Summary Report and Status of the Deep Space Network–Mariner Jupiter/Saturn 1977 Flight Project Telecommunications Compatibility

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The DSN-Mariner Jupiter/Saturn 1977 telecommunications compatibility tests, conducted during the time periods 15-20 November 1976, 7-16 December 1976 and 5 January 1977, are an ongoing series of engineering level tests to determine the flight-ground interface compatibility and performance characteristics between these two systems. This report describes these tests in summary form and provides a status of the interface.

I. Introduction

The purpose of this report is to provide an assessment and status of telecommunications compatibility between the Deep Space Network (DSN) and the Mariner Jupiter/Saturn 1977 (MJS'77) spacecrafts. This assessment and status is derived from test results obtained between the Network, as represented in the Compatibility Test Area and the Flight-1, Flight-2 and Prototype Telecommunications Systems.

II. Test Report

The test report describes three sets of tests which were conducted between the Compatibility Test Area (CTA 21) and (1) the Flight 1 Radio Frequency and Modulation-Demodulation Subsystems, (2) the Flight 2 Radio Frequency and Modulation-Demodulation Subsystems and (3) the Prototype Spacecraft Telecommunications System.

Each of the three tests is discussed with regard to test objectives, configurations and results. In addition, Tables 1, 2, and 3 present detailed information on the DSN and MJS'77 test conditions, parameters, criteria and results. Figures 1 and 2 describe the DSN and Spacecraft operational modes. Table 4 defines the terms used in these tables.

A. DSN–MJS'77 Flight 1 Compatibility Testing

1. Test objectives. The objective of the tests was to verify the capability of the DSN to acquire and process telemetry from the spacecraft under various uplink and downlink conditions.

2. Test configuration. The MJS'77 Telecommunications System was located at the Telecommunications Development Laboratory (TDL). The hardware used was the Flight 1 Radio Frequency and Modulation-Demodulation Subsystems. The

Radio Frequency Subsystem was equipped with flight qualified X-band traveling-wave tube amplifiers (TWTAs), one S-band TWTA, and one S-band solid-state amplifier.

The DSN as represented by CTA 21 was configured to simulate a MJS'77 Flight Project committed 64-meter antenna station. The RF links between CTA 21 and the Telecommunications Development Laboratory (TDL) were provided by coax (S-band) and elliptical waveguide (X-band). These RF links were tested for amplitude and phase stability and were calibrated prior to test start.

The DSN software provided at CTA 21 to support these tests was the preliminary 64-meter MARK III Data System (MDS) telemetry software. In addition, test software was provided to enable bit error rate determination at the output of the Maximum Likelihood Convolutional Decoder (MCD).

3. **Test results.** Table 1 provides a listing of test configurations, test criteria, parameters and results. Refer to Figs. 1 and 2 for DSN and spacecraft Radio Frequency Subsystem (RFS) mode configurations.

The S- and X-band telemetry tests were run at weak signal conditions, and although the results generally met the criteria, the MCD Bit Error Rates (BER) achieved during the tests were apparently not consistent with results achieved in the Telecommunications Development Laboratory (TDL) under similar conditions. This BER measurement difference is under investigation and further tests are in progress between the Telecommunications Development Laboratory (TDL) and CTA 21 to attempt to determine the reason for the difference.

The telemetry tests, performed with command and ranging on the uplink and with the spacecraft ranging channel on, indicated a degradation of approximately 0.5 dB in the telemetry BER compared to results achieved in the tests with no modulation on the uplink and the ranging channel off.

4. **Status.** The DSN-MJS'77 Flight 1 Spacecraft Telecommunications Compatibility Tests conducted on 5 January 1977 successfully demonstrated that the telemetry interface between the DSN and the spacecraft (with X- and S-band RF amplifiers) was functional at weak signal levels and performed within specified BERs.

B. DSN–MJS'77 Flight 2 Compatibility Testing

1. **Test objectives.** The objectives of the test were to verify selected interface functions for compatibility of the DSN-MJS'77 Spacecraft Mission configuration. Compatibility is defined as satisfying the specified RF acquisition and tracking, radio metric, command, and telemetry requirements. However, the primary emphasis in this set of tests was directed toward X-band telemetry performance testing as determination of the bit error rate can be accomplished with the MJS'77 Telecommunications system in a stand-alone status in the Telecommunications Development Laboratory.

2. **Test configuration.** The MJS'77 Telecommunications System was located at the Telecommunications Development Laboratory and represented by Flight 2 Radio Frequency and Modulation-Demodulation Subsystems. The Radio Frequency Subsystem was not equipped with either S- or X-band traveling-wave tube amplifiers.

The DSN, as represented by CTA 21, was configured to simulate a MJS'77 Flight Project committed 64-meter antenna station. The S-band and X-band RF links between CTA 21 and TDL were provided by coax and elliptical waveguide. These RF links were tested for amplitude and phase stability and calibrated prior to test start.

The DSN software provided at CTA 21 to support these tests was the operational 26-meter antenna station Mark III-DSN Data Subsystems (MDS) software. In addition, test software was provided to enable operation of the DSS Telemetry Subsystem at high data rates and to enable bit error rate determination at the output of the Maximum Likelihood Convolutional Decoder (MCD).

Modulation-Demodulation Subsystem support equipment, located at the Telecommunications Development Laboratory, was utilized to determine command SNR estimates.

3. **Test results.** Table 2 provides a listing of test configurations, test criteria, parameters, results and comments. Refer to Figs. 1 and 2 for DSN and spacecraft Radio Frequency Subsystem (RFS) mode configurations. Significant test results and comments are discussed below:

a. Radio frequency acquisition and tracking. The X-band two-way phase jitter measurements verify that the DSN must provide an uplink carrier margin of 35 dB in order to provide simultaneous X-band telemetry and doppler without degradation. The two-way X-band phase jitter was measured as 64.7 degrees rms with an uplink signal level of -130 dBm and a downlink signal level of -100 dBm to the CTA 21 Block IV Receiver.

The 35-dB uplink carrier margin (Pc/No X 2 BLo) requirement translates to a carrier power level of approximately -120 dBm to the transponder. This level is approximately equivalent to what can be obtained at Saturn Encounter with a 100-kilowatt transmitter and a 64-meter antenna station (assuming 6-dB ranging and 5-dB command carrier suppres-

sion). Operation at greater distances or with a 26- or 34-meter antenna station will require noncoherent operation of the X-band link and loss of X-band doppler.

