Deep Space Network

205
Command Service

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Review Acknowledgment

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Document Change Log

Rev	Issue Date	Prepared By	Affected Sections or pages	Change Summary
Initial	1/15/2001	Robert Sniffin	All	Initial Release
A	12/15/2002	Robert Sniffin	All	Provides description and capabilities of new DSN command equipment.
B	12/15/2009	A. Kwok	All	Replaced DSMS with DSN. Removed references to the decommissioned 26-m subnet. Updated Table 1 and replaced previous Figure 3 with the current Figure 3, Figure 4, and Figure 5.
C	6/1/2010	A. Kwok	Page 18	Corrected an error in Equation (1). Eliminated the Rev. E designation for the document series.
D	12/15/2014	T. Cornish	Table 1	Updated to current data. Added restrictions on S-band uplink from MDSCC. Deleted Ka-band uplink from DSS-25. Deleted DSS-27. Added DSS-35, -36 20 kW and DSS-26 80 kW.
			3.12	Changed "output of the exciter" to "output of command modulator".
			Was 4.1 is now 3.4	Added 128k and 256k data rates and removed statement about rates above 64k being unavailable due to exciter bandwidth restrictions (future Block 6 Exciter capabilities). Moved entire paragraph to 3.8, thus eliminating section 4 on "Proposed Capabilities". Changed "will be implemented" to "is available, with some restrictions". Added statement about CLTU size versus bit rate.
E	11/17/2016	T. Cornish	Table 1	Added DSS-36 S- and X-band. Deleted DSS-45.
			Section 2	Added 0239-Telecomm and CLTUF. Updated Figs. 3, 4, and 5.
			Appendix A	Updated references.
F	04/02/2021	M. Settember	Table 1	Added DSS-56 S/X-band and DSS-26 S-band Deleted DSS-15. Updated DSS-43 power level/EIRP per upgrades Removed Gain/ G/T column, not relevant to cmd. Updated EIRP column per subnet interface docs.
			Section 2 & 3 Figure 3	Removed FCLTU "Red book", 0163 support
			Section 2 & 3.1	Removed emergency recording capability.

Rev	Issue Date	Prepared By	Affected Sections or pages	Change Summary
			Section 3.2 & 3.6	Clarified step tuning limitations applicable to 20kW S-band only.
			Appendix A	Added "2010 blue book" reference. Added missing referenced 820-013 modules.
G	03/23/2023	M. Settember	Table 1 & 3, Figures 1, 2, 4, 5 & 6, Section 3.2, 3.4, 3.9, 3.10 & 3.13	Added K-band and current Ka-band capability. Updated reference figures to reflect current RF power capabilities. Added new command modulation, data rate and encoding capabilities. Removed Mean-time between Command Aborts numbers.

Contents

Paragraph   **Page**

Figures

Tables

1   Introduction

1.1   Purpose

This module provides performance parameters for the elements of the Deep Space Network (DSN) that are exclusively used for sending commands to spacecraft. It is intended to assist the telecommunications engineer in designing an uplink (or forward space link) that is compatible with currently installed DSN equipment. It also contains brief descriptions of future enhancements that have been proposed for this equipment and capabilities that are being maintained for legacy customers using the previous generation of command equipment.

1.2   Scope

The discussion in this module is limited to command equipment used with the Deep Space Network (DSN) antennas. Detailed performance of equipment used for purposes in addition to command is covered elsewhere in 810-005. Information on antennas, exciters, and transmitters have been included as a convenience and should be verified against their primary source. In particular, the following modules should be considered:

101	70-m Subnet Telecommunications Interfaces,
103	34-m HEF Subnet Telecommunications Interfaces,
104	34-m BWG Stations Telecommunications Interfaces, and
301	Coverage and Geometry.

2   General Information

Each antenna in the DSN is capable of sending commands to one spacecraft at a time. Each Deep Space Communications Complex (DSCC) contains one 70-m and multiple 34-m antennas. There are two types of 34-m antennas. The first is the so-called high-efficiency (HEF) antennas that have their feed, low-noise amplifiers, and transmitter located on the tilting structure of the antenna. These antennas were named when a less-efficient 34-m antenna was in use by the DSN and the name has survived. The efficiency of all DSN 34-m antennas is now approximately the same. Note that only one HEF antenna remains in operation, located at Madrid DSCC. The HEF at Goldstone and Canberra DSCC have been decommissioned. The second type of 34-m antenna is the beam waveguide (BWG) antenna where the feeds, low noise amplifiers and transmitters are located in a room below the antenna structure and the radio frequency energy is transferred to and from the antenna surface by a series of mirrors and dichroics encased in a protective tube.

The capabilities of each antenna type and, in some cases, of the individual antennas are different and must be considered in designing a command link. Often, the selection of antenna for uplink will depend on the downlink frequencies it supports.

Table 1 lists the uplink and downlink frequency ranges for each antenna type and provides approximate ranges for uplink Effective Isotropic Radiated Power (EIRP). The modules referred to above should be consulted for exact values and other parameters. The telecommunications link designer is cautioned against making designs dependent on the 70-m antenna, as there is only one per complex and it subject to severe scheduling constraints.

