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Reliability requirements for telecommunication systems affected by particle radiation

Recommendation ITU-T K.139

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Reliability requirements for telecommunication systems affected by particle radiation

Summary

Recommendation ITU-T K.139 describes the reliability requirements for telecommunication equipment in relation to the soft errors that are caused by particle radiation. The principles for determination of reliability requirements are described and three types of reliability requirements (alert function reliability, service reliability and maintenance reliability) are defined. Three reliability classes for each type of requirement are defined based on the acceptable soft error failure rate. Specific values are determined for each type and class of reliability requirement.

History

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Introduction

Highly integrated and miniaturized semiconductor devices are indispensable for the telecommunication equipment that makes up carrier telecommunications networks which have large capacity, high functionality, and high reliability. However, preventing the occurrence of soft errors in these semiconductor devices is not possible at an acceptable cost. Accordingly, it is necessary to implement soft error measures to ensure reliability by reducing the influence of soft errors at the time when devices and equipment are designed. This Recommendation describes the reliability requirements needed to provide the level of soft error measures to be applied to telecommunication equipment constituting carrier networks.

As soft error failures occur due to factors different from conventional physical fault failures, the number of failures caused by soft errors is added to those caused by physical faults when estimating equipment reliability. A soft error failure can be rectified by applying the automatic recovery measures described in [ITU-T K.131] and the operation can be restarted after the recovery. Reliability requirements to limit the influence of soft errors on services and the maintenance of networks are specified based on the reliability requirements for physical fault failures.

Recommendation ITU-T K.139

Reliability requirements for telecommunication systems affected by particle radiation

1 Scope

This Recommendation provides the reliability requirements for soft errors that occur in telecommunication equipment installed at telecommunications centres for carrier networks, including core network equipment (link and node equipment) and access network equipment. The classifications and specified values are defined for each type of reliability requirement defined in [ITU-T K.131]. This Recommendation provides a method to determine a required reliability class by taking into account the services to be provided as well as the number of installed equipment units in a study of specifications. Mitigation measures should be implemented to meet the requirements for the selected reliability class in order to satisfy the specified reliability for the selected class.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.124] Recommendation ITU-T K.124 (2022), *Overview of particle radiation effects on telecommunication systems*.

[ITU-T K.130] Recommendation ITU-T K.130 (2022), *Neutron irradiation test methods for telecommunication equipment*.

[ITU-T K.131] Recommendation ITU-T K.131 (2022), *Design methodologies for telecommunication systems applying soft error measures*.

[ITU-T K.138] Recommendation ITU-T K.138 (2022), *Quality estimation methods and application guidelines for mitigation measures based on particle radiation tests*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 alert function reliability (AR): Reliability of equipment operation.

3.2.2 carrier [ITU-T Y.3014]: Infrastructure provider that owns the physical network resources and provides a network as a service over these resources to its customers. A virtual network provider is a customer of the carrier.

NOTE – Definition adapted from [b-ITU-T Y.3014].

3.2.3 circuit pack: A circuit board that is inserted in a unit and easily changed by maintenance personnel.

3.2.4 failure in time (FIT): The unit that indicates the number of failures that can be expected in one billion (10^9) hours of operation.

3.2.5 maintenance reliability (MR): Reliability of equipment maintenance.

3.2.6 no-silent-failure-period: Equivalent period in natural environment evaluated from the total irradiation time in an irradiation test during which no silent failure caused by a soft error was observed.

3.2.7 physical fault failure: Hardware failures caused by physical fault.

3.2.8 service reliability (SR): Reliability of service provision.

3.2.9 silent failure: A failure where no alert is issued to network operation equipment or maintenance personnel even though there is an effect on the client signal.

3.2.10 soft error: A phenomenon in which one or more bits within the data on the device have their values reversed. A soft error does not constitute damage to the actual device.

3.2.11 soft error failure: Failure in equipment caused by a soft error in devices.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AR Alert function Reliability

CL Confidence Level

FIT Failure in Time

MR Maintenance Reliability

SR Service Reliability

SR(M) Service Reliability in relation to momentary interruption

SR(P) Service Reliability in relation to prolonged interruption

5 Conventions

None.

