2.94	1.87
TWT ALL	2.80	2.56	1.63
GaAsFET	2.10	1.78	1.58

one third of the cases (34.4 percent), the degradation was $\leq$ 1.1 dB. A degradation figure of 2.0 dB (or 1.25 dB additional degradation caused by the transmission channel), which represents reasonably good performance, was achieved in nearly two-thirds (66.2 percent) of the test cases.

Comparison of RF and BER Data

The relationship between the measured RF parameters and the corresponding BER performance of the channel was analyzed by plotting the BER as a function of each RF parameter, point by point, and applying a linear regression analysis. The results of these analyses are listed in Table III, where

TABLE III

RESULTS OF REGRESSION ANALYSES - CALCULATED SLOPES FOR BER DEGRADATION [dB] AS A FUNCTION OF RF PARAMETERS

RF PARAMETER	CALCULATED SLOPE
AMPLITUDE VARIATION [dB]	0.49
GROUP DELAY VARIATION [nsec]	0.31
AM-PM CONVERSION [deg/dB]	-0.40
OUTPUT C/N RATIO [dB]	0.09
THIRD ORDER INTERMODULATION [dBc]	0.06

the coefficients of the independent parameters, indicating the slope of the calculated regression curves, are listed. In addition, multiple regression analyses were performed for the BER as a function of combinations of RF parameters. These results are listed in Table IV, where the coefficients calculated simultaneously for several combinations of RF parameters are given.

In comparing BER results to each individual RF parameter, the amplitude variation proved to have the most significant effect on BER degradation. Figure 4 plots the data points, along with the calculated regression curve and error limits. The slope of the line is 0.49 dB, meaning that each additional dB of amplitude variation results in an additional 0.49 dB of BER degradation.

Group delay also appeared to significantly affect the BER. Figure 5 plots the BER versus group delay data points, along with the regression results. The analysis indicated that each nsec of additional group delay variation added 0.31 dB of BER degradation.

The analysis of the AM-PM conversion results yielded the unusual result that added AM-PM conversion appeared to improve BER performance, as shown in the plot of Fig. 6. Previously published analyses[11,12] have indicated that AM-PM conversion are related to the transponder linearity. As linearity decreases, amplitude variation decreases and AM-PM conversion increases. The effects of improved amplitude variation mask the weaker effects of AM-PM conversion.

As shown in Table III and Figs. 7 and 8, the C/N and third order intermodulation level have only a weak effect on BER degradation.

TABLE IV

RESULTS OF MULTI-VARIABLE REGRESSION ANALYSES - CALCULATED SLOPES FOR BER DEGRADATION [dB] AS A FUNCTION OF RF PARAMETERS

AMPLITUDE VARIATION [dB]	GROUP DELAY [nsec]	AM-PM CONV. [deg/dB]	OUTPUT C/N [dB]	3RD ORDER INTERMOD [dBc]
0.45	0.14	-	-	-
0.40	0.16	-0.23	-	-
0.41	0.16	-0.24	-0.02	-
0.32	0.05	0.07	0.03	0.02

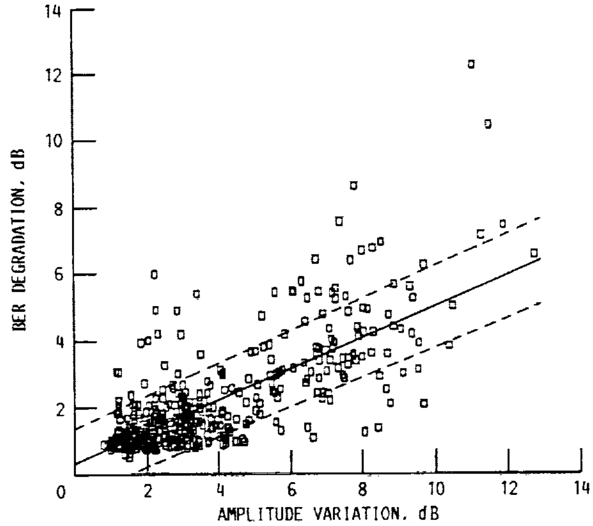

FIGURE 4. - PLOT OF BER DEGRADATION AS A FUNCTION OF AMPLITUDE VARIATION. THE LINEAR REGRESSION CURVE (SOLID LINE) AND ERROR BOUNDS (DASHED LINES) ARE SHOWN.