7

Table 1. Capabilities of DSN 70-m and 34-m Antennas

| Antenna Type	Complex/Site	DSS ID	Uplink Freq (MHz)	TXR Power (W)	EIRP (dBW)	Downlink Freq (MHz)
34M BWG	Goldstone, CA USA	DSS 24	S: 2025 - 2120	20,000	78.6 - 98.6	S: 2200 - 2300
		DSS 26	S: 2025 - 2110	250	71.9 - 78.9	S: 2200 - 2300
	Canberra, Australia	DSS 34	S: 2025 - 2120	20,000	78.6 - 98.6	S: 2200 - 2300
		DSS 36	S: 2025 - 2110	250	71.9 - 78.9	S: 2200 - 2300
	Madrid, Spain	DSS 54 [1]	S: 2025 - 2120	20,000	78.6 - 98.6	S: 2200 - 2300
		DSS 56	S: 2025 - 2110	250	71.9 - 78.9	S: 2200 - 2300
	Goldstone, CA USA	DSS 24, 25, 26	X: 7145 - 7235	20,000	89.4 - 109.4	X: 8400 - 8500
		DSS 26	X: 7145 - 7235	80,000	89.3 - 115.3	X: 8400 - 8500
	Canberra, Australia	DSS 34, 35, 36	X: 7145 - 7235	20,000	89.4 - 109.4	X: 8400 - 8500
	Madrid, Spain	DSS 54, 55, 56	X: 7145 - 7235	20,000	89.4 - 109.4	X: 8400 - 8500
	Goldstone, CA USA	DSS 26, 24[2]	K: 22550 - 23150	250	113.7 - 127.7	K: 25500 - 27000
	Canberra, Australia	DSS 36, 34[2]	K: 22550 - 23150	250	113.7 - 127.7	K: 25500 - 27000
	Madrid, Spain	DSS 56[2], 54[2]	K: 22550 - 23150	250	113.7 - 127.7	K: 25500 - 27000
	Goldstone, CA USA	DSS 25[3]	Ka: 34315 - 34415	300	125.8 - 133.6	Ka: 31800 - 32300
34M HEF	Madrid, Spain	DSS 65	S: 2025 - 2110	250	71.8 - 78.8	S: 2200 - 2300
	Madrid, Spain	DSS 65	X: 7145 - 7190	20,000	89.8 - 109.8	X: 8400 - 8500
70M	Goldstone, CA USA	DSS 14	S: 2110 - 2120	20,000	85.6 - 105.6	S: 2200 - 2300
	Canberra, Australia	DSS 43	S: 2110 - 2120	100,000	85.6 - 111.6	S: 2200 - 2300
	Madrid, Spain	DSS 63 [1]	S: 2110 - 2120	20,000	85.6 - 105.6	S: 2200 - 2300
	Goldstone, CA USA	DSS 14	X: 7145 - 7190	20,000	95.8 - 115.8	X: 8400 - 8500
	Canberra, Australia	DSS 43	X: 7145 - 7235	80,000	95.8 - 121.8	X: 8400 - 8500
	Madrid, Spain	DSS 63	X: 7145 - 7190	20,000	95.8 - 115.8	X: 8400 - 8500

Notes:

1) S-band uplink in the Deep Space frequency range of 2110-2120 MHz is not available from MDSCC except for
   Voyager support by special agreement with the Spanish Frequency Spectrum Regulator.
2) Near-earth K-band uplink capability planned to be deployed at 24 (2023), 56 (2024), 34 (2024), 54 (2026), dates subject to
   change.
3) Deep Space Ka-band uplink capability planned to be deployed at DSS 55 (2028}, 35 (2030), dates subject to change.

Figure 1 and Figure 2 illustrate the DSN command capabilities assuming a reference spacecraft employing a residual carrier uplink and having the characteristics specified in Table 2. These figures show that command range at low bit rates is limited by the spacecraft carrier tracking performance. At higher bit rates, the range is limited by available E_b/N_o.

Figure 1 is intended to show performance during a spacecraft emergency that forces the use of an omnidirectional antenna. The uplink modulation index has been intentionally lowered to 0.5 radians to direct more power to the carrier. Figure 2 assumes a more typical spacecraft configuration using a high-gain antenna and an uplink modulation index of 1.2 radians.
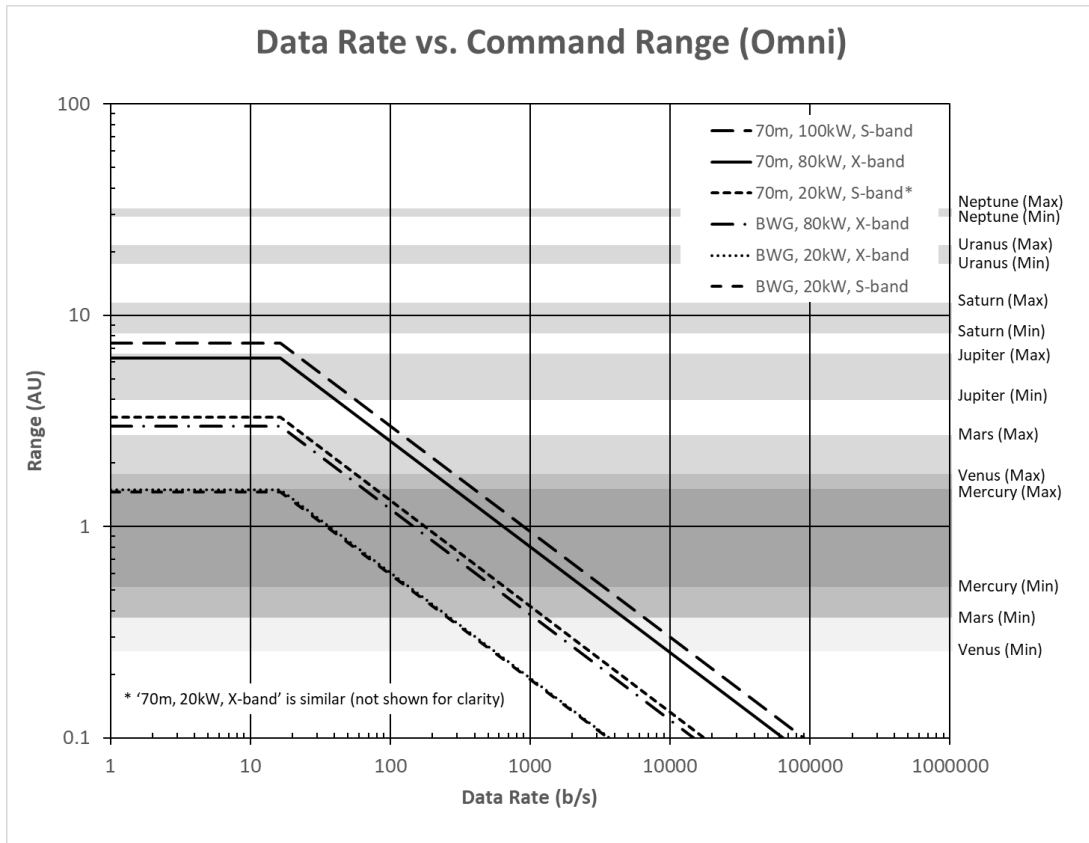
Figure 1. Maximum Command Range for a Reference Spacecraft with an Omni-directional Antenna and a 0.5 Radian Command Modulation Index.

