RECOMMENDATION ITU-R S.579-6

Availability objectives for 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

(Question ITU-R 73/4)

(1982-1986-1992-1994-1997-2001-2005)

Scope

This Recommendation deals with Availability objectives for 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. It is based on the availability objectives specified in some ITU-T Recommendations.

The Recommendation has been updated in order to appropriately reflect the new changes in associated ITU-T Recommendations. A new section in the Annex is introduced to give guidance on the way to apply Recommendation ITU-R P.1623 to compute the statistics of fade attenuation due to propagation.

The ITU Radiocommunication Assembly,

considering

a) that the hypothetical reference circuit (HRC), as defined in Recommendation ITU-R S.352, and the hypothetical reference digital path (HRDP), as defined in Recommendation ITU-R S.521, in the FSS are intended as a guide to designers and planners;

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

c) that the availability of an HRC or an HRDP is determined by the equipment availability and the effects of propagation on the link;

d) that the unavailability due to propagation has two components, the exceedance of an attenuation threshold and the frequency of such exceedances;

e) that it is desirable to apply similar availability objectives to cable, radio-relay and fixed-satellite systems;

f) that ISDN traffic can be carried at rates below, at and above the primary rate (1.544 Mbit/s or 2.048 Mbit/s),

recommends

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

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

where: (1)

$$\text{Unavailability} = \frac{\text{unavailable time}}{\text{required time}} \times 100 \quad \%$$

where the required time is defined as the period of time during which the user requires the circuit or digital path to be in a condition to perform a required function, and unavailable time is the cumulative time of circuit or digital path interruptions within the required time;

2 that the unavailability of an HRC or HRDP in the FSS due to equipment should be not more than 0.2% of a year;

3 that the unavailability due to propagation should be not more than:

3.1 0.2% of any month for one direction of an HRDP in the FSS (see Note 6);

3.2 0.1% of any year (referring to the term of "any year", see Note 11 of Recommendation ITU-R S.353) for one direction of an HRC in the FSS;

4 that a link in the FSS defined between the ends of the HRC or HRDP in Recommendations ITU-R S.352 and ITU-R S.521 should be considered unavailable if one or more of the conditions in *recommends* 4.1 to 4.5 below exist at either of the receiving ends of the link for 10 consecutive seconds or more (see Note 5). (A period of unavailable time begins when one of the conditions in *recommends* 4.1 to 4.5 persists for a period of 10 consecutive seconds. These 10 seconds are considered to be unavailable time. The period of unavailable time terminates when the same condition ceases for a period of 10 consecutive seconds. These 10 seconds are considered to be available time.):

4.1 for analogue transmission the wanted signal is received at the far end at a level 10 dB or more below its expected level;

4.2 for analogue transmission, the unweighted noise power in a telephone channel at a point of zero relative level, with 5 ms integration time is higher than 10^6 pW0;

4.3 for digital transmission the digital signal is interrupted (i.e. alignment or timing is lost);

4.4 for digital 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};

4.5 for digital 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. An SES is defined as a second which contains ≥30% errored blocks or at least one severely disturbed period (SDP) (see ITU-T Recommendation G.826);

5 that the following Notes should be regarded as part of this Recommendation.

NOTE 1 – The unavailability of analogue multiplexing equipment is not taken into account. The unavailability of digital multiplexing equipment in the earth station is included in *recommends* 2.

NOTE 2 – This Recommendation only applies to digital traffic (below, at and above the primary rate) transported within the plesiochronous digital hierarchy (PDH) or the synchronous digital hierarchies (SDH) and combinations thereof (see ITU-T Recommendation G.823).

NOTE 3 – Periods of degraded performance lasting less than 10 consecutive seconds, during which conditions in *recommends* 4.1 to 4.5 exist, are considered available time and are taken into account in the application of error performance Recommendations.

NOTE 4 – All outages due to solar eclipses and interference from the Sun are included as part of the unavailable time in *recommends* 2 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 Annex 1 and Recommendation ITU-R S.1525.

NOTE 5 – 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 6 – A percentage of unavailability 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.

