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Transmission media and optical systems characteristics –
Optical fibre cables

Test methods for installed single-mode optical fibre cable links

Recommendation ITU-T G.650.3

ITU-T

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Recommendation ITU-T G.650.3

Test methods for installed single-mode optical fibre cable links

Summary

Recommendation ITU-T G.650.3 outlines the tests normally carried out on installed single-mode optical fibre cable links. It includes a collection of references to the main measurement methods and gives an indication of which are most suitable for installed cable links, depending on the required inspection level. Optical fibre cable links are comprised of multiple cable sections, splices and other connections. This term is more completely defined in this Recommendation.

This Recommendation uses a tiered approach. The first level indicates measurements that are normally carried out to commission new optical fibre cable links. The second level indicates measurements that may be carried out to satisfy service level agreements (e.g., when a dark fibre contract is signed) or to verify attributes of older links that may be used at higher bit rates or over extended wavelength ranges.

Recommendation ITU-T G.650.3 (2017) introduces the provision of information of splice loss measurement based on the quasi-bidirectional technique in Appendix IV. The method for differentiating splice loss and macrobending loss in installed links, which was issued as Amendment 1 to ITU-T G.650.3 (2008), is also included as Appendix III.

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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.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Recommendation ITU-T G.650.3

Test methods for installed single-mode optical fibre cable links

1 Scope

This Recommendation describes test methods that are particularly suited to the characterization of single-mode optical fibre cable links. The methods are not intended for application to links that contain optical network elements, amplifiers, dispersion compensators, passive splitters or combiners. Measurements associated with these devices in combination with optical fibre cable are defined in ITU-T G.66x or ITU-T G.67x series Recommendations. These measurements of the cable links between such devices and the calculation methods for combining the results of concatenated cable links are also presented.

This Recommendation uses a tiered approach. The first level indicates measurements that are normally carried out to commission new optical fibre cable links. The second level indicates measurements that may be carried out to satisfy service level agreements (e.g., when a dark fibre contract is signed) or to verify attributes of older links that may be used at higher bit rates or over extended wavelength ranges.

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 G.650.1] Recommendation ITU-T G.650.1 (2010), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable.*
- [ITU-T G.650.2] Recommendation ITU-T G.650.2 (2015), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable.*
- [ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a 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.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable.*
- [ITU-T G.671] Recommendation ITU-T G.671 (2012), *Transmission characteristics of optical components and subsystems.*
- [ITU-T G.957] Recommendation ITU-T G.957 (2006), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*
- [IEC 60793-1-40] IEC 60793-1-402001, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation.*
- [IEC 61280-4-2] IEC 61280-4-2:2014, *Fibre-optic communication subsystem test procedures – Part 4-2: Installed cable plant – Single-mode attenuation and optical return loss measurement.*

- [IEC 61280-4-4] IEC 61280-4-4:2017, *Fibre optic communication subsystem test procedures – Part 4-4: Cable plants and links – Polarization mode dispersion measurement for installed links.*
- [IEC 61281-1] IEC 61281-1 (1999), *Fibre optic communication subsystems – Part 1: Generic specification.*
- [IEC/TR 61282-7] IEC/TR 61282-7:2003, *Fibre optic communication system design guides – Part 7: Statistical calculation of chromatic dispersion.*
- [IEC/TR 61282-9] IEC/TR 61282-9:2016, *Fibre optic communication system design guides – Part 9: Guidance on polarization mode dispersion measurements and theory.*
- [IEC 61300-3-6] IEC 61300-3-6:2008, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss.*
- [IEC 61300-3-35] IEC 61300-3-35:2015, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-35: Examinations and measurements – Visual inspection of fibre optic connectors and fibre-stub transceivers.*
- [IEC/TR 61931] IEC/TR 61931 (1998), *Fibre optic – Terminology.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

- 3.1.1 differential group delay (DGD):** [ITU-T G.650.2]
- 3.1.2 fibre optic cable plant (FOCP):** [IEC 61281-1]
- 3.1.3 fusion splice:** [IEC/TR 61931]
- 3.1.4 mechanical splice:** [IEC/TR 61931]
- 3.1.5 connector, fibre optic:** [IEC 61281-1]
- 3.1.6 optical device:** [IEC 61281-1]
- 3.1.7 optical return loss (ORL):** [IEC 61281-1]
- 3.1.8 [optical (fibre)] splice:** [IEC/TR 61931]
- 3.1.9 polarization mode dispersion (PMD):** [ITU-T G.650.2]
- 3.1.10 reflectance:** [ITU-T G.671]

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 attenuation of an optical fibre cable link: The summation of the attenuations of fibre cable sections, splices between cable sections and connections between, and at the end of, cable sections. The definition of attenuation is given in [ITU-T G.650.1]. Some examples of link attenuation measurement results are found in [b-ITU-T G-Sup.39].

