Helios B–Deep Space Network Compatibility Test Summary

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The DSN–Helios B–compatibility testing followed a very successful three-phase compatibility test program for the Helios prototype and Helios 1 spacecraft. This article covers the tests from arrival of Helios B at Cape Canaveral, Florida through launch. The compatibility tests consisted of (1) DSN–spacecraft radio frequency tests at both weak and strong signal levels, and (2) verification of radio frequency compatibility with the Helios B mated to the launch vehicle at Launch Complex 41.

I. Introduction

This report covers the DSN–Helios B compatibility testing that extended over 48 hours from October 31 through November 4, 1975, and for 8 hours on January 10, 1976. The compatibility tests performed during these periods were divided as follows:

(1) DSN–spacecraft radio frequency (RF) tests at both weak and strong signal levels during October 31 through November 4, 1975.

(2) Verification of RF compatibility performed on January 10, 1976, with Helios B mated to the launch vehicle at Launch Complex 41.

The DSN–Helios B compatibility testing followed a very successful three-phase program of compatibility testing between the DSN and the Helios prototype spacecraft (Ref. 1) and Helios 1 (Ref. 2).

II. Test Report

The DSN–Helios telecommunications compatibility testing utilized a test system that was operationally representative of a standard Deep Space Station (DSS). The test system was under control of a computer to provide appropriate test conditions in an automatic mode of operation.

The spacecraft configurations were agreed upon by the Flight Project and the DSN. Spacecraft modes were selected to exercise a representative subset of all possible configurations and to minimize the time required for completion of an adequate test program.

A. Telecommunications Compatibility Tests

These tests provided an assessment of telecommunications compatibility status between Helios B and the Network based upon the results obtained between the DSN equipment in the Spaceflight Tracking and Data Network station (STDN MIL 71) and Helios B.

These tests were the final phase of the documented three-phase plan for establishing telecommunications compatibility between the Network and the Helios B spacecraft.

Procedures for conducting the tests were prepared by the DSN. Test parameters and spacecraft design criteria were provided by the Helios spacecraft telecommunications engineers. The final procedures and test plans were approved by the DSN and the Helios Project telecommunications representatives. In particular, the latter personnel provided extensive support during the test procedure preparation and test planning phases. The successful completion of the tests was due in large measure to the excellent support provided by JPL and STDN management and operating personnel.

1. Test objectives. A selected set of standard tests for verifying transponder radio frequency, command, telemetry, and metric data compatibility were performed in accordance with the Network Test and Training Plan for the Helios Project.

2. Test description. Helios B was configured for flight operations and STDN (MIL 71) was configured to simulate a DSS. The spacecraft was located in the clean room of Building AO, Cape Canaveral Air Force Station, and STDN (MIL 71) is located at Merritt Island, Florida. An S-band radio frequency link of approximately 16 km (10 miles) was used between a 1.85-m antenna at Building AO and a 1.2-m antenna at the STDN station. RF link amplitude variations were 0.5 dB peak-to-peak for the critical tests in telemetry and command.

The STDN station software utilized in performing these tests was supplied by the DSN and was a subset of software officially released to the station for Helios Project support. The programs consisted of:

(1) Telemetry and Command Data Handling Program. This program provides independent control of the commanding and telemetry handling functions. Commands may be controlled manually from the station or automatically from the Mission Control and Computing Center in Pasadena, Calif. Telemetry may be decoded, formatted, and transmitted to the Mission Control and Computing Center for decommutation and display.

(2) Planetary Ranging Assembly Program. This program provides either continuous spectrum or discrete spectrum operation for making very accurate range estimates of a spacecraft at planetary distances.

