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 FSS BY GEOSTATIONARY ORBIT SATELLITE SYSTEMS USING FREQUENCIES BELOW 15 GHz

(Questions ITU-R 73/4 and ITU-R 78/4)

(2000)

The ITU Radiocommunication Assembly,

considering

a) that satellites operating in the FSS play an important role in providing reliable international digital communications;

b) that the hypothetical reference digital path (HRDP) in the FSS is intended as a guide to designers and users;

c) that the broadband integrated services digital network (B-ISDN) asynchronous transfer mode (ATM) semi-permanent connection availability has been specified in ITU-T Recommendation I.357;

d) that it is desirable to be compliant with the concepts, terms and definitions related to availability as given in ITU-T Recommendation I.357;

e) that in defining availability criterion, it is necessary to take into account all the specific characteristics of the transmission medium;

f) that the availability for a HRDP used for the transmission of B-ISDN ATM over satellite is determined by the aggregate effects of network congestion, transmission errors, equipment failures and propagation characteristics,

recommends

1 that a satellite HRDP carrying B-ISDN ATM semi-permanent connection traffic meet the availability objectives set forth in ITU-T Recommendation I.357;

2 that the HRDPs defined in Recommendation ITU-R S.521 and the reference model defined in Recommendation ITU-R S.1420 be considered as a basis for developing methods and techniques for meeting the availability objectives of ITU-T Recommendation I.357;

3 that a satellite HRDP carrying B-ISDN ATM connection traffic must meet the performance objectives given in ITU-T Recommendation I.356 during the available time (see Annex 1);

4 that the yearly availability of a satellite HRDP (one direction) in the FSS should be greater than 99.85% (see Notes 1 to 3);

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

NOTE 1 – The satellite HRDP availability objective encompasses the availability due to propagation and the earth station and spacecraft equipment availability. Based on previous studies for 14/11 GHz and 30/20 GHz band transmission paths, the yearly availability due to disturbed propagation is 99.96% to earth stations with a $G/T \geq 31.7$ dB(K^{-1}) and the availability of manned 14/11 GHz band earth stations with a $G/T \geq 31.7$ dB(K^{-1}) is 99.95%. Current information provided to the ITU-R shows that the spacecraft availability is better than 99.99%. Based on these considerations, the yearly availability for a satellite HRDP within *recommends* 4 applies to links between manned earth stations with $G/T \geq 31.7$ dB(K^{-1}). The yearly availability for a satellite HRDP within *recommends* 4 does not apply to unmanned earth stations nor to earth stations with $G/T < 31.7$ dB(K^{-1}). The yearly availability for links that originate or terminate at an unmanned earth station or at an earth station with $G/T < 31.7$ dB(K^{-1}) is for further study.

NOTE 2 – The equipment availability figures may be revised in the future once information from earth station operators and satellite system operators becomes available to the ITU.

NOTE 3 – The additional impact on system availability due to satellite-specific ATM equipment used at earth stations and of spacecraft that employ on-board processing and switching is for further study.

NOTE 4 – The availability requirements for HRDP that carry non-ATM traffic within a hypothetical reference connection (HRX) in the FSS are given in Recommendation ITU-R S.579.

NOTE 5 – The availability objectives for B-ISDN ATM switched connections is for further study. However, until the specific availability requirements of these type of connections are adopted by the ITU-T, the objectives given in this Recommendation may be used (see ITU-T draft Recommendation I.35av).

ANNEX 1

(Normative)

1 General considerations on B-ISDN ATM satellite connection availability

The current version of ITU-T Recommendation I.356 (B-ISDN ATM layer cell transfer performance) provides in Table 2/I.356 the QoS class definitions and the end-to-end network performance objectives. These objectives are given, for each performance parameter, as upper bounds that need to be met on a virtual channel (VC) or virtual path (VP) for the duration of the connection. ITU-T Recommendation I.356 makes no reference to the B-ISDN ATM availability requirements as this is the subject of ITU-T Recommendation I.357 (B-ISDN semi-permanent connection availability) and ITU-T draft Recommendation I.35av (B-ISDN switched virtual channel connection availability).