Table 2. Reference Spacecraft Characteristics for Figure 1 and Figure 2

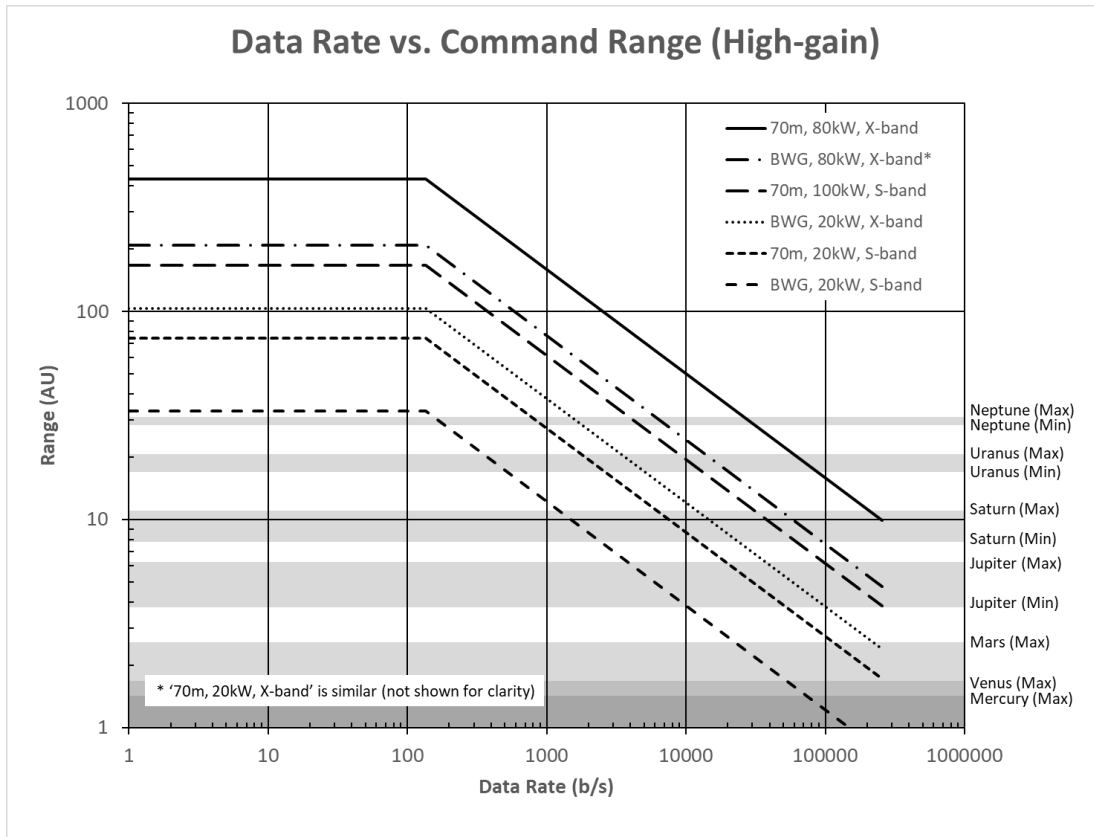| Parameter	Value
Antenna Gain including pointing loss	
Omnidirectional	0 dB
S-band Hi-gain	30 dB
X-band Hi-gain	39.7 dB
Other RF losses	−1.8 dB
System Temperature	500 K
Carrier Loop Bandwidth	100 Hz
Required Carrier Margin	12 dB
Command Detection Losses	−1.5 dB
Required E_b/N_o	9.6 dB

Figure 2. Maximum Command Range for a Reference Spacecraft with a High-gain Antenna and a 1.2 Radian Command Modulation Index.

Uplink data are delivered to the DSN using one of three services. The first is referred to as Stream Mode Command Radiation Service using the *Space Link Extension* (SLE) forward service, an implementation of the Consultative Committed for Space Data Systems (CCSDS) recommendation 912.1, Space Link Extension Forward Command Link Transmission Unit (CLTU) Service, and is described in DSN Document 820-013, module 0239-Telecomm, which describes the DSN implementation of Forward CLTU Service Specifications "2004 Blue Book", CCSDS 912.1-B-2-S, and "2010 Blue Book", CCSDS 912.1-B-3-S, and Enhanced Forward CLTU Service Specification "Orange Book", CCSDS 912.11-O-1. See the data flow diagram in Figure 3.

The SLE forward service is an online only service including service users providing command bits to be transferred to the spacecraft and ancillary information such as routing (e.g., antenna to be used for command service), ensuring the integrity of the Earth segment of the communications link, and providing the customer limited control of the command process as described in the aforementioned documents.
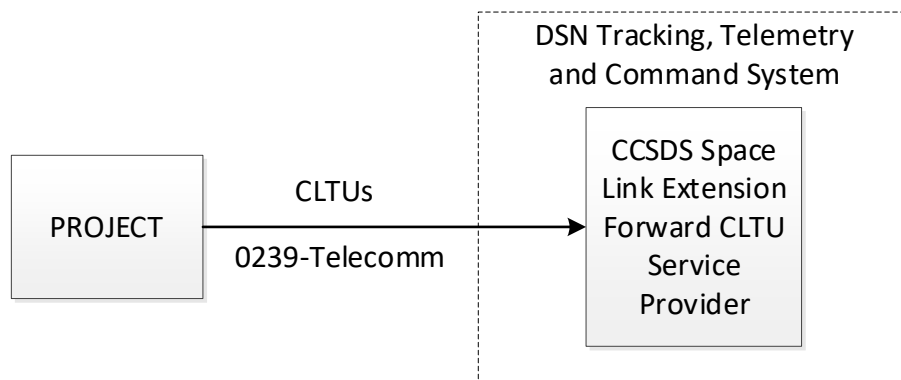
The second, File Mode Command Radiation Service, is provided by accessing a file of CLTUs from the Mission Operations Center (MOC) via DSN File Store where the individual CLTUs are extracted and passed on to the Ground Station for modulation onto the uplink carrier and radiation to the spacecraft. The file of CLTUs is referred to as a Spacecraft Command Message File (SCMF per DSN Document 820-013, module 0198-Telecomm-SCMF), or CLTU File (CLTUF per DSN Document 820-013, module 0241-Telecomm-CLTUF). See the data flow diagram in Figure 4. This service is an online or offline store and forward service that allows management of multiple stored command files.