3.2.2 chromatic dispersion of an optical fibre cable link: The summation of the chromatic dispersions of the individual cables that comprise the link at the wavelengths of interest. See [b-ITU-T G-Sup.39] for more information on how the dispersion from different cable sections is summed.

3.2.3 fibre characterization: A comprehensive suite of measurements that is carried out on an optical fibre cable link to determine the key performance attributes of that link that may affect current or future applications that operate over the link. Fibre characterization also allows the quality of the optical fibre cable link to be assessed, including the identification of the type and grade of fibre installed. Full fibre characterization includes connector end face inspection, insertion loss measurements, return loss measurements, optical time domain reflectometer (OTDR) testing, chromatic dispersion testing, polarization mode dispersion measurement and spectral attenuation.

3.2.4 single-mode optical fibre cable link: A collection of passive fibre optic components that together form a continuous optical fibre pathway between two end points. The end points will typically be patch panels or optical distribution frames where the fibres are terminated with connectors. The link will typically be comprised of many optical fibre cable sections, jointed end to end. A complex link may contain additional connectors at intermediate patch panels and therefore be made up of two or more concatenated simple links.

3.2.5 uniformity of fibre link: The longitudinal variation in the attenuation coefficient or chromatic dispersion coefficient along that link.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BOTDA	Brillouin Time Domain Analysis
CD	Chromatic Dispersion
CWDM	Coarse Wavelength Division Multiplexing
DFB	Distributed Feedback
DGD	Differential Group Delay
DWDM	Dense Wavelength Division Multiplexing
LSPM	Light Source and Power Meter
MFD	Mode Field Diameter
OCWR	Optical Continuous-Wave Reflectometer
ORL	Optical Return Loss
OTDR	Optical Time Domain Reflectometer
PMD	Polarization Mode Dispersion

5 Conventions

None.

6 Test methods

6.1 Test methods for characteristics of optical fibre cable links following installation

The purpose of testing an optical fibre cable link following installation is primarily concerned with proving that the components used (fibres, connectors, etc.) meet their specifications and that the installation has been carried out to a good standard of workmanship (e.g., splice losses meet their specification and the cable link is free from damage).

Primarily, it is the attenuation characteristics of the optical fibre cable link that are commonly tested as part of commissioning a new installation, as these are the characteristics that may be most affected by the installation process and the quality of installation workmanship.



The criteria for newly installed optical fibre links are defined by the operating company. As an example, for attenuation, these criteria may apply not only to the overall link attenuation, but also to the individual cable sections and fibres, the individual splice and connector losses, and other uniformity characteristics. One approach to defining the overall attenuation limit is to consider the attenuation coefficient and length of the individual cable sections, the number of splices or connectors and their maximum allowed losses, and combine the values according to the formulas of Appendix I of [ITU-T G.652].

See clause 6.2 for additional testing that may be required for service contract requirements or for higher (10 Gbit/s per channel and above) transmission rates, or for transmission over extended wavelength ranges. [b-ITU-T G-Sup.40] is a guide on the relationship and definition of various attributes and measurement methods found in ITU-T documents and the mapping to IEC documents.

6.1.1 Connector end face inspection

Before testing commences, it is recommended that the end face of the connectors at each end of the link be inspected to ensure that they are clean and free from any damage. If there is any dirt present, then the connector end face should be cleaned (according to the connector manufacturer's instructions) in order to obtain reliable test results and satisfactory long-term performance. Following cleaning procedures, the best practice is to re-inspect to ensure cleaning effectiveness.

Video inspection probes may be used to carry out this inspection safely with no risk to eyesight from energized fibres. They also permit the inspection of the end faces of connectors installed behind patch panels without risk of damage or interruption of traffic on other fibres.

End face images may be stored and analysed if required. [IEC 61300-3-35] provides acceptance criteria for levels of damage and defects that may be tolerated without adverse effect on optical performance.

