RECOMMENDATION ITU-R S.1806

Availability objectives for hypothetical reference digital paths in the fixed-satellite service operating below 15 GHz

(Question ITU-R 73/4)

(2008)

Scope

This Recommendation deals with availability objectives for hypothetical reference digital paths (HRDPs) in the fixed-satellite service operating below 15 GHz. It is based on the availability objectives specified in relevant ITU-T Recommendations and complements availability and performance objectives contained in relevant ITU-R Recommendations, as listed under References.

References

ITU-T Recommendation G.827: Availability performance parameters and objectives for end-to-end international constant bit-rate digital paths.

Recommendation ITU-R S.579: Availability objectives for a hypothetical reference circuits and hypothetical reference digital paths when used for telephony using pulse code modulation, or as part of an integrated services digital network hypothetical reference connection, in the fixed-satellite service operating below 15 GHz.

Recommendation ITU-R S.614: Allowable error performance for a satellite hypothetical reference digital path in the fixed-satellite service operating below 15 GHz when forming part of an international connection in an integrated services digital network.

Recommendation ITU-R S.1062: Allowable error performance for a satellite hypothetical reference digital path operating below 15 GHz.

Recommendation ITU-R S.1424: Availability objectives for a hypothetical reference digital path when used for the transmission of B-ISDN asynchronous transfer mode in the fixed-satellite service by geostationary orbit satellite systems using frequencies below 15 GHz.

The ITU Radiocommunication Assembly,

considering

a) that the hypothetical reference digital paths (HRDPs), as defined in Recommendation ITU-R S.521, in the fixed-satellite service (FSS) are intended as a guide to designers and planners;

b) that the availability of an HRDP is determined by the combined effects of equipment and propagation availability;

c) that the equipment availability (including the space station) is dependent on reliability performance, maintainability and maintenance support performance;

d) that unavailability due to propagation impairments is dependent on the exceedance of an attenuation level threshold, the frequency of these exceedances and the duration of such exceedances;

e) that satellite systems are capable of offering availability performance similar to that of terrestrial paths under service level agreements (SLAs) or service quality agreements (SQAs) for individual links (see ITU-T Recommendation E.801);

f) that the availability of a geostationary-satellite link is essentially independent of the distance between the origination and termination points of the link,

recommends

1 that the availability of an HRDP in the FSS should be defined by the following formula:

$$\text{Availability} = (100 - \text{Unavailability}) \quad \%$$

where:

$$\text{Unavailability} = \frac{\text{Unavailable time}}{\text{Required time}} \times 100 \quad \%$$

where the required time is defined as the period of time during which the user requires the digital path to be in a condition to perform a required function, and unavailable time is the cumulative time of digital path interruptions within the required time (see also *recommends* 5 for a discussion of unavailable time);

2 that the outage intensity should be defined as the number of outages (i.e. a period of unavailable time as defined in *recommends* 5) per measurement period, where the typical measurement period is one year (8 766 h) (see also Note 5);

3 that an HRDP should meet the objectives of propagation-dependent availability given in Table 1:

TABLE 1

Propagation-dependent availability objectives for an FSS digital satellite link

Rate (Mbit/s)	**Up to primary rate 1.544 to 2.048**		**Above primary rate**	
Parameter	Availability	Outage intensity (outages/year)	Availability	Outage intensity (outages/year)
Mean value for HRDP	99.9%	20	99.96%	20

4 that the additional unavailability of an HRDP in the FSS due to equipment should not be more than 0.11% of a year;

5 that a link in the FSS as defined between the ends of the HRDP in Recommendation ITU-R S.521 should be considered unavailable if one or more of the conditions in § 5.1 to 5.3 below exist at either of the receiving ends of the link for 10 consecutive seconds or more (see Note 3):

5.1 the digital signal is interrupted (i.e. alignment or timing is lost);

5.2 for a transmission below the primary rate (1.544 Mbit/s or 2.048 Mbit/s), the bit error ratio (BER), averaged over 1 s, exceeds 10^{-3};

