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**SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS**

Digital transmission systems – Digital sections and digital
line system – Parameters for optical fibre cable systems

**Parameters and calculation methodologies for
reliability and availability of fibre optic systems**

ITU-T Recommendation G.911

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION G.911**PARAMETERS AND CALCULATION METHODOLOGIES FOR RELIABILITY
AND AVAILABILITY OF FIBRE OPTIC SYSTEMS****Summary**

This Recommendation identifies a minimum set of parameters necessary to characterize the reliability and availability of fibre optic systems. Different parameters are given for system reliability and maintenance, for active optic device reliability, for passive optical device reliability, and for optical fibre and cable reliability. This Recommendation also provides guidelines and methods for calculating the predicted reliability of devices, units and systems. Examples are included.

Source

ITU-T Recommendation G.911 was revised by ITU-T Study Group 15 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 8th of April 1997.

FOREWORD

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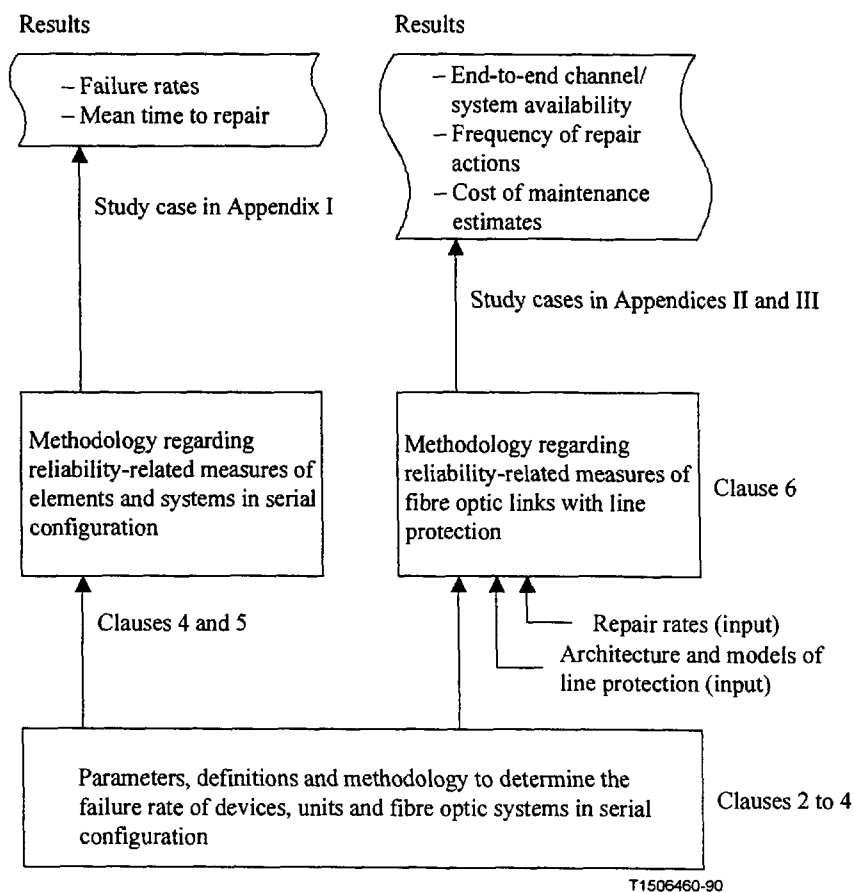
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Recommendation G.911**PARAMETERS AND CALCULATION METHODOLOGIES FOR RELIABILITY
AND AVAILABILITY OF FIBRE OPTIC SYSTEMS***(revised in 1997)***1 Introduction**

This Recommendation provides details of the parameters needed to characterize and the procedures to predict and calculate fibre optic system reliability, including reliability of the devices and availability of channels transmitted through the systems. The emphasis is on single-mode fibre systems (see Figure 1).

**Figure 1/G.911 – How to use Recommendation G.911****2 Parameters related to reliability and availability of fibre optic systems****2.1 Fibre optic system availability and maintenance reliability-related parameters**

This subclause gives the system service parameters and system maintenance parameters. The values may be provided in study cases and are for further study. It is anticipated, however, that different

parameters/values may be required for the various system applications, including point-to-point long/medium distance, local networks, etc. (see Tables 1 and 2).

Table 1/G.911

System service parameter	Units
Mean system availability ^{a)}	Min/yr unavailability
Mean channel availability	Min/yr unavailability per channel
Operation system interface availability	Min/yr unavailability
^{a)} In order to estimate the quantity of spares required.	

Table 2/G.911

System service parameter	Units
System MTBF (such as terminals, repeaters and media)	Years
Plug-in circuit pack MTBF ^{a)}	Years
Frequency of scheduled maintenance actions	Events per year
Random failure rate	Events per year
Infant mortality factor	Dimensionless
MTBF (<i>mean time between failures</i>)	
^{a)} In order to estimate the quantity of spares required.	

