

ESTRACK

# Antenna performance requirements

Cis-lunar & Sun-Earth Lagrange (SEL1/2) missions

The identified performance requirements for Cis-lunar & Sun-Earth Lagrange (SEL1/2) missions are intended to define an envelope that serves as guidance for ground stations operators developing Near Space antenna capabilities, as well as for future project design, for missions operating at distances from Earth beyond the geostationary orbit and up to 2 million km. Achieving the target data rate(s) for a given mission requires station EIRP & G/T performance levels that may vary considerably depending on the spacecraft's on-board capabilities and the efficiency of the communication link. The specific requirements shall be assessed on a case-by-case basis.

| **Frequency band, Link direction** | **RF band** |
|---|---|
| 2025 – 2110 MHz, Uplink (Earth-to-space) | S-UP |
| 2200 – 2290 MHz, Downlink (space-to-Earth) | S-DOWN |
| 7190 – 7235 MHz, Uplink (Earth-to-space) | X-UP |
| 8450 – 8500 MHz, Downlink (space-to-Earth) | X-DOWN |
| 22.55 – 23.15 GHz, Uplink (Earth-to-space) | K-UP |
| 25.5 – 27.0 GHz, Downlink (space-to-Earth) | K-DOWN |
| ITU Radio Regulations: Space Research Service. Distances from the Earth lower than 2 million km (CCSDS Category A). | |

**Generic requirements**

- Ground station availability of 95% (effective tracking uptime, considering failure mitigation & robustness of communication links, e.g., response to equipment failures, subsystem redundancy, single points of failure, power outages, network disruptions, backup system effectiveness, etc.)
- Space Link Extension (SLE) interface (Forward & Return services, CCSDS 911.1-B-5, 911.2-B-4, 911.5-B-4, 912.1-B-5): Required
- TM & TC Data Link Protocols (CCSDS 132.0-B-3, 232.0-B-4): Required
- AOS & USLP Protocols (CCSDS 732.0-B-4, 732.1-B-3): Optional
- Frequency & Timing (F&T): CCSDS 401 (2.3.7) B-2 Category A. For lunar missions, the Category B requirement applies as per CCSDS 401 (2.3.7) B-2. However, this is expected to be mission specific & less stringent performance towards the Category A requirement may suffice.
- Measurement & recording of integrated Doppler residuals: Required
- Tracking rate: > 1.0 deg/s

| **Uplink (Earth-to-space) requirements** | | **Reduced routine (NASA LEGS)** with rate limitations | **Standard routine** |
|---|---|---|---|
| **S-UP** | **EIRP [dBW]** | ~ 81.0 | ~ 84.0 [Note#1] |
| **X-UP** | **EIRP [dBW]** | ~ 86.0 | ~ 90.0 [Note#2] |
| **K-UP** | **EIRP [dBW]** | ~ 89.0 | ~ 99.0 |

- EIRP indicating the performance under worst-case operational conditions & include appropriate margin to account for antenna losses (e.g., pointing & deformation loss, model pointing inaccuracies, wind, etc.). The system shall support amplifier back-off capability. Minimum TX elevation angle: 5 deg
- Polarization: circular (RHC & LHC)
- Modulation schemes: CCSDS-401.0-B-32 (Direct PCM/PM, PCM/PM/PSK), & BPSK, OQPSK, Filtered OQPSK, GMSK. [Note#3]
- Encoding & PLOP: CCSDS 231.0-B-4 (uncoded, pre-encoded frames via SLE F-CLTU). For AOS/USLP, see CCSDS 131.0-B-5 (e.g., conv, LDPC). [Note#3]
- Ranging: ESA standard transparent (ECSS-E-ST-50-02C) & Pseudo-Noise (PN) ranging (CCSDS 414.1-B-3)
- Doppler compensation: Required

[Note#1] S-UP EIRP levels up to 97 dBW may be required for emergency & critical operations support.
[Note#2] X-UP EIRP levels up to 108 dBW may be required for emergency & critical operations support.
[Note#3] Typical maximum symbol rates (reference Rcs, see CCSDS-401.0-B-32) up to 1-2 Msps for S-UP, 10 Msps for X-UP, and 50 Msps for K-UP.