The objectives given in Table 2/I.356 had been based on some preliminary test results of QoS measurements of B-ISDN ATM services and applications. Generally, the results that were presented focused on the upper bound limits for service acceptability; that is, they should have specified the maximum cell loss ratio (CLR) and cell error ratio (CER) at which the applications are still acceptable but not degraded. This aspect is important since packet-based systems are generally very robust but tend to degrade rapidly in quality from being acceptable to unacceptable with a small region of marginal acceptability. The numbers provisionally adopted in Table 2/I.356 may be revised in the near future based on real operational experience and on more QoS test results of services and applications. However, to begin the interpretation of these numbers and their relationship with satellite link performance we must accept the premise that the QoS limits must be provided to the end-user for the duration of the connection. This means that these thresholds should not be exceeded during the available time. The availability threshold in satellite links is somewhat arbitrary since it is a point of reference (in terms of percentage of time) at which all network objectives are met.

There are at least two approaches to adopt a satellite link availability objective. The first approach is to develop a rigorous mathematical model to find the optimum curve (BER vs. per cent of time distribution) at which all performance and availability requirements are met. This model must account for the burst error characteristics of satellite modems and the link propagation characteristics; in addition, it must relate these characteristics to the network performance and availability definitions and objectives. The second approach is an empirical one, whereby measurements of performance and availability parameters of an actual satellite link demonstrate that all objectives are met. Although in practice it is common to use some combination of the two approaches, this Recommendation follows the second approach (see Note 1). The availability due to propagation is discussed in § 7.1 and in § 2 of Annex 2.

NOTE 1 – This approach may be amended in the future once Telecommunication Standardization SG 13 adopts objectives for ITU-T Recommendation I.357 and if subsequent mathematical models and propagation measurements demonstrate the need to change this Recommendation.

2 Definition of B-ISDN ATM connection availability

The network performance parameters, objectives and measurement methods for describing B-ISDN ATM semi-permanent connection availability are discussed in ITU-T Recommendation I.357. Section 4 of that Recommendation defines the availability of a B-ISDN ATM semi-permanent connection portion as the fraction of time during which the portion of an international connection is able to support a transaction.

3 Criteria for the entry and exit to the unavailable state

To define criteria for the entry and exit to the unavailable state, another cell transfer outcome parameter was introduced by Telecommunication Standardization SG 13, namely, the severely errored second (SES) in the ATM_{layer} (SES_{ATM}). Paragraph 4.3 of ITU-T Recommendation I.357 gives the definition of the SES_{ATM}.

"The onset of unavailability shall begin with the occurrence of ten consecutive SES_{ATM}. These ten seconds are part of unavailable time. A period of unavailability shall end with the occurrence of ten consecutive seconds, none of which are SES_{ATM}. These ten seconds are part of available time. The ten-second criteria are supported using a sliding window with one-second granularity."

4 B-ISDN ATM availability parameters

ITU-T Recommendation I.357 defines two parameters for the ATM availability of semi-permanent connection portions: the availability ratio (AR) and the mean time between outages (MTBO).

The AR is defined as the proportion of time that the connection portion is in the available state over an observation period. The MTBO is defined as the average duration of a continuous time interval during which the portion is available.

5 B-ISDN ATM availability objectives

The allocation of AR and MTBO objectives, according to the connection portion (i.e., national, international, international inter-operator) is still under study by Telecommunication Standardization SG 13.

6 Definition of satellite HRDP availability

The following discussion (§ 6 and 7) applies to the new AR parameter. Further studies are necessary to assess the MTBO figures representative of ATM satellite links.