6 Principles to determine reliability requirements

Figure 6-1 shows the procedures for recovering from physical fault failures and soft error failures when the measures described in [ITU-T K.131] are correctly applied.

The procedures are the same for both physical fault failures and soft error failures, except that maintenance personnel always need to work to restore services after physical fault failures, whereas maintenance personnel are rarely required to fix soft error failures if adequate countermeasures have been previously incorporated into the equipment.

To specify the reliability requirements related to soft error failures, the failures are classified into three types based on the following criteria:

1) whether it is possible to detect a failure and issue an alarm correctly,
2) whether the service can be restored within an acceptable time frame and the client signal can be handled properly, and
3) whether all the equipment can be restored automatically.

As soft error failures occur independently from physical fault failures due to their having different causes, the number of soft error failures is added to physical fault failures when estimating equipment reliability. Equipment can automatically recover from soft error failures by implementing measures such as error data correction and reinitialization, meaning that the equipment can then be used without degradation of performance after the recovery. Based on the above characteristics, reliability requirements are specified so that the impact on services and maintenance due to soft error failures is negligible compared to physical fault failures.

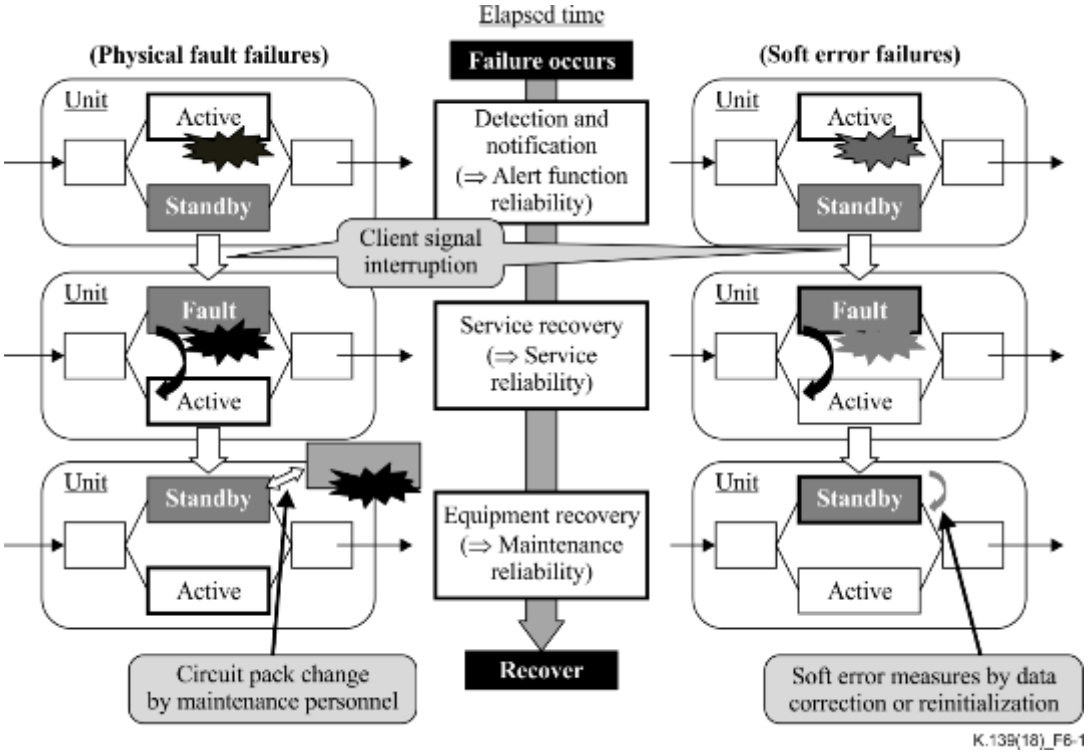

Figure 6-1 – Recovery procedures following failures and their impacts

7 Types of reliability requirements

Table 7-1 shows the types of reliability requirements and their definitions for telecommunication equipment for the impacts shown in Figure 6-1. The following three types of reliability requirements are defined in this Recommendation:

1) the alert function reliability (AR) requirement relating to equipment operation,
2) the service reliability (SR) requirement relating to service provision, and
3) the maintenance reliability (MR) requirement relating to equipment maintenance.

