RECOMMENDATION ITU-R S.579-5

Availability objectives for a hypothetical reference circuit and a hypothetical reference digital path 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

(Question ITU-R 73/4)

The ITU Radiocommunication Assembly,

considering

a)   that the hypothetical reference circuit (HRC) and the hypothetical reference digital paths (HRDP) in the fixed-satellite service (FSS) are intended as a guide to designers and planners;

b)   that it is desirable to be compliant with concepts, terms and definitions related to availability as given in ITU-T Recommendation G.106;

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

d)   that the availability of an HRC or digital path is determined by the combined effects of equipment and propagation availability;

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

f)   that the availability objectives for a HRDP used to carry B-ISDN ATM traffic will be defined in a future Recommendation;

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

h)   the material presented in Annex 1,

recommends

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

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

where: (1)

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

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 (see Note 7);

3   that the unavailability due to propagation (see Note 7) should be not more than:

3.1   0.2% of any month for one direction of a HRDP in the FSS (see Note 8);

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 § 4.1 to 4.5 below exist at either of the receiving ends of the link for 10 consecutive seconds or more (see Note 6). (A period of unavailable time begins when one of the conditions in § 4.1 to 4.5 persists for a period of 10 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 10 consecutive seconds. These 10 s 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 digital transmission the digital signal is interrupted (i.e. alignment or timing is lost);

4.3   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;

4.4   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} (see § 4.2.1 of ITU-T Recommendation G.821);

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 $\geq 30\%$ errored blocks or at least one severely disturbed period (SDP) (see § 4.1.1 of 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 in the foregoing. The unavailability of digital multiplexing equipment is included in *recommends* 2.

NOTE 2 – The unavailability value of the circuit or digital path is a planning objective for fixed-satellite systems; it should neither be included in system specifications nor used for acceptance tests.

NOTE 3 – This Recommendation should be used for digital traffic (below, at and above the primary rate) transported within the plesiochronous digital hierarchy (PDH) or the synchronous digital hierarchies (SDH). However, for B-ISDN ATM services transported within the PDH or SDH the availability objectives are for further study.

NOTE 4 – Periods of less than 10 consecutive seconds, during which conditions in *recommends* 4.1 to 4.5 exist, are considered available time and should be taken into account in applying the Recommendations.

NOTE 5 – 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 6 – Availability calculations should explicitly take into account mean time between failures, mean time for resumption of service, precautions taken against interruptions and impairment of satellite performance (especially use of reserve channels and back-up systems).

NOTE 7 – The unavailability of a circuit or digital path in the FSS for national portions with alternative transmission systems may be excluded from *recommends* 2 and 3 and can be determined by administrations in accordance with local conditions (i.e., propagation, geographical size, population distribution, organization of maintenance, etc.).

NOTE 8 – In *recommends* 3.1 the value of 0.2% of 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 9 – Operational digital satellite systems may include monitoring functions, such as high BER alarms, which have a potential for causing call interruption or disengagement when the BER exceeds 10^{-3} for periods of less than 10 s. This is related to the use of an alarm identification signal (AIS) and depends on factors specific to the network. A possible allowance for this type of performance degradation due to propagation effects is a subject for further study.

NOTE 10 – This Recommendation applies to satellite systems operating below 15 GHz. The extension of the availability requirements given in this Recommendation to systems operating at higher frequencies is the subject of further study.

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 propagation availability.

2   General considerations

The Handbook on Satellite Communications (Fixed-Satellite Service) (Geneva, 1988) contains an extensive discussion on availability (§ 2.4). In particular, it discusses the impact on availability of factors such as the following:

–   mean time between interruptions. This is to ensure that interruptions of extended duration do not occur too frequently;

–   total interruption over a long period. This ensures a maximum value of availability for the system;

–   mean duration of interruption. This ensures that, if an interruption occurs, it is not too long;

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

–   the total interruption time over a period (e.g. of any month or year);

–   the statistically defined duration of interruptions, which could be specified by several points on a statistical distribution.

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.

Substantial discussion of many of these mechanisms, plus information regarding availability achieved in practice with operational satellites and earth stations is given in the Handbook on Satellite Communications (Fixed-Satellite Service) referred to above.

4   Unavailability due to propagation

This heading covers interruptions caused by interference and propagation effects. Limited information is available at present on the impact of intra- and inter-system (including radio-relay) interference as they affect availability, and studies in this area are necessary.

Some studies have been carried out into the impact of propagation on availability. In particular, it has been found necessary to distinguish between short breaks due to propagation mechanisms 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.

