RECOMMENDATION ITU-R SA.1016

SHARING CONSIDERATIONS RELATING TO DEEP-SPACE RESEARCH

(Question ITU-R 210/7)

(1994)

The ITU Radiocommunication Assembly,

considering

a) that the feasibility of frequency sharing between deep-space research stations and stations of other services is presented in Annex 1,

recommends

1. that, with coordination, deep-space research can share frequency bands in the Earth-to-space direction with stations in other services except:

– receiving aeronautical mobile stations, receiving satellite stations, and microwave sensor satellites, when any of these may come within line-of-sight;

– receiving mobile stations that come within the separation distance required for interference protection;

– transmitting terrestrial stations having an average e.i.r.p. exceeding 81 dBW in the bands near 2 GHz and 84 dBW in the bands near 7 GHz;

2. that, with coordination, deep-space research can share frequency bands in the space-to-Earth direction with stations in other services except:

– the radioastronomy service;

– transmitting aeronautical mobile stations, transmitting satellite stations, and active microwave sensor satellites, when any of these may come within line-of-sight;

– transmitting mobile stations that come within the separation distance required for interference protection.

ANNEX 1

Sharing considerations relating to deep-space research

1. Sharing considerations: deep-space Earth-to-space bands

Table 1 and the following paragraphs consider the possibility of interference in the deep-space research Earth-to-space bands.

TABLE 1

Potential interference in Earth-to-space bands

Source	Receiver
Deep-space earth station	Terrestrial or earth station
Deep-space earth station	Earth orbiting satellite
Terrestrial or earth station	Deep-space station
Near-earth station	Deep-space station

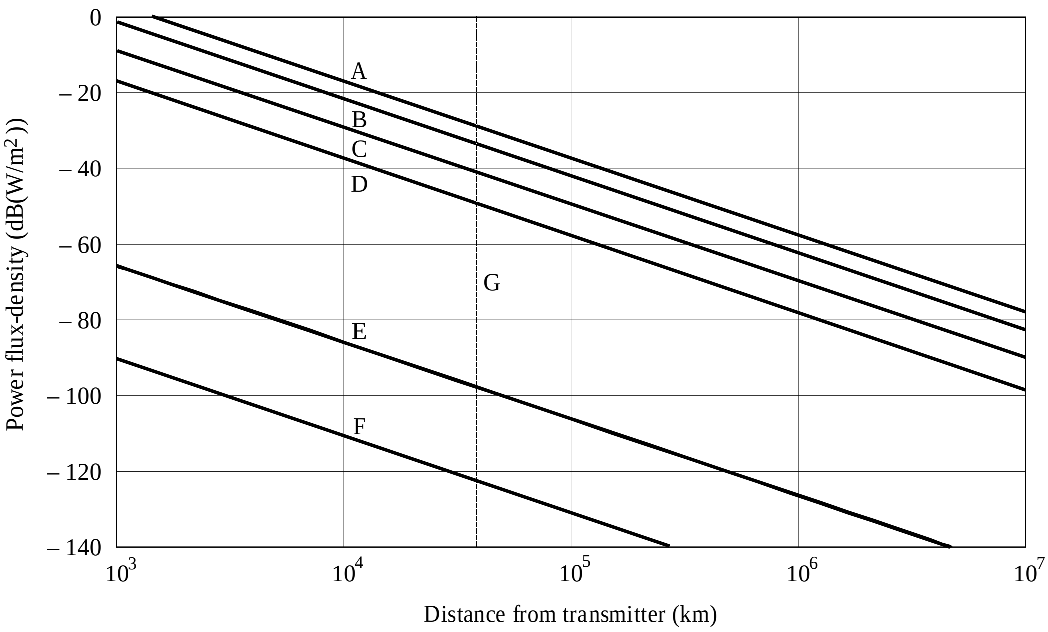
1.1 Potential interference to terrestrial or earth station receivers from deep-space earth station transmitters

The normal maximum total power for current deep-space earth stations is 50 dBW. For a minimum elevation angle of 10°, the e.i.r.p. directed towards the horizon does not exceed 57 dB(W/4 kHz), assuming the reference earth station antenna radiation pattern of Recommendation ITU-R SA.509. For spacecraft emergencies, the maximum total power may be increased to 56 dBW, giving not more than 63 dB(W/4 kHz) at the horizon. These values of e.i.r.p. meet the requirements of No. 2540 of the Radio Regulations (RR).