The availability of a satellite HRDP that carries B-ISDN ATM traffic, as defined by the HRDPs given in Recommendation ITU-R S.521 and the reference model given in Recommendation ITU-R S.1420, comprises the propagation availability, and equipment availability. The overall availability of the satellite portion of an end-to-end connection, as defined in Fig. 1 of Recommendation ITU-R S.521, can be expressed as follows:

$$A_{satellite\ HRDP} = A_{link} \cdot A_{earth\ station} \cdot A_{spacecraft}$$

where:

A_{link}: availability component due to uplink and downlink rain attenuation and interference effects

$A_{earth\ station}$: availability (equipment reliability) of all transmit and receive earth station equipment up to the terrestrial interface; also, it includes sun interference effects. The availability of any ATM equipment that may be used specifically in a satellite connection is for further study

$A_{spacecraft}$: total availability (equipment reliability) of the spacecraft including eclipse outages. The availability of any on-board ATM processing and/or switching equipment is for further study

$A_{satellite\ HRDP}$: product of all availability components on a satellite link.

NOTE 1 – In addition to the parameters mentioned above, ITU-T Recommendation I.357 includes, as part of its scope, another component of availability due to traffic congestion. Once this parameter is formally adopted we would expect that a clear definition of this parameter will be provided by Telecommunication Standardization SG 13. As applied to satellite systems, this availability parameter may include the availability due to traffic congestion or queuing from on-board ATM equipment and/or any ATM earth station equipment that may be used specifically in a satellite connection.

General comments

– A discussion of propagation effects on unavailable time, for satellite links operating at frequencies below 15 GHz, is given in Recommendation ITU-R S.579.

– The impact of the use of inter-satellite links (ISL) on the satellite system availability is for further study.

– The use of site diversity to improve the earth segment availability is for further study.

– Further studies are also required for the availability of the satellite portion of an end-to-end connection for the HRDPs defined in Figs. 2 to 4 of Recommendation ITU-R S.521.

7 Satellite HRDP availability objectives

As described in § 6, the total B-ISDN ATM satellite HRDP availability is defined by the product of each availability component. The material presented below, based on measurement results obtained from various systems, proposes individual availability figures for each of the components of the satellite HRDP availability figure ($A_{satellite\ HRDP}$). However, these figures are not mandatory since the apportionment of individual availability values is left to the designer as long as the overall satellite system availability is met.

7.1 Link availability (A_{link})

Satellite links that carry B-ISDN ATM traffic must meet the availability objectives given in ITU-T Recommendation I.357 and hence they must comply with ITU-T Recommendation I.356 objectives (CLR, CER, severely errored cell block ratio (SECBR), cell misinsertion rate (CMR), cell transfer delay (CTD) and cell delay variation (CDV)) during the per cent of time defined as the satellite link availability. Specifically, the B-ISDN ATM performance objectives need to be met during the available time. In accordance with Recommendations ITU-R S.1062 and ITU-R S.614, applicable to systems operating below 15 GHz, it is proposed that the ITU-T Recommendation I.356 objectives should be met for 99.8% of the time (any month), or equivalently, 99.96% of the year.

– Since some B-ISDN ATM classes of service (e.g. Class-1) will carry real-time voice and interactive video and since it is envisioned that some PSTN traffic may be transported over B-ISDN ATM networks it is proposed that B-ISDN ATM satellite links that are designed to carry all QoS classes should be designed to support the performance and availability objectives of the most stringent service class. The availability objectives for B-ISDN ATM satellite links that carry other (less stringent) service classes (i.e. either Class-2, Class-3, or unbounded class) are left for further study.

– The link availability specified above should be met by all existing and future systems that will carry B-ISDN ATM traffic at any bit rate.

7.2 Earth station availability ($A_{earth\ station}$)

The availability objective for manned 6/4 GHz band earth stations is 99.95%. Availability objectives for other earth station types are for further study.

7.3 Spacecraft availability ($A_{spacecraft}$)

The availability objective for spacecraft used in GSO systems is 99.99%. Availability objectives for other non-GSO systems or for GSO systems with ISL are for further study.

7.4 Satellite HRDP availability (A_{HRDP})

For a link that operates at 6/4 GHz or 30/20 GHz band, that comprises two earth stations with a $G/T \geq 31.7$ dB(K^{-1}) and a single GSO spacecraft, the satellite system availability is 99.85%.

ANNEX 2

(Informative)

Measurements of availability of satellite links carrying B-ISDN ATM traffic

1 Introduction

This Annex contains some measurement results of the various availability components that comprise the satellite HRDP availability ($A_{satellite\ HRDP}$), as defined in § 6 of Annex 1. Further information is requested on the availability figures of other satellite systems.

