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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 G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
General	G.600–G.609
Symmetric cable pairs	G.610–G.619
Land coaxial cable pairs	G.620–G.629
Submarine cables	G.630–G.639
Free space optical systems	G.640–G.649
Optical fibre cables	**G.650–G.659**
Characteristics of optical components and subsystems	G.660–G.679
Characteristics of optical systems	G.680–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

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 needed. 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 (for example, 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.

Source

Recommendation ITU-T G.650.3 was approved on 29 March 2008 by ITU-T Study Group 15 (2005-2008) under Recommendation ITU-T A.8 procedure.

Keywords

Fibre characterization.

FOREWORD

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CONTENTS

Recommendation ITU-T G.650.3

Test methods for installed single-mode optical fibre cable links

1 Scope

This Recommendation contains test methods which 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 or passive splitters/combiners. Measurements associated with these devices, in combination with optical fibre cable are defined elsewhere. 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 (for example, 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 (2004), *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 (2007), *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 (2005), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T G.653] Recommendation ITU-T G.653 (2006), *Characteristics of a dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.655] Recommendation ITU-T G.655 (2006), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.671] Recommendation ITU-T G.671 (2005), *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 61280-4-2] IEC 61280-4-2 (1999), *Fibre optic communication subsystem basic test procedures – Part 4-2: Fibre optic cable plant – Single-mode fibre optic cable plant attenuation*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/025328>

[IEC 61280-4-4] IEC 61280-4-4 (2006), *Fibre optic communication subsystem test procedures – Part 4-4: Cable plants and links – Polarization mode dispersion measurement*

for installed links.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/035644>

[IEC 61281-1] IEC 61281-1 (1999), *Fibre optic communication subsystems – Part 1: Generic specification*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/023497>

[IEC/TR 61282-7] IEC/TR 61282-7 (2003), *Fibre optic communication system design guides – Part 7: Statistical calculation of chromatic dispersion*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/029662>

[IEC/TR 61282-9] IEC/TR 61282-9 (2006), *Fibre optic communication system design guides – Part 9: Guidance on polarization mode dispersion measurements and theory*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/036332>

[IEC/TR 61931] IEC/TR 61931 (1998), *Fibre optic – Terminology*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/023183>

[IEC 61300-3-6] IEC 61300-3-6 (2003), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/033600>

[IEC 61300-3-35] IEC/PAS 61300-3-35 (2007), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-35: Examinations and measurements – Fibre optic cylindrical connector endface visual inspection.*
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/029058>

3 Terms and 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 optical connector: [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 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 attenuation of an optical fibre cable link is 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 overall chromatic dispersion of an optical fibre cable link is 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 together.

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 which may affect current or future applications that operate over that 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, OTDR testing, chromatic dispersion testing, polarization mode dispersion measurement, and spectral attenuation.

3.2.4 single-mode optical fibre cable link: A single-mode optical fibre cable link is 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 uniformity of a fibre link is defined as the longitudinal variation in the attenuation coefficient and/or chromatic dispersion coefficient along that link.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CD Chromatic Dispersion

CWDM Coarse Wavelength Division Multiplexing

DGD Differential Group Delay

DWDM Dense Wavelength Division Multiplexing

ffs for further study

GINTY Generalized INTerferometrY

JME Jones Matrix Eigenanalysis

LSPM Light Source and Power Meter

OCWR Optical Continuous-Wave Reflectometer

OTDR Optical Time Domain Reflectometer

PMD Polarization Mode Dispersion

RMS Root Mean Square

SLA Service Level Agreement

TINTY Traditional INTerferometrY

5 Test methods

5.1 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 (for example, 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 which 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 be not only on the overall link attenuation, but also on the individual cable sections and fibres, the individual splice and connector losses, and other uniformity characteristics. One approach of 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 5.2 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 the ITU-T and the mapping to the IEC version.

5.1.1 Connector end face inspection

Before testing commences, it is recommended that the end face of the connectors at each end of the link are 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 instruction) 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/PAS 61300-3-35] provides acceptance criteria for levels of damage and defects that may be tolerated without adverse effect on optical performance.

5.1.2 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 1310 nm and 1550 nm, although, if applications using the L-band (1565-1625 nm) are to be used, then testing at 1625 nm as well is recommended (see [b-ITU-T 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 out of 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 will operate, 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 5.1.3) 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.

5.1.3 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. For example, 1310 nm and 1550 nm for [ITU-T G.652] type fibres and 1550 nm and 1625 nm for [ITU-T G.655] type fibres.