5.3 for a transmission at or above the primary rate (1.544 Mbit/s or 2.048 Mbit/s), each second is considered to be a severely errored second (SES) event, where an SES is defined – consistently with ITU-T Recommendation G.826 – as a second which contains 30% or more errored blocks or at least one severely disturbed period (SDP);

6 that the following Notes should be regarded as part of this Recommendation:

NOTE 1 – A period of unavailable time begins when one of the conditions in § 5.1 to 5.3 persists for a period of 10 or more consecutive seconds. These 10 s are considered to be unavailable time. The period of unavailable time terminates when the same condition ceases for a period of at least 10 consecutive seconds. These 10 s are considered to be available time. Periods of degraded performance lasting less than 10 consecutive seconds, during which conditions in *recommends* 5.1 to 5.3 exist, are considered available time.

NOTE 2 – All outages due to solar eclipses and interference from the Sun are included as part of the unavailable time in *recommends* 3 when they occur during the required time. The impact of solar interference during the required time can be minimized by operational measures since these events can be accurately predicted (see Recommendation ITU-R S.1525).

NOTE 3 – Availability calculations should explicitly take into account mean time between failures, mean time for resumption of service and precautions taken to mitigate interruptions and impairments of satellite performance including the use of reserve channels and back-up systems.

NOTE 4 – A percentage of unavailability, due to propagation, for any month is assumed to correspond to a period of any year by a conversion factor of 5, i.e. 0.2% of any month would correspond to 0.04% of any year (referring to the term of "any year", see Note 11 of Recommendation ITU-R S.353). This conversion factor is discussed in Annex 1 to Recommendation ITU-R S.614.

NOTE 5 – Outage intensity objectives in Table 1 are based on a value of the "mean time to restore" (i.e. the average duration of unavailable service time intervals) of 4 h. Propagation impairments, giving rise to self-healing unavailability events, are usually much shorter. In this case, they should not be taken into account.

NOTE 6 – Additional information on outage intensity objectives for digital satellite paths is given in Annex 1.

Annex 1

The applicability of the availability ratio and outage intensity parameters of ITU-T Recommendation G.827 to satellite links

1 Introduction

This Annex examines the availability objectives given in ITU-T Recommendation G.827 in the light of the predictions of fade duration and fade occurrence frequency that were performed using the methods described in Recommendation ITU-R P.1623, and to give consideration to their applicability to availability objectives for digital satellite connections. Specifically, the outage intensity objectives of ITU-T Recommendation G.827 are considered in relation to estimates of fade depth and the number of fades predicted for a satellite link.

2 Background

Recommendation ITU-R S.579 has a long history and is applicable to many "legacy" links within the FSS. It serves as a general reference on the availability of satellite links and contains information on the effects of propagation on satellite links. New satellite connections supporting Internet protocol traffic and the next generation network require additional parameters in order to specify availability performance. This annex provides information on adapting the availability parameters contained in ITU-T Recommendations to satellite portions of HRDPs.

3 ITU-T Recommendation G.827

ITU-T Recommendation G.827 provides parameters used in the specification of availability performance.

One parameter is the availability ratio (AR) that is defined in the same way as availability in Recommendation ITU-R S.579. AR is defined as:

AR = Available time/Total time

For these calculations, the total time is generally taken to be one year (365.25 days, 8 766 h). This parameter has been used as the basis for Recommendation ITU-R S.579.

A second parameter contained in ITU-T Recommendation G.827 is outage intensity (OI) and its reciprocal, the mean time between outages (Mo). According to ITU-T Recommendation G.827:

> "The mean time between outages (Mo) is the average duration of intervals when the path element is available during a measurement period. The number of outages per measurement period is called the "outage intensity". If the measurement period is one year and Mo is expressed in fractions of a year, then OI is the reciprocal of Mo."