5   Unavailability due to Sun transit

Most geostationary-satellite orbit FSS earth station operators have accepted that Sun interference 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 and customers 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 0.9996 or better. For the antennas above, the availability due solely to Sun interference ranges from 0.99998 to 0.99997. 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 into an earth station with 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 the 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
3								
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						
20								

[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
20						

[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
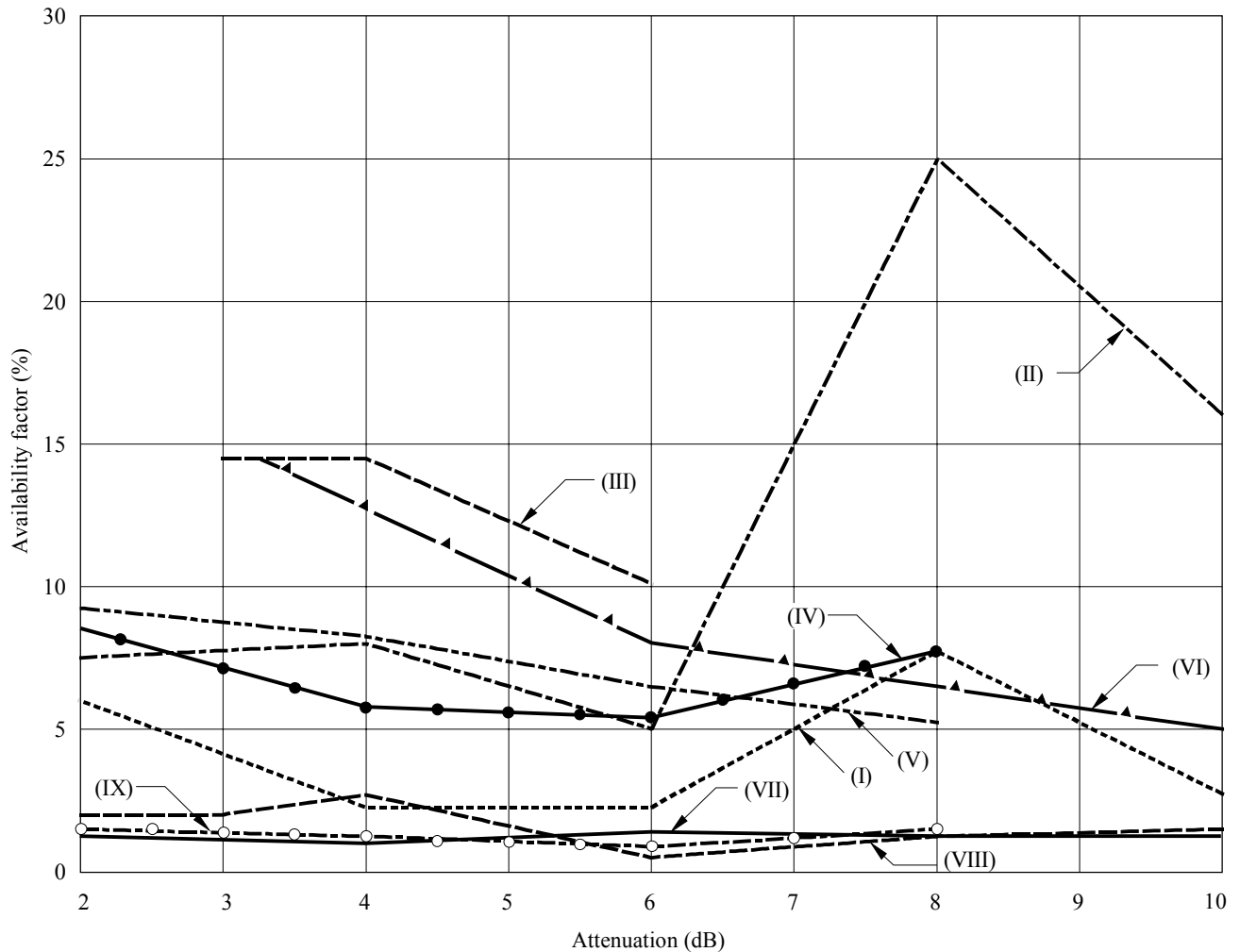
(I)	– Denmark,	11.8 GHz, elevation angle = 26.5°, climate D
(II)	– Denmark,	14.5 GHz, elevation angle = 26.5°, climate D
(III)	– Denmark,	11.4 GHz, elevation angle = 12.5°, climate D
(IV)	– United Kingdom,	11.8 GHz, elevation angle = 29.9°, climate E
(V)	– United Kingdom,	14.5 GHz, elevation angle = 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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