The SCMF contains a layer of service provision parameters (window open/close times, allowable bit rates, modulation index, etc.) in addition to the CLTUs to be radiated. The CLTUF contains just a simple header and the CLTUs to be radiated.

In addition to the files containing the actual CLTUs, there are a number of other products that may optionally be exchanged between the service user and the DSN for scheduling and reporting:

1) Radiation List (Rad_List per DSN Document 820-013, module 0197-Telecomm-CMDRAD), which contains a list of SCMFs or CLTUFs to be radiated as a batch.

2) SCMF Radiation Report (Rad_SCMF per DSN Document 820-013, module 0191-Telecomm), which is a report of SCMFs and CLTUs radiated, including information such as bit-1 times, number of bits, etc.

3) CLTUF Radiation Report (Rad_CLTUF per DSN Document 820-013, module 0242-Telecomm), which is a report of CLTUFs and CLTUs radiated, including information such as bit-1 times, number of bits, etc.

The third, Command Delivery Service, uses the CCSDS File Delivery Protocol (CFDP) and is available for spacecraft that employ this protocol. It is described in DSN Document 820-013, module 0213-Telecomm-CFDP. The service is provided by accessing files from the MOC via DSN File Store where the files are converted CLTUs which are then passed to the Ground Station for modulation onto the uplink carrier and radiation to the spacecraft. See the data flow diagram in Figure 5. This is also an online or offline service that allows generalized uplink file transfer.

Figure 3. Space Link Extension (SLE) Forward Service Data Flow
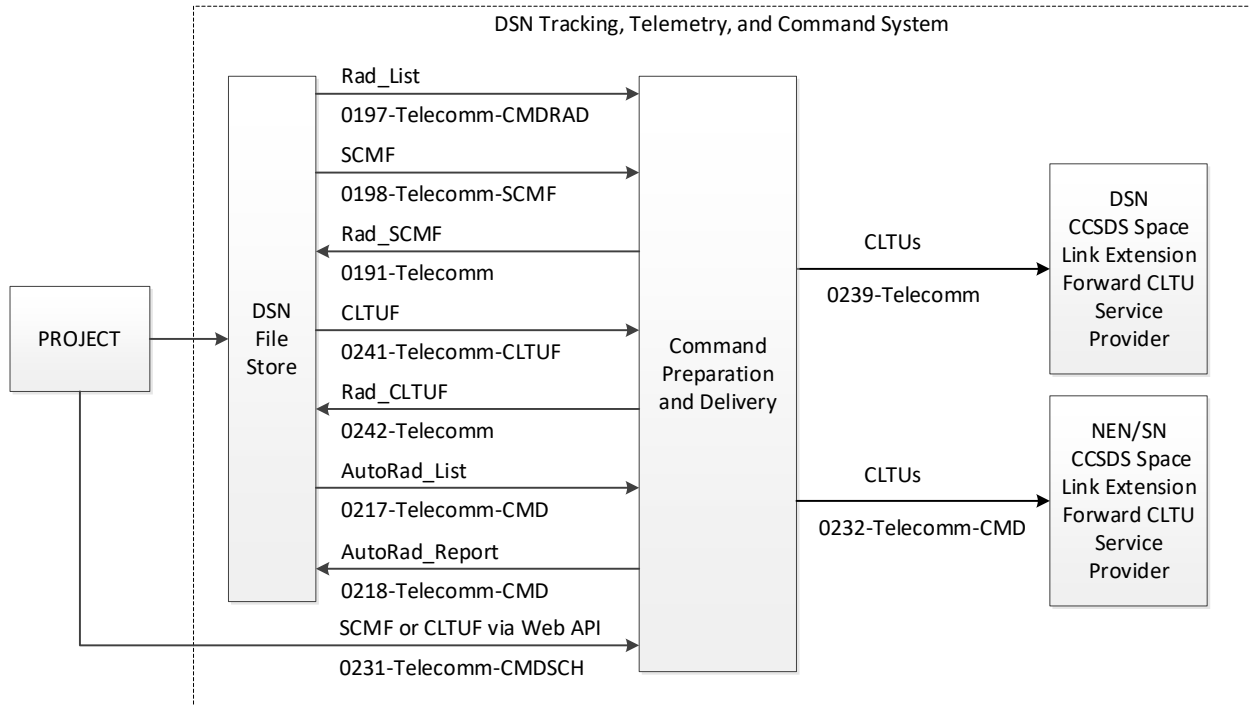
Figure 4. Command Radiation Service Data Flow – File Mode (SCMF or CLTUF)
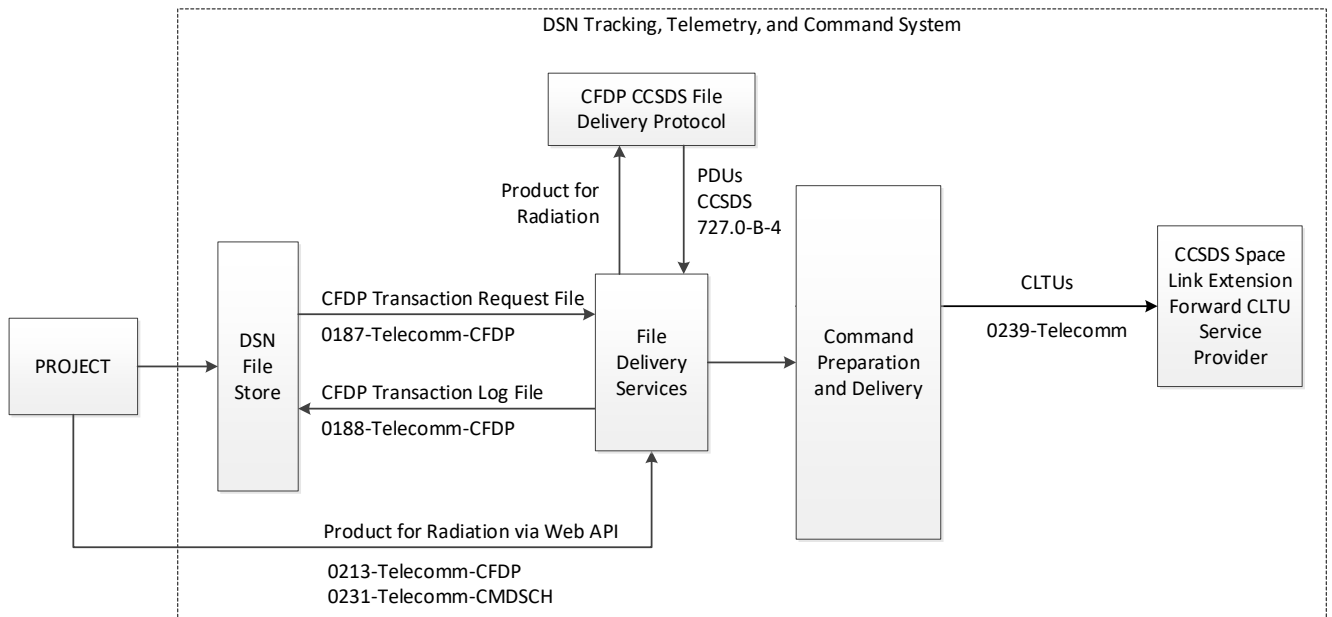
Figure 5. Command Delivery Service Data Flow – (CFDP)