Table 7-1 – Types of reliability requirements

Type	Abbreviation	Details
Alert function reliability requirements	AR	Requirements relating to equipment operation. Requirements are classified based on performance of failure detection and the issuing an alert when a failure that impacts the client signals caused by a soft error occurs.
Service reliability requirements	SR	Requirements relating to service provision. Requirements are classified based on both the period and frequency of occurrences of a continuous interruption of client signals resulting from a soft error.
Maintenance reliability requirements	MR	Requirements relating to equipment maintenance. Requirements are classified based on the frequency of maintenance where maintenance personnel are required to carry out remote operation or on-site replacement of circuit packs to restore equipment after a soft error failure.

8 Classification of reliability requirements

Depending on the scale and the services provided by the target carrier network, the required reliability for equipment differs depending on the equipment in question. Three classes of reliability level, classes X, A and B, are defined for each type of reliability requirement in order to appropriately select the requirement for equipment that is both sufficient and economically viable to ensure reliability specific to the usage of equipment. The criteria when selecting a class are shown in Table 8-1. Class A indicates the level of reliability applicable to typical equipment installed in a network operated by a carrier. Class X is a high-quality class. High-quality requirements differ among carriers. As an exceptional case, the class X value shall be decided by negotiation between the carrier and the manufacturer. Class B is a low-quality class. It is a class that allows freedom of choice in terms of quality requirements depending on the size of the carrier network and service and operational conditions.

Table 8-1 – Criteria for selection of reliability class

Reliability class	Criteria for selection
X	Applies to equipment which is installed in networks for which particularly high operational reliability is required in relation to the operational conditions such as type of service and number of equipment units to be installed.
A	Applies to equipment for which a standard level of reliability is required in a carrier network
B	Applies to equipment installed in carrier networks for which a lower level of reliability is acceptable in relation to service and operational conditions. This class is defined as having a reliability requirement 1/5 of that of class A.

9 Reliability requirements

This clause describes each type of requirement in detail. Requirement values are specified for each piece of equipment comprising carrier networks. The target equipment is defined in terms of the typical configuration representing the installation configuration in a carrier network as shown in [ITU-T K.138] in order to estimate reliability as a carrier network. The values of requirements are determined based on the neutron flux at sea level in New York.

9.1 Requirements for the alert function reliability

The requirements for the alert function reliability (AR) are specified as the equivalent period in the natural environment determined from the total irradiation time in an irradiation test during which no silent failure caused by a soft error was observed. The period is referred to as "no-silent-failure-period" in this Recommendation. Figure 9-1 shows a conceptual diagram of alert function reliability and Table 9-1 shows the requirements. The longer the no-silent-failure-period is, the greater the confidence can be that a silent failure caused by soft error will not occur.