Table 2/G.827 gives the end-to-end availability performance objectives for a 27 500 km international digital hypothetical reference path (HRP) at or above the primary rate. These objectives are reproduced below.

"TABLE 2/G.827

End-to-end availability performance objectives for a 27 500 km international digital HRP at or above the primary rate

Performance level	Availability ratio (AR)	Outage intensity (OI)
High priority	98%	70
Standard priority	91%	250

"

Using a 35% block allocation of the end-to-end of objectives, as given in ITU-T Recommendation G.826, for the satellite portion of a 27 500 km HRP, the corresponding satellite portion availability ratio and outage intensity objectives were derived and are given in Table 2.

TABLE 2

Satellite portion G.827 availability performance objectives at or above the primary rate

Performance level	Availability ratio (AR)	Outage intensity (OI) (outages per year)
High priority	99.3%	25
Standard priority	96.8%	88

4 Link segment availabilities

In Recommendation ITU-R S.1424 an example of space segment availability is given as 99.99%. Earth station availability, for manned earth stations with a G/T of 31.7 dB/K at 11/12 GHz, is given as 99.95% for each earth station. This leads to a composite Earth segment availability of 99.90%. The availability allotted to the combined Earth segment and space segment equipment is 99.89%.

Using the ITU-T G.827 availability performance of 99.3%, for high-priority paths, as an objective, the equipment availability of 99.89% implies that the propagation availability must be 99.4% or better. This information is summarized in Table 3.

TABLE 3

Satellite portion availability performance required to meet G.827 objectives for high-priority performance level links at or above the primary rate

Satellite portion of G.827 availability ratio objectives (high priority)	99.3%
Space segment equipment availability	99.99%
Earth segment equipment availability (each earth station)	99.95%
Implied propagation availability	99.41%

It should be noted that the values of the availability ratio that are recommended in Table 3 are more stringent than the ones derived from ITU-T Recommendation G.827 because an HRDP should also meet the availability objectives of ITU-T Recommendations G.821 and G.826 (see also Recommendations ITU-R S.579, ITU-R S.614 and ITU-R S.1062).

In the absence of more precise data concerning the outage intensity of satellites and earth stations, five outages per year have been allocated to the space and Earth segments based on engineering experience. Collecting reliable data would enable the development of a more precise value and may be the subject of further studies within ITU-R.

5 Outage intensity and attenuation

Based on the application of Recommendation ITU-R P.1623, information is presented here on the derivation of outage intensity values predicted for satellite links with 99.4% propagation availability.

For 6/4 GHz links, propagation outages of greater than about 1 dB occur rarely, therefore the only significant cause of outage would be due to equipment. Modern earth stations are maintained to levels where meeting the outage intensity objectives of ITU-T Recommendation G.827 should not be a problem.

For satellite links operating above 10 GHz, outages due to propagation can be significant and are taken into account in the design of these links. Briefly describing the procedure applied here, 99.4% propagation availability corresponds to a certain fade depth that can be determined through the application of Recommendation ITU-R P.618. Using this fade-depth value, the methods given in Recommendation ITU-R P.1623 can be applied to determine the probability of fades of that depth and the number of fades per year of that depth.

Table 5 shows the fade depths that correspond to 99.4% propagation availability, computed using the methods in Recommendation ITU-R P.618, for three example locations whose characteristics are contained in Table 4.

TABLE 4

Examples of locations and associated climatic characteristics

Earth station coordinates	46.222° N 6.139° E	25.81° N 279.88° E	40.773° N 286.025° E
Elevation angle	30°	24°	23°
Rain rate for 0.01% of a year	25 mm/h	96 mm/h	43 mm/h

TABLE 5

Fade depths corresponding to a propagation availability of 99.4%

Earth station location	46.222° N 6.139° E		25.81° N 279.88° E		40.773° N 286.025° E	
Path frequency (GHz)	11	14	11	14	11	14
Fade depth (dB)	0.6	1.1	2.7	4.7	1.5	2.6

Note that the fade depths given in Table 5 do not take into account the additional margin required to overcome the increase in noise temperature of the receiving station due to cloudy sky conditions.

