



Report ITU-R SA.2177
(10/2010)

**Selection of frequency bands
in the 1-120 GHz range for
deep-space research**

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***Note:** This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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(2010)

TABLE OF CONTENTS

	<i>Page</i>
1 Introduction	3
2 Selection of frequency bands in the 1-40 GHz range	3
2.1 Equipment characteristics that concern link performance analysis	3
2.1.1 Antenna sizes and gains	3
2.1.2 Transmitter power	4
2.1.3 Receiving equipment noise temperature	4
2.2 Propagation considerations	4
2.3 Results of performance analysis	4
2.4 Preferred frequency bands in the 1-40 GHz range	10
2.5 Requirement for several allocations that are widely spaced in the spectrum	11
3 Selection of frequency bands in the 40-120 GHz range	12
3.1 Advantages of higher frequencies	12
3.1.1 Increased link performance	13
3.1.2 Wider bandwidth	13
3.1.3 More accurate measurement of phase and group-delay	13
3.1.4 Shielding from terrestrial interference	13
3.2 Basis for frequency selection	13
3.3 Frequency-dependent characteristics of interplanetary propagation	13
3.3.1 Interplanetary attenuation	14
3.3.2 Interplanetary sky noise temperature	14
3.3.3 Sky noise temperature at earth stations	15
3.3.4 Velocity of interplanetary propagation	15
3.3.5 Interplanetary scintillation	15

	<i>Page</i>
3.4 Frequency-dependent characteristics of propagation through an atmosphere....	15
3.4.1 Atmospheric attenuation	15
3.4.2 Atmospheric scintillation	17
3.5 Frequency-dependent equipment factors	17
3.6 Example of link performance analysis	18
3.7 Preferred frequency bands in the 40-120 GHz range	19
4 Conclusions	19

1 Introduction

Telecommunication link performance, equipment characteristics and mission requirements determine the frequency bands that are preferred for deep-space research. This Report presents an analysis that leads to the selection of preferred frequency bands in the 1-120 GHz range. For information on general mission requirements and equipment considerations, see Recommendation ITU-R SA.1014; for information on required bandwidths, see Recommendation ITU-R SA.1015.

The objective of identifying preferred frequency bands is to provide the technical basis for band allocations from which the designer can select operating frequencies best suited to mission requirements. Sections 2 and 3 of this Report give the technical basis for the selection of frequency bands in the 1-40 GHz and 40-120 GHz ranges.

2 Selection of frequency bands in the 1-40 GHz range

For each telecommunication function, i.e. maintenance and science telemetry, telecommand, tracking and radio science, there is a frequency band, or set of frequency bands, which will provide best performance. Best performance may be expressed in terms of lowest bit error rate, highest measurement accuracy, maximum data rate, highest link reliability, or some combination of these parameters. The best performance that is obtainable at a particular time with a particular system depends upon the characteristics of radio-wave propagation.

A convenient index of best performance is the ratio of received signal power to noise power spectral density (P_r/N_0). The frequency band which provides the highest value of P_r/N_0 ratio for a particular system and propagation conditions is defined as a preferred frequency band. From the resulting data, frequency ranges that provide optimum performance for the assumed conditions may be identified.

2.1 Equipment characteristics that concern link performance analysis

2.1.1 Antenna sizes and gains

Earth stations for deep-space research typically employ large steerable parabolic antennas which are expensive and infrequently constructed. A mission designer is generally not free to consider a range of earth station antenna diameters when selecting frequencies. For this reason, the analysis considers the earth station antenna to have a fixed diameter. The gain and beamwidth of this antenna are a function of frequency.

For space stations, the designer may consider a variety of antenna types and sizes. The analysis accounts for this freedom by considering two cases: a parabolic reflector antenna with a fixed diameter and whose beamwidth and gain are a function of frequency, and an antenna whose beamwidth (gain) does not vary with frequency.