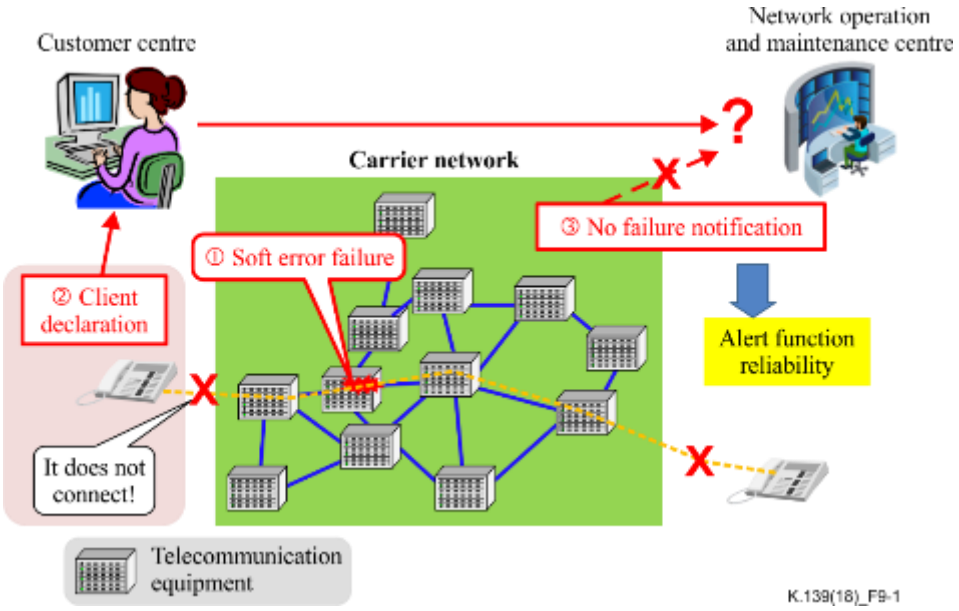

Figure 9-1 – Conceptual diagram of alert function reliability

Table 9-1 – Alert function reliability (AR) requirements

AR class	No-silent-failure-period evaluated from the test (years/equipment) (Note)
X	< (Period is determined by negotiation between carrier and manufacturer)
A	> 10,000
B	> 2,000
NOTE – Except for events caused by dual failure during an evaluation test (refer to [ITU-T K.138]).	

As defined in clause 9.7 of [ITU-T K.131], a silent failure is a failure that is not reported to the operation system of the carrier network or maintenance personnel even though the failure causes a non-negligible impact on the client signal (see Figure 9-1). There may be a report from the client before the maintenance personnel become aware of the failure. The equipment is basically designed to prevent a silent failure from occurring, but it is difficult to guarantee it. A silent failure shall not occur in a carrier network requiring high reliability. It has a severe impact on service and maintenance quality because the occurrence of a failure is not noticed and equipment with the abnormality cannot be identified so that it takes time to restore. Considering the above and a realistic test period, the no-silent-failure-period is specified as more than 10,000 years and 2,000 years for class A and class B respectively.

9.2 Service reliability requirements

The main service performed by telecommunication equipment is transmission of the client signal. The service reliability (SR) requirements are defined in relation to the occurrence frequency and

duration of client signal interruptions caused by soft errors in the entire network. Figure 9-2 shows a conceptual diagram of service reliability and Table 9-2 shows the requirements.

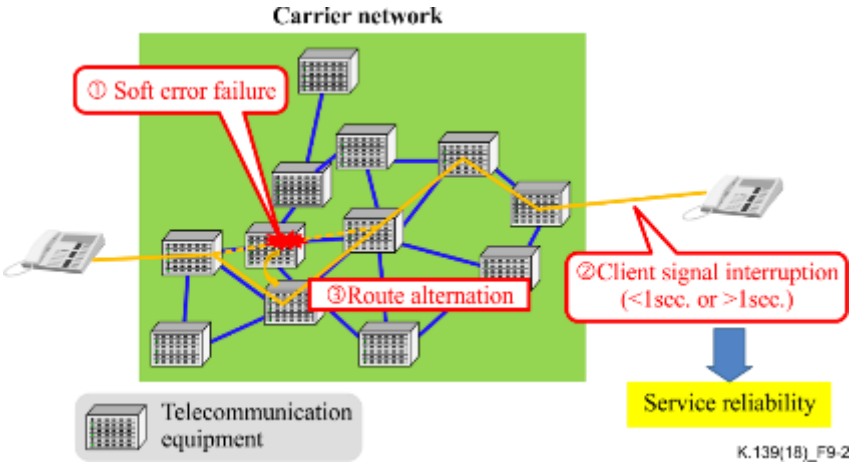

Figure 9-2 – Conceptual diagram of service reliability

Table 9-2 – Service reliability (SR) requirements

SR class	Failure occurrence rate (Both SR(M) and SR(P) shall conform, FIT/equipment) (Note 1)	
	SR(M): SR regarding momentary interruption (interruption to client signal of 0.2 to 1.0 s) (Note 2)	SR(P): SR regarding prolonged interruption (interruption to client signal for longer than 1.0 s)
X	< (FIT number is determined by negotiation between carrier and manufacturer)	
A	< 2,000 FIT	< 200 FIT
B	< 10,000 FIT	< 1,000 FIT
NOTE 1 – Except for events caused by dual failure during an evaluation test (refer to [ITU-T K.138]). NOTE2 – The switching period is the failure detection protection duration (1 second) plus processing duration (50 milliseconds or less) in the SDH interface specification. The switching period is treated in SR(M).		

