



ISO/IEC 14763-3

Edition 3.0 2024-05

INTERNATIONAL STANDARD



Information technology – Implementation and operation of customer premises cabling –
Part 3: Testing of optical fibre cabling

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Edition 3.0 2024-05

INTERNATIONAL STANDARD



Information technology – Implementation and operation of customer premises cabling –
Part 3: Testing of optical fibre cabling

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INFORMATION TECHNOLOGY – IMPLEMENTATION AND OPERATION OF CUSTOMER PREMISES CABLING –

Part 3: Testing of optical fibre cabling

FOREWORD

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ISO/IEC 14763-3 has been prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology. It is an International Standard.

This third edition cancels and replaces the second edition published in 2014 and Amendment 1:2018. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) removal of plastic fibre testing;
- b) addition of testing of MPO cabling;
- c) restructuring of the content;
- d) addition of end-to-end link LSPM testing;
- e) addition of MPTL LSPM testing;
- f) addition of measurement uncertainty for all measurement methods;

- g) introduction of normative inspection for cleanliness to align with the ISO/IEC 11801 series;
- h) testing will support SM ranges up to 10 km;
- i) introduction of new test limits for connector attenuation against reference connector;
- j) introduction of description of reference connectors;
- k) introduction of recommended cleaning methods.

The text of this International Standard is based on the following documents:

Draft	Report on voting
JTC1-SC25/3214/FDIS	JTC1-SC25/3239/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

A list of all parts in the ISO/IEC 14763 series, published under the general title *Information technology – Implementation and operation of customer premises cabling*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document has been prepared in support of the International Standard series ISO/IEC 11801.

Figure 1 shows the inter-relationship between the ISO/IEC 11801 series and other International Standards and for cabling systems with related standards.

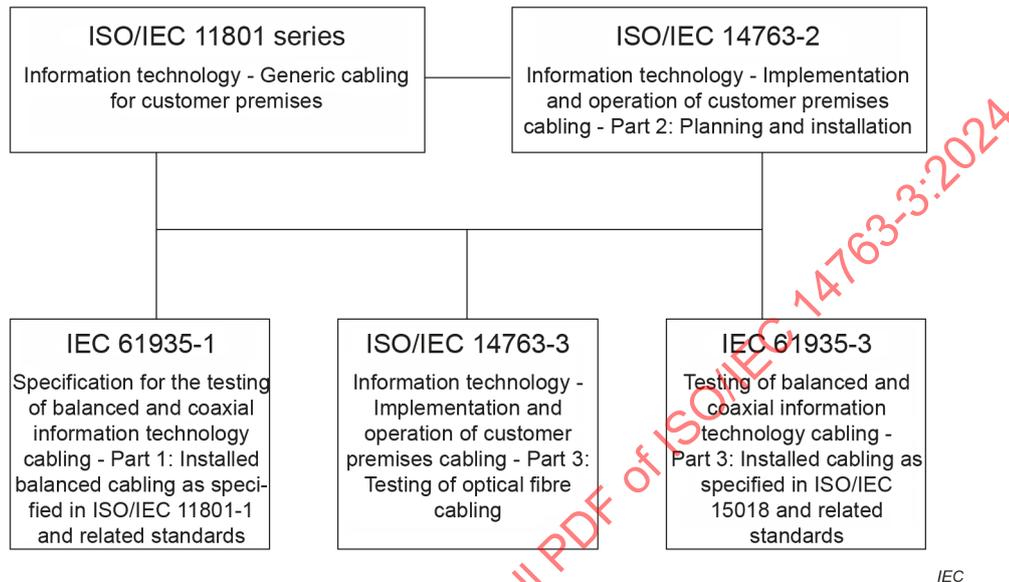


Figure 1 – Relationship of related International Standards

This document details the inspection and test procedures for optical fibre cabling designed in accordance with premises cabling standards including the ISO/IEC 11801 series and installed in accordance with the requirements and recommendations of ISO/IEC 14763-2.

Users of this document should be familiar with relevant premises cabling standards and ISO/IEC 14763-2.

The quality plan for each installation will define the acceptance tests and sampling levels selected for that installation. Requirements and recommendations for the development of a quality plan are given in ISO/IEC 14763-2.