Annex 1

1 Definition of availability

In the context of an end-to-end connection, availability comprises a number of component parts, and these are discussed in ITU-T Recommendation G.106. As applied to the satellite HRC and HRDP, availability is concerned only with equipment availability and effects of propagation.

2 General considerations

A variety of factors may have an impact on availability:

– mean time between interruptions;

– total interruption over a long period (e.g. a year);

– total interruption time over a worst period (e.g. any month);

– mean duration of interruption;

– the rate of occurrence (e.g. measured on an hourly basis);

– the statistical distribution of interruptions (e.g. attenuation, duration, frequency of occurrence).

3 Unavailability due to equipment

A number of different causes of interruption are included under this heading. They are:

– satellite-related effects, including partial or complete failure of any of the systems on board, plus eclipse outages;

– earth-station related effects, including failure of any equipment as far as the terrestrial network interface, outages caused by human error, Sun transits and the effects of natural disasters.

4 Unavailability due to propagation

Studies of the impact of propagation on availability require the separation of short breaks of less than 10 consecutive seconds which are covered by performance recommendations, and those of 10 consecutive seconds or more which contribute to unavailability. In this respect an "availability factor" has been used which can be defined as:

$$\text{Availability factor} = \frac{\text{total time for which outages of} < 10 \text{ s duration occur}}{\text{total time for which all outages occur}} \times 100\%$$

The meaning of "outages" depends on whether an analogue or digital circuit is considered, and a precise definition in each case is given in *recommends* 4.

Recommendation ITU-R S.1323 contains information on the combined effects of interference and propagation.

5 Unavailability due to Sun transit

Interference due to Sun transit is a predictable natural phenomenon that occurs for short periods twice per year. Based on the simplified Sun transit algorithm described in Annex 2 of Recommendation ITU-R S.1525, earth station operators can estimate the time and day when Sun interference will occur. With this information, they can take proactive action to mitigate the effects of Sun interference. These strategies are described in the following paragraphs.

5.1 Links carrying public switched network (PSN) traffic

Most PSN traffic routed via INTELSAT satellites is carried by earth stations with larger antennas such as Standard A (30 to 33 m), revised Standard A (16 to 18 m) in the 6/4 GHz band, or Standard C (~16 m) or revised Standard C (~9 m) in the 14/10-11 GHz band. Because of their large size and small beamwidth (0.2º to 0.3º), the impact of Sun interference is relatively small and is negligible in terms of availability. PSN circuits are designed to an annual availability standard of 99.96% or better. For the antennas above, the availability due solely to Sun interference ranges from 99.997% to 99.998%. In addition, because most PSN traffic is networked through digital switches, essential traffic can be temporarily rerouted for the few minutes of the Sun interference event, or the satellite trunk circuits can be manually or automatically locked out to prevent the seizure of degraded circuits. Unlike propagation fading that can vary up and down during rain events, Sun transit events will degrade the link performance in a continuous manner until it reaches its maximum, and then improve until the normal performance is restored.

5.2 Links carrying time division multiple access and demand assignment multiple access traffic

INTELSAT operates two services that require hub stations to provide essential reference timing or bandwidth allocation to the earth station user community. To minimize the effect of Sun interference on network availability, these stations use the Sun prediction data to transfer network control from the master station to geographically separated secondary master stations. This eliminates the effect of Sun interference and ensures the continuity of network control to provide the essential traffic control services.

5.3 Links carrying leased traffic

Links carrying leased traffic usually operate with earth stations having small antennas, and because the same signal is received by several stations, rerouting the traffic is not always realistic or cost effective. However, leased network operators typically plan around these Sun interference outage periods by informing customers that these short outages will occur and non-essential traffic be carried at that time. With foreknowledge of Sun interference, operators can schedule the operations to minimize the impact and, similarly to planned maintenance and repair, customers have accepted such outages when warned in advance.

Based on the definition of unavailability in *recommends* 1, and the preceding description of the practical steps taken by satellite operators and customers which would affect the required time, it is clear that Sun interference does not contribute to the unavailable time in a manner similar to propagation and interference outages.