When configured for Forward CLTU Service (CCSDS 912.1-B-2-S and CCSDS 912.1-B-3-S) the only function performed at the stations is the mechanism whereby command data are extracted from the delivery format and converted to an RF signal suitable for reception by a spacecraft. This means that all commands including prefix symbols and command data symbols must be generated at the appropriate MOC. If coding such as Bose-Chaudhuri-Hocquenghem (BCH) is required, it must be accomplished before the commands are delivered to the DSN. The DSN may perform checks for format compliance, but it will not interpret nor modify the contents of any command. Neither does it guarantees error free command delivery to the spacecraft. It is up to the project to provide its own error detection and correction schemes.

When configured for Enhanced Forward CLTU Service (Orange Book), the input stream to the DSN is in the form of Telecommand (TC) or Advanced Orbiter System (AOS) transfer frames. The DSN can optionally apply forward error correction block encoding, optionally randomize the frames, and optionally can attach sync markers to the frames. It will also insert user defined idle frames when no command data is present, and then radiate the frames in the form of CLTUs.

In addition to the interfaces by which command data are delivered to the DSN, a management interface is required for selecting the particular set of parameters appropriate for the spacecraft being supported. Details of this interface can be found in DSN Document 820-013 module 0211-Service_Mgmt-SEQ. A discussion of this interface is contained in DSN Document 810-007 Module 109, DSN Mission Interface Design Handbook, Service Management. (This document is still in development and not available at the time of this writing.)

3   *Command Parameters*

The following paragraphs provide a discussion of the principal command parameters. Parameters that are a function of antenna type performance capabilities are summarized in Table 1.

Parameters that are independent of antenna type are summarized in Table 3.

Table 3. Command Parameters

Parameter	Value	Remarks
RF Power Output	See Table 1	Also see modules 101, 103, and 104
Effective Isotropic Radiated Power (EIRP)	See Table 1	Also see modules 101, 103, and 104
Carrier Frequency	See Table 1	Also see modules 101, 103, and 104

Subcarrier Frequencies
    Sine wave
    Square wave
	999 Hz – 250075 Hz
	100 Hz – 1000 Hz
		The CCSDS recommends a 16 kHz sine wave subcarrier for all data rates up to and including 8 kbps. Direct carrier modulation is recommended above 8 kbps.
		
		Subcarrier Frequency Resolution is 0.1 Hz for Sine wave and Square wave
		
		Harmonic and Spurious Signals (Sine wave Subcarrier) are >45 dB below subcarrier amplitude (dB-V)
		
		Harmonic Response (Square wave Subcarrier) are < 6 dB attenuation of 7th harmonic (dB-V)
		
		Subcarrier Stability is $<1 \times 10^{-9}$ for all measurement times from 100 s through 12 h (derived from station frequency standard)

PCM Data Formats	NRZ-L, M, S Bi-ϕ-L, M, S QPSK, OQPSK	NRZ-L, M, S and Bi-ϕ-L, M, S are BPSK See Figure 4
Modulation Types	Residual carrier BPSK with or without subcarrier, Suppressed Carrier QPSK, OQPSK	Optional Square Root Raised Cosine (SRRC) Filter ($\alpha = 0.5$) available for suppressed carrier modulations

Parameter	Value	Remarks
Modulation Index Range 　　Sine wave Subcarrier 　　Square wave Subcarrier 　　No Subcarrier	0.1 – 1.52 radians 0.1 – 1.40 radians 0.1 – 1.57 radians	6 – 87 degrees 6 – 80 degrees 6 – 90 degrees Modulation Index Accuracy is ±10% of carrier suppression in dB Modulation Index Stability is ±3% of carrier suppression in dB over a 12-h period
Data Rates 　　Sine wave Subcarrier 　　Square wave Subcarrier 　　No Subcarrier	7.8 bps – 125037.5 bps 7.8 bps – 500 bps 8 kbps – 20 Mbps	Set by subcarrier frequency: Subcarrier Frequency/2^n, $1 \le n \le 11$ Max. encoded symbol rate is 40 Msps (assuming QPSK, OQPSK) Coherency to Subcarrier is ±6° offset between bit/symbol transitions and subcarrier zero crossings. Data Rate Stability is <1×10^{-9} for all measurement times from 100 s through 12 h (derived from subcarrier stability)
Inter-command modulation	None (Carrier only), carrier and command subcarrier, carrier, command subcarrier and idle pattern	
Available Encoding	RS and LDPC	
Reed Solomon (RS) Encoding Parameters	Redundancy (E) = 16 Bits / Symbol (J) = 8 Symbol /RS Codeword (n) = 255 Interleave Depth (I) = 1, 2, 3, 4, 5, or 8	CCSDS 131.0-B-3