The number of failures caused by soft errors affecting the client signal is estimated considering the actual failures of the hardware that comprises the equipment. From the viewpoint of reducing the impact on service quality, the service reliability requirements are specified as follows.

The effect of the applied measures such as redundant configuration in the equipment or network illustrated in Figure 9-2 should be taken into account when estimating the service interruption period. The details of the redundant configuration are provided in clause 6.3.2 of [ITU-T K.131].

1) A client signal interruption of 0.2 second or less is not subject to SR since an interruption of this duration would not normally affect services.

2) SR regarding momentary interruption of client signal longer than 0.2 second and shorter or equal to 1.0 second is referred to as SR(M). Considering the following, class A is set as less than 2,000 FIT which is about one fifth of the physical fault failures and class B is less than 10,000 FIT.

   The number of redundant switches impacting the client signal is estimated considering the actual physical fault failures.

   It is possible to reduce the impact of a soft error failure on the client signal to a greater extent than is possible in the case of a physical fault failure because a soft error failure can be rectified automatically.

3) SR regarding prolonged interruption of client signal longer than 1 second is referred to as SR(P). The required value is set at 10% of SR(M) since an interruption of this duration has a severe impact on service quality.

9.3 Maintenance reliability requirements

The maintenance reliability (MR) requirements are defined in relation to the frequency at which maintenance personnel have to carry out work in order to restore equipment from a soft error failure. Figure 9-3 shows a conceptual diagram of maintenance reliability and Table 9-3 shows the requirements.

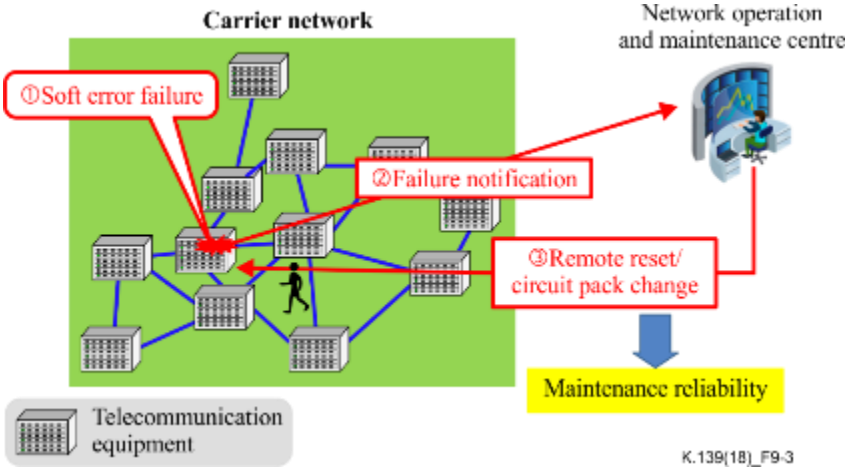

Figure 9-3 – Conceptual diagram of maintenance reliability

Table 9-3 – Maintenance reliability (MR) requirements

MR class	Failure occurrence rate (FIT/equipment) (Note)
X	< (FIT number is determined by negotiation between carrier and manufacturer)
A	< 2,000 FIT
B	< 10,000FIT
NOTE – Except for events caused by dual failure during an evaluation test (refer to [ITU-T K.131]).	

Maintenance reliability requirements cover both "remote maintenance" and "on-site maintenance" regardless of whether or not the client signal is affected. The requirements are specified by the occurrence rates as indicated by the FIT values.

The required values are specified as follows.

1) A soft error is not a physical fault and continued usage of the hardware is possible if the error is successfully rectified. Accordingly, if equipment is restored from the error state automatically by the equipment itself and intervention by the maintenance personnel is not required, the error is not counted in MR estimation.

2) The existing maintenance system including human resources is organized based on the time required to carry out maintenance operations mainly for physical fault failures in equipment. To prevent an obvious impact on the existing maintenance system, the maintenance reliability requirements are specified as follows based on the actual failure rate of the equipment. The actual number of physical fault failures in a month is less than 0.5% to 1.0% of the number of operating equipment units in a network. To make the impact of soft error invisible, the occurrence rate of soft error failures requiring the intervention of maintenance personnel for recovery (refer to Figure 9-3) in class A is specified to be less

than 2,000 FIT which is about one fifth of the physical fault failures. That in class B is set to be less than 10,000 FIT.