It should be noted that S-band performance of the spacecraft transponder is approximately equivalent (22 degree rms phase jitter under similar conditions) to that obtained on previous S-band transponders.

b. Telemetry. X-band telemetry performance was verified to be degraded by the two-way feed-through characteristics of the S-X transponder. Telemetry degradation due to the feed through of commands varied from 0.5 dB at low telemetry data rates to approximately 1 dB at 115.2 kbits/s. This command feed-through problem is independent of the requirement to maintain an approximate 35-dB uplink carrier margin, and the degradation noted above was obtained with 0.5-dB command suppression and 3-dB ranging suppression of the carrier. The effects of command feed through upon S-band telemetry is part of the severe operational limitations on the MJS'77 Mission due to the two-way S-X transmission characteristics of the MJS'77 transponder.

Other items verified during the telemetry tests were:

(1) The suggested procedure for adjusting the Block III SDA for the MJS'77 modulation indices of 80 degrees was verified to be operationally viable.

(2) Correlation of bit error rates and SNR readouts of the SSA and MCD was verified. Therefore, telemetry performance testing with a MJS'77 Spacecraft can utilize the DSS Telemetry Subsystem SNR indicators as a valid measure of performance.

c. Command. Command testing was performed to assure that at specified mission uplink conditions and a command modulation index of 0.5 dB, that a specified SNR ratio was observed in the Modulation-Demodulation Subsystem command loop. A modulation-Demodulation Subsystem performance problem was noted and reported as a Project PRF. If the uplink carrier is suppressed by 3 dB for command modulation, the Modulation-Demodulation Subsystem locked up to an alternate one zero command input during the bit sync acquisition. This improper operation did not occur with a 20-degree command modulation index (0.5-dB carrier suppression).

d. Radio metric. Ranging tests were not performed due to a lack of time and priority. After several false tests due to the sensitivity of the Metric Data Assembly software in detecting doppler cycle slips, it was verified that an uplink signal of -130 dBm to the Radio Frequency Subsystem is the Project stated threshold for X-band doppler performance (10 cycle slips/hour). This uplink threshold level could be altered by the additional phase jitter that would be introduced by the X-band amplifier (not available during these tests).

4. Status. Compatibility verification between the MJS'77 Spacecraft Telecommunication System and the DSN has been verified in only selected areas and further extensive testing is required to establish the design level compatibility of this interface. It should be noted that the final verification of the interface and determination of critical telecommunication performance parameters will depend upon testing with the S- and X-band traveling-wave tube amplifiers as part of the Spacecraft configuration.

C. DSN–MJS'77 Prototype Compatibility Testing

1. Test objectives. The objectives of this phase of testing was to functionally verify compatibility of the telecommunications interfaces between the DSN and the MJS'77 Prototype Spacecraft. In particular, this set of tests served as a test bed to insure that link performance between CTA 21 and the Space Simulator Facility (SSF) would support RF acquisition and tracking, radio metric, command, and telemetry requirements, at both S-band and X-band.

2. Test configuration. The MJS'77 Prototype Spacecraft was located at the SSF which was simulating environmental flight conditions. The Radio Frequency Subsystem was configured as follows:

(1) S-Band

(a) Receiver No. 1, Channel No. 4 (2113.312500 MHz)

(b) Receiver No. 2, Channel No. 18 (2114.676697 MHz)

(c) Ultra Stable Oscillator (USO), Channel No. 14 only (2295.000000 MHz)

(d) Exciters, Chain No. 1 and Chain No. 2, Equipped with prototype traveling wave tube (TWT) amplifiers.

(2) X-band: Exciters, Chain No. 1 with no TWT capability, Chain No. 2 equipped with a prototype traveling wave tube amplifier.

The DSN, as represented by CTA 21, was configured to simulate a MJS'77 Flight Project committed 64-meter antenna station. The ground hardware included both Block III and Block IV Receiver-Exciter Subsystems and the new Mark III Data Subsystems (MDS) for telemetry, command and radio metric data.

The S-band and X-band RF links between CTA 21 and the SSF were open air links which had previously been calibrated for amplitude and phase stability. The DSN software provided at CTA 21 was the operational 26-meter antenna station software for the MDS.

In support of the new MJS'77 Flight Project Mission specifications, the following uplink modulation indices were utilized:

(1) Ranging, 45 deg (−3.0 dB carrier suppression)

(2) Command, 20 deg (−0.54 dB carrier suppression for mission nominal) and 56 deg (−5.0 dB carrier suppression for mission threshold)

3. Test results. In response to the spacecraft Flight Data Subsystem (FDS) limitations for supplying various data rates, and the provisions for only one S-band TWT equipped exciter chain, only a selected subset of the total set were performed. The majority of these tests were performed on a functional basis to insure that a viable test condition could be established with the flight model spacecrafts. However, several significant data points were observed and accumulated as a result of these tests.

Table 3, provides a listing of test configurations, test criteria, parameters and results. Refer to Figs. 1 and 2 for DSN and spacecraft RFS mode configurations. Significant test results and comments are discussed below:

a. Radio frequency acquisition and tracking. These tests were all performed at or below project mission requirements and the results were all favorable with the exception of test RF 3-2, Receiver Static Acquisition. In particular, all requirements of this test were met with the following exception:

(1) U/L signal level: −110 dBm

(2) Spacecraft Receiver No. 2: 2114.682864 MHz (−1000 Hz offset from acquisition frequency)

(3) Spacecraft would not acquire when U/L signal was applied

It is not known what the best lock frequency should have been during this test as VCO frequency versus temperature data was not available from the ground support equipment operators.

b. Telemetry. Because of limited Flight Data System configuration support, only two telemetry processing tests were performed. Both tests were performed on a functional basis to insure that the Mark III Data Subsystems hardware and software would perform satisfactorily. Results of both tests indicated proper operation. Additionally, analyses of the X-band telemetry spectrum tests are incomplete. A report on this phase of testing will be issued at a later date.

c. Command. Command testing was performed at nominal uplink signal levels and at signal levels below expected project mission conditions. Two separate, nontimed commands (2N: X-band ranging channel ON and 2 NR: X-band ranging channel OFF) were successfully sent to the Prototype Spacecraft and successfully executed. These tests were significant in that it marked the first time that the ground command system had been utilized to send actual commands to the flight command system.

d. Radio metric. Ranging tests were performed on a functional basis only. It was, however, determined that the ranging function could be performed with the new 45 degree (−3.0 dB carrier suppression) modulation index and with an uplink signal level of −130 dBm, which is 10 dB below the minimum signal level expected at Saturn encounter with a 64-meter 20-kW transmitter.