INFORMATION TECHNOLOGY – IMPLEMENTATION AND OPERATION OF CUSTOMER PREMISES CABLING –

Part 3: Testing of optical fibre cabling

1 Scope

This part of ISO/IEC 14763 specifies systems and methods for the inspection and testing of installed optical fibre cabling designed in accordance with premises cabling standards including the ISO/IEC 11801 series. The test methods refer to existing standards-based procedures where they exist.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 11801-1, *Information technology – Generic cabling for customer premises – Part 1: General requirements*

ISO/IEC 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

IEC 60050-731, *International Electrotechnical Vocabulary – Part 731: Optical fibre communication* (available at <http://www.electropedia.org/>)

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCSs)*

IEC 61280-1-3, *Fibre optic communication subsystem test procedures – Part 1-3: General communication subsystems – Measurement of central wavelength, spectral width and additional spectral characteristics*

IEC 61280-1-4, *Fibre optic communication subsystem test procedures – Part 1-4: General communication subsystems – Light source encircled flux measurement method*

IEC 61280-4-1, *Fibre-optic communication subsystem test procedures – Part 4-1: Installed cabling plant – Multimode attenuation measurement*

IEC 61280-4-5, *Fibre-optic communication subsystem test procedures – Part 4-5: Installed cabling plant – Attenuation measurement of MPO terminated fibre optic cabling plant using test equipment with MPO interfaces*

IEC 61300-3-35, *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 61300-3-42, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-42: Examinations and measurements – Attenuation of single mode alignment sleeves and or adaptors with resilient alignment sleeves*

IEC 61315, *Calibration of fibre-optic power meters*

IEC 61746-1, *Calibration of optical time-domain reflectometers (OTDR) – Part 1: OTDR for single mode fibres*

IEC 61746-2, *Calibration of optical time-domain reflectometers (OTDR) – Part 2: OTDR for multimode fibres*

IEC 61755-2-4, *Fibre optic interconnecting devices and passive components – Connector optical interfaces – Part 2-4: Connection parameters of non-dispersion shifted single-mode physically contacting fibres – Non-angled for reference connection applications*

IEC 61755-2-5, *Fibre optic interconnecting devices and passive components – Connector optical interfaces – Part 2-5: Connection parameters of non-dispersion shifted single-mode physically contacting fibres – Angled for reference connection applications*

IEC 61755-3-1, *Fibre optic connector optical interfaces – Part 3-1: Optical interface, 2,5 mm and 1,25 mm diameter cylindrical full zirconia PC ferrule, single mode fibre*

IEC 61755-3-2, *Fibre optic connector optical interfaces – Part 3-2: Optical interface, 2,5 mm and 1,25 mm diameter cylindrical full zirconia ferrules for 8 degrees angled-PC single mode fibres*

IEC 61755-3-31, *Fibre optic interconnecting devices and passive components – Connector optical interfaces – Part 3-31: Connector parameters of non-dispersion shifted single mode physically contacting fibres – Angled polyphenylene sulphide rectangular ferrules*

IEC 62614-1, *Fibre optics – Multimode launch conditions – Part 1: Launch condition requirements for measuring multimode attenuation*

IEC PAS 63267-3-31, *Fibre optic interconnecting devices and passive components – Fibre optic connector optical interfaces – Part 3-31: End face geometry – Flat PC PPS rectangular ferrule multimode fibres*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 11801-1, IEC 60050-731 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1

adaptor

device that enables interconnection between terminated optical fibre cables

3.1.2 attenuation

A

reduction in optical power induced by transmission through a medium such as optical fibre, given as $A = -10 \log (P_{\text{out}}/P_{\text{in}})$, where P_{in} and P_{out} are the power, typically measured in mW, into and out of the cabling

Note 1 to entry: The values of *A* are in decibel (dB)

3.1.3 attenuation dead zone

<reflective or non-reflective event> region on an OTDR after the event where the displaced trace deviates from the undisturbed backscatter trace by more than a given vertical distance ΔF

Note 1 to entry: ΔF is commonly accepted to be a value of 0,5 dB

[SOURCE: IEC 61746-1:2009, and IEC 61746-2:2010, 3.3, modified – The note has been changed and Figure 1 has not been included.]