5.1 Number of fades resulting in an outage

According to the existing Recommendations on satellite performance objectives and availability, an outage on a satellite connection occurs when the performance of the connection drops below the availability threshold for 10 s or more.

Given the outage intensity numbers contained in Table 2, the fade depth corresponding to those numbers of outages can be determined. Compliance with ITU-T Recommendation G.827 implies that enough margin[1] must be designed into the satellite link to prevent the number of fades of 10 s or more from exceeding the outage intensity objectives. Thus the fade margin for the satellite link must meet or exceed the depth of the fade of 10 s duration that appears on the ordinate of Figs 1 through 6. Table 6 summarizes the implied fade margins required to meet the outage intensity objectives of ITU-T Recommendation G.827, as well as the margins required to meet the propagation availability objectives given in Table 1, for the three locations at 11 GHz and 14 GHz.

[1] Recommendation ITU-R S.1061 describes various fade countermeasure strategies and techniques in the fixed-satellite service, which may ensure that the necessary margin is provided.

TABLE 6

Fade margins required to meet the outage intensity objectives of ITU-T Recommendation G.827 for three earth station locations at 11 GHz and 14 GHz

Earth station location	46.222° N 6.139° E		25.81° N 279.88° E		40.773° N 286.025° E	
Path frequency (GHz)	11	14	11	14	11	14
Fade margin required to meet 99.9% propagation availability	1.5	2.6	6.6	11.2	3.2	5.5
Fade margin required to meet 99.96% propagation availability	2.3	4.0	9.7	16.3	4.8	8.2
Fade margin required to meet G.827 high priority outage intensity (dB)	5.4	8.7	18.0	27.0	5.3	13.6
Fade margin required to meet G.827 standard priority outage intensity (dB)	2.7	4.8	10.6	17.1	2.7	7.7

5.2 Observations

Inspection of Tables 5 and 6 shows that the availability ratio (AR) objectives of ITU-T Recommendation G.827 can be met with relatively small link margins. The additional margin required to meet the outage intensity for the standard priority connection objectives ranges from 1.9 dB to 12.5 dB depending on frequency and earth station location. Still more margin is estimated to be needed to meet the objectives for a high priority connection. Satellite links designed to meet the outage intensity objectives would provide far better availability ratio performance than called for in ITU-T Recommendation G.827 or even for the propagation availability objectives given in Table 1.

The dominant cause of outages on satellite paths is fading due to anomalous propagation. Recovery from these outages requires no intervention and, thus, the outages are "self-healing." According to the Note to Table 2/G.827 of ITU-T Recommendation G.827, outage intensity values are based on a mean time to recovery (MTTR) of 4 h. According to the propagation statistics calculated, fades of 4 h or more in length would occur on the order of a few times per year, if at all.

Given the duration and "self-healing" nature of propagation outages, meeting the outage intensity objectives from the standpoint of propagation outages would not be difficult.

Outages due to the failure, under normal circumstances, of space segment or ground segment equipment could last as long as 4 h or even longer, depending on earth station configuration, availability of spares and manning status. The values of space segment availability and ground segment availability determined during the development of Recommendation ITU-R S.1424, dealing with satellite availability for asynchronous transfer mode traffic, were determined to be 99.99% and 99.95%, respectively. Using these values, the average number of outages due to equipment failure would be 1.5 per year. Thus by providing sufficient margin to provide availability ratio requirements, the objectives of ITU-T Recommendation G.827 can be met handily for satellite digital paths.