4. Status. The DSN-MJS'77 Prototype Spacecraft Telecommunications Compatibility Tests during the period 7 December through 16 December successfully demonstrated that telecommunications interfaces between the ground station and the spacecraft were viably functional at strong signal levels. It further demonstrated that telecommunications compatibility between the DSN and the MJS'77 Flight Spacecrafts can probably be achieved providing that all flight telemetry modes and flight-rated traveling wave tube amplifiers are provided.

III. Conclusions

DSN-MJS'77 telecommunications compatibility testing so far has determined that no major incompatibilities have been discovered. The series of tests have proven that the DSN Mark III Data Subsystems are performing within expectations and are compatible within the flight-ground interface structure. It can be assumed with high probability that the DSN and MJS'77 telecommunications links will satisfy mission objectives.

The formal compatibility test program developed jointly by the DSN and the MJS'77 Flight Project is progressing satisfactorily and at anticipated cost. The success of this program so far is because of the close coordination and cooperation of all participating units.

References

1. *Deep Space Network/Flight Project Interface Compatibility Test Design Handbook*, 810-8, Rev. B, DSN Standard Practice. Jet Propulsion Laboratory, Pasadena, California (JPL internal document).

2. Bryan, A. I., and Madsen, B. D., "DSN Mariner Jupiter-Saturn 1977 Prototype Radio Frequency Subsystem Compatibility Status and Test Report," *The Deep Space Network Progress Report 42-35*, pp. 4-10, Jet Propulsion Laboratory, Pasadena, California, October 1976.

3. *Mariner Jupiter-Saturn 1977 DSN-Spacecraft Compatibility Test Plan*, PD 618-258. Jet Propulsion Laboratory, Pasadena, California, September 1, 1976 (JPL internal document).

Table 1. Deep Space Network—MJS'77 Flight 1 spacecraft telecommunications compatibility test summary

Test date	Test title	Test No.	DSN mode	Spacecraft MOD	Spacecraft RM	Test conditions	Performance	Criteria	Time, min
1/5	Telemetry performance	TM-2-4	122611	6633-16		X-band DL signal level: −125.0 dBm (Pc) X-band TLM bit rate: 44.8 kbits/s coded X-band Y-factor: 10.99 dB = STB/No. of 4.0 dB S-band UL signal level: −110 dBm Command Mod. = 20 deg Ranging Mod. = 45 deg	MCD SNR: 2.85 dB SSA SNR: 0.34 dB BER: 8.53×10^{-3}	$<5 \times 10^{-3}$ BER	70
			002611	6633-16		Same as above	MCD SNR: 3.47 dB SSA SNR: 0.48 dB BER: 2.47×10^{-3}	$<5 \times 10^{-3}$ BER	
1/5	Telemetry performance	TM-2-5	002611	6630-16		X-band DL signal level: −127.5 dBm (Pc) X-band TLM bit rate: 29.9 kbits/s coded X-band Y-factor: 9.43 = STB/No. of 4.0 dB S-band UL signal level: −110 dBm (Pc) Command Mod. = 20 deg Ranging Mod. = 45 deg	MCD SNR: 3.10 dB SSA SNR: 0.21 dB BER: 5.0×10^{-3}	$<5 \times 10^{-3}$ BER	150
			122611	6631-16		Same as above	MCD SNR: 2.93 dB SSA SNR: 0.30 dB BER: 6.78×10^{-3}	$<5 \times 10^{-3}$ BER	
			002611	6630-14		X-band DL signal level: −127.0 dBm (Pc) X-band Y-factor: 10.3 = STB/No. of 5.0 dB	MCD SNR: 3.86 dB SSA SNR: 1.09 dB BER: 2.27×10^{-3}	$<5 \times 10^{-3}$ BER	
1/5	Telemetry performance	TM-2-7	002311	6630-16		S-band DL signal level: −142.0 dBm (Pc) S-band TLM bit rate: 2.56 kbits/s coded S-band Y-factor: 12.12 dB plus 10.34 dB Pad = STB/No. of 7.0 dB S-band UL signal level: −110 dBm	MCD SNR: 6.07 dB SSA SNR: 2.89 dB BER: No bit errors	$<5 \times 10^{-3}$ BER	32

Table 1 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft MOD	Spacecraft RM	Test conditions	Performance	Criteria	Time, min
1/5	Telemetry performance	TM-2-10	002311	6630-16		S-band DL signal level: −146.0 dBm (Pc)	MCD SNR: 3.95 dB	$<5 \times 10^{-3}$ BER	27
						S-band TLM bit rate: 1.2 kbits/s coded	SSA SNR: 0.49 dB		
						S-band Y-factor: 7.5 dB plus 10.34 dB Pad = STB/No. of 5.0 dB	BER: 6.64×10^{-4}		

Table 2. Deep Space Network–MJS'77 Flight 2 spacecraft telecommunications compatibility test summary

Test date	Test title	Test No.	DSN mode	Spacecraft MOD RM	Test conditions	Performance	Criteria	Time, min
11/17	Telemetry processing	TM-3-1	122612	633-16	X-band DL signal level: −120.0 dBm X-band UL signal level: −113.5 dBm X-band TLM bit rate: 89.6 kbits/s coded MCD SNR ⩾ 10.175 dB	BER = 0	BER = 0	18
11/17	Telemetry processing	TM-3-2	122612	6633-16	X-band DL signal level: −120.0 dBm X-band UL signal level: −113.5 dBm X-band TLM bit rate: 67.2 kbits/s coded MCD SNR ⩾ 10.175 dB	BER = 0	BER = 0	56
11/17	Telemetry processing	TM-3-3	122612	6633-16	X-band DL signal level: −120.0 dBm X-band UL signal level: −113.5 dBm X-band TLM bit rate: 21.6 kbits/s coded MCD SNR ⩾ 10.175 dB	BER = 0	BER = 0	46
11/17	Telemetry processing	TM-3-4	122612	6633-16	X-band DL signal level: −120.0 dBm X-band UL signal level: −113.5 dBm X-band TLM bit rate: 19.2 kbits/s coded MCD SNR ⩾ 10.175 dB	BER = 0	BER = 0	21
11/19	Telemetry processing	TM-3-5	002312	4410-10	S-band DL signal level: −120.0 dBm S-band UL signal level: −110.0 dBm S-band TLM bit rate: 1280 bits/s coded MCD SNR ⩾ 10.175 dB	BER data not available	BER = 0	74
11/19	Telemetry processing	TM-3-6	002312	4410-10	S-band DL signal level: −118.0 dBm S-band UL signal level: −110.0 dBm S-band TLM bit rate: 320 bits/s coded MCD SNR ⩾ 10.175 dB	BER data not available	BER = 0	26
11/19	Telemetry processing	TM-3-7	002312	4410-10	S-band DL signal level: −120.0 dBm	BER data not available	BER = 0	30