2 Link availability (A_{Link})

The material presented below is based on a study of propagation characteristics of a current satellite system. The results represent the link availability and hence do not include the availability of the spacecraft or the transmit and the receive earth station equipment. Also, no satellite-ATM equipment was included at the earth stations as the signal was simply processed by a conventional modem-codec. Furthermore, the spacecraft did not include any on-board processing or switching functions.

During the AT&T, KDD, and Telstra (AKT) ATM Trial conducted in 1995, 45 Mbit/s intermediate data rate (IDR) (see Note 1) satellite links were characterized for their physical and ATM layer performance. To assess the links according to ITU-R propagation availability criteria all error events due to equipment failures were excluded from the analysis, hence the results represent the availability due to propagation and interference, only. The BER vs. per cent of time plot of one such link obtained during a month of the worst climatic conditions of the year at one of the earth stations is shown in Fig. 1. Although the CLR, CER and SECBR were also measured according to ITU-T Recommendation I.356 definitions, these results were tabulated in terms of average figures for the entire duration of the test and hence cannot be compared directly with the upper-bound figures given in Table 2/I.356. Hence, to estimate the behaviour of the CLR and CER over time, the test results of the relationships between CLR and CER vs. BER were used (see § 3 of Recommendation ITU-R S.1420). Notice that the CLR and CER objectives at the 0.2% unavailability threshold, commonly used in Recommendations ITU-R S.614 and ITU-R S.1062, were met by this link with some small margin. Hence, all ITU-T Recommendation I.356 parameters were met by this link during the available time equivalent to 99.8% of the month.

NOTE 1 – IDR is an INTELSAT service that is mainly used for PSTN traffic. IDR employs QPSK modulation and rate 3/4 FEC with convolutional encoding and Viterbi decoding.

3 Spacecraft availability ($A_{spacecraft}$) and earth station availability ($A_{earth\ station}$)

Recommendation ITU-R S.579 includes a 0.2% of any year allowance for unavailability due to earth station and spacecraft equipment (99.8% yearly availability). This section provides more recent information on the availability figures for satellites ($A_{spacecraft}$) and earth stations ($A_{earth\ station}$). It should be noted that the information provided in this section applies only to earth stations operating at C-band with $G/T \geq 31.7$ dB(K^{-1}) (about 11 m antennas).

Table 1 provides a summary of typical availability figures that can be met by satellites and earth stations as described above. The availability figure for the satellite component ($A_{spacecraft}$) can be easily met by international satellite systems. However, further studies are required to verify the suitability of the satellite availability figure for regional and domestic satellite systems.

For the earth stations under consideration, an availability figure of 99.95% of the year is a reasonable assumption. This figure is representative of all RF and IF equipment and includes the satellite modems. However, it should be pointed out that earth station availability is dependent on the customers' redundancy architectures, the operator's operations and maintenance practices (e.g. unattended operation, planned or only corrective maintenance, the number and type of spare units held on site, etc.), and the geological and meteorological factors considered in the design of the station (e.g.; high wind speed survival; seismic tolerance, etc.). These are all factors that satellite operators cannot enforce, since they do

not own or operate the customers' earth segment. Thus, a station designed for inner-city (low wind-speed, manned operations with ready access to spare units) would be unlikely to achieve the availability criteria, if used in a situation not conforming to the original design. Therefore, further investigation is needed to assess the applicability of earth station availability figure to a broader range of earth stations worldwide (e.g. earth stations with smaller antennas operating at 6/4 GHz band, earth stations operating at 14/11 GHz band, and ATM earth station equipment that may be used specifically in a satellite connection.).