Tests performed for radio frequency acquisition and tracking performance, telemetry, command and metric data generation are as follows:

Radio Frequency Acquisition and Tracking
- Noncoherent downlink threshold
- Uplink threshold
- Coherent downlink threshold
- Spacecraft maximum sweep and acquisition
- Carrier residual phase jitter
- Subcarrier frequency and phase jitter

Command
- Spacecraft command threshold, 512-Hz subcarrier
- Spacecraft command threshold, 448-Hz subcarrier

Radio Metric
- Ranging channel delay
- Ranging polarity
- Ranging system acquisition time

Telemetry
- Downlink spectrum analysis
- Telemetry bit error rate test
- Telemetry erasure rate

3. Test results. Table 1 provides the test results. Significant events and/or other items are discussed below:

(1) During the radio frequency acquisition and tracking tests and radio metric tests, the first downlink threshold measurement was unsuccessful because of excessive RF leakage into the ground receiver. A faulty antenna system was discovered at MIL 71 and replaced. Testing was successfully completed.

(2) Because of ranging channel problems encountered with Helios 1 in October 1975, the radio metric tests performed on Helios B were monitored very closely for any significant deviation from expected performance. There were no anomalies or out-of-tolerance results observed. The spacecraft ranging function performed successfully to all criteria and operating parameters.

(3) In performing the telemetry bit error rate test, it was necessary to modify the procedure. It was noted that large concentrations of low transition densities were present in the data. This condition was manifesting itself in erratic signal-to-noise estimations and bit error counts in the Symbol Synchronizer Assembly. A check with the spacecraft revealed that all experiments were turned off, thereby resulting in no data when these experiments appeared on the spacecraft commutator. By direction of the project, the spacecraft test conductor was not allowed to turn all experiments on. In order to perform the bit error rate tests in the most meaningful manner, it was decided to switch the spacecraft to the coded mode, thereby increasing the data transition density. Therefore, the 8-b/s test was performed at 16 s/s, and the 32-b/s test was performed at 64 s/s. The downlink signal levels were adjusted to correct for the different data rate, and the tests were successfully completed.

B. Radio Frequency and Data Verification Tests

These tests provided an assessment of telecommunications compatibility status between the DSN, represented by STDN (MIL 71) and Helios B after encapsulation and mating to the launch vehicle. These tests, conducted on January 10, 1976, were a subset of tests performed previously between Helios B and STDN (MIL 71) in October and November 1975.

Procedures for conducting these tests were prepared by the DSN, and spacecraft test parameters and design criteria were provided by the Helios spacecraft telecommunications engineers. The final procedures were approved by the DSN and Helios Project telecommunications representatives.

1. Test objective. The objective of the tests was to verify continued compatibility between the DSN and the Helios spacecraft after the spacecraft had been configured for launch operations. All tests were accomplished in accordance with the Network Test and Training Plan for the Helios Project.

2. Test description. The Helios spacecraft was in launch configuration, and STDN (MIL 71) was configured to simulate a DSN station. The spacecraft was located at Launch Complex 41, Cape Canaveral Air Force Station, Florida, and STDN (MIL 71) was located at Merritt Island, Florida. An S-band link of approximately 16 km (10 miles) was utilized to establish the spacecraft–ground station interface. The spacecraft transmit–receive function was performed by connecting a test point at the shroud to a 1.2-m antenna connected to the launch service tower.

The ground station software utilized in performing these tests was supplied by the DSN and was a subset of software officially released to the station for Helios Project support. The programs consisted of:

(1) Telemetry and Command Data Handling Program. This program provides independent control of the commanding and telemetry handling functions. Commands may be controlled manually from the station or automatically from the Mission Control and Computing Center in Pasadena. Telemetry may be decoded, formatted, and transmitted to the Mission Control and Computing Center for decommutation and display.

(2) Planetary Ranging Assembly Program. This program provides either continuous spectrum or discrete spectrum operation for determining very accurate range estimates of a spacecraft at planetary distances.

(3) Helios Decommutation and Data Validation Program. This program provides the capability of decommutating spacecraft engineering data and display at the station for verifying spacecraft parameters during compatibility testing.