3) Maintenance is classified into "remote maintenance", carried out by remote control from a maintenance centre, and "on-site maintenance", where the maintenance personnel have to go to the site where the failure occurred. The on-site maintenance for soft error failures should be decreased as much as possible. Remote maintenance should be basically applied to soft error failures that can be rectified without having to change the hardware such as circuit packs.

Appendix I

Relationship between each reliability requirement and occurrence frequency of soft error failures

(This appendix does not form an integral part of this Recommendation.)

This appendix provides information about actual reliability and the occurrence frequency of soft error failures when the requirements in this Recommendation are conformed to.

I.1 Alert function reliability requirement

The AR is defined by the no-silent-failure-period as described in clause 9.1. The range of the silent failure occurrence rate can be estimated from the no-silent-failure-period and the required statistical confidence level (CL). The CL indicates the level of confidence that the reliability lies within the estimated range (confidence interval). The upper value of the confidence interval of the silent failure occurrence rate versus CL is shown in Figure I.1. The larger the required confidence level, the higher the upper value of the silent failure occurrence rate for class A and B requirements, as shown in Figure I.1.

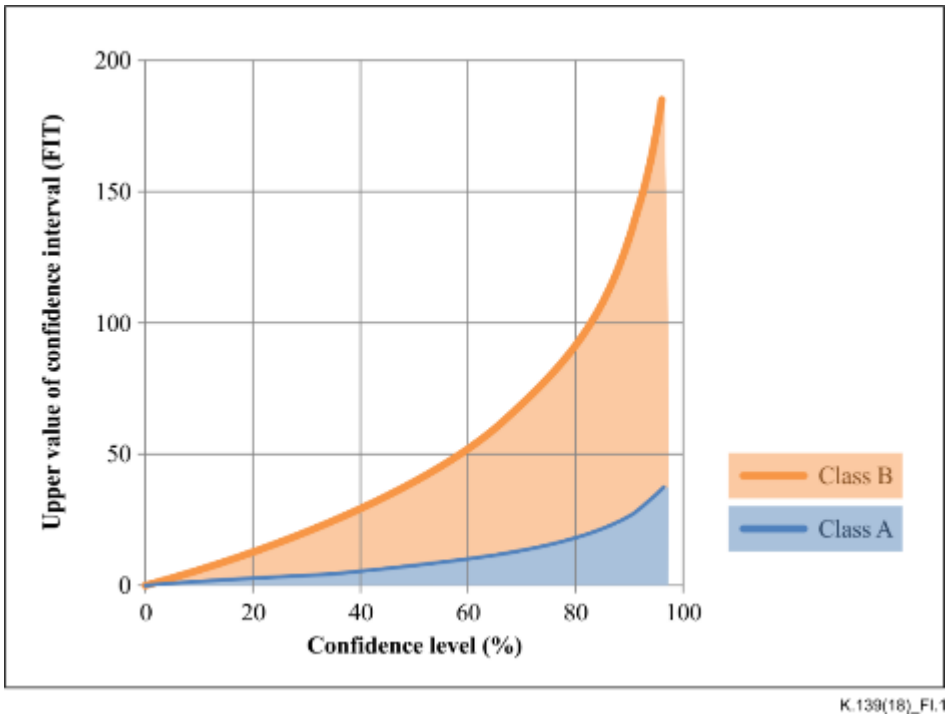

Figure I.1 – Upper value of confidence interval versus confidence level for AR

I.2 Service reliability requirement

The number of operating equipment units in a target network versus the expected occurrence frequency of the interruption of the client signal is shown in Figures I.2 and I.3. For example, momentary and prolonged signal interruptions occur less than 1.5 times a month and less than 1.8 times a year respectively in a network composed of 1000 equipment units satisfying class A of SR(M) and SR(P).