2.2 Active optical device reliability parameters

This subclause includes reliability parameters for characterizing active fibre optic devices such as lasers, LEDs and detectors. The values may be provided in study cases and are for further study (see Table 3).

Table 3/G.911

Active optical device reliability parameter	Units
Median Life (ML)	Years
Standard deviation (σ)	
Wear-out failure rate at 10 years (λ_{10})	FITs
Wear-out failure rate at 20 years (λ_{20})	FITs
Wear-out activation energy (E_n)	eV
Random (steady-state) failure rate (λ_r)	FITs
Random failure activation energy (E_n)	eV

2.3 Passive optical device reliability parameters

This subclause includes the necessary reliability parameters for characterizing passive fibre optic devices such as connectors, splices and splitters. Identification of the parameters and their values are for further study (see Table 4).

Table 4/G.911

Passive optical device reliability parameter	Units

2.4 Optical fibre and cable reliability parameters

This subclause includes the necessary reliability parameters for characterizing installed optical fibres and cables. These parameters distinguish extrinsic failure modes and intrinsic failure modes. Extrinsic failure modes, such as cable dig-ups or installation/maintenance errors, dominate the overall reliability. Intrinsic modes, such as fibre fatigue or cable degradation, are typically only a small fraction of total reliability. Clarification of these modes, extrinsic versus intrinsic, in actual cases is under study. Assessment or prediction methods are also under study (see Table 5).

Table 5/G.911

Optical fibre and cable reliability parameter	Units
Extrinsic mode failure rate	FITs/cable-km
Intrinsic mode cable failure rate	FITs/cable-km
Intrinsic mode fibre failure rate	FITs/fibre-km

3 Definitions

This clause includes definitions for the reliability parameters for characterizing fibre optic systems and device reliability.

3.1 item; entity (such as a system or a channel): Any part, device, sub-system, functional unit, equipment or system that can be individually considered.

3.2 constant failure rate period: That possible period in the life of a non-repaired item during which the failure rate is approximately constant.

NOTE – In any particular case it is necessary to explain what is meant "by approximately constant".

3.3 availability performance: The ability of an item to be in a state to perform a required function at a given instant of time or at any instant of time within a given time interval, assuming that the external resources, if required, are provided.

NOTE 1 – This ability depends on the combined aspects of the reliability performance, the maintainability performance and the maintenance support performance of an item.

NOTE 2 – In the definition of the item, the external resources required must be delineated.

NOTE 3 – The term availability is used as an availability performance measure.

3.4 instantaneous availability: The probability that an item is in an up-state at a given instant of time, t .

3.5 mean availability: The normalized integral of the instantaneous availability in a given time interval (t_1, t_2) .

3.6 mean time between failures (MTBF): The expectation of the time between failures.

3.7 early failure period (infant mortality): That possible early period in the life of an item, beginning at a given instant of time and during which the instantaneous failure intensity for a repaired item or the instantaneous failure rate for a non-repaired item decreases rapidly.

NOTE – In any particular case, it is necessary to explain what is meant by "decreases rapidly".

3.8 infant mortality factor (IMF): Ratio of the expected number of failures in a specific early period (e.g. the first year) of service to the expected number of failures in a period of the same length of time in steady-state operation (before wear out).

3.9 median life (ML): With respect to optoelectronic devices, the median life refers to the point, on a lognormal probability plot of device times-to-failure at which 50% of the devices fail earlier and 50% of the devices fail later.

3.10 standard deviation (σ): With respect to optoelectronic devices, the standard deviation refers to the normal mathematical expression for this statistic as calculated from the natural logarithms of the device times-to-failure.

3.11 wear-out failure period: That possible later period in the life of a repaired item during which the instantaneous failure intensity for a repaired item or the instantaneous failure rate for a non-repaired item increases rapidly.

NOTE – In any particular case, it is necessary to explain what is meant by "increases rapidly".

3.12 wear-out failure rate: The wear-out failure rate is a measure of the number of items that fail per unit time due to wear-out mechanisms. It is not calculated directly for optoelectronic devices, but is obtained from the statistical expectation for a lognormal distribution for which the median life and standard deviation have been estimated.

3.13 wear-out failures: A failure whose probability of occurrence increases with the passage of time, as a result of processes inherent in the item.

3.14 activation energy (E_a): The minimum centre-of-mass kinetic energy required before a chemical reaction can occur. Normally expressed in units of electron volts (eV). Used as a part of the early life Arrhenius acceleration factor.

3.15 Arrhenius acceleration factor: An expression detailing the relationship between failure times at two different temperatures.

$$\frac{t_1}{t_2} = e^{\frac{E_0}{k} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)}$$

where:

- $t_{1,2}$ is the time to failure,
- E_0 is the activation energy in electron volts (eV),
- k Boltzman constant, 8.6×10^{-5} eV/K,
- $T_{1,2}$ is the absolute temperature, K.

