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Guidance on optical fibre and cable reliability

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Supplement 59 to ITU-T G-series Recommendations

Guidance on optical fibre and cable reliability

Summary

Supplement 59 to ITU-T G-series Recommendations provides guidance regarding the long term reliability of cabled optical fibres. This Supplement uses currently accepted models combined with current experience to describe items that can impact the performance of an optical fibre over time. The document describes "optical reliability" for fibres, "mechanical reliability" for fibres and describes how optical cables impact these properties.

History

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Introduction

Supplement 59 to the ITU-T G-series Recommendations provides information on long-term reliability of optical fibre and cable. ITU-T establishes optical fibre and cable Recommendations such as [ITU-T G.651.1], [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656], and [ITU-T G.657]. Also, ITU-T standardized optical cables as described in some of the L series Recommendations. This Supplement also provides more detail on optical fibres reliability described in [ITU-T G-Sup.40].

Supplement 59 to ITU-T G-series Recommendations

Guidance on optical fibre and cable reliability

1 Scope

The scope of this Supplement is to give the end user guidance on the long-term performance of optical fibre and cables. Though it is difficult to address all situations and to guarantee long-term performances, this supplement helps understand general long-term behaviour of optical fibres and cables and provides guidelines to help the end users minimize the number of mechanical and optical failures during the expected lifetime of the fibre and cable.

2 References

- [ITU-T G.651.1] Recommendation ITU-T G.651.1 (2007), *Characteristics of a 50/125 μm multimode graded index optical fibre cable for the optical access network.*
- [ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable.*
- [ITU-T G.653] Recommendation ITU-T G.653 (2010), *Characteristics of a dispersion-shifted, single-mode optical fibre and cable.*
- [ITU-T G.654] Recommendation ITU-T G.654 (2016), *Characteristics of a cut-off shifted single-mode optical fibre and cable.*
- [ITU-T G.655] Recommendation ITU-T G.655 (2009), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable.*
- [ITU-T G.656] Recommendation ITU-T G.656 (2010), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport.*
- [ITU-T G.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network.*
- [ITU-T G-Sup.40] Supplement ITU-T G.Sup40 (2010), *Optical fibre and cable Recommendations and standards guideline.*
- [ITU-T L.126] Recommendation ITU-T L.126/L.27 (1996), *Method for estimating the concentration of hydrogen in optical fibre cables.*

3 Definitions

None.

4 Abbreviations and acronyms

None.

5 Conventions

None.

6 General comments on reliability

Optical cables were first deployed commercially in 1977. Thus, our knowledge of their performance in the field is less than 40 years and much information provided in this Supplement is speculative, although today significant spontaneous fibre breakage in these old fibres is not known. Detailed

analysis of attenuation characteristics and mechanical attributes for cabled fibre that have been installed for 25 years [b-Hopland 1] [b-Hopland 2] indicate that the optical properties are very stable over time. With this background we can use our accumulated field knowledge combined with accelerated aging to estimate the reliability of optical cables.

Reliability falls into two major categories:

- Mechanical reliability (will the fibre break over the cable lifetime)
- Optical reliability (will optical transmission be maintained over the cable lifetime)

It is hard to separate optical fibre reliability from optical cable reliability as the two are intimately related, but in this Supplement we will focus primarily on the fibre attributes and how they relate to cabled optical fibre.

General trends in optical transmission must be considered in our evaluation of optical reliability. The general trend is towards more information traveling down optical fibres. Optical cables are trending toward higher fibre counts in smaller optical cables resulting in the potential for more residual strain on the individual optical fibres. There is a trend towards the use of more of the optical spectrum and thus a desire to preserve the attenuation across the full spectrum from 1260 to 1625 nm to allow the most opportunities for bandwidth upgrades.

In general, the reliability of an optical cable during the course of its deployment is strongly impacted by the attention paid to the reliability during the phases of work carried out before the cable is put into service.