FIGURE 1

Number of fades of duration, *D*, per year at 11 GHz
46.222° N, 6.139° E; *R*0.01 = 25; elevation angle = 30°

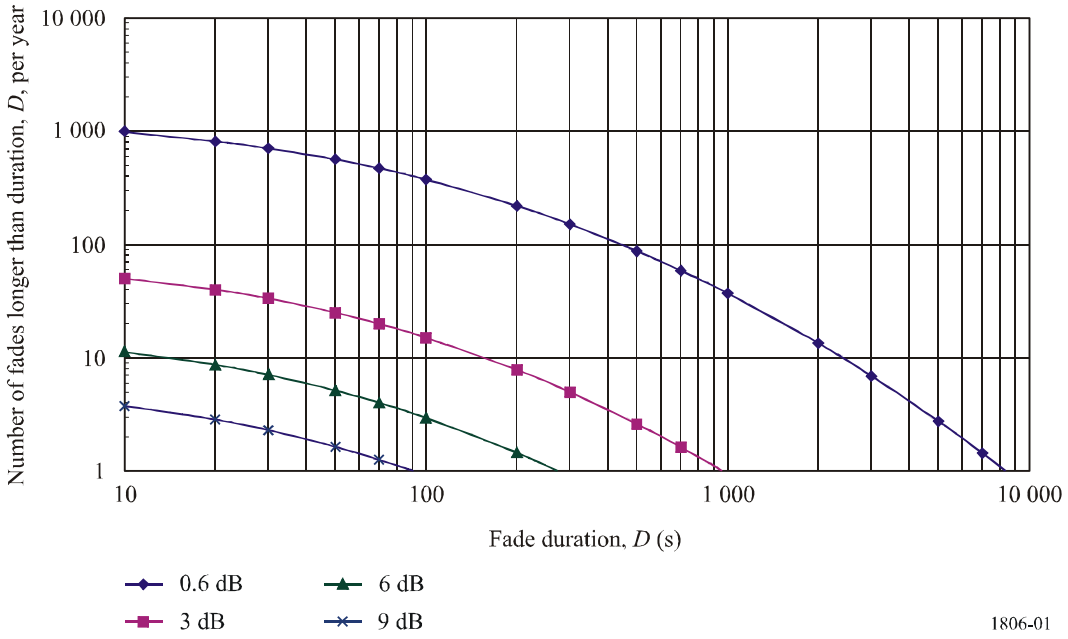


FIGURE 2

Number of fades of duration, *D*, per year at 14 GHz
46.222° N, 6.139° E; *R*0.01 = 25; elevation angle = 30°

