Recommendation ITU-R SA.2169-0

(06/2025)

SA Series: Space applications and meteorology

Technical and operational characteristics of the space operation service (SOS) systems that use the 2 025-2 110 MHz (Earth-to-space) (space-to-space) and 2 200-2 290 MHz (space-to-Earth) (space-to-space) frequency bands for use in assessing of interference and for conducting sharing studies

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| ***Note***: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.* |

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RECOMMENDATION ITU-R SA.2169-0

Technical and operational characteristics of the space operation service (SOS) systems that use the 2 025-2 110 MHz (Earth-to-space) (space-to-space) and 2 200-2 290 MHz (space-to-Earth) (space-to-space) frequency bands for
use in assessing of interference and for conducting sharing studies

(2025)

Scope

This Recommendation provides technical and operational characteristics for use in sharing studies for the space operation service (SOS) systems that use the 2 025-2 110 MHz (Earth-to-space) (space-to-space) and 2 200‑2 290 MHz (space-to-Earth) (space-to-space) frequency bands.

Keywords

Tracking, Telemetry, Command, Space Operation, TT&C, SOS, DRS, POCS

Abbreviations/Glossary

CP Circular polarization

DRS Data relay satellite

GSO Geostationary-satellite orbit

HEO Highly-elliptical orbit

LEO Low-Earth orbit

MEO Medium-Earth orbit

ND Non-directional

non-GSO Non-geostationary-satellite orbit

POCS Proximity operations communication system

SOS Space operation service

TT&C Telemetry, tracking and command

Related ITU-R Recommendations and Reports

Recommendation [ITU-R SA.3](https://www.itu.int/rec/R-REC-SA.363)63 – Space operation systems

Recommendation [ITU-R SA.1018](https://www.itu.int/rec/R-REC-SA.1018) – Hypothetical reference system for systems comprising data relay satellites in the geostationary orbit and user spacecraft in low Earth-orbits

Recommendation [ITU-R SA.1020](https://www.itu.int/rec/R-REC-SA.1020) – Hypothetical reference system for the Earth exploration-satellite and meteorological satellite services

Recommendation [ITU-R SA.1414](https://www.itu.int/rec/R-REC-SA.1414) – Characteristics of data relay satellite systems

The ITU Radiocommunication Assembly,

considering

*a)* that the frequency band 2 025-2 110 MHz is allocated to the SOS on a primary basis among other services in the Earth-to-space and space-to-space directions;

*b)* that the frequency band 2 200-2 290 MHz is allocated to the SOS on a primary basis among other services in the space-to-Earth and space-to-space directions,

recommends

that the technical and operational characteristics for the SOS systems operating in the 2 025‑2 110 MHz (Earth-to-space) (space-to-space) and 2 200-2 290 MHz (space-to-Earth) (space-to-space) frequency bands detailed in the Annex should be used in sharing studies.

Annex

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# 1 Introduction

This Annex provides the technical and operational characteristics of telemetry, tracking and command (TT&C) systems operating in the space operation service in the 2 025-2 110 MHz and 2 200‑2 290 MHz frequency bands.

The TT&C system performs the following functions for ensuring the successful operation of a satellite:

1 Telemetry to enable ground controllers to monitor the operational health and status of the satellite, and the measured values are transmitted from satellite to the ground control centre.

2 Tracking/ranging to enable ground controllers to determine the satellite’s location and orientation.

3 Telecommand to enable ground controllers to command the various electronic units aboard the satellite, sending commands from the ground to the satellite.

The frequency band 2 025-2 110 MHz is allocated to space operation service (SOS) (Earth-to-space) (space-to-space) and the frequency band 2 200-2 290 MHz is allocated to SOS (space-to-Earth) (space-to-space). These frequency bands are used by geostationary and non-geostationary satellites and the inter-satellite links.

# 2 Technical and operational characteristics of the geostationary satellites

Representative characteristics of the TT&C systems for GSO SOS systems are listed in Tables 1 and 2.

## 2.1 Telemetry in the 2 200-2 290 MHz frequency band

Table 1 lists the system parameters for telemetry downlinks in the frequency band 2 200-2 290 MHz for the GSO SOS systems.