The OTDR testing should be carried out using a launch lead that is long enough (typically 1-2 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 such as 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 a judgement. 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:

$$\text{Splice loss} = \frac{\alpha_{A-B} + \alpha_{B-A}}{2}$$

Where,

$\alpha_{A\text{-}B}$ is the shown (not real) splice loss test from A-end to B-end of cable sections

$\alpha_{B\text{-}A}$ is the shown (not real) splice loss test from B-end to 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.

5.1.4 Other parameters needed to be measured 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 of optical cable sections, but can affect the mechanical reliability. Standard tests for these attributes have not been developed, but continue to be under study.

5.2 Test methods for verification of service contracts or transmission at particular bit rates

This second level of testing, defined as 'fibre characterization', indicates measurements that may be carried out to satisfy service level agreements (for example, when a dark fibre contract is signed) or to verify attributes of older links that may be used at higher bit rates (10 Gbit/s or above) or over extended wavelength ranges (for example DWDM in the L-band or CWDM over the O, E, S, C and L bands).

In addition to the testing detailed in clause 5.1, fibre characterization also includes dispersion measurements (CD and PMD) and may extend the wavelength ranges covered by the attenuation-related measurements of clause 5.1, for example by including 1625 nm OTDR testing or spectral attenuation measurements over the O, E, S, C and L bands.

Fibre characterization is defined in clause 3.2.3. Often it is important to carry out full fibre characterization, particularly on a dark fibre contract, because once the fibres are brought into service it may not be possible to access the fibres again to assess their suitability for further upgrades in the future.

5.2.1 Connector end face inspection

This is required in accordance with clause 5.1.1

5.2.2 Overall link attenuation

This is required in accordance with clause 5.1.2. Measurements at additional wavelengths may also be required.

5.2.3 Attenuation and related characteristics

For higher bit-rate transmission, the attenuation, splice loss, attenuation uniformity and section length after cable installation are also needed to be verified. The test methods for these characteristics are the backscattering technique; as described in clause 5.1.3. Measurements at additional wavelengths may also be required.

5.2.4 Spectral attenuation

If the optical fibre cable link may be used for CWDM applications then there may be a wide variation in the attenuation of the link across the broad range of wavelengths used. In this case, it is recommended that the attenuation of the link be measured at all relevant wavelengths. This may be achieved as described in clause 5.4.3 of [ITU-T G.650.1] using a suitable broadband light source and an optical spectrum analyser to compare the input and output spectra of the link to determine the attenuation as a function of wavelength across the wavelength range of interest. It is only required to carry out this measurement in one direction on the link.

5.2.5 PMD

For transmission rates lower than 10 Gbit/s and/or short distance transmission, measurement of the PMD of cable links may not be required. [IEC 61280-4-4] provides a detailed description of the PMD measurement of links, and further guidance on PMD measurements is given in [IEC/TR 61282-9].

There are several test methods identified in [IEC 61280-4-4] and [IEC/TR 61282-9] as being suitable for measuring PMD of installed links. Particular care should be applied in selecting the method used, depending on aspects such as whether the cable could be moving during the measurement.

It is sufficient to measure the PMD of the fibre in just one direction. The range of wavelengths used should be representative of the wavelengths at which the fibres may be operated.

The above test methods can all be used to test individual cable links, and some equipment may also be used to test through amplifiers. For a complex link made up of a number of simple links concatenated together, the overall PMD can be calculated from the individual PMD values by adding them in quadrature. This means that the total PMD of the complex link is the square root of the sum of the squares of the PMD of the individual links. The detailed calculation method is described in [b-IEC 61282-3]. For example, if there are three simple links making up a complex link then the total PMD of the complex link may be calculated as follows:

$$\mathrm{PMD}_{\mathrm{Total}} = \sqrt{\left(\mathrm{PMD}_1^2 + \mathrm{PMD}_2^2 + \mathrm{PMD}_3^2\right)}$$

5.2.6 Chromatic dispersion

Chromatic dispersion measurement is not essential for a low bit-rate and/or short distance transmission, although it is useful for identifying the type of fibre installed, i.e., G.652 or G.653 or G.655.

NOTE – If the cable section is less than 40 km long to comprise an optical link used for 2.5 Gbit/s transmissions, the chromatic dispersion does not need to be tested. This measurement is conditional with respect to the planned bit rate, transmission distance and fibre type.

For chromatic dispersion, there are a number of test methods that can be used. These are detailed in clause 5.5 of [ITU-T G.650.1]. Field test equipment is available from a number of manufacturers for testing installed links that implement the following test methods:

– phase shift technique and differential phase shift technique;

– time of flight technique including single-ended (OTDR based) and dual-ended methods.