6 Effect of propagation on unavailable time

This section summarizes the information available to date on the way propagation effects contribute to unavailable time. Much of the information has been studied by Radiocommunication Study Group 3 who have analysed the data in terms of available time (with attenuation events less than 10 s, corresponding to "severely errored seconds") and unavailable time (with attenuation events greater than 10 s), in accordance with the definition of unavailable time given in this Recommendation.

The limited information available is presented in Tables 1 and 2, and Fig. 1 as percentages of worst month. Table 1 is derived from satellite beacon measurements, Table 2 from radiometer measurements.

TABLE 1

Percentage of the worst month for which the indicated values of attenuation were exceeded

A division into available and unavailable time (see *recommends* 4) has been made at each attenuation value

Attenuation level exceeded (dB)	Denmark (I, II)[(1)] Elevation angle = 26.5°						Denmark (III)[(1)] Elevation angle = 12.5°	
	11.8 GHz				14.5 GHz		11.4 GHz	
	Single site (% of month)		Single division (% of month)		Single site (% of month)		Single site (% of month)	
	Available time	Unavailable time	Available time	Unavailable time	Available time	Unavailable time	Available time	Unavailable time
2	0.0070	0.112	0.0110	0.143	0.0165	0.213	0.0343	0.201
4	0.00053	0.0222			0.0038	0.0462	0.00355	0.0215
6	0.00028	0.0106			0.00070	0.0138	0.00035	0.00305
8	0.00047	0.0056			0.0013	0.0039		0.00131
10	0.000096	0.0033			0.00014	0.00070		
15	0.00017	0.00054						

(1) See Fig. 1.

Attenuation level exceeded (dB)	UK (IV, V)(1) Elevation angle = 29.9°				Japan (VI)(1) Elevation angle = 6.6°	
	11.8 GHz		14.5 GHz		11.5 GHz	
	Single site (% of month)		Single site (% of month)		Single site (% of month)	
	Available time	Unavailable time	Available time	Unavailable time	Available time	Unavailable time
2	0.015	0.16	0.03	0.03		
3					0.96	5.7
4	0.0022	0.035	0.009	0.10		
6	0.0008	0.014	0.0022	0.033	0.16	1.84
8	0.0005	0.006	0.0009	0.016		
10					0.027	0.52
15					0.008	0.17

(1) See Fig. 1.

TABLE 2

Percentage of the worst month for which the indicated values of attenuation were exceeded in Canada

Attenuation level exceeded (dB)	Climate K (VII, IX)(1) 13 GHz				Climate E (VIII)(1) 13 GHz	
	Site 1 Elevation angle = 20°		Site 2 Elevation angle = 29°		Elevation angle = 31°	
	Available time	Unavailable time	Available time	Unavailable time	Available time	Unavailable time
2	0.017	1.10	0.0081	0.51	0.014	0.68
3	0.007	0.54	0.0042	0.31	0.0046	0.22
4	0.0039	0.36	0.0028	0.22	0.003	0.11
6	0.0022	0.16	0.0017	0.16	0.0004	0.058
8	0.0011	0.089	0.0017	0.12	0.0005	0.041
10	0.0007	0.056	0.0007	0.099	0.0004	0.031

(1) See Fig. 1.

The following general conclusions have been drawn from Table 1:

– For elevation angles in the range 26°-30° and for attenuation values of 2-8 dB, the ratio of attenuation time during available time to that during total time was found to be between 3% and 10%. At greater values of attenuation, this proportion tended to increase, since event duration would decrease as the attenuation approached its maximum value.

– At lower elevation angles, 6°-12°, the ratio of attenuation time during available time to that during total time was found to be about 14% at the 3 dB attenuation value, decreasing to about 5% at values in the range 10-15 dB. For even greater values of attenuation, the above ratio is likely to increase again. Scintillations would be expected to make a greater contribution to the attenuation time at the lower elevation angles than in the cases for the measurements corresponding to the higher elevation angles.