TABLE 1

GSO SOS system parameters for telemetry downlinks in the frequency band 2 200-2 290 MHz

| Function | Telemetry |
| --- | --- |
| **System** | **System A** |
| Maximum necessary bandwidth (MHz) | 4.930 |
| **Transmitting Satellite parameters** |
| Satellite antenna input power (dBW) (1) | 1.8 |
| Satellite antenna type | Bicone/Crossed-dipole |
| Satellite maximum antenna gain (dBi) | 1.0 |
| Satellite antenna polarization | CP |
| Satellite antenna radiation pattern | Cardioid−13 dB at 170 degrees |
| **Receiving Earth station parameters** |
| Earth station antenna type | Parabolic |
| Earth station antenna radiation pattern | Rec. [ITU-R S.465-6](https://www.itu.int/rec/R-REC-S.465-6-201001-I/en) |
| Earth station maximum antenna gain (dBi) | 50 |
| Earth station antenna polarization | CP |
| Earth station receiver noise temperature (K) | 130 |
| Minimum elevation angle (degree) | 5 |
| (1) “satellite antenna input power” includes the antenna feeder loss. |

## 2.2 Command in the 2 025-2 110 MHz frequency band

Table 2 lists the system parameters for command uplinks in the 2 025-2 110 MHz frequency band for GSO SOS systems.

TABLE 2

GSO SOS system parameters for command uplinks in the frequency band 2 025-2 110 MHz

|  |  |
| --- | --- |
| Function | Command |
| System | System A |
| Maximum necessary bandwidth (MHz) | 0.084 |
| **Transmitting Earth station parameters** |
| Earth station antenna input power (dBW) | 21.9 |
| Earth station antenna type | Parabolic |
| Earth station antenna radiation pattern | 34.6 dB at 0.95 degreesRec. ITU-R S.465-6 |
| Earth station maximum antenna gain (dBi) | 49.5 |
| Earth station antenna polarization | CP |
| Minimum elevation angle (degree) | 5 |
| **Receiving satellite parameters** |
| Satellite antenna type | Crossed-dipole |
| Satellite maximum antenna gain (dBi) | 1 |
| Satellite antenna polarization | CP |
| Satellite antenna radiation pattern | −11 dB at 165 degrees |
| Satellite receiver noise temperature (K) | 650 |

# 3 Technical and operational characteristics of the non-geostationary satellites

Representative characteristics of the TT&C systems for non-geostationary-satellite orbit (non-GSO) SOS systems are listed below in Tables 3 and 4.

Non-GSO satellites operate in a variety of orbits depending on their mission objectives, and characteristics of the TT&C systems are designed according to orbital features such as shape of orbit, orbital altitude, so the characteristics of the TT&C systems are provided for representative orbits of the LEO sun-synchronous orbit, LEO low latitude orbit, MEO, HEO, and Lagrange L1/L2 orbit.

## 3.1 Telemetry/ranging in the 2 200-2 290 MHz frequency band

Table 3 lists the system parameters for telemetry/ranging downlinks in the frequency band 2 200‑2 290 MHz for the non-GSO SOS systems. Ranging is used on non-GSO satellites to locate the satellite’s position. Ranging is accomplished alone or together with the telemetry transmission.

TABLE 3

Non-GSO SOS system parameters for telemetry/ranging downlinks in the frequency band 2 200-2 290 MHz

| Function | Command/ranging |
| --- | --- |
| Orbit type | LEO, Sun synchronous |
| System | System B | System C | System D | System E | System F | System G | System H |
| Maximum necessary bandwidth (MHz) | 3.2 | 6 | 2.2 (2) / 2.5 (3) | 0.8 | 3 | 3.32 | 0.5 |
| **Orbit information** |
| Shape of orbit | Circular | Circular | Circular | Circular | Circular | Circular | Circular |
| Orbital altitude (km) | 824 | 510 | 628 | 600 | 773 | 550 | 500-800 |
| Inclination angle (degree) | 98.7 | 97 | 97.9 | 97.8 | 98.3 | 97.6 | 97-98.5 |
| **Satellite parameters** |
| Satellite antenna input power (1) (dBW) | 7 | −0.2 | −22.2 (2) / −5.2 (3) | −3 | 1 | 0.3 | -4 |
| Satellite antenna type | Helix | Crossed dipole with a reflector | Crossed dipoles with a reflector | Quadrifilar helix | Quadrifilar helix | Broadband patch panel | Quadrifilar Helix / Patch |
| Satellite maximum antenna gain (dBi) | 3 | 2 | 7.5 | 3 | 3.5 | 5.6 | 0 |
| Satellite antenna polarization | CP | CP | CP | CP | CP | CP | CP |
| Satellite antenna radiation pattern  | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | Constant gain over ¼ of the sphere | ND |
| **Receiving Earth station parameters** |
| Earth station antenna type  | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic |
| Earth station antenna radiation pattern | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.580-6 |
| Earth station maximum antenna gain (dBi) | 42 / 44.8 / 46.8 | 34.9 / 39 | 44.2 | 42 / 45 / 47 | 42 / 45 / 47 | 42 / 45 / 47 | 44 |
| Earth station antenna polarization | CP | CP | CP | CP | CP | CP | CP |
| Earth station receiver noise temperature (K) | 130 / 190 / 245 | 75 / 100 | 148 | 139 / 145 / 152 | 139 / 145 / 152 | 139 / 145 / 152 | 200 |
| Minimum elevation angle (degree) | 5 | 5 | 5 | 3 | 3 | 3 | 3 |