It is not necessary for this measurement to be conducted from both ends of the link.

The wavelength range of the measurement should include the anticipated wavelength range of any transmission systems that may operate over the link. For DWDM systems, it may be sufficient to measure just the C-band or the C and L bands, however for CWDM systems, the wavelength range should cover the full O, E, S, C and L bands.

The above test methods can all be used to test individual cable links, and some equipment may also be used to test through amplifiers and also some types of dispersion-compensating modules. For a complex link made up of a number of simple links concatenated together, the overall chromatic dispersion (ps/nm) at a particular wavelength can be calculated simply by adding the individual chromatic dispersion values together. Note that for typical dispersion-compensating modules and for standard fibres operating at wavelengths below their zero dispersion wavelength, the dispersion values will be negative. Further guidance on calculating overall chromatic dispersion is given in clause 10.3 of [b-ITU-T G-Sup.39] and [IEC/TR 61282-7].

5.2.7 Optical return loss (ORL)

Two measurement methods for reflections of the optical path (optical cable sections) are described in Appendix I of [ITU-T G.957]. One is with the optical continuous-wave reflectometer (OCWR) and the other is with the OTDR. The OCWR gives a measurement of the total optical return loss (ORL) of the entire link, whereas the OTDR provides reflectance measurements of discrete events such as connectors as well as a calculation of the total ORL of the link. Further details of ORL testing of fibre optic components may be found in [IEC 61300-3-6].

Appendix I

OTDR trace analysis

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

I.1 OTDR trace example

Figure I.1 shows an example of an OTDR trace taken at 1550 nm of a link approximately 20 km long. This link has been measured using a launch lead and a tail lead, each about 3.8 km long. The cable sections in the link are generally about 2 km long, although there are a few shorter sections. Note that the markers A and B are positioned to display the total loss of the link including the losses associated with the connectors at both ends of the link.

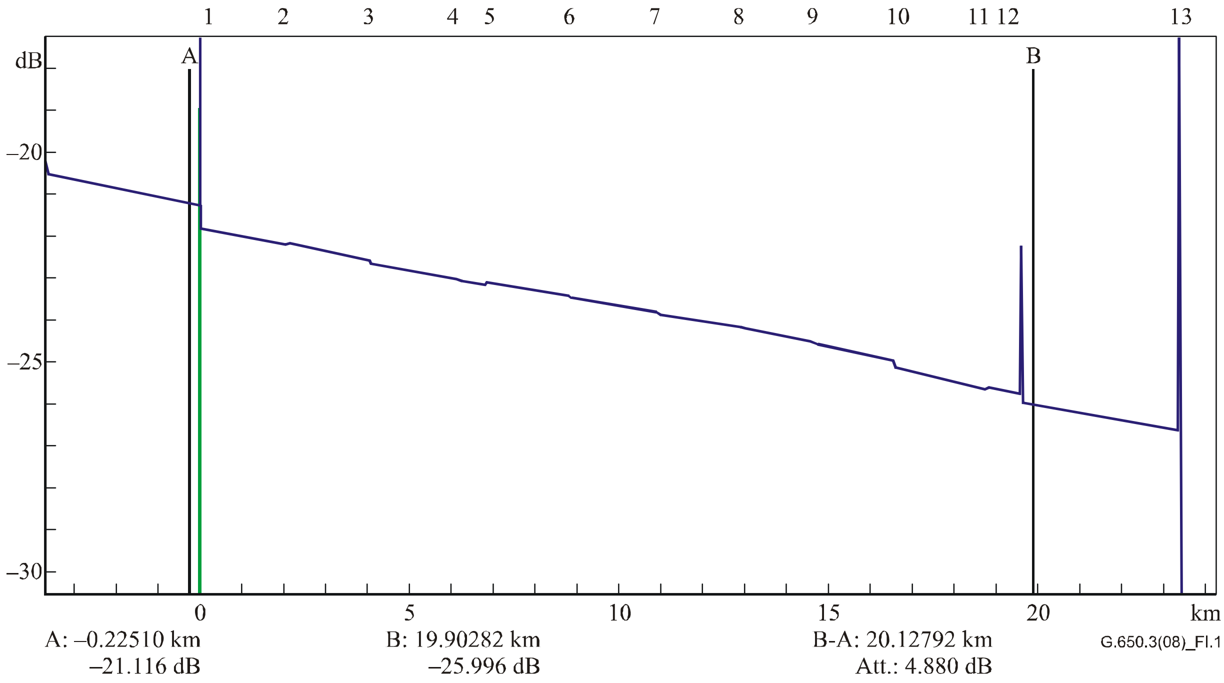
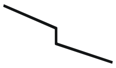
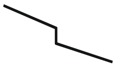
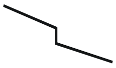
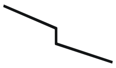
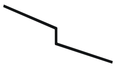
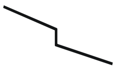
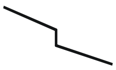
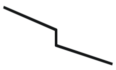
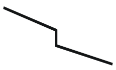
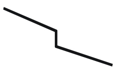