Table 2 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft MOD	Spacecraft RM	Test conditions	Performance	Criteria	Time, min
						S-band UL signal level: −110.0 dBm S-band TLM bit rate: 80 bits/s coded MCD SNR ⩾ 10.175 dB			
11/18	Telemetry performance	TM-2-5				X-band DL signal level: −128.0 dBm X-band TLM bit rate: 29.9 kbits/s coded			60
			122612	6633-16		X-band UL signal level: −113.5 dBm	BER = 8.33×10^{-4}	BER ⩽ 5×10^{-3}	
			002612	6633-16		X-band UL signal level: −110.0 dBm	BER = 1.91×10^{-4}	BER ⩽ 5×10^{-3}	
11/18	Telemetry performance	TM-2-6				X-band DL signal level: −128.0 dBm X-band TLM bit rate: 7.2 kbits/s coded			156
			122612	6633-16		X-band UL signal level: −113.5 dBm	BER = 6.07×10^{-4}	BER ⩽ 5×10^{-3}	
			002612	6633-16		X-band UL signal level: −110.0 dBm	BER = 2.04×10^{-4}	BER ⩽ 5×10^{-3}	
11/18	Telemetry performance	TM-2-7	002312	6633-16		S-band DL signal level: −152.0 dBm S-band UL signal level: −110.0 dBm S-band TLM bit rate: 2.56 kbits/s coded ST_B/N_o = 4.0 dB	BER = 7.09×10^{-4}	BER ⩽ 5×10^{-3}	80
11/19	Telemetry performance	TM-2-8	002312	4410-10		S-band DL signal level: −151.5 dBm S-band UL signal level: −110.0 dBm S-band TLM bit rate: 640 bits/s coded ST_B/N_o = 4.0 dB	BER = 4.27×10^{-4}	BER ⩽ 5×10^{-3}	131
11/19	Telemetry performance	TM-2-9	002312	4410-10		S-band DL signal level: −154.5 dBm S-band UL signal level: −110.0 dBm S-band TLM bit rate: 160 bits/s coded ST_B/N_o = 6.0 dB	BER = 7.58×10^{-4}	BER ⩽ 5×10^{-3}	130
11/19	Telemetry performance	TM-2-10	002312	4410-10		S-band DL signal level: −151.5 dBm S-band UL signal level: −110.0 dBm	BER = 1.26×10^{-4}	BER ⩽ 5×10^{-3}	51

Table 2 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft MOD	Spacecraft RM	Test conditions	Performance	Criteria	Time, min
						S-band TLM bit rate: 1.2 kbits/s coded			
						ST_B/N_o = 5.0 dB			
11/15	Downlink RF carrier threshold (one-way) S- and X-band	RF-1-1	000100	4400-10		S-band DL frequency: 2295.001088 MHz	−157.2 dBm	−158.0 ± 1.0 dBm	118
			000600	4400-10		X-band DL frequency: 8414.960510 MHz	−152.8 dBm	−154.0 ± 1.0 dBm	
11/15 11/16	Downlink RF carrier (two-way) S- and X-band	RF-1-5				S-band UL frequency: 2113.310408 MHz			69
						S-band DL frequency: 2294.997728 MHz			
						X-band DL frequency: 8414.990873 MHz			
			002100	4413-10		S-band UL signal level: −100.0 dBm	S-band; −156.8 dBm	−158.0 ± 1.0 dBm	
			002500				X-band; −152.8 dBm	−154.0 ± 1.0 dBm	
						S-band UL signal level: −130.0 dBm	S-band; −156.6 dBm	−158.0 ± 1.0 dBm	
							X-band; −150.0 dBm	−154.0 ± 1.0 dBm	
			122100			S-band UL signal level: −100.0 dBm	S-band; −156.5 dBm	−158.0 ± 1.0 dBm	
							X-band; −149.4 dBm	−154.0 ± 1.0 dBm	
11/16	Spacecraft transmitter carrier phase jitter (one-way)	RF-5-1	000$\frac{1}{2}$00	4400-10		S-band DL frequency: 2294.997728 MHz	1.55 deg rms	⩽3.0 deg rms	65
			000$\frac{5}{6}$00	4400-10		X-band DL frequency: 8414.991669 MHz	8.32 deg rms	⩽11.0 deg rms	
	(two-way)		002$\frac{1}{2}$00	4410-10		S-band DL frequency: 2294.997719 MHz	21.8 deg rms	⩽2.3 deg rms*	
			002$\frac{5}{6}$00	4410-10		X-band DL frequency: 8414.991638 MHz	64.13 deg rms	⩽8.4 deg rms*	
						*UL signal level −130.0 dBm instead of −70.0 dBm for criteria shown			
11/16	Spacecraft transmitter carrier phase jitter (one-way)	RF-5-2	000$\frac{1}{2}$00	6620-16		S-band DL frequency: 2295.000992 MHz	0.76 deg rms	⩽3.0 deg rms	68
			000$\frac{5}{6}$00	6620-16		X-band DL frequency: 8415.003637 MHz	7.01 deg rms	⩽11.0 deg rms	
	(two-way)		002$\frac{1}{2}$00	6630-16		S-band DL frequency: 2295.008140 MHz	22.04 deg rms	⩽2.3 deg rms*	
			002$\frac{5}{6}$00	6630-16		X-band DL frequency: 8414.994850 MHz	64.7 deg rms	⩽8.4 deg rms*	
						*UL signal level −130.0 dBm instead of −70.0 dBm for criteria shown			

Table 2 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft MOD	Spacecraft RM	Test conditions	Performance	Criteria	Time, min
11/18	Telemetry performance	TM-2-3				X-band DL signal level: −122.0 dBm			165
						X-band TLM bit rate 115.2 kbits/s coded			
						ST_B/N_o = 4.0 dB			
			122612	6633-16		X-band UL signal level: −133.5 dBm	BER = 4.78×10^{-4}	BER $\leqslant 5 \times 10^{-3}$	
			002612	6633-16		X-band UL signal level: −110.0 dBm	BER = 7.8×10^{-5}	BER $\leqslant 5 \times 10^{-3}$	
			002612	6633-16		X-band UL signal level: −110.0 dBm	BER = 1.03×10^{-4}	BER $\leqslant 5 \times 10^{-3}$	
						X-band UL frequency Offset: +72.5 kHz			
11/18	Telemetry performance	TM-2-4				X-band DL signal level: −126.0 dBm			65
						X-band TLM bit rate: 44.8 kbits/s coded			
						ST_B/N_o = 4.0 dB			
			122612	6633-16		X-band UL signal level: −113.5 dBm	BER = 5.5×10^{-4}	BER $\leqslant 5 \times 10^{-3}$	
			002612	6633-16		X-band UL signal level: −110.0 dBm	BER = 3.97×10^{-5}	BER $\leqslant 5 \times 10^{-3}$	
11/22	Command SNR verification	CM-2-2	022000	4410-10		UL carrier suppression: −0.54 dB		Special investigative tests; no criteria	186
						UL signal level: −125.5 dBm	SNR = 18.5 dB		
						UL signal level: −133.5 dBm	SNR = 7.66 dB		
						UL carrier suppression: −3.0 dB			
						UL signal level: −114.0 dBm	SNR = 36.0 dB		
						UL signal level: −124.0 dBm	SNR = 27.5 dB		
						UL signal level: −141.0 dBm	SNR = 9.0 dB		