TABLE 3 (*end*)

| Function | Command/ranging |
| --- | --- |
| Orbit type | LEO, low latitude | MEO | HEO | L1/L2 |
| System | System I | System J | System K | System L | System M | System N |
| Maximum necessary bandwidth (MHz) | 0.064 | 2.4 (2) / 3 (3) | 2.3 | 2.5 (2) / 2.0 (3) | 0.075 | 1.15 |
| **Orbit information** |
| Shape of orbit | Circular | Circular | Circular | elliptical | Highly elliptical | Heliocentric (L1) |
| Orbital altitude (km) | 550 | 550 | 200-500 | 32 700 (apogee)300 (perigee) | 41885 (apogee) 9710 (perigee) | 1 500 000 |
| Inclination angle (degree) | 24 | 31 | 51.6 | 31 | 63.435 | N/A |
| **Satellite parameters** |
| Satellite antenna input power (1) (dBW) | −12.0 | −23.5 (2) / −3 (3) | −1.5 / 1.5 | 5.1 (apogee)−14.9 (2) / 5.1 (3) (perigee) | 5.5 | 5 |
| Satellite antenna type | Quadrifilar helix | Crossed dipoles with a reflector | Helix | Crossed dipoles with a reflector / dipole | Quadrifilar helix | 2 omni antennas |
| Satellite maximum antenna gain (dBi) | 2.5 | 7 | 5 | 6 | 8 | −4.5 |
| Satellite antenna polarization | CP | CP | CP | CP / Vertical polarization | CP | CP |
| Satellite antenna radiation pattern  | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna |
| **Receiving Earth station parameters** |
| Earth station antenna type  | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic |
| Earth station antenna radiation pattern | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | RR App. **8** |
| Earth station maximum antenna gain (dBi) | 34.2 / 46.6 | 56.3 | 47.1 | 47.1 | 46.7 | 50.5 / 51.8 |
| Earth station antenna polarization | CP | CP | CP | CP | CP | CP |
| Earth station receiver noise temperature (K) | 70 / 157 | 70 | 147 | 147 | 247 | 251 |
| Minimum elevation angle (degree) | 5 | 5 | 5 | 5 | 5 | 5 |
| (1) “satellite antenna input power” includes the antenna feeder loss.(2) For PCM-PSK/PM.(3) For QPSK. |

## 3.2 Command/ranging in the 2 025-2 110 MHz frequency band

Table 4 lists the system parameters for command/ranging uplinks in the 2 025-2 110 MHz frequency band for non‑GSO SOS systems. Ranging is used on non-GSO satellites to locate the satellite’s position. Ranging is accomplished alone or together with the command transmission.

TABLE 4

Non-GSO SOS system parameters for command/ranging uplinks in the frequency band 2 025-2 110 MHz