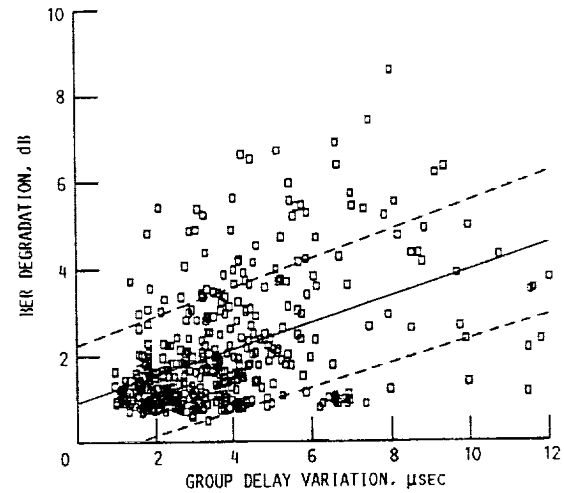

FIGURE 5. - PLOT OF BER DEGRADATION AS A FUNCTION OF GROUP DELAY VARIATION. THE LINEAR REGRESSION CURVE (SOLID LINE) AND ERROR BOUNDS (DASHED LINES) ARE SHOWN.

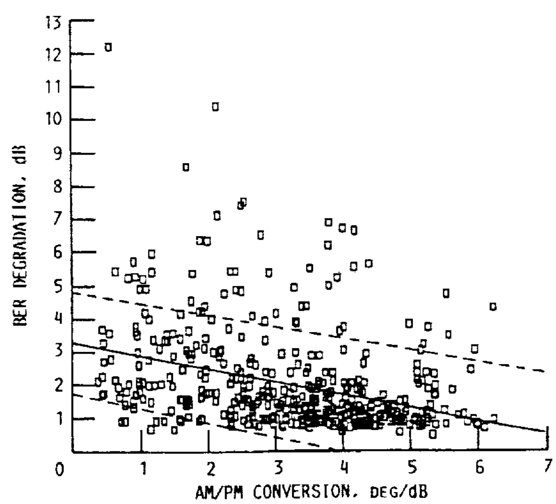

FIGURE 6. - PLOT OF BER DEGRADATION AS A FUNCTION OF AM-PM CONVERSION. THE LINEAR REGRESSION CURVE (SOLID LINE) AND ERROR BOUNDS (DASHED LINES) ARE SHOWN.

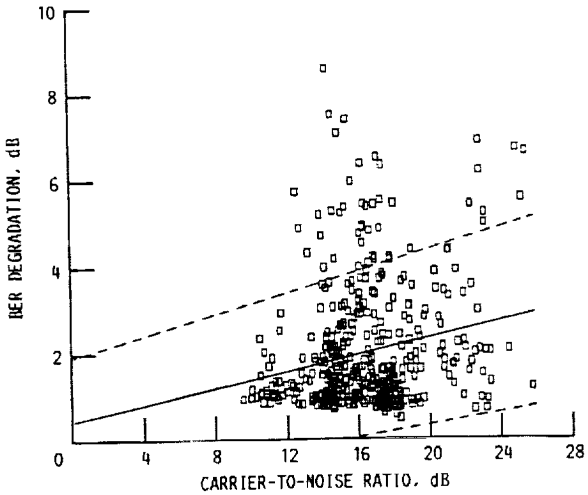

FIGURE 7. - PLOT OF BER DEGRADATION AS A FUNCTION OF OUTPUT C/N. THE LINEAR REGRESSION (SOLID LINE) AND ERROR BOUNDS (DASHED LINES) ARE SHOWN.