Tests performed for radio frequency acquisition and tracking performance, telemetry, command and metric data generation are as follows:

Radio Frequency Acquisition and Tracking
- Noncoherent downlink threshold
- Uplink threshold
- Spacecraft maximum sweep and acquisition

Command
- Spacecraft command performance, 512-Hz subcarrier
- Spacecraft command performance, 448-Hz subcarrier

Radio Metric
- Ranging system acquisition time

Telemetry
- Telemetry performance test, 128 b/s
- Telemetry performance test, 1024 b/s

3. Test results. Table 2 provides the test results. (Table 3 gives definitions for abbreviations in Tables 1

and 2.) Significant events and/or other items are discussed below:

(1) During the radio frequency acquisition and tracking tests, the initial efforts to perform the spacecraft maximum sweep and acquisition test and the uplink threshold tests were seriously hampered by large fluctuations of the link (5 dB). These fluctuations were isolated to the heavy traffic and activities being conducted on the launch tower by launch vehicle personnel. When that activity ceased, the tests were successfully performed. It is highly recommended that future tests be conducted during periods of minimum activity at the launch vehicle.

(2) No problems were encountered in the command, radio metric, and telemetry tests.

III. Conclusions

The formal DSN–Helios compatibility program was very successful and terminated in the successful launching of both Helios 1 and Helios 2 spacecraft. Helios 1 was launched on December 10, 1974, followed by Helios 2 on January 15, 1976.

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

(1) Deficiencies in the engineering model transponder. The transponder exhibited lack of sensitivity, pushing effects at strong uplink signal levels, instability of the voltage-controlled crystal oscillator, and improper shielding.

(2) Polarity of the ranging channel in the Helios 1 spacecraft was inverted. This condition was different from the prototype spacecraft.

(3) Many hundreds of hours of test time were used at the old DSN station (DSS 71) to determine optimum modulation indices for the Helios Mission. A full description of this testing was published in Ref. 3.

(4) An elaborate test system to simulate uplink and downlink amplitude, phase, and frequency modulation conditions during the spacecraft Step II maneuver was performed. This simulation demonstrated that the spacecraft could be successfully commanded during this very critical phase of flight.

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., "Helios Prototype Spacecraft Deep Space Network Compatibility Test Summary," in *The Deep Space Network Progress Report 42-23*, pp. 22–36, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1974.

2. Bryan, A. I., "Helios Flight 1 Spacecraft/Deep Space Network Compatibility Test Summary," in *The Deep Space Network Progress Report 42-26*, pp. 27–40, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1975.

3. Layland, J. W., "DSS Tests of Sequential Decoding Performance," in *The Deep Space Network Progress Report 42-20*, pp. 69–77, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1974.

Test date, 1975	Test title	Test No.	Deep Space Network									
			RCV	EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate
10/10	SC maximum sweep and acquisition rate	I.1	Blk IV, 2295.404288 MHz	BLK IV, 2113.65300 MHz	Off	Off	500 Hz	−30.0 KHz	NA	NA	High	2048
			Same	Same	Off	Off	500 Hz	+30.0 KHz	NA	NA	High	2048
			Same	Same	Off	Off	80 Hz	−9.7 KHz	NA	NA	High	2048
			Same	Same	Off	Off	80 Hz	+9.9 KHz	NA	NA	High	2048
11/3	Downlink spectrum analysis	II.1	BLK IV, −110 dBm, 2295.369920 MHz,	NA	Off	Off	NA	NA	NA	NA	High	2048
		II.2	Same	NA	Off	Off	NA	NA	NA	NA	High	128
		II.3	Same	NA	Off	Off	NA	NA	NA	NA	Low	32
		II.7	2295.359896 MHz −79 dBm	2113.643904 MHz	On (idle seq.)	NA	NA	NA	NA	NA	High	2048
		II.10	Same	Same	On	On	NA	NA	NA	NA	High	128
11/31	Uplink threshold	III.1	BLK IV, −100 dBm, 2295.369632 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	128
		III.2	Same	Same	On	Off	NA	NA	NA	NA	High	128
		III.3	Same	Same	Off	Off	NA	NA	NA	NA	High	128
10/31	Carrier residual phase jitter	IV.1	BLK IV, −104 dBm, 2295.369728 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	2048
		IV.2	BLK IV, −100 dBm, 2295.365024 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	2048
		IV.3	BLK IV. −104 dBm, 2295.369728 MHz	BLK IV. 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	2048
					Off	Off	NA	NA	NA	NA	High	2048

