RECOMMENDATION ITU-R F.557-4

AVAILABILITY OBJECTIVE FOR RADIO-RELAY SYSTEMS OVER A HYPOTHETICAL REFERENCE CIRCUIT AND A HYPOTHETICAL REFERENCE DIGITAL PATH

(Question ITU-R 102/9)

(1978-1986-1990-1991-1997)

The ITU Radiocommunication Assembly,

considering

a) that the hypothetical reference circuit (HRC) and the hypothetical reference digital path (HRDP) are intended as a guide to designers and planners;

b) that the availability of a radio-relay system is dependent upon many factors and particularly upon: the maintenance organization (which determines the time to restore), the reliability of equipments and the system design and propagation conditions. The relative importance of these various factors may vary significantly, sometimes without possibility of control, from one area to another;

c) that it is desirable to apply common availability objectives to both cable and radio-relay systems,

recommends

1 that the availability objective appropriate to a 2 500 km HRC for frequency division multiplex radio-relay systems (Recommendation ITU-R F.392) and for a 2 500 km HRDP for digital radio-relay systems (Recommendation ITU-R F.556) should be 99.7% of the time, the percentage being considered over a period of time sufficiently long to be statistically valid, this period is probably greater than one year; the period of time is under study (see Notes 2, 3 and 4);

2 that the concept of unavailability of an analogue HRC should be as follows: in at least one direction of transmission, one or both of the following conditions occur, for at least 10 consecutive seconds (see Note 9):

2.1 the level of the baseband frequencies falls by 10 dB or more from reference level;

2.2 for any telephone channel the unweighted noise power with an integrating time of 5 ms is greater than 10^6 pW0 (see Note 10);

3 that the concept of unavailability of a HRDP should be as follows:

3.1 the period of unavailable time begins at the onset of ten consecutive severely errored second (SES) events, in at least one direction of transmission (see Notes 1 and 9). These ten seconds are considered to be unavailable time. For the definition of SES refer to related ITU-T Recommendations G.821 and G.826;

3.2 a new period of available time begins at the onset of ten consecutive non-SES events for both directions of transmission. These ten seconds are considered to be available time. For the definition of SES refer to related ITU-T Recommendations G.821 and G.826;

4 that in the estimate of unavailability, one must include all causes which are statistically predictable, unintentional and resulting from the radio equipment*, power supplies, propagation, interference and from auxiliary equipment and human activity. The estimate of unavailability includes consideration of the mean time to restore (see Notes 6 and 7);

* This includes all equipment between points R and R′ defined in Recommendation 380 (Volume IX, Part 1, (Düsseldorf, 1990)) for analogue systems, and all equipment within a digital radio section for digital systems.

5 that Annex 1 should be used for guidance on availability and reliability of radio-relay systems;

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

NOTE 1 – Overall availability A is defined by the following formula:

$$A = 100\,[1 - \{(T_1 + T_2 - T_b)/T_e\}]$$

where:

A: percentage availability

T_1: total unavailability time for one direction of transmission

T_2: total unavailability time for the other direction of transmission

T_b: bidirectional unavailability time

T_e: period of time for evaluation.

For unidirectional transmission $T_2 = 0$; $T_b = 0$.

NOTE 2 – The value of 99.7% is a provisional one and it is recognized that, in practice, the objectives selected may fall into the range 99.5% to 99.9%. The choice of a specific value in this range depends on the optimum allocation of outage time among the various causes which may not be the same when local conditions are taken into account (i.e. propagation, geographical size, population distribution, organization of maintenance).

Furthermore, the availability of radio-relay systems is only one of the many aspects that ensure the acceptable grade of service of the telephony traffic; the choice of an optimum value for this particular aspect can only be done by considering all transmission systems either existing or planned in the network under study.

For these many reasons, administrations may select different values of availability objective for the use of their planning organization, the said values lying in the range shown above.

NOTE 3 – Availability of multiplex equipments is excluded from the foregoing. The ITU-T is expected to establish availability objectives for these equipments.

NOTE 4 – This Recommendation relates to the HRC and to the HRDP. Its purpose is to set an availability figure as planning objective for new radio-relay systems.

It is not intended that it will be quoted in specifications of real systems, for acceptance tests, or for operational agreements. Recommendations relating to real circuits availability have to be established.

The measured data on availability figures for real circuits shows a wide distribution, a reliable figure of the actual availability can be estimated only as an average of a large amount of data collected from many radio-relay routes for a sufficiently long period of time.

NOTE 5 – The sub-division of the availability objective in the high grade portion of circuits to be established over real links is given in Recommendation ITU-R F.695. Availability objectives for real links in the medium and local grade portions of an integrated services digital network (ISDN) connection are under study.