Table 3. Deep Space Network–MJS'77 prototype spacecraft telecommunications compatibility test summary

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
12/7	DL threshold (one-way)	RF-1-3	000300	6720-16	S-band DL frequency : 2294.999640 MHz	−159.0 ± 3.0 dBm	−159.0 dBm	55
			000600	6720-16	X-band DL frequency: 8414.998820 MHz	−150.0 ± 3.0 dBm	−149.8 dBm	
12/8	DL threshold (two-way)	RF-1-4	002300	6703-16	S-band UL frequency: 2113.315008 MHz			39
					S-band DL frequency: 2295.002600 MHz	−159.0 ± 3.0 dBm	−161.0 dBm	
			002600	6703-16	X-band DL frequency: 8415.010745 MHz	−150.0 ± 3.0 dBm	−149.5 dBm	
12/8	DL threshold (two-way)	RF-1-6	002300	6720-16	S-band UL frequency: 2114.682864 MHz			54
					S-band DL frequency: 2296.488200 MHz	−159.0 ± 3.0 dBm	−161.0 dBm	
					X-band DL frequency: 8420.456695 MHz	−150.0 ± 3.0 dBm	−149.0 dBm	
12/8	UL threshold	RF-2-1	002300	6713-16	S-band UL frequency: 2113.315008 MHz Spacecraft Receiver No. 1 high-gain antenna	⩽−152.0 dBm	−156.0 dBm	17
12/8	UL threshold	RF-2-2	002300	6733-16	S-band UL frequency: 2114.683872 MHz Spacecraft Receiver No. 2 low-gain antenna	⩽−152.0 dBm	−156.0 dBm	22
12/8	UL threshold	RF-2-3	122300	6753-16	S-band UL frequency: 2113.315008 MHz Spacecraft Receiver No. 1 low-gain antenna	⩽−152.0 dBm	−155.0 dBm	34
2/8	UL threshold	RF-2-4	122300	6773-16	S-band UL frequency: 2114.683872 MHz Spacecraft Receiver No. 2 low-gain antenna	⩽−152.0 dBm	−156.0 dBm	31
12/8	Spacecraft receiver static acquisition	RF-3-1	002300	6603-16	Spacecraft best lock frequency: 2113.312512 MHz			32
					−200 Hz OFFSET	⩽15 s	Lock at 1 s	
					−400 Hz OFFSET	⩽30 s	Lock at 3 s	
					−600 Hz OFFSET	⩽60 s	Lock at 7 s	
					−800 Hz OFFSET	⩽150 s	Lock at 16 s	
					−1000 Hz OFFSET	⩽300 s	Lock at 48 s	
					+200 Hz OFFSET	⩽15 s	Lock at 1 s	
					+400 Hz OFFSET	⩽30 s	Lock at 3 s	
					+600 Hz OFFSET	⩽60 s	Lock at 6 s	
					+800 Hz OFFSET	⩽150 s	Lock at 14 s	
					+1000 Hz OFFSET	⩽300 s	Lock at 18 s	

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
2/8	Spacecraft receiver station acquisition	RF-3-2	002300	6733-16	Spacecraft best lock frequency: 2114.683872 MHz			64
					-200 Hz OFFSET	≤15 s	Lock at 1 s	
					-400 Hz OFFSET	≤30 s	Lock at 3 s	
					-600 Hz OFFSET	≤60 s	Lock at 6 s	
					-800 Hz OFFSET	≤150 s	Lock at 20 s	
					-1000 Hz OFFSET	≤300 s	No lock	
					+200 Hz OFFSET	≤15 s	Lock at 1 s	
					+400 Hz OFFSET	≤30 s	Lock at 3 s	
					+600 Hz OFFSET	≤60 s	Lock at 6 s	
					+800 Hz OFFSET	≤150 s	Lock at 12 s	
					+1000 Hz OFFSET	≤300 s	Lock at 25 s	
12/8	Spacecraft receiver sweep acquisition	RF-3-3	002300	6603-16	Spacecraft best lock frequency: 2113.312512 MHz			22
					UL signal level: -144.0 dBm	Acquire at Offset: +7 kHz Rate: 60 Hz/s	Acquired	
						Acquire at Offset: -7 kHz Rate: 60 Hz/s	Acquired	
12/8	Spacecraft receiver sweep acquisition	RF-3-4	002300	6623-16	Spacecraft best lock frequency: 2114.676672 MHz			
					UL signal level: -144.0 dBm	Acquire at Offset: +7 kHz Rate: 60 Hz/s	Acquired	
						Acquire at Offset: -7 kHz Rate: 60 Hz/s	Acquired	
12/8	Spacecraft receiver tracking	RF-4-1	122300	6713-16	UL signal level: -120.0 dBm Ramp rate: 100 Hz/s Offset: +72.5 kHz	≤60 deg static phase error	Maintained proper operation	57
					UL signal level: -120.0 dBm Ramp rate: 100 Hz/s Offset: -72.5 kHz	≤60 deg static phase error	Maintained proper operation	
12/8	Spacecraft receiver tracking	RF-4-2	122300	6733-16	UL signal level: -120.0 dBm Ramp rate: 100 Hz/s Offset: +72.5 kHz	≤60 deg static phase error	Maintained proper operation	44
					UL signal level: -120.0 dBm Ramp rate: 100 Hz/s Offset: -72.5 kHz	≤60 deg static phase error	Maintained proper operation	