Table 1. DSN–Helios B telecommunications test summary

Spacecraft								Test data		Test time	Test Comments
EXC	RCV	PWR	ANT	TWT	RNG	SC DM	SC FM	Performance	Criteria		
1	1 −102 dBm	HP	MGA	2	Off	0	4	Acquired at −100 dBm; tracked to +65 kHz	Acquire at −100 dBm; track to +32.5 kHz	2 hr 32 min	Acquired UL at best lock (VCX01)
1	1 −102 dBm	HP	MGA	2	Off	0	4	Acquired at −100 dBm; tracked to −32.5 kHz	Acquire at −100 dBm; track to −32.5 kHz	2 hr 32 min	Acquired UL at best lock (VCX01)
1	1 −102 dBm	HP	MGA	2	Off	0	4	Acquired at −141 dBm; tracked to +32.5 kHz	Acquire at −141 dBm; track to +32.5 kHz	2 hr 32 min	Rcvr 2 OK; Rcvr 1 dropped +7 kHz at −141 ±1; both rcvr's OK at −139 ±1
1	1 −102 dBm	HP	MGA	2	Off	0	4	Acquired at −141 dBm; tracked to −32.5 kHz	Acquire at −141 dBm; track to −32.5 kHz	2 hr 32 min	Acquired UL at best lock (VCX01)
1	1	HP	MGA	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	9 min	Subcarrier osc No. 2 noncoherent mode
1	1	LP	LGA	NA	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	41 min	Subcarrier osc No. 1 noncoherent mode
1	1	LP	LGA	NA	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	10 min	Subcarrier osc No. 1 noncoherent mode
1	1 −103.5 dBm	LP	LGA	1	Off	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	22 min	VCX01, coherent (Goldstone first acq.) mode
1	1 −103.5 dBm	HP	MGA	1	On	0	4	No spurs observed	No spurious signal within 30 dB of the carrier	15 min	VCX01, coherent
1	1	HP	MGA	2	Off	0	4	−154.5 dBm	−155.0 ±1.0 dBm	50 min	Threshold value is average of 3 measurements. Link variations of ±1.5 dB were noted in Subtest 2
1	1	HP	MGA	2	On	0	4	−153.5 dBm	−155.0 ±1.0 dBm	31 min	
1	2	HP	LGA	2	Off	0	4	−154.83 dBm	−155.0 ±1.0 dBm	48 min	
1	1 −105 dBm	HP	MGA	1	Off	0	4	4.93 deg rms	5.7 deg rms	16 min	
2	1 −102 dBm	HP	MGA	2	Off	0	4	3.275 deg rms	5.7 deg rms	30 min	RF link variation
1	1 −104 dBm	HP	MGA	2	Off	0	4	1.77 deg rms	2.86 deg rms	36 min	10 dB p-p
1	1 −104 dBm	HP	MGA	2	Off	0	4	14.08 deg rms	22.9 deg rms		F-2 SC exhibited greater residual phase jitter than F-1 SC because of aux. osc. crystals. Inferior performance not unexpected but still met criteria.

Test date, 1975	Test title	Test No.	Deep Space Network									
			RCV	EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate
10/31		IV.4	BLK IV, −104 dBm, 2295.369728 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	2048
					Off	Off	NA	NA	NA	NA	High	2048
11/4	Bit error rate	VIII.1	BLK IV, −146 dBm, 2295.369774 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	Low	8 (coded)
		VIII.2	BLK IV, −140 dBm	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	Low	32 (coded)
11/4	Telemetry erasure rate	IX.1	BLK IV, −143.5 dBm, 2295.369800 MHz	BLK IV, 2113.653024 MHz	Off	On	NA	NA	NA	NA	High	128
		IX.2	BLK IV, −138 dBm, 2295.369800 MHz	2113.653024 MHz	On	On	NA	NA	NA	NA	High	512
		IX.3	BLK IV, −134.5 dBm, 2295.369800 MHz	BLK IV, 2113.653024 MHz	Off	On	NA	NA	NA	NA	High	1024
10/31	Subcarrier frequency and phase jitter	X.1	BLK IV, −104 dBm, 2295.369728 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	128
		X.2	BLK IV. −104 dBm, 2295.369728 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	128
		X.3	Blk IV, −104 dBm, 2295.369728 MHz	BLK IV, 2113.653000 MHz	Off	Off	NA	NA	NA	NA	High	128
10/31	SC command	XI.1	BLK IV, −100 dBm, 2295.369774 MHz	BLK IV, 2113.653000 MHz	Off	On	NA	NA	NA	NA	High	128
		XI.2	Same	Same	On	On	NA	NA	NA	NA	High	512
		XI.3	Same	Same	Off	On	NA	NA	NA	NA	High	1024