Parameter	Value	Remarks
Low Density Parity Check (LDPC) Encoding Parameters	(r) = 1/2, (k) = 64 or 256 (r) = 1/2, (k) = 1024, 4096 or 16384 (r) = 2/3, (k) = 1024, 4096 or 16384 (r) = 4/5, (k) = 1024, 4096 or 16384 (r) = 7/8, (k) = 7136	CCSDS 231.0-B-3 CCSDS 131.0-B-3 (r)=Code Rate (k)= Block Length
Idle Pattern	8-bit repetitive or idle PDU	
Command Timing	0.1 s	0.1 s plus 1 – 8 bit times if idle pattern is present
Pre-track Calibration	20 minute 5 minute	With Transmitter warm-up or band change Transmitter already warmed-up
Availability	95% 98%	Nominal Mission critical events (with backup station allocation)

3.1   RF Power

RF power is produced by solid state or variable beam klystron amplifiers that permit saturated operation over a relatively wide power range. Refer to Table 1 for the power levels available at each antenna. Since DSN can support simultaneous command and ranging, carrier power is a function of both the data modulation index and ranging modulation index.

3.2   Carrier Frequency

The DSN considers establishment of carrier frequency to be a tracking function as opposed to a command function. Small frequency changes such as might be required for Doppler compensation will have little effect on the transmitter output. Larger frequency changes such as might be required to command two spacecraft within the same beamwidth may cause the transmitter output to vary by as much as 1-dB due to ripple across the klystron passband. Should this happen, the operator at the station will be warned that the transmitter should be re-calibrated. This warning may be ignored to no detriment other than the power output being as much as 1 dB from the requested value.

The S/X 20kW capable BWG's have two klystron amplifiers that share a common power supply and cooling system. Therefore, a change of band will require a minimum of 20-minutes to cool-down the klystron that is no longer needed and warm-up and calibrate the other klystron. Additionally, the S-band 20kW klystron at these stations is step-tunable to provide coverage over the entire uplink band. Changing from one band segment to another requires turning off the transmitter, changing the band segment, and re-calibrating at the new frequency.

K-band (Near-Earth) or Ka-band (Deep-Space) command link capability, where equipped, can be supported independent and simultaneous with an S-band or X-band command link on a common aperture (Deep Space Station).

3.3   Subcarriers

Both sine wave and square wave subcarriers are available. Subcarrier frequencies are initialized from an entry in the Forward Spacelink Carrier Profile (see interface 820-013 module 0211-Service_Mgmt-SEQ) but may be changed during a support activity providing no command waveform is being radiated. This technique can be used to provide a limited amount of subcarrier Doppler compensation recognizing that command modulation (including the subcarrier) must be removed when the subcarrier frequency is changed. Changing the subcarrier frequency will cause a corresponding change in data rate because these two items are coherent. See the discussion on data rate for details.

3.4   Direct Carrier Modulation

CCSDS Medium Rate Command Recommendation (CCSDS Recommendation 401.0-B, paragraph 2.2.7) is available, with some restrictions. NRZ bit rates and bi-phase symbol rates of 8000, 16000, 32000, 64000, 128000, and 256000 are supported. Carrier and data suppression for direct carrier modulation are calculated using the equations for square wave modulation (3) and (4).

Suppressed carrier modulation formats, similar to those used in telemetry (space to earth) links are available with some restrictions. DSN Command Service supports Binary Phase-shift keying

(BPSK), Quadrature Phase-shift Keying (QPSK) and Offset QPSK (OQPSK) formats at data rates up to 40 Mega-symbols per second. A Square-root-raised-cosine (SRRC) filter option (α = 0.5) is available and recommended to optimize bandwidth efficiency. Maximum data rates will be limited by operational RF band and allocated bandwidth.

3.5 Modulation Index

The modulation index is established by applying a variable-amplitude voltage to the phase modulator in the exciter. The amplitude of this voltage can be adjusted in 255 steps of approximately 0.0065 radians. The range of 0.1 radians through 1.52 radians occupies approximately 220 of these steps. The modulating voltage is calibrated periodically at the 3-dB carrier suppression point for both sine wave and square wave subcarriers. The calibration interval is selected to assure a carrier suppression within 10% of the specified value in dB at any time between calibrations. For example, a sine wave modulation index of 0.67 radians (38.5°) will produce a carrier suppression of 1.0 dB ± 0.1 dB. A sine wave modulation index of 1.13 radians (64.5°) will produce a carrier suppression of 3.0 dB ±0.3 dB.

The modulation index is initialized from an entry in the activity service table but may be changed during a support activity providing no command waveform is being radiated. Carrier power suppression and data power suppression as functions of modulation index angle are:

Sine-wave subcarrier:

$$\frac{P_C}{P_T}(\text{dB}) = 10\log\left[J_0^2(\theta_D)\right], \text{dB} \tag{1}$$

$$\frac{P_D}{P_T}(\text{dB}) = 10\log\left[2J_1^2(\theta_D)\right], \text{dB \{first upper and lower sidebands\}} \tag{2}$$

Square-wave subcarrier:

$$\frac{P_C}{P_T}(\text{dB}) = 10\log\left[\cos^2(\theta_D)\right], \text{dB} \tag{3}$$

$$\frac{P_D}{P_T}(\text{dB}) = 10\log\left[\sin^2(\theta_D)\right], \text{dB \{all sidebands\}} \tag{4}$$

where

θ_D	=	data modulation index, radians, peak
P_T	=	total power
P_C	=	carrier power
P_D	=	data power
J_0	=	zero-order Bessel function
J_1	=	first-order Bessel Function

3.6   Modulation Losses

The bandpass of all elements in the command path, with the exception of the S-band power amplifier at the 20kW capable BWG stations, is adequate to make modulation losses negligible over the frequency and power ranges specified in Table 1. The modulation losses at the S-band 20kW BWG stations are negligible provided the klystron frequency step is properly selected.