| Function | Command/ranging |
| --- | --- |
| Orbit type | LEO, Sun synchronous |
| System | System B | System C | System D | System E | System F | System G | System H |
| Maximum necessary bandwidth (MHz) | Command 0.032Configuration Data 0.256 | 6 | 1.1 | 0.38 | 0.3 | 0.2 | 0.5 |
| **Orbit information** |
| Shape of orbit | Circular | Circular | Circular | Circular | Circular | Circular | Circular |
| Orbital altitude (km) | 824 | 510 | 628 | 600 | 773 | 550 | 500-800 |
| Inclination angle (degree) | 98.7 | 97 | 97.9 | 97.8 | 98.3 | 97.6 | 97-98.5 |
| **Transmitting Earth station parameters** |
| Earth station antenna input power (dBW) | 9.8 | 22 | 20 | 11.7 | 11.7 | 11.7 | 30 |
| Earth station antenna type | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic | Parabolic |
| Earth station antenna radiation pattern | Rec. ITU-R S.465-6 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.580-6 |
| Earth station maximum antenna gain (dBi) | 41.4 / 42 / 46.2 | 34.2/38 | 43.2 | 41 / 44 / 46 | 41 / 44 / 46 | 41 / 44 / 46 | 43 |
| Earth station antenna polarization | CP | CP | CP | CP | CP | CP | CP |
| Minimum elevation angle (degree) | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Satellite parameters** |
| Satellite antenna type | Helix | Crossed dipoles with a reflector | Crossed dipoles with a reflector | Quadrifilar helix | Quadrifilar helix | Broadband patch panel | Quadrifilar Helix / Patch |
| Satellite maximum antenna gain (dBi) | 3 | 2 | 7.5 | 3 | 3.5 | 5.6 | 0 |
| Satellite antenna polarization | CP | CP | CP | CP | CP | CP | CP |
| Satellite antenna radiation pattern  | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | Constant gain over ¼ of the sphere | ND |
| Satellite receiver noise temperature (K) | 263 | 450 | 515 | 999 | 1892 | 8300 | 1200 |

TABLE 4 (*end*)

| Function | Command/ranging |
| --- | --- |
| Orbit type | LEO, low latitude | MEO | HEO | L1/L2 |
| System | System I | System J | System K | System O | System L | System M | System N |
| Maximum necessary bandwidth (MHz) | 0.064 | 2 | 0.044 | 0.095 | 2 | 0.1 | 1.0 |
| **Orbit information** |
| Shape of orbit | Circular | Circular | Circular | Circular | elliptical | Highly elliptical | Heliocentric (L1) |
| Orbital altitude (km) | 550 | 550 | 200-500 | 1336 | 32 700 (apogee)300 (perigee) | 41885 (apogee) 9710 (perigee) | 1 500 000 |
| Inclination angle (degree) | 24 | 31 | 51.6 | 66 | 31 | 63.435 | N/A |
| **Transmitting Earth station parameters** |
| Earth station antenna input power (dBW) | 11 | 20 | 20 | 8 | 30 | 13.9 | 22.8 / 31 |
| Earth station antenna type | Parabolic | Parabolic | Parabolic | Omni | Parabolic | Parabolic | Parabolic |
| Earth station antenna radiation pattern | Rec. ITU-R S.465-6 | Rec. ITU-R S.465 | Rec. ITU-R S.465 | ND | Rec. ITU-R S.465 | Rec. ITU-R S.465 | RR App. **8** |
| Earth station maximum antenna gain (dBi) | 36.5 / 46.8 | 55.6 | 47 | 6 | 47 | 46.3 | 49.8 / 51.1 |
| Earth station antenna polarization | CP | CP | CP | Linear | CP | CP | CP |
| Minimum elevation angle | 5 | 5 | 5 | 3 | 5 | 5 | 5 |
| **Satellite parameters** |
| Satellite antenna type | Quadrifilar helix | Crossed dipoles with a reflector | Helix | Omni | Crossed dipoles with a reflector / dipole | Quadrifilar helix | 2 omni antennas |
| Satellite maximum antenna gain (dBi) | 2.5 | 7 | 5 | 5.2 | 6 | 8 | −4.5 |
| Satellite antenna polarization | CP | CP | CP | CP | CP | CP | CP |
| Satellite antenna radiation pattern  | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna | ND | ND by multiple antenna | ND by multiple antenna | ND by multiple antenna |
| Satellite receiver noise temperature (K) | 1697 | 2674 | 537 | 170 | 789 | 840 | 603 |

# 4 Technical and operational characteristics of the SOS space-to-space links

The SOS space-to-space links typically include the use of a Data Relay Satellite (DRS) system and a Proximity Operations Communication System (POCS).