3.1.4 bi-directional measurement

technique consisting of two measurements of the same optical fibre, made by launching light into opposite ends of that fibre

3.1.5 cable sheath

covering over the optical fibre or conductor assembly that can include one or more metallic members, strength members or jackets

Note 1 to entry: Sometimes simply referred to as "sheath".

3.1.6 connection

mated device including terminations connecting two cables or cable elements

3.1.7 encircled flux

fraction of cumulative near-field power to the total output power as a function of radial distance from the optical centre of the core

3.1.8 fail result

measured value which fails to meet the specified requirement and where the absolute value of the difference between the measured value and the specified requirement is greater than the stated measurement uncertainty

3.1.9 launch test cord

cable assembly used to connect from a light source to the cabling under test or as part of a test reference measurement

3.1.10 light source and power meter

test system consisting of a light source (LS), power meter (PM) and associated test cords used to measure the attenuation of installed cable plant

3.1.11

marginal result

measured value which differs from the specified requirement by an amount not exceeding the stated measurement uncertainty

3.1.12

multimode fibre

optical fibre along whose core the radiation of two or more bound modes can propagate at the wavelength of interest

Note 1 to entry: A typical multimode fibre propagates 100 modes or more.

[SOURCE: IEC 60050-731:1991, 731-02-03, modified – The definition has been slightly changed and Note 1 to entry added.]

3.1.13

optical fibre

waveguide shaped as a filament, made of dielectric materials for guiding optical waves

[SOURCE: IEC 60050-151:2001/AMD3:2019, 151-12-35]

3.1.14

optical time domain reflectometer

OTDR

test system consisting of an optical time-domain reflectometer and associated test cords used to characterize and measure the attenuation of installed cable plant and specific elements within that cable plant

3.1.15

pass result

measured value which meets the specified requirements and where the absolute value of the difference between the measured value and the specified requirement is greater than the stated measurement uncertainty, provided any apparent gain does not exceed the measurement uncertainty

3.1.16

pin conversion test cord

PCTC

cord used to change the mated connector from pinned to unpinned, and vice versa when there is a pinning incompatibility between the launch test cord and link under test.

3.1.17

reference adaptor

adaptor with tightened tolerances (for example, a single-mode adaptor), to ensure reference connections can be attained

3.1.18

reference connector

connector with tightened tolerances terminated onto an optical fibre that can require tightened tolerances such that the expected attenuation formed by mating two such assemblies is less than or equal to a specified value that is lower than the normal expected attenuation

3.1.19

reference measurement

measurement of the output power of the light source that is used to determine the input power level to the cabling under test

3.1.20

reference plane

theoretical plane without thickness or tolerances.

Note 1 to entry: The reference plane is used to define spaces in mechanical structures.

[SOURCE: IEC 60050-581:2008, 581-25-30]

3.1.21

single-mode fibre

optical fibre which supports only one mode of light transmission

3.1.22

substitution test cord

test cord used within a reference measurement which is replaced during the measurement of the attenuation of the cabling under test

3.1.23

tail test cord

cable assembly used to connect from a power meter to the cabling under test or as part of a test reference measurement

3.1.24

test cord

cable assembly used either to connect test equipment to the cabling under test or as part of a test reference measurement

3.1.25

test operator

skilled person who tests in accordance with instructions provided by the test system designer

3.1.26

test system

test equipment, test cords and adaptors necessary to undertake a given test in accordance with the requirements of this document

3.1.27

defect

surface feature such as pits, scratches, chips and loose debris

3.1.28

loose debris

particles and debris on the surface that can be removed by cleaning

3.1.29

pit

permanent non-linear surface damage

3.1.30

scratch

permanent linear surface damage

3.2 Abbreviated terms

For the purposes of this document, the abbreviated terms of ISO/IEC 11801-1 and the following apply.

APC	angled physical contact
BIMMF	bend insensitive multimode fibre referred to as enhanced macrobend loss fibre
CP	consolidation point
DUT	device under test
EQP	equipment
E2E	end-to-end
EC	equipment cord
ffs	for further study
IOR	index of refraction
LC	LC connector
LTC	launch test cord
LS	light source
MF	multi fibre
MM	multimode
MMF	multimode fibre
MPO	multi-fibre push on (based on rectangular ferrule)
MPTL	modular plug terminated link
N/A	not applicable
OTDR	optical time domain reflectometer
PC	physical contact
PCTC	pin conversion test cord
PM	power meter
RL	return loss
RMS	root mean square
SC	subscriber connector
SF	single fibre
SFC	single fibre connector
SM	single-mode
SMF	single-mode fibre
STC	substitution test cord
TTC	tail test cord

3.3 Symbols

For the purposes of this document the following symbols apply.

