Voyager Flight Project — DSN Telecommunications Compatibility Test Program

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The Voyager Flight Project – DSN Telecommunications Compatibility Test Program consisted of three phases: Subsystem Design, System Design and System Verification Tests, which were performed at JPL and at the U.S. Air Force Eastern Test Range and Kennedy Space Center Complexes. Subsystem Design Tests were performed during mid 1976. System Design Tests were performed during late 1976 and early 1977. System Verification Tests were performed during the spring and summer of 1977. This article describes the System Design Tests and test results that provided the basis for establishment of telecommunications design between the DSN and the Voyager Flight Project.

I. Introduction

This report summarizes the DSN–Voyager Flight Project Telecommunications Compatibility Test Program, covering the period from May 1976 through August 1977. This test program followed the standard three-phase plan of establishing telecommunications compatibility as specified in the DSN Standard Practice Document, Deep Space Network – Flight Project Interface Compatibility Test Design Handbook, and in the Mariner Jupiter/Saturn 1977 DSN-Spacecraft Compatibility Test Plan.

The plan specified that telecommunications design compatibility would be established at the subsystem and system levels and conclude with a final verification at Cape Canaveral, Florida, prior to launch. In addition, the DSN and flight project equipment, software configurations, requirements and test objectives in all phases were specified.

Procedures for conducting the tests as well as test design criteria and test parameters for the ground station hardware and software were prepared by Network personnel. Spacecraft telecommunications design performance criteria and test parameters to establish flight project nominal and threshold telecommunications conditions were provided by the Voyager Telecommunications group. The test criteria were included as part of the test procedures to provide real-time assessment of performance. All test procedures were jointly approved by the DSN and flight project representatives.

II. Types of Tests

The test program included tests between two DSN stations (CTA 21 and MIL 71) and three Voyager Project spacecraft (VGR 77-1, VGR 77-2 and VGR 77-3). Tests between the DSN and VGR 77-1 (designated the Proof Test Model)

included only phases I and II of the total test program and were conducted only at CTA 21. Tests between the DSN and VGR 77-2 and VGR 77-3 (designated Flight Models) included phases II and III of the total test program and were conducted at both CTA 21 and MIL 71.

III. Objectives

The objectives of the test program were to demonstrate, in the major areas of radio frequency acquisition and tracking, command, telemetry and radio metric data (ranging), compatibility between the spacecraft telecommunications subsystems and the Network, to establish system design compatibility between the spacecraft and the Network, and to verify continued interface integrity and maintenance of compatibility during prelaunch activities.

IV. DSN — Subsystem and System Compatibility Tests

The results of the DSN-Subsystem Compatibility Testing, Phase I, are documented in Ref. 1; the results of the DSN–System Compatibility Testing, Phase II, are documented in Refs. 2 and 3.

V. DSN — System Verification Tests

The DSN–System Verification Tests, Phase III, began in May 1977. Results of the May 25 tests conducted on VGR 77-2 are documented in Ref. 3. The balance of the testing with VGR 77-2 was conducted on July 14 and 15, 1977. Tests with VGR 77-3 were conducted on June 14 and 22, July 29, and August 1, 1977.

A. Voyager 77-2, May 25, 1977

1. **Test objectives.** The objective of this phase of testing was to verify telecommunications compatibility between the DSN and the Voyager 77-2 spacecraft for both S- and X-band operation. The test criteria and parameters simulated direct communications between a Voyager spacecraft and a Deep Space Station (DSS) for S-band operation only.

Selected standard tests were performed for verifying telecommunications radio frequency, telemetry and radio metric (ranging) for the X-band mode of operation.

2. **Test conditions.** The Voyager spacecraft was located at the Spacecraft Assembly and Encapsulation Facility No. 1, Kennedy Space Center, Florida. The Radio Frequency Subsystem was configured as follows:

S-band

Receiver 1, Channel 18 (2114.676697 MHz)

Receiver 2, Channel 18 (2114.676697 MHz)

Auxiliary oscillator, Channel 18 (2296.481481 MHz)

Exciter chain 1, equipped with a Watkins-Johnson flight-rated traveling wave tube (TWT) amplifier.