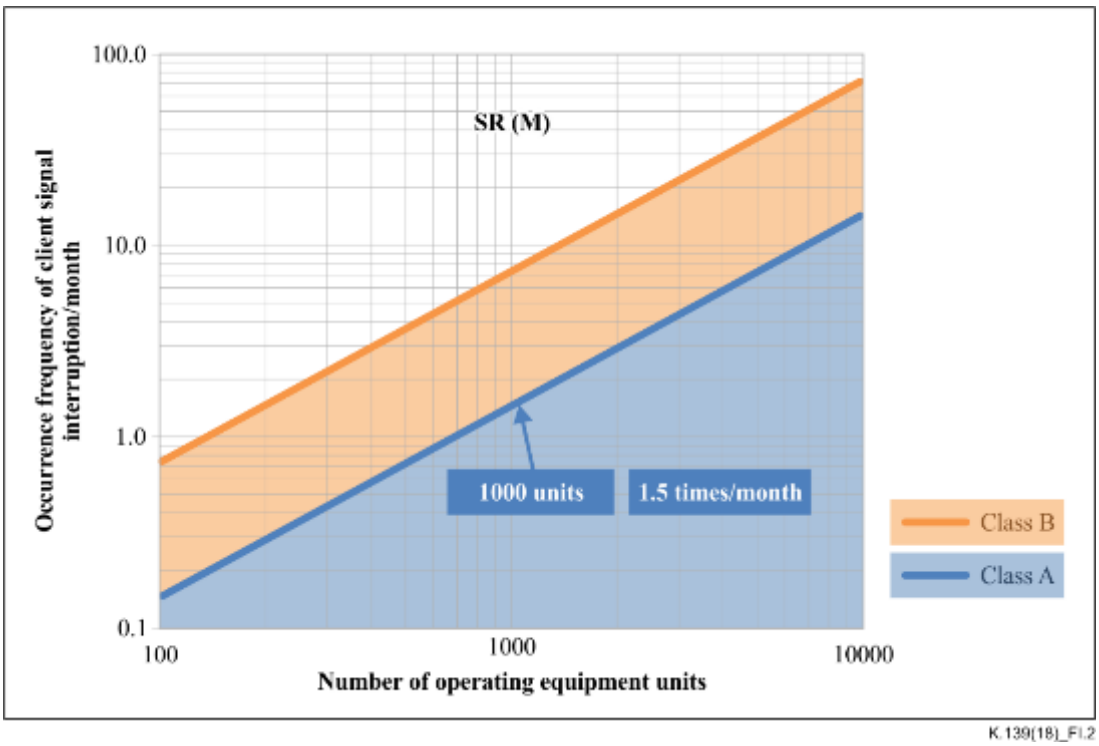

Figure I.2 – Expected occurrence frequency of momentary interruption of signal for SR(M)