	Optical fibre connector (general)
	Optical fibre connector on installed cabling
	Optical fibre connector with reference termination
	Optical fibre adaptor (general)
	Optical fibre adaptor embedded in cabling
	Optical fibre reference adaptor
	Splice

4 Conformance

To test installed cabling in accordance with this document:

- a) the reference connectors shall conform to the requirements of 5.6;
- b) the requirements of Clause 6 shall be met;
- c) the test equipment and test cords shall conform to the requirements of Clause 5;
- d) the test method, as appropriate, and treatment of results shall conform to Clauses 6 and 7;
- e) information about the test equipment shall be documented in accordance with 5.2;
- f) the test results shall be documented in accordance with Clause 6 and ISO/IEC 14763-2:2019, 10.3.3.

To inspect installed cabling in accordance with this document:

- 1) the inspection equipment shall conform to the requirements of 5.8;
- 2) the inspection method, as appropriate, shall conform to 6.8.

This document does not specify which test or sampling level is to be adopted as this is specified in the quality plan (see Annex B) meeting the requirements of ISO/IEC 14763-2. This document does define the test method and equipment to be utilized for specific tests.

Laser safety is outside the scope of this document, and is covered by other standards and by regulations. However, information given by this document can be of assistance.

5 Test equipment

5.1 General requirements

The test equipment and particularly the adaptors, test cords terminated with reference connectors and reference connectors, affect the uncertainty of the attenuation measurement for a given component, link or channel.

The test equipment shall be calibrated using standardized procedures (e.g. IEC 61315 for optical power meter and IEC 61746 series for OTDR), or tester manufacturer's documented procedures, as appropriate.

The test operator shall have evidence, in the form of a valid calibration certificate, to support the use of the test equipment at the time the tests are carried out.

Index matching materials (gels or fluids) between the polished end faces of connectors shall not be used.

5.2 Documentation

Test equipment used for conformance testing should include apparatus specific documentation, certificates of compliance to specific standards (i.e. encircled flux), test cord test data, and the factory calibration date.

5.3 Apparatus

Apparatus requirements apply to single-fibre and multi-fibre LSPM and OTDR devices. An LSPM uses a light source and power meter at each end of the fibre cabling. An OTDR makes a measurement single-ended, from either fibre end.

5.4 Light source and power meter

5.4.1 Light source

5.4.1.1 General

The light source shall be capable of producing a stable optical output power and an optical interface compatible with the single fibre ferrule test reference cords.

For a multimode MPO interfaced light source, the connector shall have a PC or APC end face. For single-mode MPO ported light source, the connector shall have an APC end face.

5.4.1.2 Stability

The performance of the light source is defined at the output of the launch cord. This is achieved by transmitting the output of a source, such as a laser or light emitting diode, into the launch cord. The source shall be stable in position, wavelength and power over the duration of the entire measurement procedure. Power stability should be high to minimize uncertainty. When verified using the method described in IEC TR 61282-14, power stability shall be less than or equal to 0,20 dB.

5.4.1.3 Launch condition

For single-mode fibre cabling, no specific launch condition is required.

For multimode fibre cabling (MMF), the launch modal condition shall meet the requirements of IEC 62614-1, IEC 61280-4-1, and IEC 61280-4-5 at either:

- a) the output of the launch test cord; or
- b) the output of the bulkhead of the light source when the associated test cords achieve launch modal condition at the output of the launch test cord by design; or
- c) the output of the bulkhead of the light source for MPO light sources if the following conditions are met:
 - 1) the measurement uncertainty is known and documentation is available as specified in 5.2;
 - 2) the agreed quality plan supports the test method and associated measurement uncertainty (ISO/IEC 14763-2);
 - 3) the measurement uncertainty for the tests is documented within the test result documentation (ISO/IEC 14763-2).