Exciter chain 2, equipped with a Ford Aerospace flight-rated solid-state amplifier.

X-band

Exciters chain 1 and chain 2, equipped with Watkins-Johnson flight-rated traveling wave tube (TWT) amplifiers.

The DSN, as represented by MIL 71, Kennedy Space Center, Florida, was configured to simulate a Voyager flight project-committed 64-meter antenna station. The ground hardware included both Block III and Block IV receiver-exciter subsystems and the Mark III data subsystems (MDS) for telemetry, command and radio metric data.

The S- and X-band RF links between MIL 71 and SAEF-1 were open air links which had previously been calibrated for amplitude stability. The DSN software provided at MIL 71 was the operational 64-meter antenna station software for the MDS.

3. **Test results.** Table 1, DSN (MIL 71) – Voyager 77-2 (SAEF 1) Spacecraft Telecommunications Compatibility Test Summary, 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:

(1) Radio Frequency Acquisition and Tracking. All objectives of these tests were met with no problems noted. Testing consisted of threshold-testing the downlink for both one- and two-way X-band operation.

(2) Telemetry. These tests were supported using the 64-meter DSS operational telemetry software. The telemetry rates of 115.2 kbps, 44.8 kbps, 7.2 kbps and 40 bps were tested during this series of tests and operation was satisfactory.

(3) Radio Metric. A special test was performed to ascertain ranging delay as a function of uplink frequency sweep. Initial test conditions were as follows:

Uplink signal level, −100.0 dBm.

Spacecraft receiver at best lock frequency (2114.676672 MHz).

Ranging acquisition performed for simultaneous S- and X-band operation.

A negative sweep ramp was initiated at 100.0 Hz/sec toward a limit of −60.0 kHz. The DRVID values for S- and X-band were averaged over 30-second intervals and printed out on the MDA terminet typewriter. During the course of the sweep ramp, the S-band DRVID printouts observed varied only two range units. The X-band DRVID printouts observed varied by three range units. It is concluded from this test that no noticeable change in ranging delay can be determined as a function of uplink frequency offset.

B. Voyager 77-3, June 14 and 22, 1977

1. Test Objectives. The objective of this phase of testing was to verify telecommunications compatibility between the DSN and the Voyager 77-3 spacecraft. The test criteria and parameters simulated direct communications between a Voyager spacecraft and a Deep Space Station for S-band operation only. X-band operation was not attempted because of the excess RF losses over the MIL 71 – Building AO link.

2. Test Conditions. The Voyager spacecraft was located at Building AO, Cape Canaveral Air Force Station, Florida. The radio frequency subsystem was configured as follows:

S-band

Receiver 1, Channel 14 (2113.312500 MHz)

Receiver 2, Channel 14 (2113.312500 MHz)

Ultrastable oscillator (USO), Channel 18 (2296.481481 MHz)

Exciter chain 1, equipped with a Watkins-Johnson flight-rated traveling wave tube amplifier.

Exciter chain 2, equipped with a Ford Aerospace flight-rated solid-state amplifier.

The DSN, as represented by MIL 71, Kennedy Space Center, Florida, was configured to simulate a Voyager flight project-committed 64-meter antenna station. The ground hardware included both Block III and Block IV receiver-exciter subsystems and the Mark III data subsystems (MDS) for telemetry, command and radio metric data.

The S-band RF links between MIL 71 and Building AO were open air links which had previously been calibrated for amplitude stability. The DSN software provided at MIL 71 was the operational 64-meter antenna station software for the MDS.

3. Test Results. During the compatibility test on June 14, while reconfiguring the spacecraft RFS from exciter chain 1 active to exciter chain 2 active, a failure occurred. The solid-state amplifier (TWT 2) of exciter chain 2 was determined to be at fault and was sent to the manufacturer for resolution of the failure. The problem was found to be a malfunctioning relay in the solid-state amplifier (SSA). The relay circuit was redesigned and repaired, and the SSA was reinstalled in the VGR 77-3 spacecraft to enable continuation of compatibility testing on June 22.