Aircraft stations within line-of-sight of a deep-space earth station may encounter total power flux-densities as shown in Fig. 1. For an aircraft altitude of 12 km, the maximum line-of-sight distance to an earth station is 391 km and the total power flux-density at the aircraft can never be lower than –83 dB(W/m^2), again assuming the antenna pattern of Recommendation ITU-R SA.509. Depending on distance and earth station antenna direction, the aircraft station may experience much higher flux densities and interference levels. Coordination with airborne stations is generally not practicable.

FIGURE 1

Power flux-density vs. distance from earth station



Transmitter: Deep-space earth station 100 kW, 70 m diameter antenna

A: main beam, 34.5 GHz
B: main beam, 17 GHz
C: main beam, 7 170 MHz
D: main beam, 2 115 MHz
E: 5° off main beam axis (14.5 dBi gain, Recommendation ITU-R SA.509)
F: > 48° off main beam axis (–10 dBi gain, Recommendation ITU-R SA.509)
G: geostationary orbit altitude: 35 800 km

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Super refraction, ducting, and precipitation scatter may couple emissions from deep-space earth station transmitters into terrestrial receivers, and receivers of other earth stations. Except for airborne terrestrial receivers, coordination for these conditions is generally practicable. See § 2.3 for discussion of interference from airborne transmitters, and § 3 for coordination considerations.

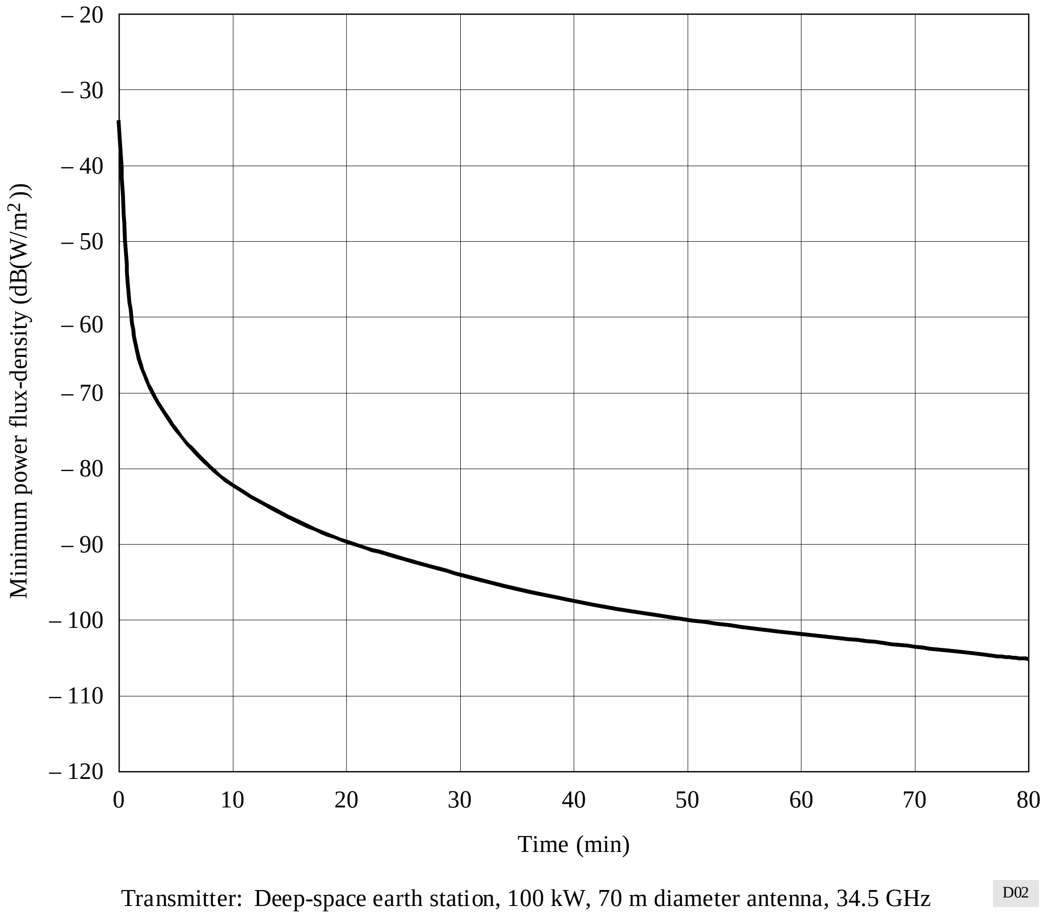
1.2 Potential interference to satellite receivers from deep-space earth station transmitters

