Jet Propulsion Laboratory
California Institute of Technology

CCSDS Standards for NASA's Future Lunar Exploration Missions

Wallace Tai,
Jet Propulsion Laboratory, California Institute of Technology

Source/Destination	Frequency Bands[1]	Modulation[2]	Coding[3]	Space Data Link Protocol	Space Data Link Security	Ranging
Earth to Moon (Lunar orbiter or surface vehicles)	RF – low rate: 7190-7235 MHz	Nominal: ≤ 10 Msps				
		• GMSK with PN	LDPC[8,3]: • Coding rates – 1/2, 2/3, 4/5, 7/8	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	CCSDS PN[9] • Non-regenerative Simultaneous data and PN ranging.
		Spacecraft emergency/Contingency: ≤ 4 Ksps				
		• PCM/PSK/PM - Modulation on subcarrier	• Option 1- BCH[12] • Option 2 – LDPC[8,3] Coding rates – 1/2	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	CCSDS PN[9] • Non-regenerative.
	RF – high rate: 22.55-23.15 GHz	• Filtered OQPSK - Modulation on suppressed carrier	LDPC [8, 3] • Coding rates – 1/2, 2/3, 4/5, 7/8	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	None
	Optical: 1064 nm[4]	PPM[4]	LDPC[5] (TBD)	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	None
Moon (Lunar orbiter or surface vehicles) to Earth	RF – low rate: 8450-8500 MHz	Nominal: ≤ 4 Msps				
		GMSK with PN	LDPC[3] • Coding rates – 1/2, 2/3, 4/5, 7/8	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	CCSDS PN[9] • Non-regenerative Simultaneous data and PN ranging.
		Spacecraft emergency/Contingency: ≤ 20 Ksps				

© 2018 California Institute of Technology. Government sponsorship acknowledged.

Source/Destination	Frequency Bands[1]	Modulation[2]	Coding[3]	Space Data Link Protocol	Space Data Link Security	Ranging
		• PCM/PSK/PM - Modulation on subcarrier	• Option 1 - Concatenated (Convolutional + Reed-Solomon[3] • Option 2 – LDPC[3] Coding rates – 1/2	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	CCSDS PN[9] • Non-regenerative.
	RF – high-rate: 25.5-27.0 GHz	• Filtered OQPSK - Modulation on suppressed carrier	LDPC[3] • Coding rates – 1/2, 2/3, 4/5, 7/8	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	None
	Optical: 1550 nm[4]	PPM[4]	SCPPM[5]	AOS[6], USLP[7]	CCSDS Space Data Link Security Protocol[11]	None
Cross-Link (lunar relay orbiter-other relay orbiters)	22.55-23.55 GHz 25.6-27.225 GHz	• Filtered OQPSK - Modulation on suppressed carrier	LDPC[8,3] • Coding rates – 1/2, 2/3, 4/5, 7/8	USLP[7]	None	None
	Optical: 1550 nm[4]	PPM[4]	LDPC[5] (TBD)	AOS[6], USLP[7]	None	None
Proximity-Link (lunar relay orbiter to lunar surface or user orbiter)	RF – low rate: 2025-2110 MHz	Option 1 - PCM/PM/NRZ • Modulation on residual carrier (for FDMA); Option 2 - CDMA[20]	LDPC[8,3] • Coding rates – 1/2, 2/3, 4/5, 7/8	USLP[7]	None	Option 1 - CCSDS PN[9] (for residual carrier) • Non-regenerative. Option 2 – CCSDS PN[10] (for CDMA link) • CCSDS PN patterns and SN PN patterns

© 2018 California Institute of Technology. Government sponsorship acknowledged.

Source/Destination	Frequency Bands[1]	Modulation[2]	Coding[3]	Space Data Link Protocol	Space Data Link Security	Ranging
						to support visiting vehicles like EM-2.
	RF- high rate: 22.55-23.15 GHz	• Filtered OQPSK - Modulation on suppressed carrier	LDPC[8,3] • Coding rates – 1/2, 2/3, 4/5, 7/8	USLP[7]	None	None
	Optical: 1550 nm[4]	PPM[4]	LDPC[5] (TBD)	USLP[7]	None	None
Proximity-Link (lunar surface or user orbiter to lunar relay orbiter)	RF – low rate: 2200-2290 MHz	Option 1 - PCM/PM/NRZ • Modulation on residual carrier (for FDMA); Option 2 - CDMA[20]	LDPC[3] • Coding rates – 1/2, 2/3, 4/5, 7/8	USLP[7] -	None	Option 1 - CCSDS PN[9] (for residual carrier) • Non-regenerative. Option 2 – CCSDS PN[10] (for CDMA link) • CCSDS PN patterns and SN PN patterns to support visiting vehicles like EM-2.
	RF- high rate: 25.5-27 GHz	• Filtered OQPSK - Modulation on suppressed carrier	LDPC[3] • Coding rates – 1/2, 2/3, 4/5, 7/8	USLP[7]	None	None
	Optical: 1550 nm[4]	PPM[4]	SCPPM[5]	USLP[7]	None	None
Lunar Surface to Lunar Surface	2.4-2.48 GHz	IEEE 802.11[13]	IEEE 802.11[13]	IEEE 802.11[13]	None	None

Recommendations on FCMLP for Deep Space Gateway (DSG) and some future systems

© 2018 California Institute of Technology. Government sponsorship acknowledged.

References

The above table was created using the following references:

1. SFCG 32-2R1 Communication Frequency Allocations and Sharing in the Lunar Region.
2. CCSDS 401.0-B-27 Radio Frequency and Modulation Systems--Part 1: Earth Stations and Spacecraft. Blue Book. Issue 27. November 2017.
3. CCSDS 131.0-B-3 TM Synchronization and Channel Coding. Blue Book. Issue 3. September 2017.
4. CCSDS 141.0-R-1 Optical Communications Physical Layer, Red Book November 2017, currently undergoing publication.
5. CCSDS (Reference TBD) Optical Communications Coding & Synchronization – publication date TBD.
6. CCSDS 732.0-B-3 AOS Space Data Link Protocol. Blue Book. Issue 3. September 2015.
7. CCSDS 732.1-R-3.1 Unified Space Data Link Protocol. Red Book. November 2017, currently undergoing publication.
8. CCSDS (TBD Reference) Coding & Synchronization Sub-layer High Rate Uplink Protocol for AOS & USLP.
9. CCSDS 414.1-B-2 Pseudo-Noise (PN) Ranging Systems. Blue Book. Issue 2. February 2014.
10. CCSDS 415.1-B-1 Data Transmission and PN Ranging for 2 GHz CDMA Link via Data Relay Satellite. Blue Book. Issue 1. February 2011.
11. CCSDS 355.0-B-1 Space Data Link Security Protocol. Blue Book. Issue 1. September 2015.
12. CCSDS 231.0-B-3 TC Synchronization and Channel Coding. Blue Book. Issue 3. September 2017.
13. IEEE 802 Part 11 Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, IEEE Standard 802.11-2007

Key considerations in identifying the lunar communication standards:

I. Interoperability between a lunar relay orbiter and its user vehicles
II. Interoperability between the lunar orbiters and the supporting network assets (owned by NASA, international partners, and commercial providers)
III. Costs of implementation
IV. Constraints due to spectral limitation: ITU, SFCG and NTIA imposed

© 2018 California Institute of Technology. Government sponsorship acknowledged.