Table II, DSN (MIL 71) – Voyager 77-3 (Bldg. AO) Spacecraft Telecommunications Compatibility Test Summary, 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:

(1) Radio Frequency Acquisition and Tracking. All objectives of these tests were met with no problems noted. Testing consisted of threshold testing the uplink and the downlink for both one-way and two-way operation.

(2) Telemetry. These tests were supported using the 64-meter DSS telemetry software. Telemetry rates of 80, 1200, 1280, and 7200 bps were tested and operation was satisfactory. In addition, the remaining open item of wide band data and original data recording with the 64-meter DSS software was successfully demonstrated during a MEIVT 14 test between CTA 21 and MCCC on June 29, 1977, for data rates up through 115.2 kbps using SCA-generated data.

(3) 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 transmitted by MIL 71 and successfully executed by the spacecraft. The software used for these tests was the operational version.

C. Voyager 77-3, July 29 and August 1, 1977

1. Test Objectives. The objective of this phase of testing was to verify telecommunications compatibility between the DSN and the Voyager 77-3 spacecraft for both S- and X-band operation. The test criteria and parameters simulated direct communications between a Voyager spacecraft and a Deep Space Station for both S- and X-band operation.

2. Test Conditions. The Voyager spacecraft was located at the Spacecraft Assembly and Encapsulation Facility No. 2, Kennedy Space Center, Florida. The Radio Frequency Subsystem was configured as follows:

S-band

Receiver 1, Channel 14 (2113.312512 MHz)

Receiver 2, Channel 14 (2113.312512 MHz)

Auxiliary oscillator, Channel 14 (2295.000000 MHz)

Exciter chain 1, equipped with a Watkins-Johnson flight-rated traveling wave tube amplifier.

Exciter chain 2, equipped with a Ford Aerospace flight-rated solid-state amplifier.

X-band

Exciters chain 1 and chain 2, equipped with Watkins-Johnson flight-rated traveling wave tube amplifiers.

The DSN, as represented by MIL 71, Kennedy Space Center, Florida, was configured to simulate a Voyager flight project-committed 64-meter antenna station. The ground hardware included both Block III and Block IV receiver-exciter subsystems and the Mark III data subsystems (MDS) for telemetry, command and radio metric data.

The S- and X-band RF links between MIL 71 and SAEF 2 were open air links which had previously been calibrated for amplitude stability. The DSN software provided at MIL 71 was the operational 64-meter antenna station software for the MDS.

3. Test Results. Table III, DSN (MIL 71) – Voyager 77-3 (SAEF 2) Spacecraft Telecommunications Compatibility Test Summary, 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:

(1) Radio Frequency. This set of tests consisted of threshold testing the X-band downlink in the one-way modes of operation for the two spacecraft exciter and power amplifier string configurations. These tests were successfully completed and met the criteria specified. RF carrier residual phase jitter measurements were not completed during this phase of testing because of a hardware problem in the Block IV receiver. Preflight activities of the spacecraft did not permit enough time to correct the receiver problem without impacting the schedule. However, based on other observations, e.g., downlink threshold measurements, both one-way and two-way, the residual carrier phase jitter appears to be well within specified tolerances as no degradation of the thresholds was observed.

(2) Telemetry. These tests were supported using the 64-meter DSS operational telemetry software. Telemetry rates of 115.2 kbps, 44.8 kbps and 7.2 kbps were tested during this series of tests and operation was satisfactory.

(3) Radio Metric (Ranging). Ranging delay calibration measurements were performed with the spacecraft in three radio mode configurations. These tests were supported utilizing the operational ranging software. All results were well within specified limits.

VI. Conclusions

The DSN–Voyager Project Telecommunications Compatibility Test Program was successfully completed on schedule and was culminated by the successful launches of Voyager 2 on August 20, 1977 and Voyager 1 on September 5, 1977.

The importance of a formal compatibility test program is clearly demonstrated by the problems uncovered, verified and resolved during the DSN–Voyager testing. Major problem areas discovered, tested, and resolved during the test program were:

(1) The DSN must provide an uplink carrier power margin of 35 dB in the spacecraft transponder tracking loop in order to provide simultaneous X-band telemetry and doppler without degradation.