Satellites that come within the deep-space earth station beam will encounter power flux-densities as shown in Fig. 1. When the earth station is tracking a spacecraft whose direction is such that the antenna beam passes through the geostationary satellite orbit (GSO), the power flux-density at that point on the orbit will vary with time as shown in Fig. 2. For example, the total power flux-density will be –95 dB(W/m^2) or more for 32 min. The figure assumes a transmitter power of 50 dBW, a 70 m antenna, and the reference earth station antenna pattern of Recommendation ITU-R SA.509. An important observation is that the minimum power flux-density at the GSO within line-of-sight of a deep-space earth station is at least –122 dB(W/m^2), regardless of antenna pointing direction.

The duration and magnitude of signals from deep-space earth station transmitters which may interfere with satellites in non-geostationary orbits depends upon those orbits and the direction in which the earth station antenna is pointing.

FIGURE 2

Time during which the power flux-density at a point on the geostationary satellite orbit may exceed a minimum power flux-density

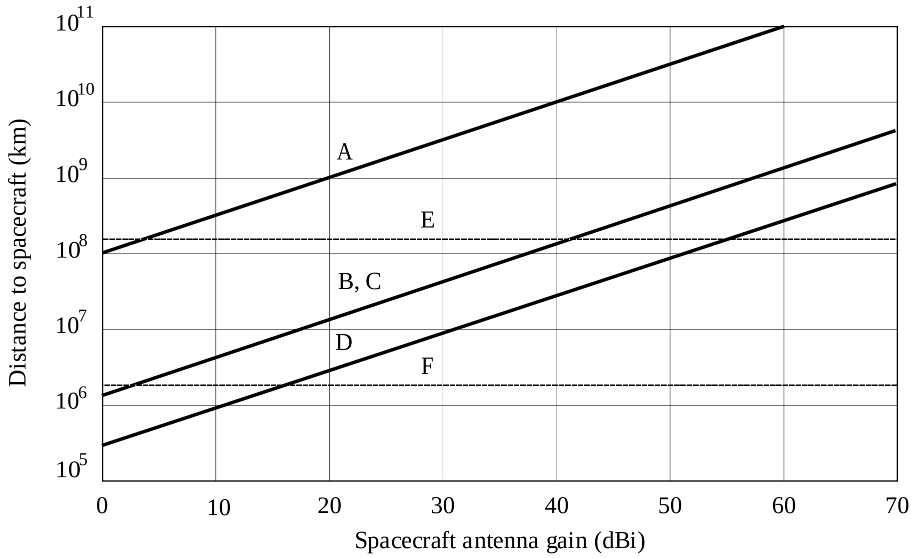


1.3 Potential interference to deep-space station receivers from terrestrial or earth station transmitters

Terrestrial or earth station transmitters within sight of a deep-space station are potential sources of interference. Figure 3 shows the space station distance at which the interference power density from such a transmitter equals the receiver noise power density. For example, a trans-horizon station with 93 dB(W/10 kHz) e.i.r.p. in the 2.1 GHz band could interfere with a space station receiver at ranges up to 4.1 × 10^9 km (600 K noise temperature, 3.7 m spacecraft antenna). The possibility of interference at such a great distance poses a threat to space missions to planets as far away as Uranus. Stations with lower e.i.r.p., or with antennas pointing away from the ecliptic plane, have less potential for interference.