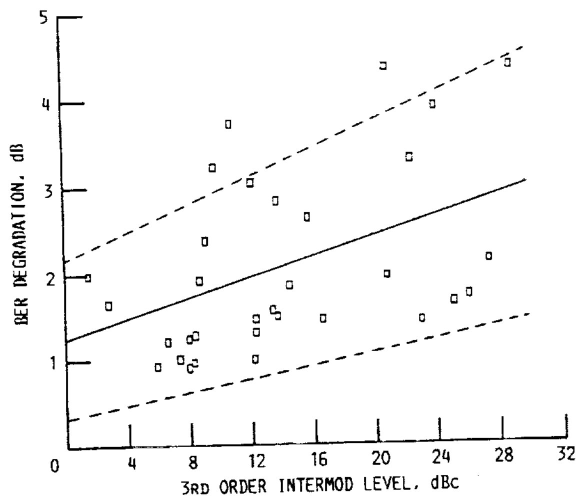

FIGURE 8. - PLOT OF BER DEGRADATION AS A FUNCTION OF THIRD ORDER INTERMODULATION LEVEL. THE LINEAR REGRESSION (SOLID LINE) AND ERROR BOUNDS (DASHED LINES) ARE SHOWN.

In performing multiple regression analyses using several combinations of RF parameters, the results as listed in Table IV reaffirm the dominance of the transponder amplitude response as the RF parameter with the most significant impact on BER performance. Group delay has a smaller effect, while AM-PM conversion effects are still masked by the amplitude variation effects. The output C/N and third order intermodulation have very weak effects.

Conclusions

Results have been given which represent a summary of a large volume of test data taken for a laboratory simulated 30/20 GHz transponder; in terms of RF performance, digitally-modulated data transmission performance, and the interrelationships between the two. Because of the relative simplicity of the SITE transponder compared to typical operational satellite transponders, the results obtained can be applied in general to other types of systems. In particular, the effects of RF parameter variations on BER performance can be applied to the general case of digital data transmission through a nonregenerative satellite transponder. The results pertaining to variation of transponder performance with operating parameters (such as HPA operating point or matrix switch cross point) are somewhat dependent on the specific hardware comprising the SITE transponder, and are thus not as easily applied to the general case.

In any consideration of the data which has been presented here, it is important to remember the specific characteristics of the system and applied signals which are unique to NASA's SITE transponder. Of these, the most important is the modulation format, SMSK, and the data rate, 220 Mbps. SMSK is a unique modulation format due to the absence of significant sidelobes. This results in lower susceptibility to system nonlinearities and phase distortions occurring at band edges due to channel filtering. The data rate, and corresponding channel bandwidth represent a relatively wideband transmission system compared to satellite systems currently employed or planned for the future. Many of the results are nonetheless applicable to narrowband systems.

Other unique characteristics in system design and operation should be noted. In particular, the absence of channel filtering and demultiplexing is unusual compared to operational systems. As mentioned above, such filtering would have had negligible effect on the SMSK-modulated signal. However, filters and demultiplexers often affect the performance of systems employing the more standard modulations such as QPSK or BPSK. In terms of system operation, the variety of operational configurations used during baseline testing represent the majority of configurations seen in operational systems. The exception is the receiver input power level, which was set to a higher level than would be seen in an operational system, in order to negate the effect of several spurious responses occurring in the receiver passband.

The system baselines that were developed for each combination of HPA, TWT mode, HPA operating point, and frequency band resulted in a large variety of system RF characteristics. This allowed for significant variation of BER performance to be observed, and consequently an analysis of the effects of RF distortions on BER performance was possible. Additionally, it was possible to observe the optimum operating conditions for the SITE system in terms of BER performance.