NOTE A controlled encircled flux, defined by target and limits, is the standardized distribution of light in fibre required for multimode attenuation measurements. For a light source that produces a uniform or overfilled mode power distribution and using a test cord that has an integrated mode filter, the output of the test cord is measured to be compliant. For test cords that have a mode scrambler and mode filter, capable of attaching to any light source, the output of the test cord is measured to be compliant. For devices that use a test cord without a mode scrambler or mode filter, modal transparency is dependent on matching the core diameter and numerical aperture of the fibre inside the light source to the test cord fibre; this is the case for example with MPO test cords. This could have an impact on the launch modal condition, measured attenuation, and uncertainty.

The specified encircled flux modal condition shall be achieved by:

- use of conformant equipment including a mode conditioner and a corresponding test cord;
- use of equipment with unknown modal condition but use of a conformant modal conditioning device in the launch test cord;
- use of equipment with a source that requires mode filtering and a controlled output at reference connector with launch modal condition that has been measured in accordance with IEC 61280-1-4.

Launch test cords shall include reference grade connectors in accordance with 5.6.

The following launch conditions are considered normative for MMF cabling:

- 850 nm for 50 µm core diameter;
- 1 300 nm for 50 µm core diameter;
- 850 nm for 62,5 µm core diameter;
- 1 300 nm for 62,5 µm core diameter.

5.4.1.4 Spectral characteristics

For required test wavelengths, see ISO/IEC 11801-1 and ISO/IEC 14763-2. LEDs and Fabry-Pérot lasers should be used for multimode and single-mode testing, respectively. VCSELs should not be used.

Light sources for testing MMF cabling and components shall conform to the spectral characteristics of Table 1 when measured in accordance with IEC 61280-1-3. The MMF supported by this document are defined in IEC 60793-2-10.

Table 1 – MMF spectral requirements

Centroidal wavelength nm	Spectral width range ^a nm
850 ± 25 (on A1-OMx fibre)	10 to 38 (RMS)
1 280 to 1 330 (on A1-OMx fibre)	10 to 75 (RMS)
^a The spectral width range applies only to the LSPM apparatus.	

Light sources for testing single-mode fibre (SMF) shall conform to the spectral characteristics of Table 2 when measured in accordance with IEC 61280-1-3. The SMF supported by this document are defined in IEC 60793-2-50.

Table 2 – SMF spectral requirements

Centroidal wavelength nm	Spectral width range nm
1 310 ± 30 (on B-652 and B-657 fibre)	≤ 5 (RMS) for laser diode
1 550 ± 30 (on B-652 and B-657 fibre)	≤ 5 (RMS) for laser diode

5.4.2 Power meter

The power meter shall be capable of measuring the range of power normally associated with the cabling, including considerations on the power launched into the cabling. The meter shall have a detecting surface of sufficient size to capture all the power coming from the optical fibre that is put into it. If a fibre pigtail is used, the pigtailed optical fibre core and numerical aperture (NA) shall be sufficiently large to capture all the power coming from the test cord.

The receiver connector of the power meter shall be the same connector used in the system under test at the end of the link where the light source is to be attached.

The power meter having an MPO compatible port, either pinned or unpinned, shall interface with either an MPO multimode plug or MPO/APC single-mode plug.

Caution is advised when interfacing to the power meter MPO port, since it can be pinned or unpinned.

Further information on power meter features for MPO connectors can be found in IEC TR 61282-15.

The power meter shall enable optical power measurements to be recorded to at least two significant digits in the decimal place (e.g. -14,32 dBm, 2,19 dB).

5.5 OTDR

5.5.1 General

OTDR equipment for testing MMF cabling and components shall conform to the centroidal wavelengths of Table 1.

OTDR equipment for testing SMF cabling shall conform to the centroidal wavelengths of Table 2.

OTDR characterization shall be undertaken using a launch test cord and a tail test cord. The LTC and TTC shall be terminated with reference grade test connectors.

For testing optical fibre cabling terminated with MPO connectors, an optical switch is needed. It can be installed within the OTDR mainframe and provide a single MPO interface port. Alternatively, the optical switch can be implemented outside of the OTDR mainframe with a single fibre to multi-fibre interface. Where an optical switch is not available, suitable MPO to single fibre link can be utilized.