The fixed diameter case may be applied over the frequency band to be considered if the diameter is small enough (beamwidth at highest frequency is wide enough) so that the antenna pointing accuracy does not limit the minimum beamwidth.

The fixed beamwidth (fixed gain) case arises when antenna pointing accuracy determines the minimum beamwidth, or when the antenna must give very wide coverage to permit communication without regard to space station attitude. An omnidirectional antenna is an example of the fixed beamwidth case.

Link analysis in this Report assumes that a fixed diameter antenna for a space station is 60% efficient and has a gain which increases directly as the frequency squared. For the fixed beamwidth (fixed gain) case the gain is assumed to be 0 dBi and independent of frequency.

The earth station antenna gain used in the analysis is taken from Recommendation ITU-R SA.1014.

2.1.2 Transmitter power

For space station transmitters, the RF output power depends on the amount of primary power that can be provided by the spacecraft and is further limited by transmitter efficiency. For earth stations these limitations are much less significant.

For link performance analysis in this Report, transmitter power is considered to be independent of frequency.

2.1.3 Receiving equipment noise temperature

The space station receiving system noise temperature is dominated by the input preamplifier and associated pre-selection filter. Antenna feedline losses are relatively unimportant in their noise contribution. The space station noise temperature used in this Report is representative of current technology utilizing uncooled solid state devices. At earth stations there is no important size, weight, or complexity limitation and the most sensitive possible receiver is needed. Cryogenically cooled MASER preamplifiers are commonly used. Link analysis in this Report assumes that the earth station noise temperatures are as shown in Recommendation ITU-R SA.1014.

2.2 Propagation considerations

Analysis of link performance requires assumptions about propagation conditions. A critical assumption is the rain rate and resulting attenuation. For low noise receiving systems typical of deep-space research, particularly the earth station receivers, even a small increase in attenuation caused by rain results in a significant reduction in P_r/N_0 . This is because the increase in sky noise is several times as large as the receiver noise temperature and therefore dominates the overall system noise temperature.

The analysis for this Report assumes a rain rate of 10 mm/h (the amount exceeded 0.1% of the time at an earth station near Madrid, Spain).

Although this rate results in only 0.7 dB of attenuation compared to the clear air case at 8.4 GHz with 30° elevation angle, it causes a 5 dB degradation in the space-to-Earth P_r/N_0 . As a result of the sensitivity of system performance (P_r/N_0) to small changes in attenuation along the propagation path, the performance curves shown later are strongly influenced by the assumed rain rate.

2.3 Results of performance analysis

The variation of P_r/N_0 shown in Figs 1 to 4 was determined by the method of Report ITU-R SA.2183 for the following assumed set of equipment characteristics and operating conditions:

- Communication distance: 8×10^8 km
- Diameter of earth station antenna: 70 m
- Power of earth station transmitter: 20 kW
- Diameter of space station antenna: 3.7 m (Case 1: fixed diameter)
- Fixed gain of space station antenna: 0 dB (Case 2: fixed gain)
- Power of space station transmitter: 25 W

The important features of the performance curves are the location of maxima and the effects of elevation angle and weather. The absolute values of P_r/N_0 depend upon the assumed link parameters. Different assumptions about communication distance, antenna characteristics and transmitter power would alter the absolute values but would not change the shape of the curves.

The figures show curves for clear and rainy weather and for earth station antenna elevation angles of 15°, 30° and 75° above the horizon. Figures 1a), 2a), 3a) and 4a) assume the use of perfect antennas and noiseless receivers. These curves illustrate performance as limited only by natural propagation phenomena. Figures 1b), 2b), 3b) and 4b) reflect the limitations imposed by typical equipment of earth and deep-space stations. Comparison of the (a) and (b) curves in each figure shows the potential for better link performance that could result from improvement of equipment technology.

FIGURE 1a)

Ideal space-to-Earth link performance as limited only by natural propagation phenomena
(space station antenna = 3.7 m, earth station antenna = 70 m)