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
12/9	Spacecraft transmitter carrier phase jitter (one-way)	RF-5-2	$000\frac{1}{2}00$	6620-16	S-band DL frequency: 2296.487552 MHz	3.0 deg rms	0.4 deg rms	43
			$000\frac{5}{6}00$	6620-16	X-band DL frequency: 8420.450575 MHz	11.0 deg rms	6.62 deg rms	
12/9	Spacecraft transmitter carrier phase jitter (one-way)	RF-5-3	$000\frac{1}{2}00$	6724-16	S-band DL frequency: 2294.999648 MHz	3.0 deg rms	0.4 deg rms	54
			$000\frac{5}{6}00$		X-band DL frequency: 8414.994765 MHz	11.0 deg rms	6.08 deg rms	
	(two-way)		$002\frac{1}{2}00$	6734-16	S-band DL frequency: 2296.493756 MHz	2.3 deg rms	0.47 deg rms	
			$002\frac{5}{6}00$		X-band DL frequency: 8420.477104 MHz	8.4 deg rms	6.27 deg rms	
12/9	Spacecraft transmitter carrier phase jitter (one-way)	RF-5-4	$000\frac{1}{2}00$	6720-16	S-band DL frequency: 2294.999552 MHz	3.0 deg rms	0.55 deg rms	112
			$000\frac{5}{6}00$		X-band DL frequency: 8414.994765 MHz	11.0 deg rms	6.13 deg rms	
	(two-way)		$002\frac{1}{2}00$	6730-16	S-band DL frequency: 2296.491983 MHz	2.3 deg rms at −108 dbm UL	1.98 deg rms	
			$002\frac{5}{6}00$		X-band DL frequency: 8420.470606 MHz	8.42 deg rms at −108 dBm UL	5.34 deg rms	
12/11	Command processing	CM-1-1	121100	7513-16	S-band UL frequency: 2113.312512 MHz UL signal level, P_T: −143.0 dBm UL carrier suppression: −5.0 dB Subcarrier offset: 0.0 Hz +0.2 Hz −0.2 Hz	Proper subcarrier and bit sync acquisition; verification of command execution	 O.K. O.K. O.K.	111
12/10	Command processing	CM-1-2	022000	5772-16	S-band UL frequency: 2114.676672 MHz UL signal level, P_T: −143.0 dBm UL carrier suppression: −5.0 dB Subcarrier offset: 0.0 Hz +0.2 Hz −0.2 Hz	Proper subcarrier and bit sync acquisition; verification of command execution	 O.K. O.K. O.K.	74

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
12/16	Command processing	CM-1-3	021000	2530-02	S-band UL frequency: 2114.676672 MHz UL signal level, P_T: −5.0 dB UL carrier suppression: −5.0 dB Subcarrier offset 0.0 Hz −0.2 Hz +0.2 Hz	Proper subcarrier and bit sync acquisition; verification of command execution	 O.K. O.K. O.K.	80
12/11	Command SNR verification	CM-2-1	022000	6712-16	UL signal level: −139.0 dBm, P_C UL carrier suppression: −5.0 dB	> 1.5 dB	2.5 dB SNR	45
12/10	Telemetry spectrum analysis	TM-1-1			S-band DL frequency: 2296.486976 MHz X-band DL frequency: 8420.452700 MHz	Identify all spurious spectral components greater than −30.0 dB		80
			000200	6623-12	S-band TLM: 40 bits/s		None noted	
			000600	6623-12	X-band TLM: 230.4 kbits/s S-band UL frequency: 2114.690880 MHz S-band DL frequency: 2296.496883 MHz X-band DL frequency: 8420.488572 MHz		Analysis incomplete	
			002200	6633-12	S-band TLM: 40 bits/s		None noted	
			002600	6633-12	X-band TLM: 230.4 kbits/s		Analysis incomplete	
			122200	6633-12	S-band TLM: 40 bits/s		None noted	
			122600	6633-12	X-band TLM: 230.4 kbits/s		Analysis incomplete	
12/10	Telemetry spectrum analysis	TM-1-2			S-band DL frequency: 2295.054560 MHz X-band DL frequency: 8415.189755 MHz	Identify all spurious spectral components greater than −30.0 dB		60
			000200	5703-12	S-band TLM: 230.4 kbits/s		None noted	
			000600	5703-12	X-band TLM: 230.4 kbits/s S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000013 MHz X-band DL frequency: 8415.000048 MHz		Analysis incomplete	

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
			002200	5703-12	S-band TLM: 230.4 KSPS		None noted	
			002600	5703-12	X-band TLM: 230.4 KSPS		Analysis incomplete	
			122200	5703-12	S-band TLM: 230.4 KSPS		None noted	
			122600	5703-12	X-band TLM: 230.4 KSPS		Analysis incomplete	
12/10	Telemetry spectrum analysis	TM-1-3			S-band DL frequency: 2295.038912 MHz X-band DL frequency: 8415.189755	Identify all spurious spectral components greater than −30.0 dB		44
			000200	5703-16	S-band TLM: 40 bits/s		None noted	
			000600	5703-16	X-band TLM: 89.6 KSPS S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000013 MHz X-band DL frequency: 8415.000048 MHz		Analysis incomplete	
			002200	5713-16	S-band TLM: 40 bits/s		None noted	
			002600	5713-16	X-band TLM: 89.6 KSPS		Analysis incomplete	
			122200	5713-16	S-band TLM: 40 bits/s		None noted	
			122600	5713-16	X-band TLM: 89.6 KSPS		Analysis incomplete	
12/10	Telemetry spectrum analysis	TM-1-4			S-band DL frequency: 2295.004352 MHz X-band DL frequency: 8415.015957 MHz	Identify all spurious spectral components greater than −30.0 dB		40
			000200	5703-16	S-band TLM: 40 bits/s		None noted	
			000600	5703-16	X-band TLM: 14.4 KSPS S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000032 MHz X-band DL frequency: 8415.000290 MHz		Analysis incomplete	
			002200	5713-16	S-band TLM: 40 bits/s		None noted	
			002600	5713-16	X-band TLM: 14.4 KSPS		Analysis incomplete	
			122200	5713-16	S-band TLM: 40 bits/s		None noted	
			122600	5713-16	X-band TLM: 14.4 KSPS		Analysis incomplete	