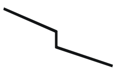
Figure I.1 – Sample OTDR trace

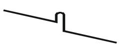
Table I.1 – OTDR event table from trace in Figure I.1

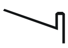
	Event (13)	Distance (km)	Attenuation (dB)	Reflectance (dB)	Slope (dB/km)	Rel. dist. (km)	Link budget (dB)
1		0.00000	0.534	–52.39	0.200	3.68282	
2		2.07258	–0.038		0.198	2.07258	0.944
3		4.10104	0.076		0.190	2.02846	1.291
4		6.15188	0.007		0.196	2.05084	1.768
5		6.82591	–0.094		0.203	0.67402	1.912
6		8.83262	0.004		0.191	2.00672	2.202
7		10.96404	–0.034		0.194	2.13142	2.619
8		12.94837	0.029		0.192	1.98433	2.966
9		14.82975	0.025		0.190	1.88138	3.353
10		16.65293	0.362		0.184	1.82318	3.714
11		18.71848	–0.062		0.190	2.06555	4.468
12		19.61185		–53.69	0.187	0.89337	4.574
13		23.40722			0.193	3.79537	5.484

NOTE – In the 'event' column, graphical symbols are used to denote particular types of events – the following icons are commonly used:

 denotes a connector interface at the start or end of a launch or tail lead

 denotes a fusion splice (non-reflective loss event) in the link under test

 denotes a connector (reflective loss event) in the link under test

 denotes the end of the fibre under test (when the tail lead has not been used)

I.2 OTDR event table example

Table I.1 shows the complete analysis of the events on the trace shown in Figure I.1. Note that some splices (e.g., event 5) are shown as having a negative loss. This is due to slight variations in the backscattering characteristics of the fibre on either side of the splice. Where the fibre after the splice scatters more light than the fibre before the splice, the apparent loss is reduced and may even show up as an apparent gain. If the opposite is true (i.e., the fibre before the splice scatters more light than the fibre after the splice) then the apparent loss may be larger than the true loss. This is the case for the connector at the first patch panel (event 2) and for event 10 on Figure I.1 and Table I.1. This is why it is necessary to carry out OTDR testing from both ends of the fibre using a launch lead and a tail lead and to average the results bidirectionally. Some OTDRs allow this procedure to be carried out in real time using an OTDR at each end of the link, otherwise this bidirectional analysis may be carried out using PC-based software.

I.3 OTDR bidirectional trace analysis

Figure I.2 shows a typical bidirectional OTDR display – the trace from Figure I.1 is shown reversed and superimposed on the trace from the opposite end of the same fibre so that the position of all of the events correlates. The event table shows the results bidirectionally averaged. Note for example that the high loss splice that was event 10 in Table I.1 is now event 3, and there is a 'gainer' (apparent negative splice loss) when measured from the opposite end. Note also that the loss of the connector (now event 12) is much less when measured in this direction, significantly reducing the bidirectionally averaged connector loss.