NOTE 6 – Planners should indicate their assumptions concerning the mean time between failures (MTBF), the mean time to restore (MTTR), the precautions taken against interruptions and fading (in particular the use of protection channels and the number of hops per switching section) and the distribution of fading with a duration longer than 10 s.

NOTE 7 – The time to restore, which is the time elapsing between an interruption to traffic and its restoration, includes recognition time, travelling time as well as repair time. Differences in the time to restore will occur between administrations due to various factors such as site accessibility, weather, maintenance policy and other economic considerations.

NOTE 8 – This Recommendation does not take into account the improvements which could be obtained by means of rerouting traffic over other systems, e.g. cables and other radio-relay systems.

NOTE 9 – For interruptions with durations less than 10 s further study is necessary taking also into account intermittent interruptions.

NOTE 10 – Periods of less than 10 s during which the noise power in a telephone channel in frequency division multiplex systems is greater than 10^6 pW0 are taken into account in Recommendation ITU-R F.393.

NOTE 11 – Periods of less than 10 s during which the error ratio is greater than 1×10^{-3} are taken into account in Recommendation ITU-R F.594.

ANNEX 1

Availability and reliability of radio-relay systems

1 Introduction

This Annex provides guidance useful in the interpretation of this Recommendation. It should be noted, however, that the figures and parameters quoted are by way of example only.

The terms reliability and availability in this Annex follow the definition agreed upon by the ITU-R and the International Electrotechnical Commission (IEC).

2 Causes of unavailability

The concepts of unavailability of both analogue and digital radio-relay systems are stated in *recommends* 2 and 3, respectively. System planners should take into account all causes of interruption or quality degradation affecting system unavailability.

Features of the major causes of unavailability in radio-relay systems are described below.

2.1 Equipment

– Failure or degradation of radio equipment including modulators and demodulators,

– failure of auxiliary equipment such as switch-over equipment,

– failure of radio system power supply equipment,

– failure of antenna or feeder.

The latest radio-relay systems are designed to be highly reliable and the MTBF becomes extremely long. Unavailability depends also on the MTTR as stated in Note 6.

Within a typical switching section, unavailability due to equipment failures may be of the order of 0.01% (see Recommendation ITU-R F.695). This is representative of a typical equipment with an MTBF of the order of several 10^4 hours and an MTTR of several hours. However, an HRC or HRDP consists of a large number of switching sections. Naturally, the probability of a failure in each switching section is low, and may perhaps only occur once in several years. It is therefore reasonable to select a long integration period with which to measure unavailability, e.g. one year.

2.2 Propagation

System interruptions due to deep multipath fading often recover within 10 s, however, they sometimes occur for more than 10 s causing unavailability.

Excessive precipitation-attenuation due to heavy rainfall or snow fall lasts for a fairly long time and causes unavailability in systems operating in the frequency bands above 10 GHz. It may be possible to derive prediction statistics on propagation effects by applying the formulae or methods given in P-series ITU-R Recommendations. Also, since there is generally a low probability of heavy precipitation occurring, the unavailability time it causes may differ from year to year. To evaluate the unavailability time, the same considerations as described in § 2.1 could be applied.

2.3 Other causes

Unpredictable noise bursts due to interference mainly from sources outside the interfered-with system may cause unavailability when the noise power exceeds a certain threshold. This kind of interruption includes interference from space systems or radar systems associated with anomalous propagation.

Disasters such as earthquakes may bring about collapse of towers or buildings and result in unavailability of radio-relay systems.

Human intervention during maintenance activities can also cause unavailability. The contribution of these factors is generally difficult to predict through mathematical analysis. However, they should be considered when designing radio-relay systems.

3 Protection switching

Protection switching is often effective to improve system availability. In radio-relay systems the so-called multi-line switching method is usually used. In this method one or $P(P > 1)$ protection radio channels are prepared for N working channels. When one of the N working channels is interrupted the signal in the interrupted channel will immediately be recovered by one of the protection channels over m radio hops. In such a case, the unavailability U of each both-way radio channels due only to equipment failure, assuming that the failure rate of switching equipments is negligibly small, can be expressed by the following formula:

$$U = \frac{2}{N}\left[\binom{N + P}{P + 1}\right] (mq)^{P+1} \tag{1}$$

where:

m : number of radio hops contained in a switching section

q : probability of an interruption of each hop (as far as equipment failure is concerned, q = MTTR/MTBF)

$$\binom{N + P}{P + 1} = \frac{(N + P)!}{(P + 1)!\,(N - 1)!}$$

In many cases the number of the protection channels $P = 1$ and formula (1) can be written by the following:

$$U = \frac{2}{N}\left[\binom{N + 1}{2}\right] (mq)^2$$

Protection switching is effective not only for equipment failure but also for multipath fading through frequency diversity effects. Information on frequency diversity is given in Recommendation ITU-R F.752.