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
12/16	Telemetry spectrum analysis	TM-1-10			S-band DL frequency: 2294.999880 MHz S-band TLM: 2400 SPS	Identify all spurious spectral components greater than −30.0 dB	None noted	47
12/9	Telemetry spectrum analysis	TM-1-13			S-band DL frequency: 2296.487168 MHz X-band DL frequency: 8420.452949 MHz	Identify all spurious spectral components greater than −30.0 dB		120
			000200	6623-12	S-band TLM: 40 bits/s		None noted	
			000600	6623-12	X-band TLM: 134.4 KSPS S-band UL frequency: 2114.686368 MHz S-band DL frequency: 2296.491960 MHz X-band DL frequency: 8420.470720 MHz		Analysis incomplete	
			122200	6633-12	S-band TLM: 40 bits/s		None noted	
			122600	6633-12	X-band TLM: 134.4 KSPS		Analysis incomplete	
12/9	Telemetry processing	TM-3-2	122322	6633-12	S-band DL signal level: −120.0 dBm			69
					S-band TLM bit rate: 40 bits/s	>10.0 dB	25.0 dB SNR	
			122612	6633-12	X-band DL signal level: −120.0 dBm			
					X-band TLM bit rate: 67.2 kbits/s	>2.5 dB	5.35 dB SNR	
12/16	Telemetry processing	TM-3-10	000322	4550-02	S-band DL signal level: −121.0 dBm			46
					S-band TLM bit rate: 1200 bits/s	>10.0 dB	19.85 dB SNR	
					X-band DL signal level: −121.0 dBm			
					X-band DL bit rate: 1200 bits/s	>2.5 dB	10.18 dB SNR	
12/11	Range delay performance test	RM-1-1			S-band UL frequency: 2113.312512 MHz UL signal level: −130 dBm DL frequency: 2295.000000 MHz DL signal level: −108.5 dBm	Functional test only. −130.0 dBm UL signal level is 10 dB below minimum signal level expected at Saturn encounter		90

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
					X-band			
					DL frequency: 8415.000205 MHz			
					DL signal level: −112.0 dBm			
					0.0 Hz offset			
			$102\frac{3}{6}00$	7713-16	S-band		5434.4 RU	
					X-band		5157.0 RU	
					+72.5 kHz offset			
			$122\frac{3}{6}00$	7713-16	S-band		5436.6 RU	
					X-band		5175.8 RU	
					−72.5 kHz offset			
			$122\frac{3}{6}00$	7713-16	S-band		5436.2 RU	
					X-band		5137.3 RU	
12/10	Range delay performance test	RM-1-3			S-band			
					UL frequency: 2114.677152 MHz	Functional test only.		163
					UL signal level: −130.0 dBm	−130.0 dBm UL signal level is 10 dB below minimum signal level expected at Saturn encounter		
					DL frequency: 2296.481975 MHz			
					DL signal level: −110.0 dBm			
					X-band			
					DL frequency: 8420.433908 MHz			
					DL signal level: −111.5 dBm			
					0.0 Hz offset			
			$102\frac{3}{6}00$	7733-16	S-band		5453.8 RU	
					X-band		5138.8 RU	
					+72.5 kHz offset			
			$122\frac{3}{6}00$	7733-16	S-band		5454.6 RU	
					X-band		5144.9 RU	
					−72.5 kHz offset			
			$122\frac{3}{6}00$	7733-16	S-band		5452.3 RU	
					X-band		5138.4 RU	
12/10	Range delay calibration verification test	RM-2-1	$102\frac{3}{6}00$	7733-16	S-band UL frequency: 2114.677152 MHz	Functional test only		28
					S-band DL frequency: 2296.481975 MHz			
					S-band DL signal level: −108.5 dBm			

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
					X-band DL frequency: 8420.433908 MHz			
					X-band DL signal level: −100.5 dBm			
					UL signal level: −112.5 dBm			
					S-band		5482.9 RU	
					X-band		5132.4 RU	
					UL signal level: −120.0 dBm			
					S-band		5468.8 RU	
					X-band		5140.0 RU	
					UL signal level: −130.0 dBm			
					S-band		5457.0 RU	
					X-band		5143.6 RU	
12/10	Range delay calibration verification test	RM-2-2	$102\frac{3}{6}00$	7773-16	S-band UL frequency: 2114.677152 MHz	Functional test only		25
					S-band DL frequency: 2296.481975 MHz			
					S-band DL signal level: −108.5 dBm			
					X-band DL frequency: 8420.433908 MHz			
					S-band DL signal level: −100.5 dBm			
					UL signal level: −113.0 dBm			
					S-band		5446.0 RU	
					X-band		5135.8 RU	
					UL signal level: −120.0 dBm			
					S-band		5447.4 RU	
					X-band		5141.6 RU	
					UL signal level: −130.0 dBm			
					S-band		5459.6 RU	
					X-band		5136.0 RU	
12/11	Range delay calibration verification test	RM-2-5	$102\frac{3}{6}00$	7513-16	S-band UL frequency: 2113.312512 MHz	Functional test only		17
					S-band DL frequency: 2295.000013 MHz			
					S-band DL signal level: −108.5 dBm			
					X-band DL frequency: 8115.000048 MHz			

Table 3 (contd)

Test date	Test title	Test No.	DSN mode	Spacecraft RFS mode	Test conditions	Criteria	Performance	Time, min
					X-band DL signal level: −112.0 dBm			
					UL signal level: −113.0 dBm			
					S-band		5430.5 RU	
					X-band		5177.3 RU	
					UL signal level: −120.0 dBm			
					S-band		5447.3 RU	
					X-band		5161.5 RU	
					UL signal level: −130.0 dBm			
					S-band		5442.3 RU	
					X-band		5151.3 RU	
12/11	Range delay calibration verification test	RM-2-6	$102\frac{3}{6}00$	7713-16	S-band UL frequency: 2113.312512 MHz	Functional		21
					S-band DL frequency: 2295.000013 MHz			
					S-band DL signal level: −108.5 dBm			
					X-band DL frequency: 8415.000048 MHz			
					X-band DL signal level: −112.0 dBm			
					UL signal level: −113.0 dBm			
					S-band		5424.8 RU	
					X-band		5188.0 RU	
					UL signal level: −120.0 dBm			
					S-band		5435.5 RU	
					X-band			
					UL signal level: −130.0 dBm			
					S-band		5438.8 RU	
					X-band		5148.5 RU	