(2) Uplink carrier suppression for command modulation of -0.5 dB was selected in order to assure acceptable operation of the Spacecraft Modulation–Demodulation Subsystem.

(3) Uplink carrier suppression for ranging modulation of −3.0 dB was selected in order to assure acceptable operation of downlink X-band telemetry.

(4) Verification of proper Block III SDA operation with 80 deg modulation index in order to optimize Voyager high-rate telemetry.

(5) Verification that the DSN can support the simultaneous channel 14 and channel 18 downlink frequency support requirements of the mission.

Had these problems remained undetected and unresolved prior to launch, serious operational problems to the Network with the spacecraft in flight would have resulted.

References

1. 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, Calif., Oct. 15, 1976.

2. Bryan, A. I., et al., "Summary Report and Status of the Deep Space Network–Mariner Jupiter/Saturn 1977 Flight Project Telecommunications Compatibility," *The Deep Space Network Progress Report 42-38*, pp. 16-37, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1977.

3. Bryan, A. I., et al., "Summary Report and Status of the Deep Space Network–Voyager Flight Project Telecommunications Compatibility," *The Deep Space Network Progress Report 42-40*, pp. 21-40, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1977.

Table 1. DSN(MIL 71) — Voyager 77-2 (SAEF 1) Spacecraft Telecommunications Compatibility Test Summary

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
7/15/77	DL Threshold One Way	RF-1-2	000500	5403-10	X-band DL frequency: 8420.454145 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−144.7 dBm	15
7/14/77	DL Threshold One Way	RF-1-3	000500	6730-16 (Spacecraft Two-Way with SE)	X-band DL frequency: 8420.426350 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−145.0 dBm	38
7/15/77	DL Threshold Two Way	RF-1-4	002500	5413-10	X-band DL frequency: 8420.432470 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−144.5 dBm	14
7/14/77	DL Threshold Two Way	RF-1-5	002500	6730-16	X-band DL frequency: 8420.432215 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−144.3 dBm	23
7/16/77	Transmitter Phase Jitter	RF-5-1	$000\frac{3}{4}00$	5403-10	S-band DL frequency: 2296.483140 MHz (one-way)	≤3.0 deg rms	1.18 deg rms	65
			$000\frac{5}{6}00$		X-band DL frequency: 8420.453380 MHz (one-way) S-band UL frequency: 2114.676672 MHz	≤11.0 deg rms	4.87 deg rms	
			$002\frac{3}{4}00$	5413-10	S-band DL frequency: 2296.481440 MHz (two-way)	≤2.3 deg rms	1.74 deg rms	
			$002\frac{5}{6}00$		X-band DL frequency: 8420.432215 MHz (two-way)	≤8.4 deg rms	4.97 deg rms	
7/15/77	Transmitter Phase Jitter	RF-5-4	$000\frac{3}{4}00$	7624-16	S-band DL frequency: (one-way) 2296.479488 MHz	≤3.0 deg rms	2.03 deg rms	107
			$000\frac{5}{6}00$		X-band DL frequency: (one-way) 8420.424990 MHz	≤11.0 deg rms	6.30 deg rms	
			$002\frac{3}{4}00$	7634-16	S-band UL frequency: 2114.676672 MHz S-band DL frequency: (two-way) 2296.481408 MHz	≤2.3 deg rms	2.07 deg rms	
			$002\frac{5}{6}00$		X-band DL frequency: (two-way) 8420.432215 MHz	≤8.4 deg rms	6.00 deg rms	

Table 1 (contd)