5.5.2 OTDR requirements

5.5.2.1 General

The OTDR shall be capable of supporting a range of pulse widths and averaging times to achieve measurements for a given fibre length with sufficient signal-to-noise ratio. The OTDR should have a short attenuation dead zone following a standard connector to adequately measure connector attenuation and return loss at connections to the installed cabling under test.

5.5.2.2 OTDR characterization using test cords

Characterization of cabling using an OTDR with a launch test cord and a tail test cord:

- a) produces a unidirectional characterization of the form shown in Figure 2;
- b) provides a continuity measurement for the cabling under test;
- c) provides information about the general quality of both the local and remote interface to the cabling under test, the quality of the cabled fibre like in the ISO/IEC 11801 series and any embedded connecting hardware;
- d) provides a quantitative measurement of the local (i.e. near-end) and remote (i.e. far-end) interfaces to the cabling under test when using measurements taken in each direction (i.e. bi-directional);
- e) provides a quantitative measurement of the channel or link (see Clause 6) attenuation when the measurement is taken in one direction provided that the backscattering characteristics of the optical fibre within the launch test cord and tail test cord are the same;
- f) provides a quantitative attenuation measurement of the channel, or link embedded connecting hardware (see Clause 6) when the measurement is taken from two directions provided that:
 - attenuation measurements of permanent links, channel or embedded connecting hardware are derived by averaging the associated bi-directional test results;
 - the distance between embedded connecting hardware is not less than the dead zone of the OTDR (see 7.3.5).

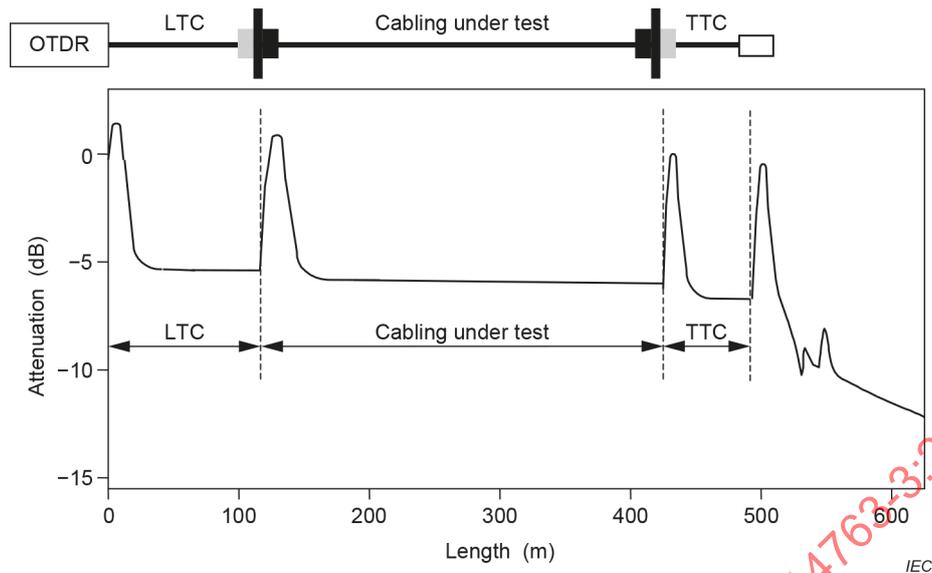


Figure 2 – OTDR characterization using a launch test cord and a tail test cord

5.6 Test cord connectors

5.6.1 Connecting hardware at test interfaces

The connecting hardware to be connected to the cabling under test (i.e. launch test cords and tail test cords) together with the hardware that terminates the substitution test cords and any connecting hardware adaptors are specified as part of the test methods specified by this document and are called reference connectors.

Reference connectors are used to reduce the measurement uncertainty for the attenuation measurements and are used for multimode and single-mode in single fibre (i.e. LC connector) and multi-fibre connectors (e.g. MPO connectors).

The multimode LC and MPO reference connectors are terminated on 50 μm fibre and are in accordance with IEC 63267-2-1¹ for LC and other single fibre connectors. IEC 63267-2-2² specifies requirements for MPO connectors.

5.6.2 Connecting hardware attenuation requirements

The key performance requirements of different connector types are listed in Table 3. The attenuation value of the reference connector to the reference connector in a reference adaptor shall be met in order to achieve the attenuation values of ISO/IEC 11801-1.