FIGURE 3

Spacecraft distance from terrestrial transmitter for interference power equal to receiver noise power



A: trans-horizon transmitter: 2 115 MHz
e.i.r.p.: 93 dB(W/10 kHz)
receiver noise power: –191 dB(W/20 Hz)

B: radiolocation transmitter: 34.5 GHz
e.i.r.p.: 48.8 dB(W/Hz)
receiver noise power: –182.6 dB(W/20 Hz)

C: radiolocation transmitter: 17 GHz
e.i.r.p.: 40.9 dB(W/Hz)
receiver noise power: –186 dB(W/20 Hz)

D: radio-relay transmitter: 7 170 MHz
e.i.r.p.: 55 dB(W/10 kHz)
receiver noise power: –189 dB(W/20 kHz)

E: 1 AU = 1.5×10^{8} km

F: inner boundary of deep space: 2×10^{6} km

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1.4 Potential interference to deep-space station receivers from Earth orbiting satellite transmitters

Earth orbiting satellites typically have antennas directed to the Earth or to other satellites. Interference with deep-space station receivers may occur for those brief periods when the satellite antenna is directed so as to permit main beam coupling. As received at deep-space stations, signals from satellites will almost always be weaker than those from earth stations.

2. Sharing considerations: space-to-Earth bands

Table 2 and the following sections consider the possibility of interference in the deep-space research space-to-Earth bands.

TABLE 2

Potential interference in space-to-Earth bands

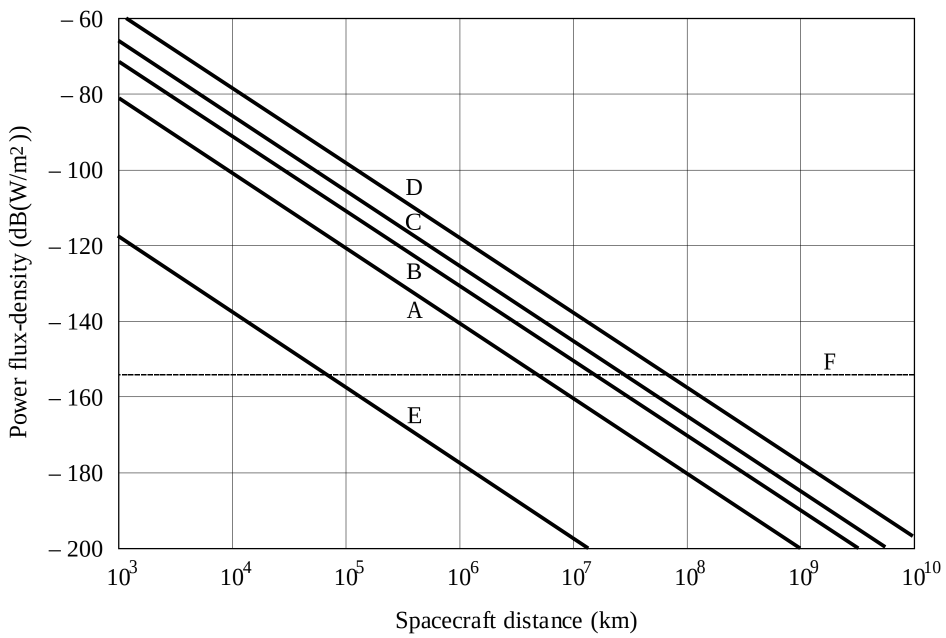
Source	Receiver
Deep-space station	Terrestrial or earth station
Deep-space station	Earth orbiting satellite
Terrestrial or earth station	Deep-space earth station
Earth orbiting satellite	Deep-space earth station

2.1 Potential interference to terrestrial or earth station receivers from deep-space station transmitters

Figure 4 shows the power flux-density at the surface of the Earth caused by typical deep-space stations. These stations often use low gain, wide beam antennas while near Earth. After a time not exceeding six hours after launch, they are usually at a sufficient distance for the power flux-density at the surface of the Earth to be less than the maximum permitted by the RR for protection of line-of-sight radio-relay systems.