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
7/14/77	Telemetry Performance Verification Test	TM-2-1	002511	7634-16	X-band DL signal level: −116.0 dBm TLM bit rate: 115.2 kpbs coded STb/No = 8.0 dB Subcarrier frequency: 360 kHz S-band DL signal level: −150.0 dBm TLM bit rate: 40 bps UNC STb/No = 5.0 dB Subcarrier frequency: 22.5 kHz	Ability to process	MCD SNR: 6.33 dB SSA 1 SNR: 3.75 dB SSA 2 SNR: 6.15 dB	35
7/14/77	Telemetry Performance Verification Test	TM-2-4	002511	7634-16	X-band DL signal level: −120.5 dBm TLM bit rate: 44.8 kbps coded STb/No = 8.0 dB Subcarrier frequency: 360.0 kHz	Ability to process	MCD SNR: 8.39 dB SSA SNR: 5.25 dB	16
7/14/77	Telemetry Performance Verification Test	TM-2-6	002511	7634-16	X-band DL signal level: −128.5 dBm TLM bit rate: 7.2 kbps coded STb/No = 8.0 dB Subcarrier frequency: 360.0 kHz	Ability to process	MCD SNR: 8.74 dB SSA SNR: 5.53 dB	10
7/15/77	Range Delay Calibration Verification Test	RM-2-A	$102\frac{5}{4}00$	5413-10	S-band UL frequency: 2114.676672 MHz S-band DL frequency: 2296.481580 MHz S-band DL signal level: −100.0 dBm X-band DL frequency: 8420.432130 MHz X-band DL signal level: −100.0 dBm	⩽1000 ns		14

Table 1 (contd)

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
7/15/77	Range Delay Calibration Verification Test (contd)				Spacecraft VCO temp: 37.82°C			
					UL signal level: −100.0 dBm		S delay: 690.13 ns	
							X delay: 617.09 ns	
7/15/77	Range Delay Calibration Verification Test	RM-2-B	$102\frac{5}{4}00$	7413-12	S-band UL frequency: 2114.676672 MHz	<1000 ns		
					S-band DL frequency: 2296.481440 MHz			
					S-band DL signal level: −100.0 dBm			
					X-band DL frequency: 8420.432045 MHz			
					X-band DL signal level: −100.0 dBm			
					Spacecraft VCO Temp: 27.82°C			
					UL signal level: −100.0 dBm		S delay: 694.39 ns	
							X delay: 619.08 ns	
7/15/77	Range Delay Calibration Verification Test	RF-2-C	$102\frac{5}{4}00$	7633-16	S-band UL frequency: 2114.676672 MHz	<1000 ns		
					S-band DL frequency: 2296.481440 MHz			
					S-band DL signal level: −100.0 dBm			
					X-band DL frequency: 8420.432045 MHz			
					X-band DL signal level: −100.0 dBm			
					Spacecraft VCO Temp: 27.82°C			
					UL signal level: −100.0 dBm		S delay: 691.3 ns	
							X delay 630.9 ns	

Table 1 (contd)

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
7/15/77	Range Delay Calibration Versus Static Phase Error Test	RM-3-1	$102\frac{5}{4}00$	5413-10	S-band UL signal level: −100.0 dBm S-band DL signal level: −100.0 dBm X-band DL signal level: −100.0 dBm	Observe change in range delay as a function of UL frequency ramp from 0 Hz offset to −60.0 kHz offset	S-band DRVID changed 2 RU X-band DRVID changed 3 RU	21

Table 2. DSN(MIL 71) — Voyager 77-3 (Bldg. AO) Spacecraft Telecommunications Compatibility Test Summary

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
6/14/77	DL Threshold One Way	RF-1-2	000300	4500-14	S-band DL frequency: 2296.481100 MHz 10 Hz 2 BLo	−158.0 ±1.0 dBm	−157.2 dBm	15
6/22/77	DL Threshold One Way	RF-1-3	000300	7722-16	S-band DL frequency: 2296.481080 MHz 10 Hz 2 BLo	−158.0 ±1.0 dBm	−158.3 dBm	18
6/14/77	DL Threshold Two Way	RF-1-4	002300	4510-16	S-band DL frequency: 2295.000040 MHz 10 Hz 2 BLo	−158.0 ±1.0 dBm	−157.2 dBm	13
6/22/77	DL Threshold Two Way	RF-1-5	002300	6772-16	S-band DL frequency: 2295.000004 MHz 10 Hz 2 BLo	−158.0 ±1.0 dBm	−159.0 dBm	14
6/14/77	UL Receiver Threshold	RF-2-1	002300	4510-16	S-band UL frequency: 2113.312512 MHz	≤−152.0 dBm	−154.5 dBm	17
6/22/77	UL Receiver Threshold	RF-2-2	002300	6732-16	S-band UL frequency: 2113.312512 MHz	≤−152.0 dBm	−155.5 dBm	9
6/14/77	UL Receiver Threshold	RF-2-3	002300	4550-16	S-band UL frequency: 2113.312512 MHz	≤−152.0 dBm	−154.7 dBm	17
6/23/77	UL Receiver Threshold	RF-2-4	002300	6772-17	S-band UL frequency: 2113.312512 MHz	≤−152.0 dBm	−155.2 dBm	12
6/14/77	Command Processing	CM-1-1	112300	4550-16	S-band frequency: 2113.312512 MHz UL carrier suppression: −5.0 dB Subcarrier offset: 0.0 Hz @ −144 dBm, P_T +0.2 Hz @ −144 dBm, P_T −0.2 Hz @ −144 dBm, P_T	Proper subcarrier and bit sync acquisition	 OK OK OK	23