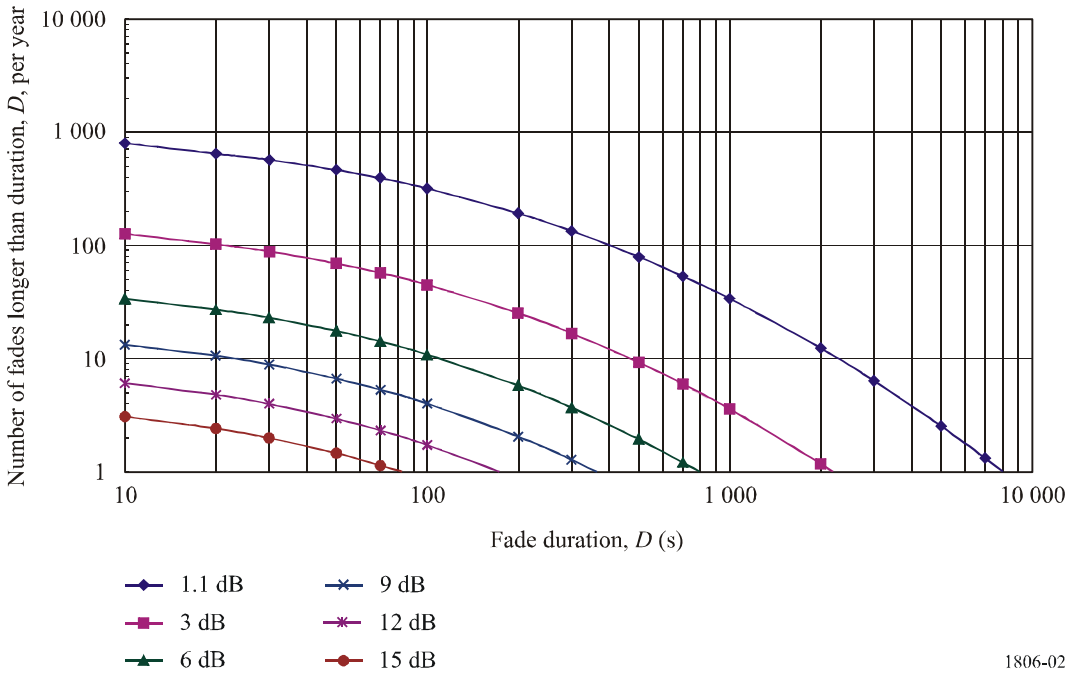


FIGURE 3

Number of fades of duration, *D*, per year at 11 GHz
25.81° N 279.88° E; *R*0.01 = 96; elevation angle = 24°

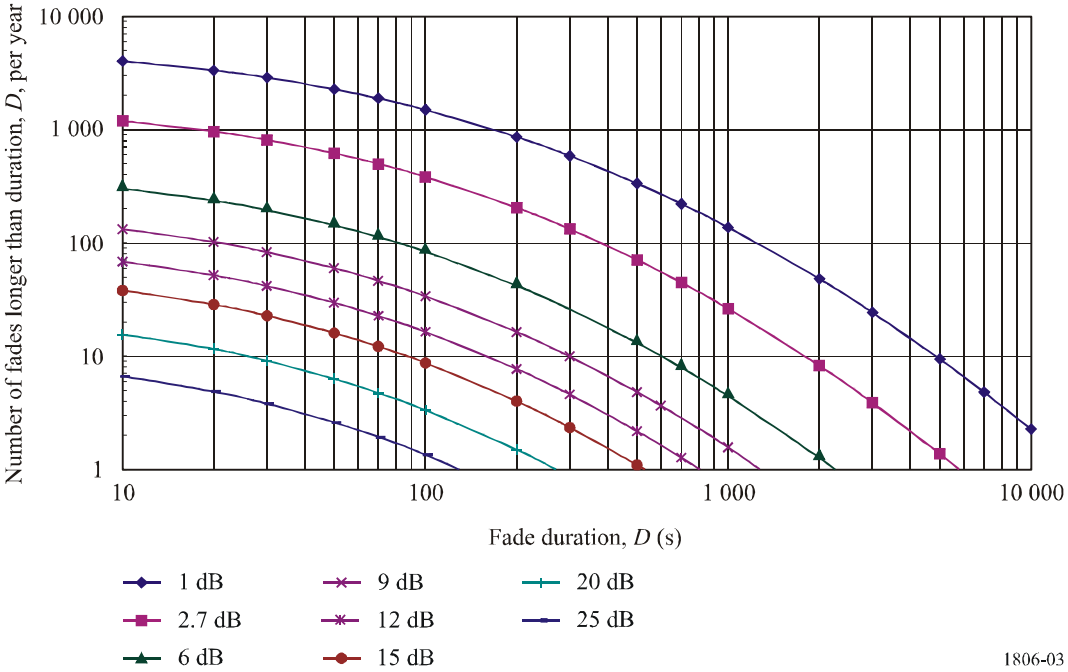


FIGURE 4

Number of fades of duration, *D*, per year at 14 GHz
25.81° N 279.88° E; *R*0.01 = 96; elevation angle = 24°