Block III Receiver I, Exciter 1 used for all tests.

Table 1 (contd)

Spacecraft								Test data		Test time	Comments
EXC	RCV	PWR	ANT	TWT	RNG	SC DM	SC FM	Performance	Criteria		
1	2 −104 dBm	HP	LGA	2	Off	0	4	2.05 deg rms	2.86 deg rms	23 min	
1	2, −104 dBm	HP	LGA	2	Off	0	4	14.57 deg rms	22.9 deg rms		
1	1 −135 dBm	HP	MGA	2	Off	0	4	1.7×10^{-4}	10^{-4}	2 hr 27 min	Coded mode
1	1 −130 dBm	HP	MGA	2	Off	0	4	1.3×10^{-5}	10^{-4}	3 hr 4 min	Coded mode
1	1 −128.1 dBm	HP	MGA	2	Off	0	4	TCP $\alpha = 0$ TCP $\beta = 0$	10^{-3}	628 min	
1	1 −126 dBm	HP	MGA	2	On	0	4	TCP $\alpha = 0$ TCP $\beta = 0$	10^{-3}	115 min	
1	1 −133 dBm	HP	HGA	2	Off	0	4	TCP $\alpha = 1.99 \times 10^{-4}$ TCP $\beta = 7.98 \times 10^{-4}$	10^{-3}	208 min	
1	−105 dBm	LP	LGA	NA	Off	0	4	0.505 deg rms 32,768 Hz	1.15 deg rms 32,768 Hz	38 min	SC DHE osc. No. 1 Chain 1
2	NA −105 dBm	LP	LGA	NA	Off	0	4	0.505 deg rms 32,768 Hz	1.15 deg rms 32,768 Hz	12 min	SC DHE osc. No. 1 Chain 2
2	NA −105 dBm	LP	LGA	NA	Off	0	4	0.51 deg rms 32,768 Hz	1.15 deg rms 32,768 Hz	10 min	SC DHE osc. No. 2 Chain 2
1	1 −144 dBm	HP	MGA	2	Off	0	4	54 commands accepted and processed	All commands accepted by SC	37 min	VCOX1, coherent, command SC at 512 Hz
1	1 −137 dBm	HP	MGA		On	0	4	54 commands accepted and processed	All commands accepted by SC	25 min	
1	2 −144 dBm	HP	HGA	2	Off	0	4	54 commands accepted and processed	All commands (continuous) accepted and processed	38 min	VCX02, coherent, command SC at 448 Hz

Test date, 1976	Test title	Test No.	Deep Space Network									
			RCV	EXC	PRA RNG	CMD	Uplink doppler	Uplink offset	CMA SUBC offset	SDA SUBC offset	CAR SUP	Bit rate
1/10	SC maximum sweep and acquisition rate	I.1	−97 dBm	2113.621152 MHz to 2113.685856 MHz	Off	Off	500 Hz	−30 kHz to +32.5 kHz	NA	NA	High	2048
			−97 dBm	2113.682976 MHz to 2113.618560 MHz	Off	Off	500 Hz	+30 kHz to −32.9 kHz	NA	NA	High	2048
1/10	Uplink threshold	III.1	−115 dBm, 2295.368688 MHz	2113.652000 MHz	Off	Off	NA	NA	NA	NA	High	2048
		III.3	−115 dBm, 2295.368688 MHz	2113.652000 MHz	Off	Off	NA	NA	NA	NA	High	2048
1/10	Downlink threshold	V.1	2295.369056 MHz	2113.652000 MHz	Off	Off	NA	NA	NA	NA	High	128
1/10	Ranging system acquisition time	VII.1	−112 dBm, 2295.368688 MHz	2113.652000 MHz	On	Off	NA	NA	NA	NA	High	128
1/10	Telemetry performance	IX.1	2295.368688 MHz	2113.652000 MHz	Off	On	NA	NA	NA	NA	High	128
		IX.3	−114 dBm, 2295.368688 MHz	2113.652000 MHz	Off	On	NA	NA	NA	NA	High	1024
1/10	Spacecraft command	XI.1	−115 dBm, 2295.368688 MHz	2113.652000 MHz	Off	On	NA	NA	NA	NA	High	2048
		XI.3	−115 dBm, 2295.368688 MHz	2113.652000 MHz	Off	On	NA	NA	NA	NA	High	2048