| **Downlink (space-to-Earth) requirements** | | **NS40 (NASA LEGS)** Relative rates of ~ 40% | **NS100** Reference performance | **NS200** Relative rates of ~ 200% | **NS500** Relative rates up to ~ 500% |
|---|---|---|---|---|---|
| **S-DOWN G/T [dB/K]** | **Clear sky, 5-deg elevation** | ~ 27.5 [Note#4] | ~ 31.0 | ~ 34.0 | ~ 38.0 |
| | **Clear sky, 60-deg elevation** | ~ 29.0 | ~ 33.0 | ~ 36.0 | ~ 40.0 |
| **X-DOWN G/T [dB/K]** | **Clear sky, 5-deg elevation** | ~ 39.0 [Note#4] | ~ 43.0 | ~ 46.0 | ~ 50.0 [Note#5] |
| | **Clear sky, 60-deg elevation** | ~ 42.0 | ~ 46.0 | ~ 49.0 | ~ 53.0 |
| **K-DOWN G/T [dB/K]** | **Clear sky, 20-deg elevation** | ~ 47.5 | ~ 51.5 | ~ 54.5 | ~ 58.5 |
| | **Clear sky, 60-deg elevation** | ~ 48.5 | ~ 52.5 | ~ 55.5 | ~ 59.5 |

- G/T indicating the performance under worst-case operational conditions, including appropriate margin to account for antenna losses (e.g., pointing & deformation loss, pointing inaccuracies, wind, etc.). Availability of weather & radio propagation statistics would be advantageous.
- Polarization: circular (RHC & LHC)
- Modulation schemes: CCSDS-401.0-B-32 (Direct PCM/PM, PCM/PM/PSK, BPSK, QPSK, OQPSK, Filtered OQPSK, 8PSK, GMSK). [Note#6]
- Decoding: CCSDS 131.0-B-5 (LDPC, Convolutional, Reed-Solomon, Concatenated RS + Conv, Turbo, uncoded). [Note#6]
- Ranging: ESA standard transparent (ECSS-E-ST-50-02C) & Pseudo-Noise (PN) ranging (CCSDS 414.1-B-3)
- Open loop recording (raw I/Q data of the available radio spectrum): Required
- Search & Acquisition Aids (e.g., auto-track/closed-loop antenna tracking, scans, etc.): Optional
- Multiple Spacecraft per Aperture (MSPA): Optional

[Note#4] Performance below NS40 may suffice for low-rate transmissions (e.g., for 24/7) & LEOP operations (Search & Acquisition Aids required with tracking rates up to 10-15 deg/s).
[Note#5] High-rate transmissions (e.g., at Sun-Earth L2, GMSK 5–9 Mbps, S/C EIRP 35 dBW) may require G/T values comparable to those of Deep Space stations (NS500 ≈ DS100).
[Note#6] Typical maximum symbol rates (reference Rcs, see CCSDS-401.0-B-32) up to 10 Msps for S-DOWN, 20 Msps for X-DOWN & 500-600 Msps for K-DOWN.

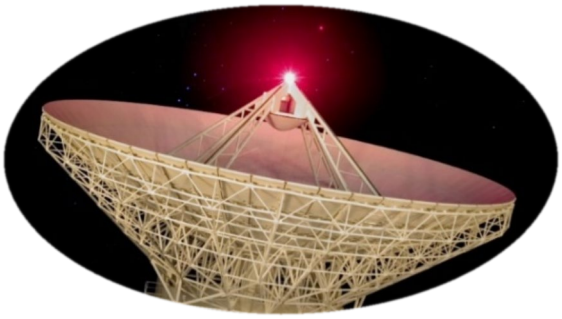


# Antenna performance requirements

Deep Space missions

ESTRACK

The identified performance requirements are intended to define an envelope that serves as guidance for ground stations operators developing Deep Space antenna capabilities, as well as for future project design, for missions operating at distances from Earth beyond 2 million km. Achieving the target data rate(s) for a given mission requires station EIRP & G/T performance levels that may vary considerably depending on the spacecraft's on-board capabilities and the efficiency of the communication link. Moreover, for Deep Space missions, these requirements may change significantly over the course of the mission (e.g., during the initial cruise phase or due to varying planetary distances from Earth). As such, different performance levels may be needed at different mission stages. The specific requirements and conditions shall be assessed on a case-by-case basis.



| **Frequency band, Link direction** | **RF band** |
|---|---|
| 7145 – 7190 MHz, Uplink (Earth-to-space) | X-UP |
| 8400 – 8450 MHz, Downlink (space-to-Earth) | X-DOWN |
| 31.8 – 32.3 GHz, Downlink (space-to-Earth) | Ka-DOWN |
| ITU Radio Regulations: Space Research (deep space) Service. Distances from the Earth greater than 2 million km (CCSDS Category B). | |