FIGURE 4

Power flux-density at the surface of the Earth vs. spacecraft distance



A: 13 dBW transmitter, 37 dBi antenna gain, 2 295 MHz
B: 13 dBW transmitter, 48 dBi antenna gain, 8 425 MHz
C: 13 dBW transmitter, 52 dBi antenna gain, 13 GHz
D: 13 dBW transmitter, 60 dBi antenna gain, 32 GHz
E: 13 dBW transmitter, 0 dBi antenna gain
F: –154 dB(W/m^2) power flux-density, RR No. 2557

When the transmitting space station is using a higher gain directional antenna, there is the potential for interference with sensitive terrestrial receivers if their antennas are directed so as to permit main beam coupling. A space station operating at 2.3 GHz with an e.i.r.p. of 51 dBW at a distance of 5×10^8 km could create an input of –168 dBW to a trans-horizon receiver (27 m antenna, main beam). The duration of such interference would be of the order of a few minutes, once a day, because of the rotation of the Earth.

2.2 Potential interference to Earth orbiting satellite receivers from deep-space transmitters

Considerations of this interference are similar to those for the space station to terrestrial receiver case, § 2.1, with the exception of the path geometry. Depending on the changing conditions of that geometry, occasional brief interference is possible.

2.3 Potential interference to deep-space earth station receivers from terrestrial or earth station transmitters

Interference to deep-space earth station receivers may come from terrestrial or earth stations over line-of-sight paths, by tropospheric phenomena, or by rain scatter. For coordination considerations see § 3.

Terrestrial services utilizing high power transmitters and high gain antennas are potential interference sources. Earth station transmitters are less likely sources of interference, depending on e.i.r.p. in the direction of the deep-space earth station. Coordination should enable adequate protection from radio-relay stations to be provided.

Aircraft transmitters within sight of a deep-space earth station may cause serious interference. At maximum line-of-sight distance in any direction (391 km for an aircraft at 12 km altitude), an e.i.r.p. of –26 dB(W/Hz) (for example, 10 dB(W/4 kHz) and 0 dBi antenna gain) will exceed the earth station interference limit by at least the amount shown in Table 3, assuming the reference earth station antenna pattern.

TABLE 3

Interference from assumed aircraft transmitter

Frequency (GHz)	Maximum allowable interference power spectral density (dB(W/Hz))	Amount by which aircraft signal exceeds maximum allowable interference power(1) (dB)
2.3	–222.5	35.0
8.4	–220.9	22.1
13.0	–220.5	17.9
32.0	–217.3	6.9

(1) Aircraft signal minus the deep-space earth station interference limit.

Airborne radionavigation transmitters that may operate in the 32 GHz region of the spectrum are a particular example of potential sources of harmful interference to deep-space earth station receivers. This class of transmitter includes a wide variety of characteristics: output power; CW, pulse, or chirp modulation; fixed or scanning antennas with narrow or wide beam patterns. The probability and degree of interference from a particular transmitter can be determined on a case-by-case basis that is beyond the scope of this Annex. Nevertheless, it is generally true that if an airborne radionavigation transmitter is within line-of-sight of the earth station receiver, the maximum allowable level of interference can be exceeded for a time sufficient to cause degradation to, or interruption of, service.

Coordination with airborne stations is generally not practicable.

2.4 Potential interference to deep-space earth station receivers from Earth orbiting satellite transmitters

An analysis of the potential for interference in the 2 290-2 300 MHz band from satellites in highly eccentric orbits may be found in ex-CCIR Report 688 (Geneva, 1982). It is concluded that sharing is not feasible. This conclusion is also valid for satellites in circular and moderately eccentric orbits.

2.5 Potential interference to deep-space earth station receivers from Earth orbiting satellites that are transmitting to a geostationary relay satellite

Table 4 presents an analysis of a situation where a link between a user spacecraft and a geostationary data relay satellite (DRS) grazes the surface of the Earth near the location of a deep-space earth station. It is assumed that the main beam of the earth station antenna is directed at the user satellite. The negative interference margin means that the protection criterion for the earth station receiver has been violated.