Block III Receiver I, Exciter 1 used for all tests.

Table 2. DSN–Helios B–Launch Complex 41 telecommunications test summary

Spacecraft								Test data		Test time	Test Comments
EXC	RCV	PWR	ANT	TWT	RNG	SC DM	SC FM	Performance	Criteria		
1	1 and 2 −110 dBm	HP	LGA	2	Off	0	4	Acquired and tracked	Acquire at best lock, track to +32.5 kHz	15 min	2113.652000 kHz, best lock frequency SC receiver 1/2
1	1 and 2 −110 dBm	HP	LGA	2	Off	0	4	Acquired and tracked	Acquire at best lock. track to −32.5 kHz		
1	1	HP	LGA	2	Off	0	4	−157.2 dBm	To be measured	2 hr 4 min	Average of 3 runs, link variance 1.5 dB p-p
1	2	HP	LGA	2	Off	0	4	−157.0 dBm	To be measured		Average of 2 runs, link variance 1.5 dB p-p
1	1	HP	LGA	1	Off	0	4	−157.5 dBm	−159.0 ±3 dBm	20 min	Average of 3 runs, link variance 8.0 dB p-p
1	1 −116.5 dBm	HP	LGA	1	On	0	4	1-minute acquisition 98827 RU	TBD	8 min	15 components, discrete 1 minute integration time
1	1 −113 dBm	HP	LGA	1	Off	0	4	Decommutated data satisfactory	30 min of decommutated data	33 min	SDA freq. 131072.0 Hz
1	2 −113 dBm	HP	LGA	1	Off	0	4	Decommutated data satisfactory	30 min of decommutated data	33 min	SDA freq. 131072.0 Hz
1	1 −108 dBm	HP	LGA	2	Off	0	4	All good commands (210 commands)	All commands successfully received by SC	39 min	Commands 501-506, 512-Hz subcarrier
1	2 −108 dBm	HP	LGA	2	Off	0	4	All good commands (210 commands)	All commands successfully received by SC	42 min	Commands 501-506, 448-Hz subcarrier

Table 3. Definitions for Tables 1 and 2

ANT	Spacecraft antenna
Bit rate	Clock frequency of the telemetry bit information
BLK III exciter	The standard DSN S-band exciter equipment
BLK III receiver	The standard DSN S-band receiving equipment
CAR SUP	Downlink carrier suppression due to telemetry modulation
CMA SUBC offset	Command modulation assembly subcarrier frequency offset relative to nominal
CMD	Telemetry and command data handling command modulation
EXC	Spacecraft S-band exciter equipment
HGA	High-gain antenna
LGA	Low-gain antenna
MGA	Medium-gain antenna
PRA RNG	Planetary ranging assembly modulation
PWR	Spacecraft transmitter power mode
RCV	Spacecraft S-band receiving equipment
RNG	Spacecraft ranging channel
SC DHE	Spacecraft data handling equipment
SC DM	Spacecraft data mode
SC FM	Spacecraft data format
SDA SUBC offset	Subcarrier demodulator assembly subcarrier frequency offset relative to nominal
TWT	Traveling wave tube amplifier
UNC	Uncoded
Uplink doppler	Ramp rate of the uplink carrier frequency
Uplink offset	Uplink carrier frequency offset relative to the spacecraft receiver rest frequency