3.16 random failure rate: The random failure rate is a measure of the number of units that fail per unit time due to a variety of fabrication or (more often) assembly defects not associated with the usual wear-out mechanism(s). A common assumption for optoelectronic devices is that the collection of random failure mechanisms can be roughly modelled by an exponential distribution. In that case, the failure rate is not obtained directly from the data, but is obtained from the (one-sided) statistical expectation for an exponential distribution for a given level of confidence (e.g. a 60% confidence limit).

3.17 maintenance time: The time interval during which a maintenance action is performed on an item either manually or automatically, including technical delays and logistic delays.

3.18 mean time to repair (MTTR): The total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time.

3.19 frequency of maintenance actions: The inverse of the mean time interval between the starts of successive maintenance actions over a given time period (in events per a given period of time).

3.20 FITs (failures in time): Normally expressed as failures per billion device hours.

3.21 steady-state availability: The steady-state availability is the limit of $A(t)$ when t goes to infinity. Being $A(t)$ the probability that the item is operating at a specified time t and is given by:

$$A(t) = \text{Probability } (X(t) = 1)$$

where:

$X(t)$ denotes the state at time t of a system undergoing maintenance. If the system is operating at time t then $X(t) = 1$, if not, then $X(t) = 0$.

4 Steady-state reliability prediction method of devices, units and fibre optic systems in serial configuration

4.1 Purpose and scope

As used here, reliability is a measure of the frequency of equipment failure as a function of time. Reliability has impact on maintenance cost and on the continuity of service. Reliability predictions can be used to assist in deciding which product from a list of competing products should be purchased. As a result, it is essential that reliability predictions from competing products be based on common procedures (see Note 1).

The purpose of this procedure for reliability prediction is to recommend a common procedure for reliability prediction. The method is intended to be applicable to electronic units/systems, in general, and for those units/systems to be used with fibre cables in particular.

This reliability prediction method is based in a failure-rate "parts count" approach (see Note 2).

NOTE 1 – It is important to recognize that failure rates of component parts may be based on standards that may be different from one manufacturer to another (such discrepancies can arise from differences in generic failure rates and other factors related to environment, stress, quality, etc.).

NOTE 2 – Other methods exist for reliability prediction purposes, including:

- statistical estimates based upon combining data from a laboratory test with predictions from the "parts count" method;
- statistical estimates of in-service reliability based upon field tracking studies.

The scope is limited to hardware-related failures under steady-state conditions. The infant mortality factor prediction method is for further study. Complex systems with reliability objectives for individual functions or for various states of reduced service capability are outside the scope of this Recommendation.

4.2 Applications of the predicted failure rate method

It may be used in the following situations.

4.2.1 Equipment manufacturers/suppliers

The method contains instructions for product suppliers to follow when providing predictions of their product's reliability.

The supplier may employ another method (see above) for reliability prediction of devices, units and systems in serial configuration; however, the parts-count is also needed as reference method.

4.2.2 Equipment owners and network operators

It can be used by equipment owners and/or network operators to perform the following tasks:

a) To request and evaluate the reliability of products to be purchased. Reliability predictions provide data for life cycle cost analysis.

b) To measure service-affecting parameters related to the product reliability.

By combining reliability predictions with maintenance parameters (such as mean time to repair), the following service-affecting parameters can be calculated:

- frequency of outages in steady-state;
- frequency of maintenance actions;
- expected value of the downtime per year.

c) To provide a measure of line system reliability as it affects maintenance activity. For example, predictions of the frequency of maintenance and/or repair actions can be obtained.

4.3 Guidelines

4.3.1 Definition of failure

The definition of failures should be made specific. The definition of failure is a critical element in predicting system reliability. For simple equipment the definition of failure is usually clear.

Faults in complex equipment (as could be the case of line system in fibre cables) may distinguish between those affecting maintenance or repair and those affecting service (e.g. "major fault" $BER > 10^{-4}$).

4.3.2 Operating conditions

The physical environment in which the units/systems will be used should be described, including:

- temperature and humidity, and their variations;
- single or redundant line facility;
- commercial power outages;
- EMI, lightning.

4.3.3 Environmental description

Failure rates vary as a function of the intended operating environment. The appropriate environmental failure rate multiplication factor(s) should be specified. If the overall system will be exposed to more than one environment, each factor should be specified as appropriate.

4.3.4 Adjusting the estimates given by this method

Although the method specified here is intended to be the reference one, this does not preclude use of other technically-sound sources of data and/or technically-sound engineering techniques in estimating device, unit or system failure rate. This could include (as mentioned above) device manufacturer's data, unit supplier data, reliability physics considerations and engineering analysis.