## 4.1 Data Relay Satellite (DRS) systems

The hypothetical reference system of the DRS systems is described in Recommendations [ITU-R SA.1018](https://www.itu.int/rec/R-REC-SA.1018/en) and [ITU-R SA.1020](https://www.itu.int/rec/R-REC-SA.1020/en). The DRS spacecraft is typically located on the geostationary orbit, and the space-to-space links of the DRS system are established between the DRS spacecraft and low-Earth orbiting user spacecraft.

The 2 025-2 110 MHz frequency band is used for SOS Earth-to-space links. This frequency band is also used for SOS forward space-to-space links, typically for radiocommunications from DRS spacecraft to low-Earth orbiting spacecraft. The characteristics of DRS-to-spacecraft links can be found in Table 2 of Recommendation [ITU-R SA.1414](https://www.itu.int/rec/R-REC-SA.1414/en).

The 2 200-2 290 MHz frequency band is used for SOS space-to-Earth links. This frequency band is also used for SOS return space-to-space links, typically for radiocommunications from low-Earth orbiting spacecraft to DRS spacecraft. The characteristics of spacecraft-to-DRS links can be found in Table 3 of Recommendation ITU-R SA.1414.

## 4.2 Proximity Operations Communication System (POCS)

The proximity space links are short-range, bi-directional, fixed or mobile radio links, generally used to communicate among probes, landers, rovers, orbiting constellations, and orbiting relays. The POCS supports several communications needs between such a variety of network elements for manned and unmanned missions.

The 2 025-2 110 MHz frequency band is used for the POCS forward space-to-space radiocommunications links and the 2 200-2 290 MHz frequency band is used for the POCS return space-to-space radiocommunications links.

Table 5 lists typical POCS operation scenarios.

TABLE 5

Examples of POCS operation scenario

| System | Example 1 |
| --- | --- |
| Location to operate | Near-Earth circular orbit of about 400 km altitude |
| Communication system 1 | Visiting spacecraft |
| Communication system 2 | Manned spacecraft |
| Objectives of operations | Inter-orbit communication when visiting spacecraft approaches manned spacecraft |
| Maximum distance between POCS systems | 23 km |

### 4.2.1 Telemetry/ranging in the 2 200-2 290 MHz frequency band

Table 6 lists the system parameters of telemetry/ranging return links in the frequency band 2 200‑2 290 MHz for both transmitting and receiving sides of the POCS systems. Ranging is used on the POCS links to measure distance between two POCS systems.

TABLE 6

POCS system parameters for telemetry/ranging return links
in the frequency band 2 200-2 290 MHz

| Function | Telemetry/ranging |
| --- | --- |
| System | System P |
| Maximum necessary bandwidth (MHz) | 6 (2) |
| **Communication system 1 parameters (transmitting side)** |
| Antenna input power (1) (dBW) | −0.02 |
| Antenna type | Helix |
| Maximum antenna gain (dBi) | 5 |
| Antenna polarization | CP |
| Antenna radiation pattern | ND by multiple antenna |
| **Communication system 2 parameters (receiving side)** |
| Antenna type | Micro-strip |
| Antenna radiation pattern | ND by multiple antenna |
| Maximum antenna gain (dBi) | 7.5 |
| Antenna polarization | CP |
| Receiver noise temperature (K) | 525 |
| (1) “antenna input power” includes the antenna feeder loss.(2) Spread spectrum. |

### 4.2.2 Command/ranging in the 2 025-2 110 MHz frequency band

Table 7 lists the system parameters for command links in the 2 025-2 110 MHz frequency band for both transmitting and receiving sides of the POCS systems. Ranging is used on the POCS links to measure distance between two POCS systems.

TABLE 7

POCS system parameters for command/ranging forward links
in the frequency band 2 025-2 110 MHz

| Function | Command/ranging |
| --- | --- |
| System | System P |
| Maximum necessary bandwidth (MHz) | 10 (2) |
| **Communication system 2 parameters (transmitting side)** |
| Antenna input power (1) (dBW) | −7.6 |
| Antenna type | Micro-strip |
| Antenna radiation pattern  | ND by multiple antenna |
| Maximum antenna gain (dBi) | 7.5 |
| Antenna polarization | CP |
| **Communication system 1 parameters (receiving side)** |
| Antenna type | Helix |
| Maximum antenna gain (dBi) | 5.0 |
| Antenna polarization | CP |
| Antenna radiation pattern | ND by multiple antenna |
| Receiver noise temperature (K) | 455 |
| (1) “antenna input power” includes the antenna feeder loss.(2) Spread spectrum. |