6.1.2 Link attenuation

The link attenuation is very important for all applications regardless of data rate. It is usual to measure the overall link attenuation at wavelengths that are representative of the wavelengths at which the link will be operated. Commonly, this measurement is carried out at 1 310 nm and 1 550 nm, although, if applications using the L-band (1 565 nm to 1 625 nm) are to be used, then testing at 1 625 nm is also recommended (see [b-ITU-T L.313/L.66] on wavelength allocation for maintenance). The recommended technique is to use a light source and power meter (LSPM) method as detailed in [IEC 61280-4-2] to compare the power level injected at one end of the link with the power level received at the other end of the link. The difference between these two power levels is the overall link attenuation measured in decibels. Since this technique operates in the same way as the system operates, it is the preferred technique for determining the total link attenuation. It may be a requirement for this measurement to be carried out in both directions on every fibre in the link, since it is not usually known at this stage which direction each fibre will operate in. Note, however, that the total link attenuation should be similar in both directions when measured using this technique.

While insertion loss is the most fundamental attenuation measurement for links, the OTDR (see clause 6.1.3) is often used either as a bidirectional measurement or as a unidirectional measurement. The use of OTDR can shorten the measurement time, but also has risks. For either case, the OTDR can, for example, miss a broken fibre near the end of the link, unless tail cords are used. It can also allow crossed-over fibres to go undetected. It is well known that bidirectional OTDR measurement is more accurate than unidirectional measurement, but unidirectional measurements are often done as an initial check. When the results of such a check are marginal, follow-up with bidirectional measurement is recommended. See [b-IEC/TR 62316] for more information on the interpretation of backscattering traces.

If a complex link is to be formed by patching together a number of simple links, then the total attenuation of the complex link is obtained by simply adding together the decibel attenuation figures for each simple link.

6.1.3 Splice loss, splice location, fibre uniformity and length of cable sections and links

For these characteristics, the OTDR measurement method is recommended. Dependent upon the measurement configuration, this method may also be used to measure the overall link attenuation. This is described in [IEC 61280-4-2] for measuring the attenuation of installed links or in [ITU-T G.650.1] for fibres and cables. An OTDR is an instrument able to measure the optical power backscattered along a fibre as a function of distance. The detailed measurement technique, test apparatus and measurement procedure are described in [IEC 61280-4-2].

Normally, for commissioning a new cable link, OTDR testing is carried out in both directions on every fibre using at least two wavelengths. These wavelengths should be representative of the wavelengths at which the fibre may operate, e.g., 1 310 nm and 1 550 nm for ITU-T G.652-type fibres and 1 550 nm and 1 625 nm for ITU-T G.655-type fibres.

The OTDR testing should be carried out using a launch lead that is long enough (typically 1 km to 2 km) to allow measurement of the first connector in the link, a similar length tail lead should also be connected at the far end of the fibre under test to allow the loss of the connector at the far end to be measured.

Detailed analysis of these OTDR traces then allows accurate measurement of total link attenuation, total link optical return loss, as well as a full breakdown of component losses along the link including fibre section attenuation, splice losses, connector insertion and return loss. In addition, excessive mismatches between fibres in different cable sections along the route can be identified, as well as any problems, e.g., bends on the fibre. See Appendix I for examples of OTDR traces and their analysis.

If the OTDR is only used for length measurements or for overall attenuation checking of the cable link using a launch lead and a tail lead, then unidirectional OTDR test results can be used. If more careful evaluation of non-uniformities must be investigated, bidirectional OTDR test results need to be considered as confirmation. See Appendix I for an example of bidirectional analysis.

In practical engineering, unidirectional OTDR test results can be used to roughly judge the splice quality, but accurate splice loss measurement must be based on the bidirectional OTDR test. A formula for calculation of splice loss is:

$$\frac{\alpha_{A-B} + \alpha_{B-A}}{2}$$

where

- α_{A-B} is the shown (not real) splice loss test from the A-end to the B-end of cable sections;
- α_{B-A} is the shown (not real) splice loss test from the B-end to the A-end of cable sections.

NOTE – OTDRs can be used to test cable attenuation for all link lengths supported by ITU-T applications, dependent upon the performance of the OTDR used. Consult OTDR manufacturers' specifications for suitability of OTDR modules for testing particular links. For concatenated cable links, the total attenuation can be derived directly by summing the attenuations of individual cable links.

If the bidirectional OTDR test cannot be employed, the quasi-bidirectional test method can be considered a candidate for measuring splice loss. It is noted that the quasi-bidirectional test is not recommended as a standard method since it is challenging to deploy on existing networks. See Appendix IV for an overview of the quasi-bidirectional test.

6.1.4 Measurements of other parameters needed following installation

The sheath isolation and the pneumatic resistance of the joint boxes are examples of tests that are sometimes performed. These characteristics are not directly related to the transmission performance