TABLE 4

Interference from relay satellite link to deep-space earth station (32 GHz)

DRS user-satellite altitude (km)	500.0	1 000.0
Transmitter power (dBW)	10.0	10.0
Bandwidth convervion (300 Mbit/s, QPSK) (dB/Hz)	–84.8	–84.8
Transmitting antenna gain (dBi)	52	52.0
Off-axis gain reduction (dB)	–39.3	–32.3
Path loss (32.1 GHz) (dB)	–184.7	–190.2
Earth-station antenna gain (dBi)	83.6	83.6
Received interference (dB(W/Hz))	–163.2	–161.7
Harmful interference criterion (dB(W/Hz))	–217.3	–217.3
Interference margin (dB)	–54.1	–55.6

To reduce the negative interference margin shown in the table to 0 dB, the DRS user satellite must remain at least 1.7° away from the main beam axis of the earth station antenna. If the earth station is tracking a particular spacecraft in deep-space each day, and if the DRS user satellite passes through the earth station antenna beam at some time during a given day, then the satellite will pass through the beam at less than 1.7° from the beam axis with a frequency ranging between once every 12 days to once each day. The frequency depends upon the satellite orbit period. For example, a satellite with an orbit period of 84 min can produce a negative interference margin of up to 0.8 min duration every seventh day.

Although an interference interval of less than 1 min is relatively unimportant for some radio services, in the space research service it can result in irreplaceable loss of scientific data for several minutes (see § 1.1).

The analysis presented above considers only a single user-satellite and one deep-space earth station. A greater number of satellites would increase the probability of interference. It is concluded that band sharing by deep-space research and links between user spacecraft and geostationary relay satellites is not feasible.

3. Discussion

3.1 Intersections of satellite orbits and antenna beams from deep-space earth stations

The probability that a satellite will be in the main beam of the antenna of a deep-space earth station strongly affects the possibility of band sharing between the concerned links.

Statistics on antenna pointing have been analysed for a comprehensive set of deep-space missions. It was found that the earth station antenna gain in the direction of the geostationary-satellite orbit will be 10 dBi or more for 20% of the time.

Satellites that are not geostationary can pass through one or more deep-space tracking beams each day. Details of visibility statistics and in-beam duration times for satellites in low orbits are contained in Report ITU-R SA.684 (ex-CCIR Report 684, Düsseldorf, 1990).

3.2 Coordination and sharing

The very high e.i.r.p. and extreme sensitivity of deep-space earth stations usually result in exceptionally large coordination areas.

Sharing with stations that are within line-of-sight (LOS) of deep-space earth stations is not feasible. Stations within LOS will create excessive interference to receivers of deep-space earth stations, or will be exposed to excessive interference from transmitters of these stations. Aeronautical mobile stations and earth orbiting satellites frequently come within LOS of deep-space earth stations.

Sharing of deep-space Earth-to-space bands with stations utilizing high average e.i.r.p. is not feasible because of potential interference to stations in deep space. It is currently considered that stations with an e.i.r.p. that is more than 30 dB below the implemented or planned e.i.r.p. for space research earth stations do not pose a significant problem. Typically, this means an average e.i.r.p. no greater than 81 dBW at 2 GHz, and 84 dBW at 7 GHz.

4. Conclusion

Criteria and considerations presented in this Annex lead to the following conclusions.

4.1 Sharing of Earth-to-space bands

With coordination, deep-space research can share Earth-to-space bands with stations in other services except:

– receiving aeronautical mobile stations, receiving satellite stations, and microwave sensor satellites, when these may come within line-of-sight,

– receiving mobile stations that may come within the separation distance required for interference protection,

– transmitting terrestrial stations having an average e.i.r.p. exceeding 81 dBW in the 2 GHz region and 84 dBW in the 7 GHz region.

4.2 Sharing of space-to-Earth bands

With coordination, deep-space research can share space-to-Earth bands with stations in other services except:

– the radioastronomy service,

– transmitting aeronautical mobile stations, transmitting satellite stations and active microwave sensor satellites when any of these may come within line-of-sight,

– transmitting mobile stations that may come within the separation distance required for the interference protection.