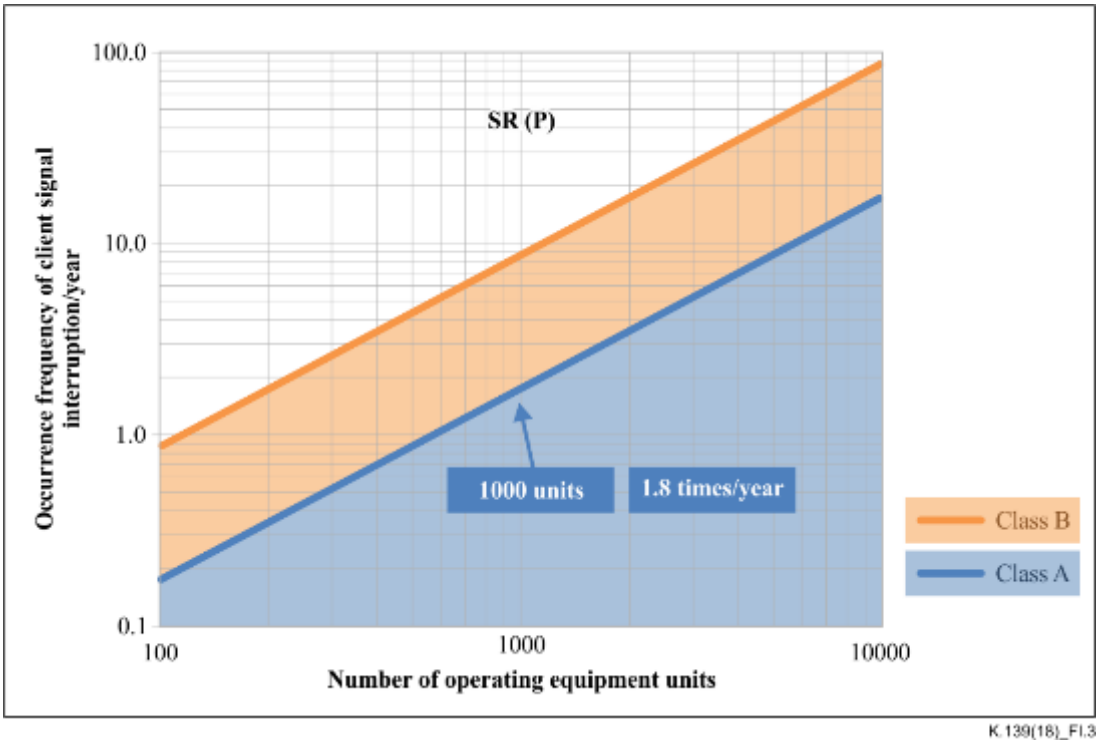

Figure I.3 – Expected occurrence frequency of prolonged interruption of signal for SR(P)

I.3 Maintenance reliability requirement

The number of operating equipment units in a target network versus the occurrence frequency of maintenance work is shown in Figure I.4. For example, the frequency at which maintenance

personnel have to work in order to restore equipment from a soft error failure is less than 1.5 times a month in a network composed of 1000 equipment units satisfying class A.

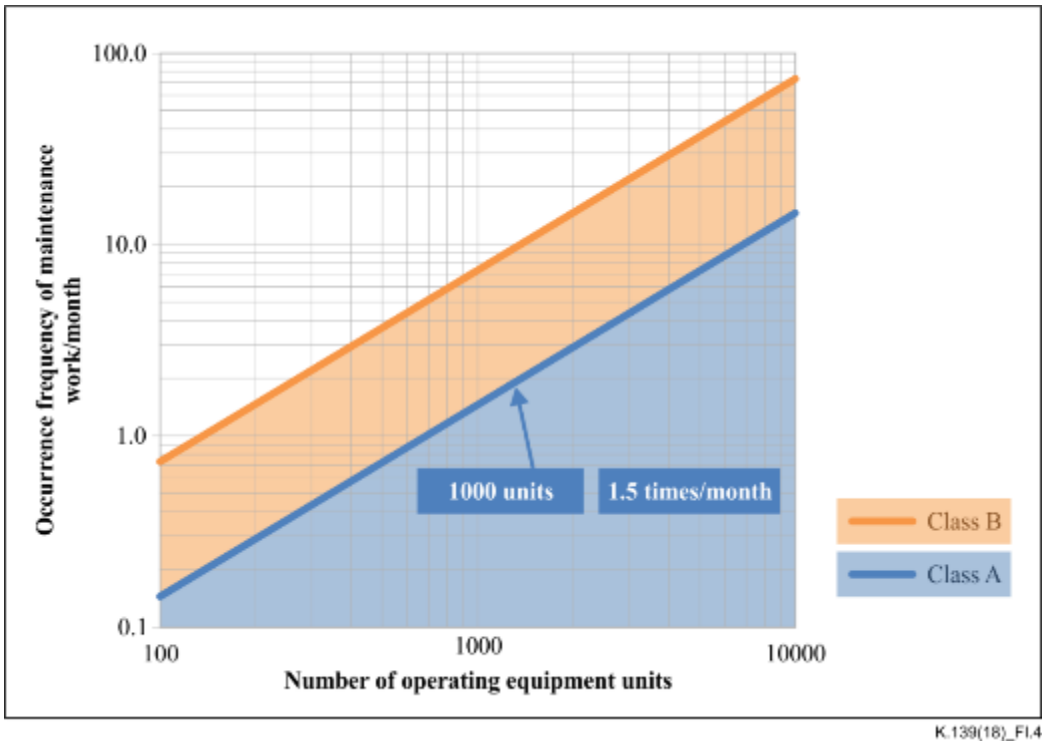

Figure I.4 – Expected frequency of maintenance work for two classes of MR

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[b-ITU-T Y.3014] Recommendation ITU-T Y.3014 (2016), *Resource control and management function for virtual networks for carriers (vRCMF).*

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