These phases can be described as follows:

i) Manufactory of the optical fibres (fibre drawing and primary protection, storage)

The manufacturing phase of the fibres is critical from the point of view of reliability of the optical cable during the commercial operation. In this phase it is recommended that tests be carried out to ensure that optical and mechanical degradations will not adversely impact system performance during the lifetime of the cable deployment and storage.

ii) Design of the optical cable structure

The structural characteristics of the optical cables (fibre protection, strength member, filling materials, protections sheaths, armour, etc.) should be chosen so they will comply with the limits stated in *i)* for stress and for minimum bending radius, during all the next phases.

Important inputs for the definition of these characteristics are the foreseen installation method and mechanical stress (cable directly put underground, laid in ducts, laid on external poles, etc.) and, possibly, also an indication of the path that the cable will follow.

Finally, the choice of the characteristics of the cable should also be compliant, without degradation of the characteristics of the fibres, with the maximum temperature or humidity excursions that the cable has to face during the lifetime.

iii) Insertion of the fibres in the optical cable (cabling)

The cabling of the optical fibres should comply with all conditions set out in points *i)* and *ii)*

iv) Design of the infrastructure for the cable laying

The infrastructure for the cable laying installation should be designed and implemented in order to preserve as much as possible the cable, from external damages different from those indicated in point *i)*.

v) Laying operations

Even in this phase, attention should be placed on maximum stress and minimum bending radius of the fibres in order to respect the limits mentioned in point *i)*.

vi) *Life of the deployed optical cable*

The cable faults during the lifetime of the deployed optical cables can be divided into two categories: internal faults and external faults.

The internal faults (fibre breakage, increase of attenuation, etc.) are those related to the quality of the optical fibres. With the adoption of the reliability objectives pointed out in *i)* and *ii)* these internal faults should be kept to a minimum or not present at all.

External faults are those caused by external elements (excavations for other services, floods, landslides, etc.). The number of this type of faults mainly depends on the quality of the protections used in the laying of the cable (depth of the excavation, dimensioning of the infrastructure of overhead lines, etc.). External faults are outside the scope of this Supplement.

The main purpose of this Supplement is limited to the study of the reliability objectives quoted in point i), i.e., the following:

- illustrate the processes by which the quality of the fibres degrades from the point of view of mechanical strength and from that of the increase in attenuation;
- list the test methods to check these degradations;
- give the quality objectives currently adopted during the manufacturing process of the fibres.

It should be clearly pointed out that in this framework the reliability objectives during the commercial life of optical cables, and the input for defining those to be considered during the production of the fibres (point *i)*) are not specified in ITU-T. Examples of the main factors that have an impact on the choice of the reliability objectives to be considered during the commercial life of the optical cables are outlined in Appendix II.

However, the more than thirty years of satisfactory operating experience on optical cables and their wide deployment in all parts of the telecommunications networks (from the access network to intercontinental deployment) is a guarantee that the reliability objectives currently adopted in ITU-T for the production of optical fibres described in clauses 7 and 8 are suitable to ensure a very high reliability with respect to internal faults in all operating conditions.

7 **Optical reliability**

In the 30 years of commercial optical cable deployment, several mechanisms have been identified that deteriorate the optical performance of glass fibres. These mechanisms can be considered as starting points in identifying processes that need to be accounted for to assure the optical performances of manufactured and cabled fibres prescribed in ITU-T G.65x series Recommendations. This clause focuses on three known mechanisms that have an impact on optical reliability:

- Bending loss (microbending and macrobending)
- Chemical attacks (hydrogen being the most common contributor)
- Radiation sensitivity

Many of the tests performed on optical fibre and cable found in IEC and ITU-T documents were developed to help assure long term reliability of optical cables. All the tests focused on optical reliability and monitored the fibre or cabled attenuation during the course of the test to see if any change occurs. If the change is under the recommended threshold the optical cable is expected to operate in the field for a reasonable period of time (typically 20-30 years) without significant degradation in the transmission properties.

7.1 **Bending loss**

Bending loss falls into two types, macrobend loss and microbend loss. In the simplest terms macrobends are visible bends on the scale of several millimetres in radius and microbends are very