3.7   PCM Data Formats

The baseband signal is a pulse code modulated (PCM) waveform that is binary phase-shift keyed (BPSK) onto a subcarrier. That is, phase-shift keyed with a signaling level of ±90° and resulting in a fully suppressed subcarrier. The six supported PCM data formats are illustrated in Figure 4. The data format is established at the start of a support activity by an entry in the activity service table.
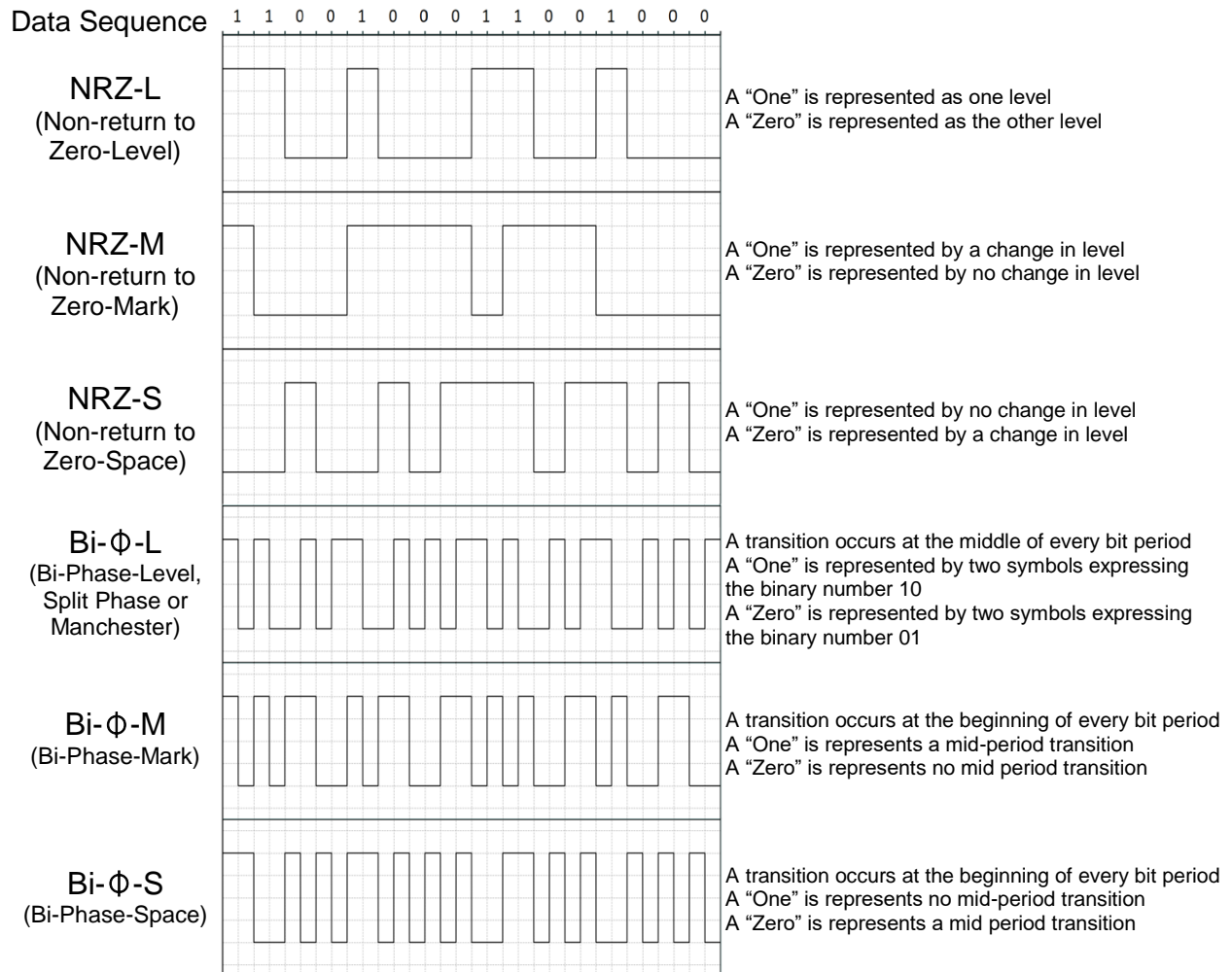
When configured for direct modulation, BPSK PCM types are modulated on the carrier based on the modulation index. When configured for QPSK or OQPSK data is modulated resulting in a fully suppressed carrier.

3.8   Subcarrier to Data Rate Ratios

Bit rates for NRZ modulation and symbol rates for bi-phase modulation are available over the range of 7.8 to 125,037.5 bps or sps. They are derived from the subcarrier frequency generator using a binary divider of 2^n where n can be from 1 to 11 depending on the combination of subcarrier frequency and data rate desired. Thus, a 7.8 bps data stream would require a sine wave subcarrier of no more than 8000 Hz and the lowest bit rate available for a 1000 Hz subcarrier would be 1.953125 bps. For a 16000 Hz subcarrier, the bit can be between 7.8125 and 8000 bps. For a 250075 Hz subcarrier, the bit can be between 122.1069 and 125037.5 bps.

The data rate entry in the activity service table is rounded to the nearest acceptable value depending on the subcarrier frequency selected divided by 2^n. If Doppler correction to the nominal subcarrier frequency and data rate are desired, it should be applied to the subcarrier frequency only. The data rate will be correspondingly Doppler compensated, since it is the subcarrier frequency divided by 2^n, and 2^n is a fixed integer. The data rate may be changed during a support activity providing no command waveform is being radiated.