Table 4. Definition of terms for Tables 1, 2, and 3

BER	bit error rate
BIT RATE	clock frequency of the telemetry bit information
bits/s	bits per second
CPA	Command Processor Assembly
CMF	Communications Monitor and Formatting Assembly
CTA 21	The Deep Space Network Ground Station Compatibility Test Area at JPL
dB	decibel
dBm	decibel referenced to one milliwatt
DL	RF downlink signal
DSN mode	The Deep Space Network Ground Station operational configuration
FDS	Spacecraft Flight Data Subsystem
JPL	Jet Propulsion Laboratory
MCD	Maximum Likelihood Convolutional Decoder
MDA	Metric Data Assembly
MDS	Spacecraft Modulation/Demodulation Subsystem
MDS	The DSN-MARK III Data Subsystems Implementation Project
No	noise spectral density
P_c	Power in RF carrier
P_T	Power total
PRA	Planetary Ranging Assembly
PFR	Problem/Failure Report
RDA	Ranging Demodulator Assembly
RF	radio frequency
RFS	Spacecraft Radio Frequency Subsystem
RU	range unit
SAF	Spacecraft Assembly Facility (JPL Building 179)
S/C RFS Mode	The Spacecraft Radio Frequency Subsystem operational configuration
SDA	Subcarrier Demodulator Assembly
SER	symbol error rate
SNR	signal-to-noise ratio
SPS	symbols per second
SSA	Symbol Synchronizer Assembly
SSF	Space Simulator Facility (JPL Building 150)
STb/No	signal-to-noise spectral density ratio
SYMBOL RATE	clock frequency of the telemetry symbol information
TBD	to be determined
TBS	to be supplied
TDL	Telemetry Development Laboratory
TLM	telemetry
TPA	Telemetry Processor Assembly
TWT	Traveling Wave Tube Amplifier
UL	RF uplink signal
Uplink Doppler	ramp rate of uplink RF carrier frequency
Uplink Offset	uplink RF carrier frequency displacement relative to the spacecraft receiver rest frequency
USO	ultra stable oscillator
VCO	voltage controlled oscillator

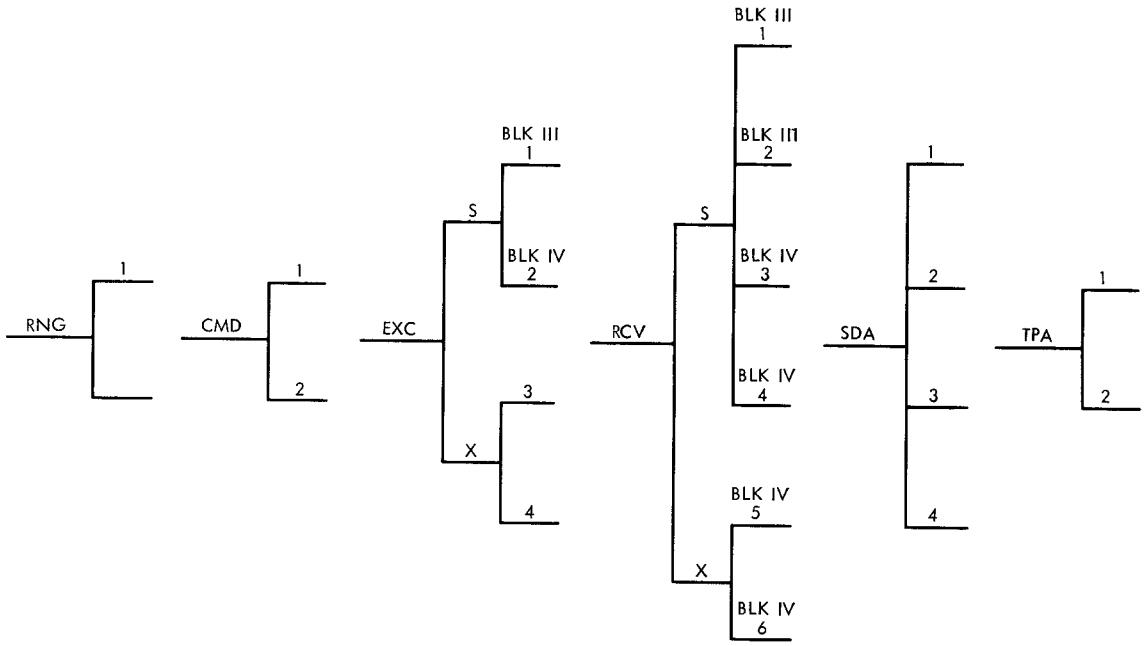

Fig. 1. DSN modes

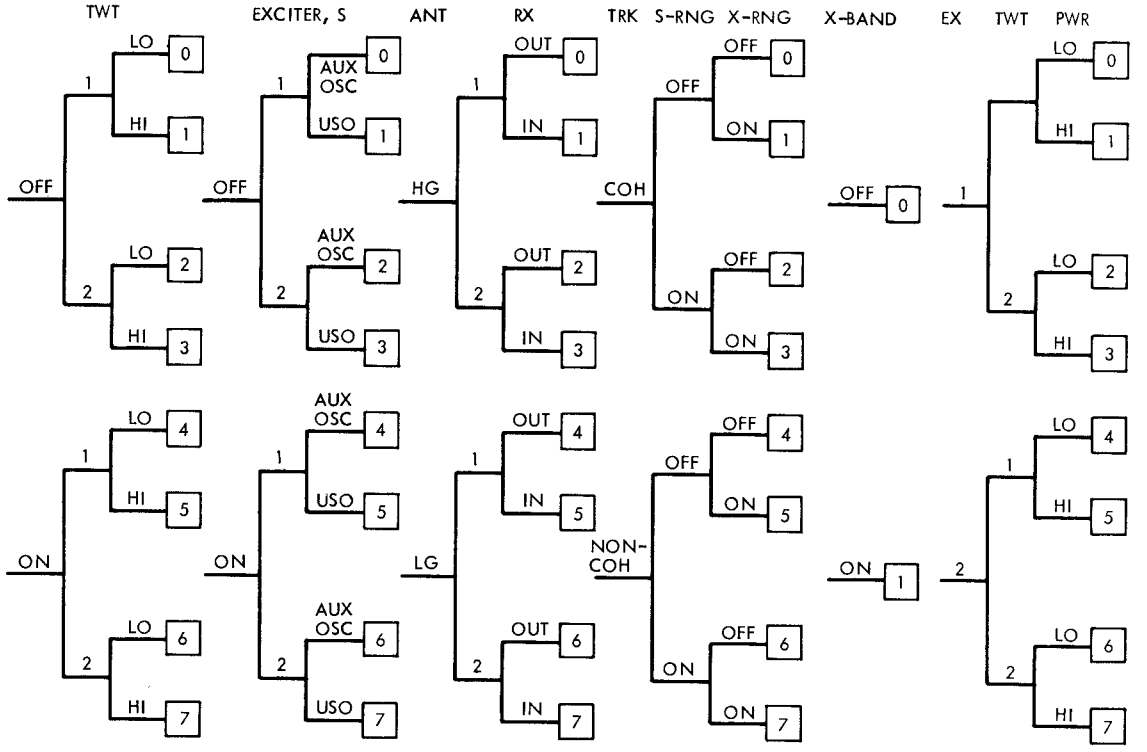

Fig. 2. MJS'77 operational RFS modes