FIGURE 1

Error ratios (BER, CLR, CER) vs. percentage of time

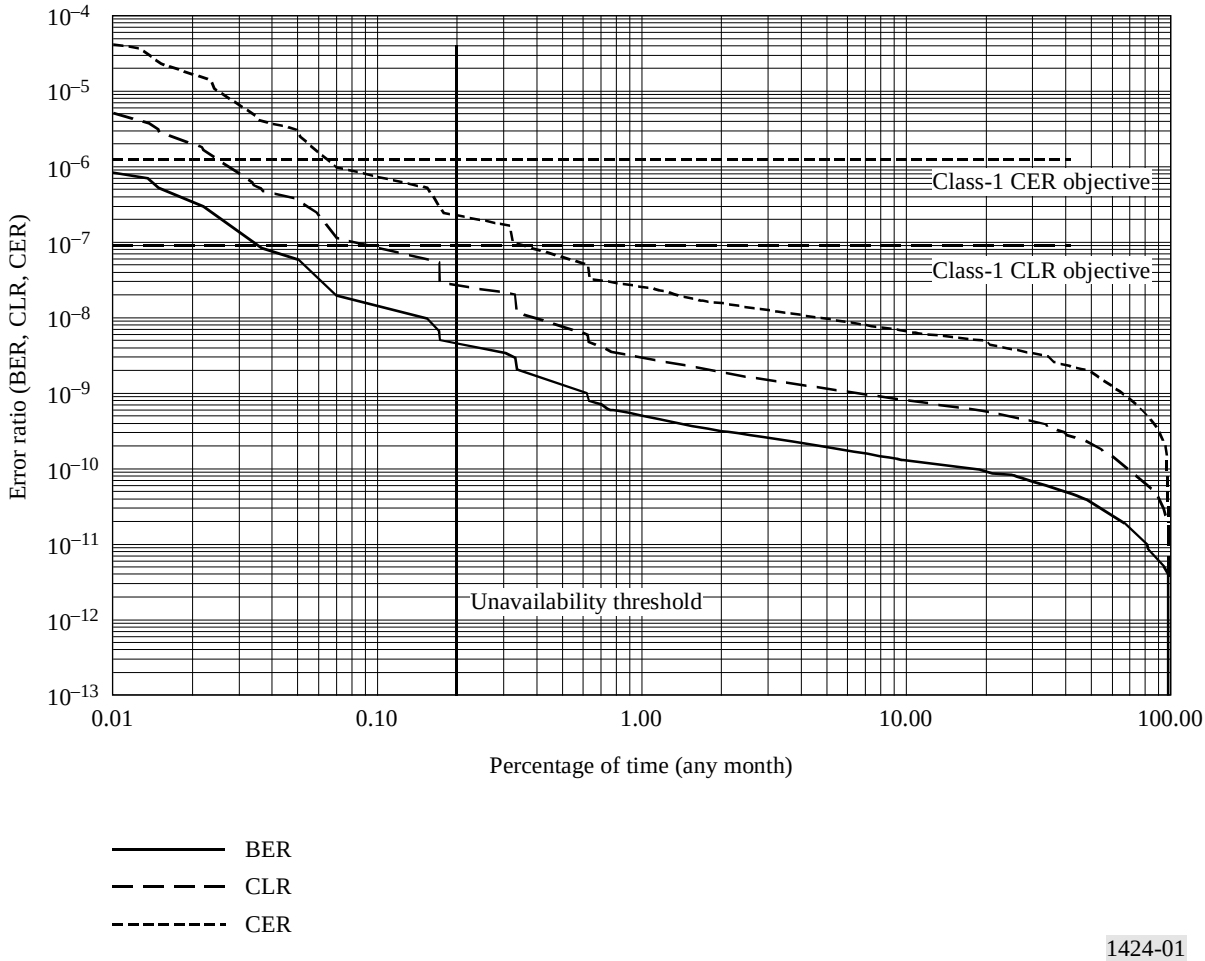

TABLE 1

Typical satellite and earth station availability

	Yearly availability requirement (%)
Satellite – $A_{spacecraft}$	99.99
Earth station 1 – $A_{earth\ station-1}$	99.95
Earth station 2 – $A_{earth\ station-2}$	99.95

The data summarized in Table 1 results in a total equipment yearly unavailability (satellite plus RF/IF earth station equipment) of 0.11%. This number is better than the 0.2% yearly unavailability objective specified in *recommends* 2 of Recommendation ITU-R S.579.