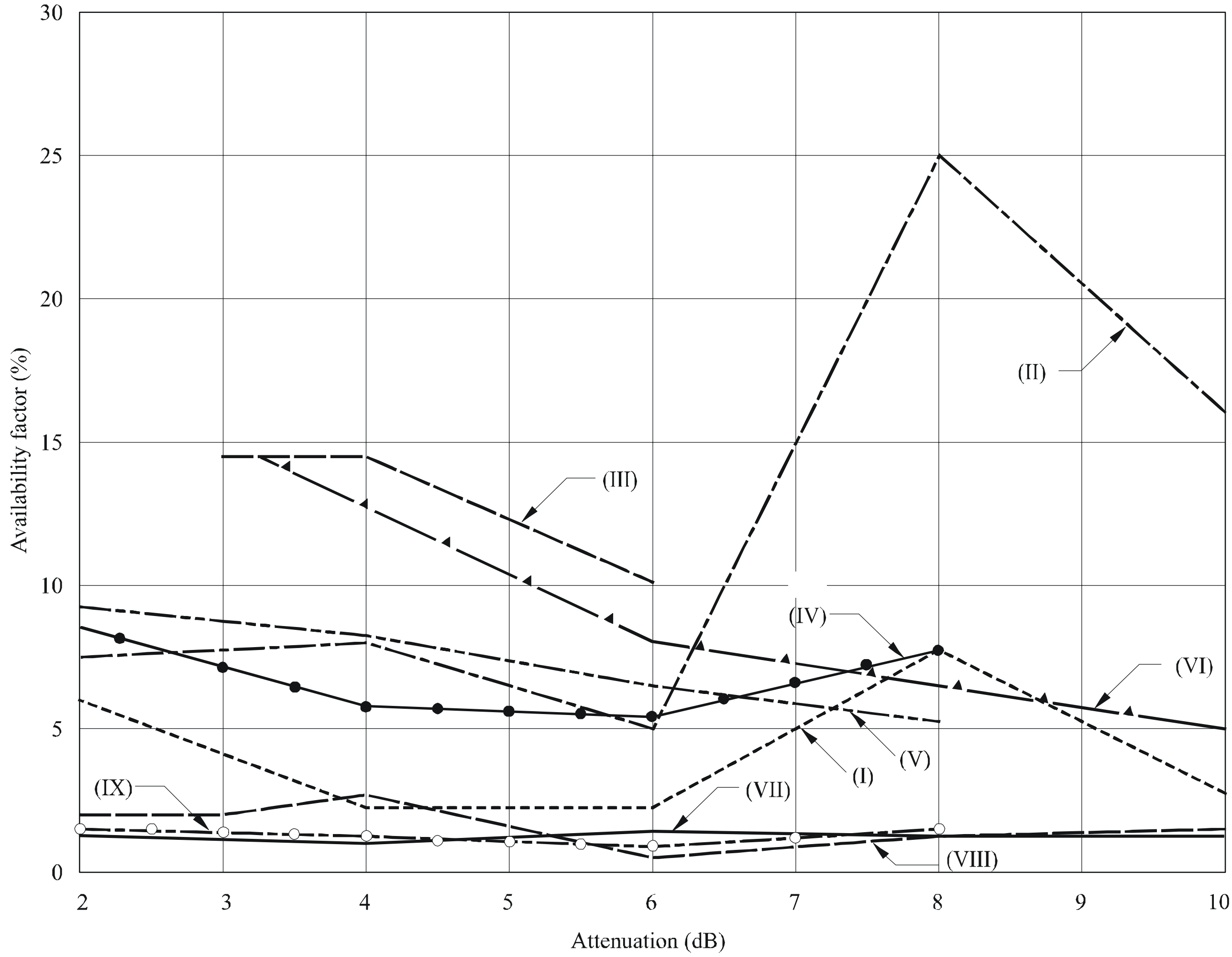
The site diversity data are based only on attenuation values of 2 dB; no simultaneous attenuation value of 4 dB was measured at both sites during the experiment in Denmark. The only data supplied therefore correspond to the 2 dB value. The ratio of attenuation time during available time to that during total time was found to be very close to that for a single site. However, for regions of the world with higher rainfall rates, the ratio in the diversity case may be greater than for a single site as a result of the increased impact of site diversity in such climates.

The data contained in Table 2 are based on radiometer measurements made in Canada at 13 GHz. Propagation data was collected at six sites where fades from 2-10 dB were recorded and the fade durations calculated for those lasting shorter than 10 s and those lasting longer or equal to 10 s. Results for two typical K climate sites and one E climate site have been presented. These results indicate that the availability would be in the range 1-4%. Using the availability factor definition given in § 6, these results reduce to less than 1%. The data also indicate that for system design margins in the 3-6 dB range, a total unavailable time of up to 0.54% of the worst month could be experienced.