**Generic requirements**

- Ground station availability of 95% (effective tracking uptime, considering failure mitigation & robustness of communication links, e.g., response to equipment failures, subsystem redundancy, single points of failure, power outages, network disruptions, backup system effectiveness, etc.)
- Space Link Extension (SLE) interface (Forward & Return services, CCSDS 911.1-B-5, 911.2-B-4, 911.5-B-4, 912.1-B-5): Required
- TM & TC Data Link Protocols (CCSDS 132.0-B-3, 232.0-B-4): Required
- AOS & USLP Protocols (CCSDS 732.0-B-4, 732.1-B-3): Optional
- Frequency & Timing (F&T): Recommendation CCSDS 401 (2.3.7) B-2 Category B
- Measurement & recording of integrated Doppler residuals: Required
- Tracking rate: > 1.0 deg/s

| **Uplink (Earth-to-space) requirements** | | **Reduced routine** (rate & distance limitations) | **Standard routine** | **Complete routine** (partial emergency support) | **Full emergency support** |
|---|---|---|---|---|---|
| **X-UP** | **EIRP [dBW]** | ~ 92.0 | ~ 98.0 | ~ 108.0 | ~ 114.0 |

- EIRP indicating the performance under worst-case operational conditions & include appropriate margin to account for antenna losses (e.g., pointing & deformation loss, model pointing inaccuracies, wind, etc.). The system shall support amplifier back-off capability. Minimum TX elevation angle: 10 deg
- Polarization: circular (RHC & LHC)
- Modulation schemes: CCSDS-401.0-B-32 (Direct PCM/PM, PCM/PM/PSK). [Note#1]
- Encoding & PLOP: CCSDS 231.0-B-4 (uncoded, pre-encoded frames via SLE F-CLTU). For AOS/USLP, see CCSDS 131.0-B-5 (e.g., conv, LDPC). [Note#1]
- Ranging: ESA standard transparent (ECSS-E-ST-50-02C) & Pseudo-Noise (PN) ranging (CCSDS 414.1-B-3)
- Doppler compensation: Required

[Note#1] Typical maximum symbol rates (reference Rcs, see CCSDS-401.0-B-32) up to 4 ksps for X-UP.

| **Downlink (space-to-Earth) requirements** | | **DS40** Relative rates of ~ 40% | **DS100** Reference performance | **DS200** Relative rates of ~ 200% |
|---|---|---|---|---|
| **X-DOWN G/T [dB/K]** | **Clear sky, 10-deg elevation** | ~ 47.7 [Note#2], [Note#3] | ~ 51.7 [Note#3] | ~ 54.7 |
| | **Clear sky, 60-deg elevation** | ~ 49.5 | ~ 53.5 | ~ 56.5 |
| **Ka-DOWN G/T [dB/K]** | **Clear sky, 20-deg elevation** | ~ 56.5 | ~ 60.5 | ~ 63.5 |
| | **Clear sky, 60-deg elevation** | ~ 58.0 | ~ 62.0 | ~ 65.0 |

- G/T indicating the performance under worst-case operational conditions, including appropriate margin to account for antenna losses (e.g., pointing & deformation loss, pointing inaccuracies, wind, etc.). Availability of weather & radio propagation statistics would be advantageous.
- Polarization: circular (RHC & LHC)
- Modulation schemes: CCSDS-401.0-B-32 (Direct PCM/PM, PCM/PM/PSK, BPSK, QPSK, OQPSK, Filtered OQPSK, GMSK). [Note#4]
- Decoding: CCSDS 131.0-B-5 (LDPC, Convolutional, Reed-Solomon, Concatenated RS + Conv, Turbo, uncoded). [Note#4]
- Ranging: ESA standard transparent (ECSS-E-ST-50-02C) & Pseudo-Noise (PN) ranging (CCSDS 414.1-B-3)
- Open loop recording (raw I/Q data of the available radio spectrum): Required
- Search & Acquisition Aids (e.g., auto-track/closed-loop antenna tracking, scans, etc.): Optional
- Multiple Spacecraft per Aperture (MSPA): Optional

[Note#2] Performance below DS40 may suffice for low-rate transmissions (e.g., for 24/7) & LEOP operations (Search & Acquisition Aids required with tracking rates up to 10-15 deg/s).
[Note#3] As example, at 1 AU with GMSK Turbo 1/4 (S/C EIRP 57 dBW): max info rates of about 370 kbps with DS100 & 150 kbps with DS40.
[Note#4] Typical maximum symbol rates (reference Rcs, see CCSDS-401.0-B-32) up to 5-10 Msps for X-DOWN & 50-300 Msps for Ka-DOWN.