Table 2 (contd)

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
6/22/77	Command Processing	CM-1-2	112300	6772-16	S-band UL frequency: 2113.312512 MHz UL carrier suppression: −5.0 dB Subcarrier offset: 0.0 Hz @ −144 dBm, P_T +0.2 Hz @ −144 dBm, P_T −0.2 Hz @ −144 dBm, P_T	Proper subcarrier and bit sync acquisition Verification of command execution	 OK OK OK	42
6/22/77	Telemetry Spectrum Analysis and Modulation Index	TM-1-4	002311	6732-16	S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000004 MHz TLM bit rate: 7.2 kbps Subcarrier frequency: 360 kHz	No unexpected radiation components within 40 dB of carrier	None observed	6
6/22/77	Telemetry Spectrum Analysis and Modulation Index	TM-1-10	002311	6732-16	S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000004 TLM bit rate: 1200 bps Subcarrier frequency: 22.5 kHz	No unexpected radiation components within 40 dB of carrier	None observed	9
6/22/77	Telemetry Performance Verification Test	TM-2-10	002311	6732-16	S-band DL signal level: −141.0 dBm TLM bit rate: 1200 bps coded STb/No = 5.0 dB Subcarrier frequency: 22.5 kHz	Ability to process	MCD SNR: 3.726 dB SSA SNR: 1.36 dB	8
6/22/77	Telemetry Performance Verification Test	TM-2-13	002311	6732-16	S-band DL signal level: −131.0 dBm TLM bit rate: 7.2 kbps coded STb/No = 8.0 dB Subcarrier frequency: 360 kHz Run 2 22.5 kHz Run 1	Ability to process	MCD SNR: 9.947 dB Run 1 9.288 dB Run 2 SSA SNR: 6.3 dB Run 1 5.35 dB Run 2	50

Table 2 (contd)

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
6/22/77	Telemetry Performance Verification Test	TM-2-14	002311	7732-16	S-band DL signal level: −141.0 dBm TLM bit rate: 1280 bps coded STb/No = 5.0 dB Subcarrier frequency: 22.5 kHz	Ability to process	MCD SNR: 3.633 dB SSA SNR: 1.488 dB	16
6/22/77	Telemetry Performance Verification Test	TM-2-15	002311	7732-16	S-band DL signal level: −146.3 dBm TLM bit rate: 80 bps coded STb/No = 6.0 dB Subcarrier frequency: 22.5 kHz	Ability to process	MCD SNR: 3.610 dB SSA SNR: 1.235 dB	25
7/29/77	DL Threshold One Way	RF-1-2	000500	4400-11	X-band DL frequency: 8415.000375 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−144.7 dBm	14
7/29/77	DL Threshold One Way	RF-1-3	000500	6623-16	X-band DL frequency: 8414.998250 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−146.3 dBm	12
7/29/77	DL Threshold Two Way	RF-1-4	002500	4410-11	X-band DL frequency: 8415.000290 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−145.0 dBm	10
7/30/77	DL Threshold Two Way	RF-1-5	002500	6633-16	X-band DL frequency: 8415.000205 MHz 30 Hz 2 BLo	−145.0 ±1.0 dBm	−147.0 dBm	10
8/1/77	Telemetry Performance Verification Test	TM-2-1	002511	6670-17	X-band DL signal level: −116.0 dBm TLM bit rate: 115.2 kbps coded STb/No = 8.0 dB Subcarrier frequency: 360 kHz	Ability to process	MCD SNR: 9.391 dB SSA 1 SNR: 5.0 dB	19

