



Report ITU-R SA.2167
(09/2009)

Factors affecting the choice of frequency bands for space research service deep-space (space-to-Earth) telecommunication links

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1 Introduction

There are a number of primary space research service (SRS) allocations that can be used by deep-space missions for telecommand, telemetry, and radiometric data collection. Some of these allocations are designated specifically for deep-space SRS missions and are not available to non-deep-space SRS missions, while other allocations are available to both deep-space and non-deep-space SRS missions. The deep-space SRS allocations are given in Table 1.

TABLE 1
Primary SRS (deep-space) allocations

Earth-to-space	space-to-Earth
2 110-2 120 MHz	2 290-2 300 MHz
7 145-7 190 MHz	8 400-8 450 MHz
34.2-34.7 GHz	31.8-32.3 GHz

The above primary SRS allocations are restricted to deep-space missions and are not available to non-deep-space missions. These allocations together provide a total of 555 MHz in the Earth-to-space direction and 560 MHz in the space-to-Earth direction.

In addition to these primary deep-space allocations in Table 1, there are two other general primary SRS allocations of 37-38 GHz (space-to-Earth) and 40-40.5 GHz (Earth-to-space). Since the 37.5-38 GHz part of the 37-38 GHz band is shared with FSS, it is not especially usable for deep-space missions, especially for manned planetary missions.

The use of the 2 110-2 120 MHz (Earth-to-space) band will be limited in the future at NASA's Madrid Deep-Space Communication Complex due to potential interference to IMT-2000 users. The 8 400-8 450 MHz (space-to-Earth) band is very congested, since it is being extensively used by all deep-space missions. The 34.2-34.7 GHz (Earth-to-space) and 31.8-32.3 GHz (space-to-Earth) allocations are not yet crowded, but deep-space missions have started using these bands. Currently, there are no known deep-space missions planning to use the 37-38 GHz (space-to-Earth) and the 40-40.5 GHz (Earth-to-space) allocations, and the ground infrastructure needed to support these frequencies has yet to be developed.

2 Spectrum requirements for future deep-space missions

The amount of spectrum needed to support the space-to-Earth links of deep-space missions is expected to increase within the next 15 to 30 years, as the number of future missions and the data rate of each mission are expected to increase. More and more space agencies are expected to send missions to explore the solar system and beyond. Furthermore, all these future deep-space missions are expected to send the data collected by the on-board instruments using a much higher data rates, perhaps in excess of hundreds of megabits per second. On-board instruments require very high data rates. For example, a radar may require a data rate of 100 Mbit/s and a hyperspectral imager may require data rates between 150 Mbit/s and 600 Mbit/s (EO-1, Moon Mineralogy Mapper, EnMAP). These instruments can be flown on both robotic and human missions. Examples of possible future spacecraft flying these high-rate science instruments are shown in Table 2.

TABLE 2
Users of science instruments requiring high downlink data rates

User spacecraft	Instrument	Data rate (Mbit/s)
Robotic rovers	Surface radar Hyperspectral imaging	100 150-600
Science orbiters	Orbiting radar Hyperspectral imaging	100 150-600
Human transports	Hyperspectral imaging	150-600

The return of science data from deep-space missions is limited by the capacity of the space-to-Earth links. Often, the amount of science data returned to Earth from a deep-space mission during its lifetime is only a small fraction of what it is capable of producing. A deep-space mission sometimes may take months or years to reach its destination, but may have only a limited time, measured in weeks or even in days, to explore its target. Increasing the amount of data returns is important scientifically and economically. This increase is already taking place in the planned deep-space missions, which have started taking advantage of the 31.8-32.3 GHz (space-to-Earth) band capability to increase data returns. The Mars Reconnaissance Orbiter (MRO), for example, has a 32.2 GHz downlink capable of sending telemetry at 6 Ms/s. While this link is experimental, the MRO project plans to use it to return science data once it has been successfully demonstrated. The data rate of MRO is about 5 times higher than the telemetry rates of all existing deep-space missions, except SIRTF, which has a downlink rate of 4.4 Ms/s. Another planned Mars mission, Mars Telecom Orbiter (MTO) would have an even higher downlink rate. In one option, the MTO telecom system was designed to support a telemetry data rate of 40 Ms/s using a 34-m ground antenna. MTO was initially planned for launch in 2009, but had recently been postponed due to budgetary constraints.

Two developments considered by NASA will enable to increase the downlink data rate and accelerate the trend towards higher and higher data returns. First, NASA is considering to implement a large array of antennas with a G/T 10 times higher than the existing 70-m antennas in the NASA's Deep-Space Network (DSN). This will enable spacecraft to transmit at a much higher rate than they presently can, without requiring a large EIRP from the spacecraft. Second, NASA is also considering to use nuclear power technology to power the spacecraft, making ample power available for sending data to the Earth. The Prometheus programme has studied large EIRP missions to Jupiter. The requirement for the Jupiter Icy Moons Orbiter (JIMO) mission is a data rate of 10 Mbit/s at a range of 6.5 AU into a 70-m equivalent aperture. To achieve this data rate, the current design has a 3 m 32 GHz band high-gain antenna with a 1 kW 32 GHz band transmitter. A similar spacecraft at Mars range would support a data rate of 62 Mbit/s at Mars maximum range (2.6 AU) and 1.1 Gbit/s at Mars minimum range. The supportable data rate would be 10 times higher using the full antenna array.

These developments together will enable future deep-space missions to send science data to the Earth at a much higher data rate than they presently can. Previous studies indicated a possible 1 000 fold increase in mission data reception throughput by 2030 for deep-space missions based on a JPL analysis. A 2009 internal JPL study estimated a downlink throughput data rate of 125 Mbit/s, 150 Mbit/s, and 1500 Mbit/s for the highest data rate user in the 2010, 2020 and 2030 time-frame, respectively. While there is a large uncertainty in these estimates, they do point to a trend toward higher and higher data rates for deep-space missions. They indicate that the bandwidth required to support future deep-space missions will far exceed the capacity of all existing allocations, even after accounting for possible use of bandwidth-efficient modulation schemes. Interests among various