BPSK

Data Sequence 1 1 0 0 1 0 0 0 1 1 0 0 1 0 0 0

NRZ-L
(Non-return to Zero-Level)

A "One" is represented as one level
A "Zero" is represented as the other level

NRZ-M
(Non-return to Zero-Mark)

A "One" is represented by a change in level
A "Zero" is represented by no change in level

NRZ-S
(Non-return to Zero-Space)

A "One" is represented by no change in level
A "Zero" is represented by a change in level

Bi-ϕ-L
(Bi-Phase-Level, Split Phase or Manchester)

A transition occurs at the middle of every bit period
A "One" is represented by two symbols expressing the binary number 10
A "Zero" is represented by two symbols expressing the binary number 01

Bi-ϕ-M
(Bi-Phase-Mark)

A transition occurs at the beginning of every bit period
A "One" is represents a mid-period transition
A "Zero" is represents no mid period transition

Bi-ϕ-S
(Bi-Phase-Space)

A transition occurs at the beginning of every bit period
A "One" is represents no mid-period transition
A "Zero" is represents a mid period transition

O/QPSK

Data Sequence 1 1 0 0 1 0 0 1 1 1 0 0 1 0 0 1

QPSK
(Quadrature Phase-Shift Keying)

Symbols represent two bits
The four possible symbol phases:
(-135, -45, 45, or 135 degrees)

OQPSK
(Offset Quadrature Phase-Shift Keying)

Symbols represent two bits
The four possible symbols phases:
(-135, -45, 45, or 135 degrees)
The even bits are offset by one bit time which limits phase shift to no more than 90 degrees at a time

Figure 6. Command Data Formats

3.9   Encoding

DSN command can optionally apply error correction encoding to data formatted as TC or AOS transfer frames, per CDSCC 912.11-0-1. Command supports Reed-Solomon (RS) code capable of correcting up to 16 encoded symbol errors out of each 255 and Low-Density Parity-Check (LDPC) codes conforming to the code family specified in the CCSDS Recommended Standards 231.0-B-3 and 131.0-B-3.

Optional frame randomization and synchronization marker attachment of coded blocks is also available per CDSCC 912.11-0-1.

3.10   Idle Patterns

The DSN command equipment can be configured to operate in one of three modes during a command support activity whenever command data is not being radiated. The command mode is initialized from an entry in the activity service table but may be changed during a support activity providing no command waveform (subcarrier or subcarrier and data) is being radiated. The first of these is carrier only as might be used during a support activity not involving commands. In this mode, all command modulation is removed whenever command data are not being radiated. The second mode is subcarrier only in which a continuous, unmodulated subcarrier is transmitted to the spacecraft at the specified frequency and modulation index. The third mode is a repeating customer defined 8-bit idle pattern or idle Protocol Data Unit (PDU), with or without a subcarrier. The most common idle pattern is an alternating sequence of ones and zeros. If a sequence cannot be specified as an 8-bit pattern, it must be originated at the MOC or POCC as command bits.

When configured for Enhanced Forward CLTU Service (Orange Book), command will insert user defined idle PDU when no command data is present.

3.11   Command Timing

The customer may specify a first bit radiation time within the command data stream to an accuracy of 0.1 s. If an idle pattern has been specified, the actual first bit radiation time will be from 1 to 8 bit times later than the specified radiation time, since the transition between an idle pattern and command bits can only occur at 8-bit boundaries. Commands will be radiated upon receipt if no first bit radiation time is specified. If contiguous radiation of commands is desired, it is the customer's responsibility to ensure that the commands are delivered at a rate sufficient to satisfy the radiation requirements while not overflowing the buffering capability of the command equipment. Further details can be found in 820-013 module 0239-Telecomm (SLE Command).

3.12   Command Verification

No test on data content is performed because there is no independent source of data available for comparison. The transmitter power level, waveguide configuration, presence of frequency and timing references, and software health are monitored. Failure of a monitored parameter will cause command radiation to abort.

3.13 Availability

The DSN Command System availability is 95 percent for nominal commanding and 98 percent for mission critical events, achieved by allocating back-up stations.

There is no history available from which an undetected command bit error rate can be determined but it is believed to be significantly less than 3 in 10^8 transmitted bits and may be as low as 1 in 10^{13} which is the error rate of the communications channel between the customer and the stations.

Appendix A
References

1   CCSDS 727.0-B-4, CCSDS file Delivery Protocol, Blue Book, January 2007.

2   CCSDS 401.0-B-25-S, Recommendations for Radio Frequency and Modulation Systems, February 2015.

3   CCSDS 912.1-B-2-S, Space Link Extension – Forward CLTU Service Specification, Silver Book, November 2004.

4   CCSDS 912.1-B-3-S, Space Link Extension – Forward CLTU Service Specification, Silver Book, July 2010.

5   CCSDS 912.11-O-1, Space Link Extension – Enhanced Forward CLTU Service Specification, Orange Book, July 2012.

6   810-007, Deep Space Mission System Mission Interface Design Handbook.

7   820-013 module 0188-Telecomm-CFPD, Transaction Log File Interface, Revision B, October 31, 2019.

8   820-013 module 0191-Telecomm, Radiated Spacecraft Command Message File (Rad_SCMF), Revision A, October 28, 2009.

9   820-013 module 0197-Telecomm-CMDRAD, Command Radiation List File Software Interface Specification, July 15, 2008.

10   820-013 module 0198-Telecomm-SCMF, Spacecraft Command Message File (SCMF) Interface, Revision C, November 26, 2012.

11   820-013 module 0211-Service_Mgmt-SEQ, Flight Project and the DSN Interface for Sequence of Events Generation, Revision C, January 4, 2022.

12   820-013 module 0213-Telecomm-CFDP, Deep Space Network (DSN) Interface for the CCSDS File Delivery Protocol (CFDP), Revision B, October 28, 2009.

13   820-013 module 0239-Telecomm, Space Link Extension Forward Link Service, Revision A, September 16, 2019.

14   820-013 module 0241-Telecomm-CLTUF, Command Link Transmission Unit File (CLTUF) Interface, December 15, 2015.

15   820-013 module 0242-Telecomm, Radiated Command Link Transmission Unit File (RAD_CLTUF) Interface, December 15, 2015.

16   CCSDS 131.0-B-3, TM Synchronization and Channel Coding Standard, Blue Book, September 2017.

17   CCSDS 231.0-B-3, TC Synchronization and Channel Coding Standard, Blue Book, September 2017