In assessing RF performance, it was found that amplitude variation varied with frequency band, HPA, HPA operating point, and matrix switch crosspoint. Group delay varied primarily with frequency band, HPA, and crosspoint. AM/PM conversion varied primarily with HPA operating point, as did third order intermodulation level. C/N varied with operating point for the TWT only.

In comparing RF parameters, the amplitude variation, AM-PM conversion, and C/N were strong functions of third order intermodulation level. Group delay and amplitude variation were related. Amplitude variation was found to be somewhat a function of AM-PM conversion.

In 66 percent of the cases tested, the system transmitted data with 2.0 dB or less of BER degradation compared to the theoretical case. Accounting for modem losses, the transmission channel in these cases added less than 1.25 dB of degradation. The system performed best, both in terms of BER and RF parameters, in frequency band B. The optimum HPA operating point was saturation, and the GaAsFET slightly outperformed the TWT.

Comparison of BER with the RF parameters showed that the BER was primarily a function of amplitude variation, and to a much lesser degree, of group delay variation. The other RF parameters showed effects that were very small, or were masked by the amplitude variation effects.

References

1. Conroy, M.J. and Kerczewski, R.J., "Testing of 30 GHz Low Noise Receivers," Eleventh Communications Satellite Systems Conference, AIAA, 1986, pp. 326-340 (NASA TM-87171).

2. Kerczewski, R.J., Ponchak, G.E., and Romanofsky, R.R., "Performance of Five 30 GHz Satellite Receivers," 1989 IEEE MTT-S International Microwave Symposium Digest, IEEE, 1989, pp. 1079-1082.

3. Saunders, A., "20x20 High Speed Microwave Switches," NASA TM-83775, 1984.

4. Kerczewski, R.J., "The Bit-Error Rate Performance of a Satellite Microwave Matrix Switch," Twelfth International Communication Satellite Systems Conference, AIAA, New York, 1988, pp. 403-414 (NASA TM-100285).

5. Saunier, P. and Nelson, S., "30/20 GHz Spacecraft GaAs FET Solid State Transmitter for Trunking and Customer Premise Service Applications," TI-08-83-42, Texas Instruments, Inc., Dallas, TX, NASA CR-168276, Aug. 1983.

6. Shalkhauser, K.A., "Test Results for 20 GHz GaAs FET Spacecraft Power Amplifier," NASA TM-87072, 1985.

7. Tomashiro, R.N., "20 GHz, 75 Watt, Helix Traveling Wave Tube for Space Communications," NASA CR-168271, 1984.

8. Shalkhauser, M.J.W. and Budinger, J.M., "Digitally Modulated Bit Error Rate Measurement System for Microwave Component Evaluation," NASA TP-2912, 1989.

9. Kerczewski, R.J., Daugherty, E.S., and Kramarchuk, I., "Automated Measurement of the Bit-Error Rate as a Function of Signal-to-Noise Ratio for Microwave Communications Systems," NASA TM-89898, 1987.

10. Rasmussen, D. and Stilwell, J., "Final Report for 30/20 GHz Modem, Phase III Project," Motorola Inc., (NASA Contract NAS3-22502) 1986.

11. Sklar, B., Digital Communications: Fundamentals and Applications, Prentice Hall, Englewood Cliffs, NJ, 1988.

12. Weinberg, A., "The Effects of Transponder Imperfections on the Error Probability Performance of a Satellite Communication System," IEEE Transactions on Communications, Vol. COM-28, No. 6, June 1980, pp. 858-872.

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16. Abstract

NASA has developed a digital satellite communications system simulator and test bed facility, known as the SITE (Systems Integration, Test and Evaluation) Project. The purpose of the facility is to evaluate satellite system components, develop and verify system concepts, and perform satellite system experiments. A recently completed set of experiments measured the performance of the 30/20 GHz satellite transponder portion of the system in terms of RF parameters and high rate digital data transmission. The results of these tests indicate the quality of data transmission which can be obtained under various transponder operating conditions, as well as the relative effects of degraded RF performance on the bit-error rate (BER) of transmitted data.

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