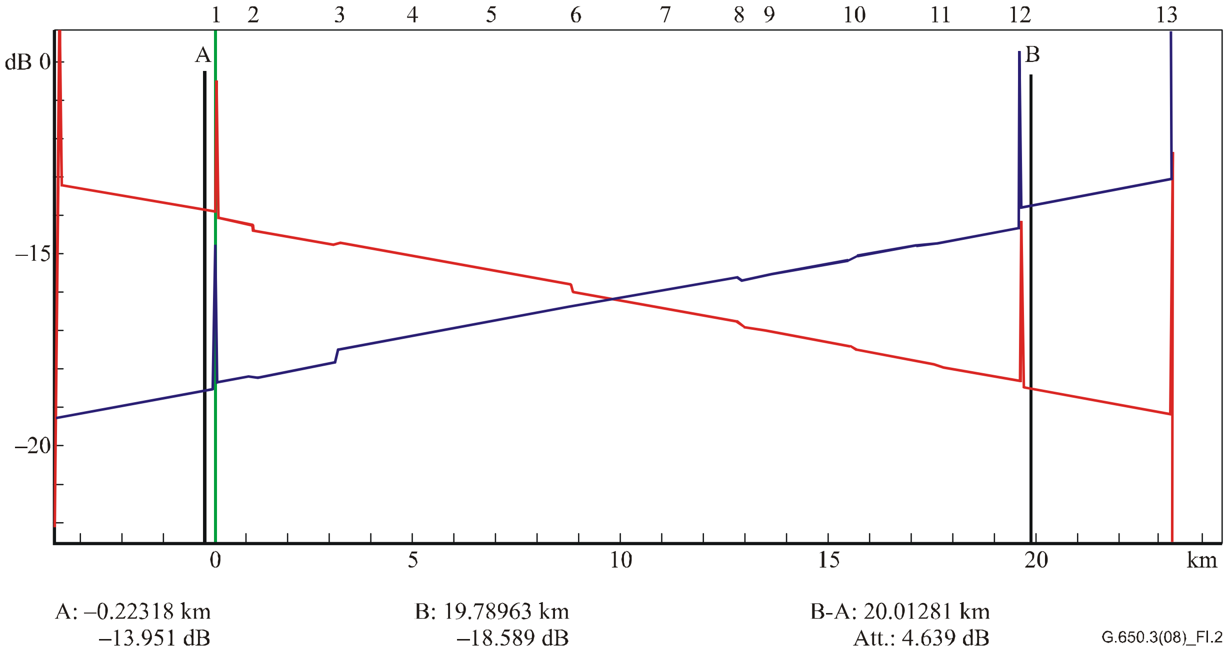


Figure I.2 – Bidirectional OTDR trace display

Table I.2 – Bidirectional OTDR trace loss analysis

	Way O→E (13)		Way O←E (13)	Distance (km)	Attenuation (dB)	Attenuation (dB)	Average (dB)	Slope (dB/km)	Slope (dB/km)	Average (dB/km)
		13								
1*		12*		0.00000	0.169			0.193	0.193	0.193
2*		11		0.91447	0.136	–0.062	0.037	0.195	0.187	0.191
3*		10		2.97362	–0.062	0.362	0.150	0.190	0.190	0.190
4*		9		4.81407	0.009	0.025	0.017	0.192	0.184	0.188
5*		8		6.67754	–0.006	0.029	0.011	0.190	0.190	0.190
6*		7		8.67659	0.177	–0.034	0.071	0.190	0.192	0.191
7*		6		10.79521	0.014	0.004	0.009	0.188	0.194	0.191
8*		5		12.81600	0.110	–0.094	0.008	0.191	0.191	0.191
9*		4		13.47659	0.034	0.007	0.021	0.186	0.203	0.195
10*		3		15.53191	0.077	0.076	0.077	0.187	0.196	0.191
11*		2		17.52776	0.067	–0.038	0.014	0.187	0.190	0.189
12*		1		19.62528	0.136	0.534	0.335	0.182	0.198	0.190
13*								0.197	0.200	0.199

Appendix II

Optical path parameters specified in ITU-T Recommendations

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

Specified parameters	Related clause	ITU-T G.691	ITU-T G.692	ITU-T G.693	ITU-T G.695	ITU-T G.696.1	ITU-T G.698.1	ITU-T G.959.1
		STM-64 and other SDH	Multi-channel	Intra-office	CWDM	Intra-Domain DWDM	DWDM	OTN
Attenuation (max/min)	5.1.2, 5.2.2	S	S	S	S	S	S	S
Chromatic dispersion (max/min)	5.2.6	S	S	S	S	S/ffs	S	S
DGD (max)	5.2.5	S	NS	S	S	S	S	S
Reflections (min ORL, max discrete)	5.2.7	S	S	S	S	S	S	S

S Specified

NS Not Specified

ffs for further study

NOTE – Minimum chromatic dispersion was not seen in [b-ITU-T G.691]. It is listed as "ffs" in [b-ITU-T G.696.1], but no frequency grids are defined.

Bibliography

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[b-ITU-T G.692] Recommendation ITU-T G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers*.

[b-ITU-T G.693] Recommendation ITU-T G.693 (2006), *Optical interfaces for intra-office systems*.

[b-ITU-T G.695] Recommendation ITU-T G.695 (2006), *Optical interfaces for coarse wavelength division multiplexing applications*.

[b-ITU-T G.696.1] Recommendation ITU-T G.696.1 (2005), *Longitudinally compatible intra-domain DWDM applications*

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