Table 3. DSN(MIL 71) — Voyager 77-3 (SAEF 2) Spacecraft Telecommunications Compatibility Test Summary

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
8/1/77	Telemetry Performance Verification Test	TM-2-4	002511	6670-17	X-band DL signal level: −120.5 dBm TLM bit rate: 44.8 kbps coded STb/No = 8.0 dB Subcarrier frequency: 360 kHz	Ability to process	MCD SNR: 8.702 dB SSA SNR: 5.1 dB	30
8/1/77	Telemetry Performance Verification Test	TM-2-6	002511	6670-17	X-band DL signal level: −128.5 dBm TLM bit rate: 7.2 kbps coded STb/No = 8.0 dB Subcarrier frequency: 360.0 kHz	Ability to process	MCD SNR: 9.356 dB SSA SNR: 5.79 dB	25
7/30/77	Range Delay Calibration Verification Test	RM-2-A	$102\frac{5}{4}00$	4413-11	S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000040 MHz S-band DL signal level: −100.0 dBm X-band DL frequency: 8415.000290 MHz X-band DL signal level: −100.0 dBm Spacecraft VCO Temp: 27.66°C UL signal level: −100.0 dBm	⩽1000 ns	S delay: 645.2 ns X delay: 632.2 ns	45
7/30/77	Range Delay Calibration Verification Test	RM-2-B	$102\frac{5}{4}00$	6413-11	S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000040 MHz S-band DL signal level: −100.0 dBm	⩽1000 ns		

Table 3 (contd)

Test date	Test title	Test no.	DSN mode	S/C RFS mode	Test conditions	Criteria	Performance	Time, min
7/30/77	Range Delay Calibration Verification Test (contd)				X-band DL frequency: 8415.000290 MHz X-band DL signal level: −100.0 dBm Spacecraft VCO Temp: 27.66°C UL signal level: −100.0 dBm		S delay: 645.2 ns X delay: 638.2 ns	20
7/30/77	Range Delay Calibration Verification Test	RM-2-C	$102\frac{5}{4}00$	6633-16	S-band UL frequency: 2113.312512 MHz S-band DL frequency: 2295.000040 MHz S-band DL signal level: −100.0 dBm X-band DL frequency: 8415.000290 MHz X-band DL signal level: −100.0 dBm Spacecraft VCO Temp: 26.4°C UL signal level: −100.0 dBm	⩽1000 ns	S delay: 632.2 ns X delay: 615.5 ns	18

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

BER	bit error rate
Bit rate	clock frequency of the telemetry bit information
bps	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
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
SCA	Simulation Conversion Assembly
SDA	Subcarrier Demodulator Assembly
SE	Spacecraft Ground Support Equipment
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	travelling 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	ultrastable oscillator
VCO	voltage-controlled oscillator