From consideration of all the information presented above, it is concluded that an availability factor of 10% is a conservative working value.

FIGURE 1

Graph of propagation availability factor versus attenuation



(I) – Denmark, 11.8 GHz, elevation angle = 26.5°, climate D
(II) – Denmark, 14.5 GHz, elevation angle = 26.5°, climate D
(III) – Denmark, 11.4 GHz, elevation angle = 12.5°, climate D
(IV) – United Kingdom, 11.8 GHz, elevation angle = 29.9°, climate E
(V) – United Kingdom, 14.5 GHz, elevation angle = 29.9°, climate E
(VI) – Japan, 11.5 GHz, elevation angle = 6.6°, climate M
(VII) – Canada, 13 GHz, elevation angle = 20°, climate K
(VIII) – Canada, 13 GHz, elevation angle = 31°, climate E
(IX) – Canada, 13 GHz, elevation angle = 29°, climate K

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Note 1– Recommendation ITU-R P.837 contains the definition of rain climate zones.

7 Fade duration and outage intensity

Recent work by Radiocommunication Study Group 3 has produced a model for fade duration and the rate of occurrence of fades for satellite links operating above 10 GHz. This model is contained in Recommendation ITU-R P.1623.

For satellite links operating below 10 GHz, the attenuation due to rain is usually small and the dominant rain impairment is depolarization which leads to increased interference from the signal on the orthogonal polarization. Rain fades occurring on links operating below 10 GHz rarely exceed a few dB and are generally accounted for in the link margin.

For satellite links operating above 10 GHz, statistics for the duration of a fade and for the frequency of occurrence of a fade can be computed using the model described in Recommendation ITU-R P.1623, as a function of operating frequency, elevation angle and fade threshold. If local overall fading data is not available for a link, the total fading time can be computed using Recommendation ITU-R P.618. This Recommendation requires additional parameters, including earth station latitude and longitude and the local point rain rate for 0.01% of the time.

In the following examples, operating frequencies of 11 and 14 GHz were assumed. The satellite path elevation angles and earth station locations are shown in Table 3. The climatic parameters associated with these locations were determined from various files contained in the Radiocommunication Study Group 3 database. These parameters are required for application of the method in Recommendation ITU-R P.618 that was used to determine the total outage time due to precipitation.

TABLE 3

Assumed earth station locations and path elevation angles

Earth station latitude	Earth station longitude	Path elevation angle (degrees)	0.01% rain rate (mm/h)
25.5° N	279° E	24	94
40.5° N	286.5° E	23	42
46.5° N	6° E	30	33

Fade duration

Estimation of the probability of fade duration for a given fade depth threshold can be performed using the method in Recommendation ITU-R P.1623.

As an example, at 11 GHz for an earth station at 46.5° N and 6° E, the probability that a 3 dB fade, once in progress, lasts at least 1 min is approximately 0.25.

Fade frequency

The frequency of occurrence of a fade of a certain depth can be estimated by taking the number of fades of that depth and dividing that number by the number of seconds in one year, i.e. 31 536 000 s.

Given that unavailability occurs after periods of degraded performance, below the availability threshold, equal to or exceeding 10 s, fade durations of 10 s or less are not taken into account.

The number of 3 dB fades lasting 10 sor more is shown in Table 4 for the earth station locations given at 11 GHz and 14 GHz. The frequency of fading is given in terms of fades per day.

TABLE 4

Fading frequency as a function of path frequency and earth station location

Earth station location	**46° N, 6° E**		**25.5° N, 279° E**		**40.5° N, 286.5° E**	
Path frequency (GHz)	11	14	11	14	11	14
Number of 3 dB fades	76	222	980	2 250	222	539
Fading frequency fades/day	0.208	0.608	2.68	6.16	0.608	1.48

In many impairment events, several fades in excess of a given threshold may occur in a relatively short-time interval, thus the fade intervals estimated are strictly statistical averages.