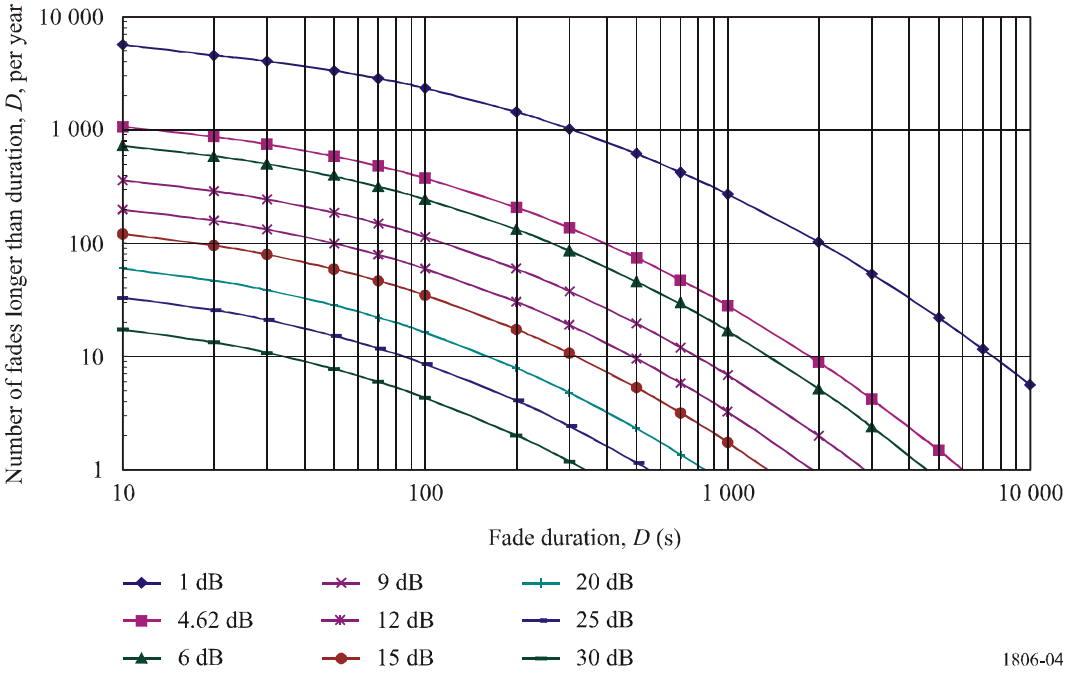


FIGURE 5

Number of fades of duration, *D*, per year at 11 GHz
40.773° N, 286.025° E; *R*0.01 = 43; elevation angle = 23°