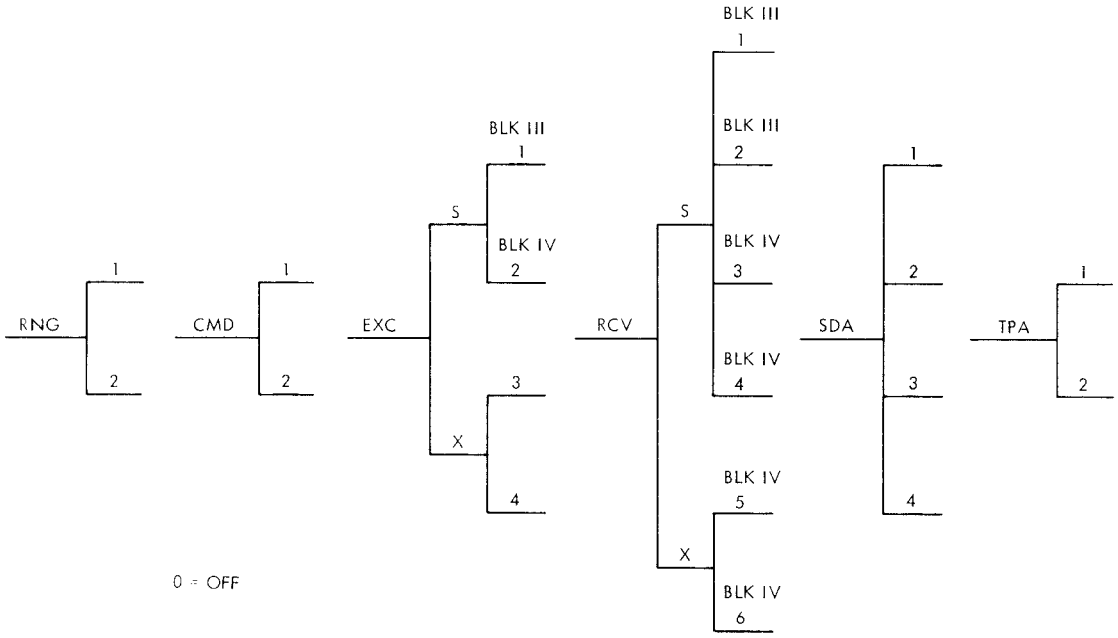

Fig. 1. DSN modes

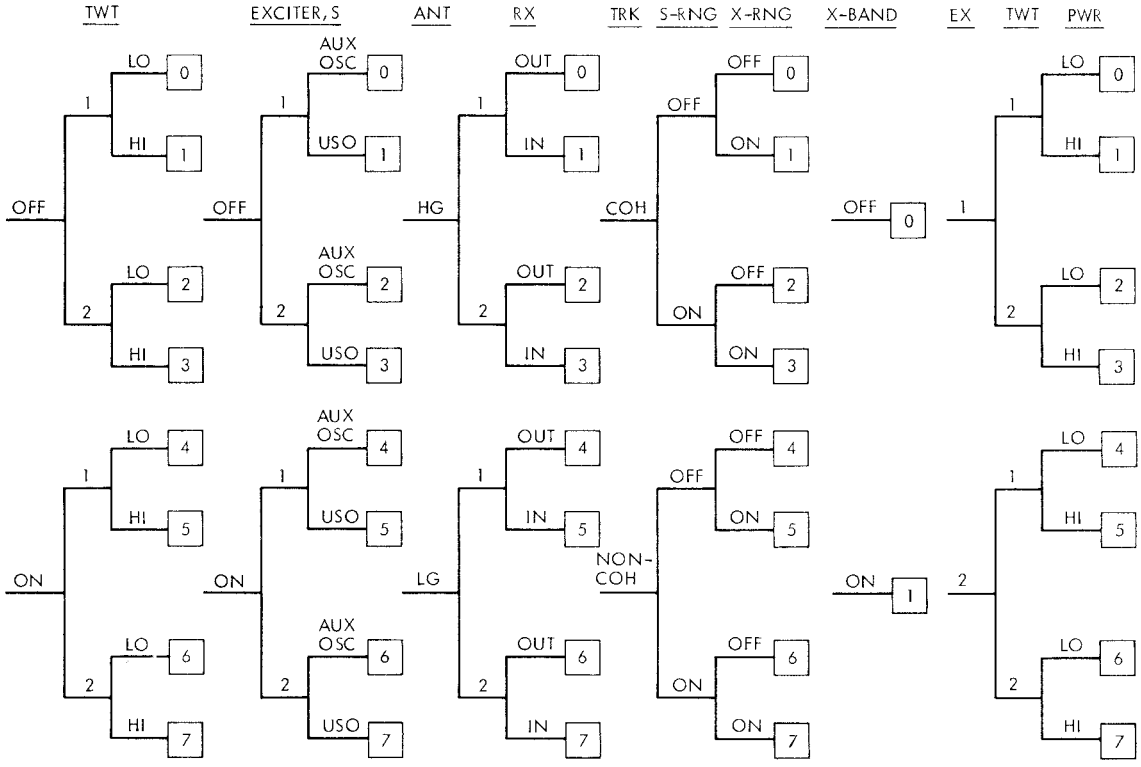

Fig. 2. Voyager operational RFS modes