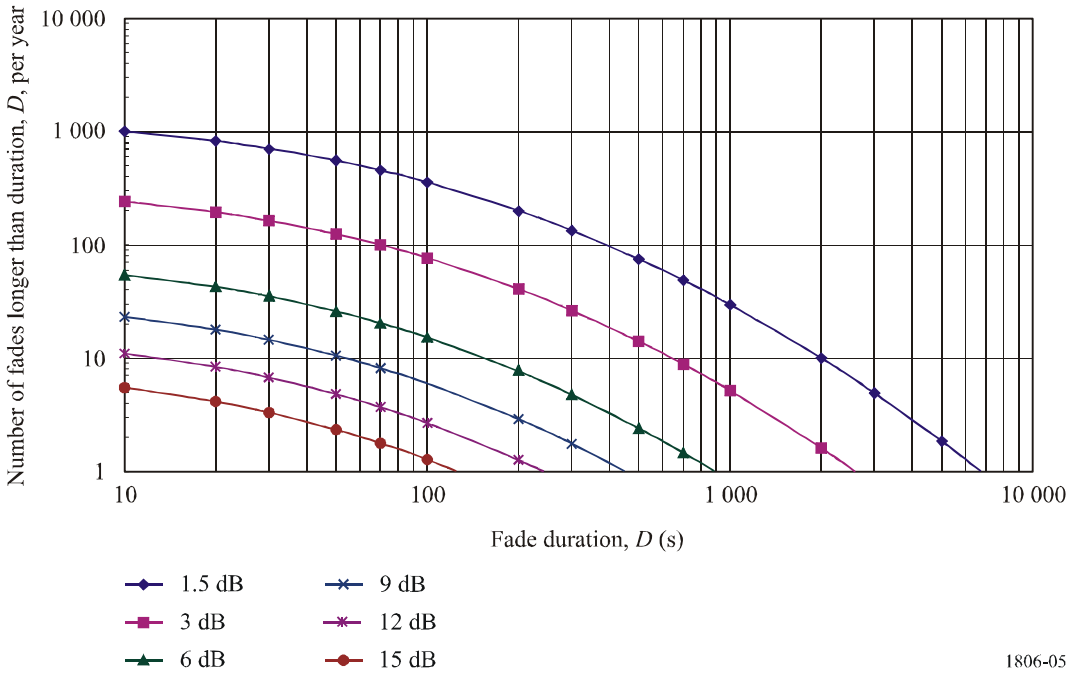
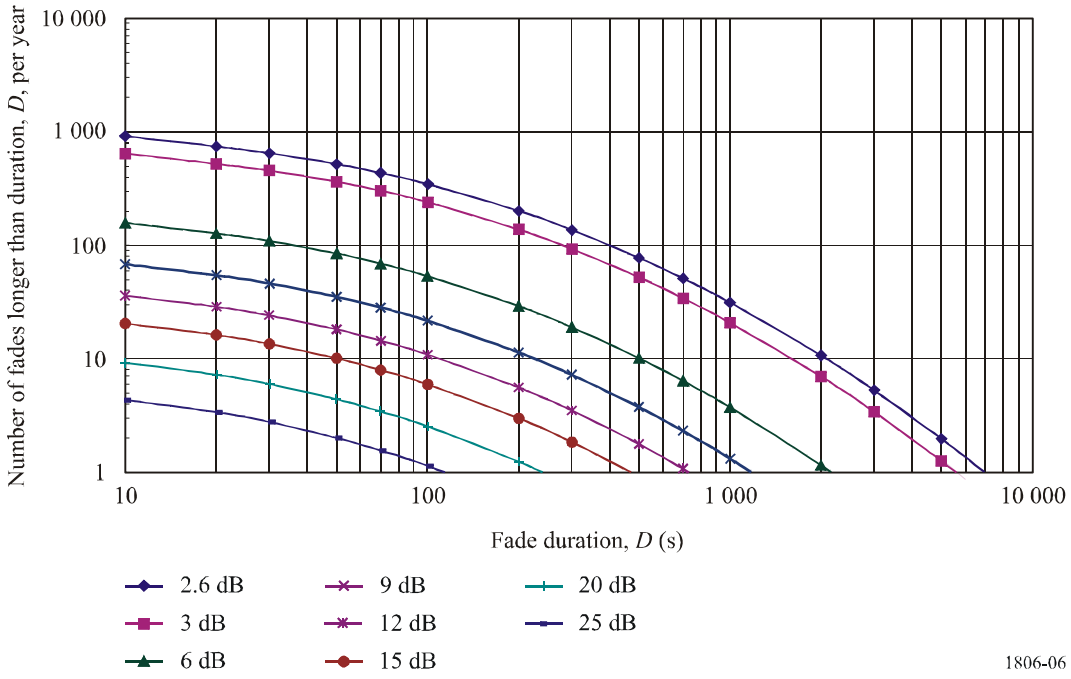


FIGURE 6

Number of fades of duration, *D*, per year at 14 GHz
40.773° N, 286.025° E; *R*0.01 = 43; elevation angle = 23°



6 Conclusions

This annex has referenced the methods contained in Recommendation ITU-R P.1623 in calculating the number of fades that will occur on a satellite link as a function of frequency, elevation angle and earth station location. Using these results, the estimated fade margin for a satellite link has been computed based on the availability ratio and outage intensity objectives given in ITU-T Recommendation G.827. A significant difference between the estimated fade margin computed to meet the availability ratio objectives and that computed for meeting the outage intensity objectives has been noted. Further work is required to characterize the performance of modern digital satellite links that make use of forward error correction, from the standpoint of outage intensity objectives as given in ITU-T Recommendation G.827.