¹ Under preparation. Stage at the time of publication: IEC CDV 63267-2-1:2023.

² Under preparation. Stage at the time of publication: IEC CDV 63267-2-2:2023.

Table 3 – Connector identification and attenuation test limits

Mode	Connector identification	Connector type	Reference connector to reference connector test limit	Reference connector to standard grade connector test limit
			dB	dB
Multimode	Rm1 ^a	MM SF	0,10	0,45
	Rm12 ^a	MM MF12	0,15	0,45
	Rm24 ^a	MM MF24	0,20	0,45
	Rm16 ^a	MM MF16	0,15	0,45
	Rm16A ^a	MM MF16 APC	0,15	0,45
Single-mode	Rs1-Grade 2 ^b	SM SF	0,2	0,7
	Rs12 ^b	SM MF12 APC	0,35	0,7
^a Rmxx: reference connector MM xx number of fibres ^b Rsxx: reference connector SM xx number of fibres				

5.6.3 Mechanical requirements for reference connectors

5.6.3.1 Requirements for MM LC and other MM single fibre reference connectors

The key performance related requirements for multimode LC and other single fibre reference connectors are given in Table 4.

Table 4 – Single fibre MM reference connector requirements

No.	Parameter	Value	Unit
1	core diameter of the used fibre	50 ± 0,5	µm
2	numerical aperture of the used fibre	0,200 ± 0,002	
3	tolerance of the outer diameter of the 1,25 mm ferrule	1,248 5 to 1,249 5	mm
	tolerance of the outer diameter of the 2,5 mm ferrule	2,499 0 to 2,499 5	mm
4	eccentricity of centre of ferrule and centre of fibre	≤ 0,5	µm

All requirements of Table 4 shall be met. The attenuation requirement in Table 3 is met by design if the parameters No. 1 to 4 are met.

5.6.3.2 Requirements for SM LC and other single fibre reference connectors

The single-mode LC and other single fibre reference connectors shall meet the requirements of IEC 61755-2-4 for PC and IEC 61755-2-5 for APC.

The key performance related requirements for single-mode LC and other single fibre reference connectors are given in Table 5.

Table 5 – Single fibre single-mode reference connector requirements

No.	Parameter	Value	Unit
1	mode field diameter of the used fibre (1310 nm)	9,2 ± 0,1	µm
2	tolerance of the outer diameter of the 1,25 mm ferrule	1,248 5 to 1,249 5	mm
	tolerance of the outer diameter of the 2,5 mm ferrule	2,499 0 to 2,499 5	mm
3	eccentricity of centre of ferrule and centre of fibre	≤ 0,5	µm

All requirements of Table 5 shall be met. The attenuation requirement in Table 3 is met by design if the parameters No. 1 to 3 are met.

5.6.3.3 End-face geometry for LC and other single fibre reference connectors

The function of LC and other single fibre reference connectors is based on physical contact of the reference connector and the DUT connector of link and channel to be tested. To ensure physical contact and the required performance, the end-face geometry of the polished ferrule shall be in accordance with the requirements of:

- IEC 61755-3-1 for MM PC reference connectors;
- IEC 61755-3-1 for SM PC reference connectors;
- IEC 61755-3-2 for SM APC reference connectors.

5.6.3.4 Requirements for MM MPO and other multi-fibre connectors

The key performance related requirements for multimode MPO and other multi-fibre reference connectors are given in Table 6.

Table 6 – Multi-fibre MM reference connector requirements

No.	Parameter	Value	Unit
1	core diameter of the used fibre	50 ± 0,5	µm
2	numerical aperture of the used fibre	0,200 ± 0,002	
3	true position of centre of fibre	≤ 2,0	µm

All requirements of Table 6 shall be met. The attenuation requirement in Table 3 is met by design if the parameters No. 1 to 3 are met.

5.6.3.5 Requirements for SM MPO and other multi-fibre connectors

The key mechanical requirements for single-mode MPO and other multi-fibre reference connectors are given in Table 7.

Table 7 – Multi-fibre single-mode reference connector requirements

No.	Parameter	Value	Unit
1	mode field diameter of the used fibre (1 310 nm)	9,2 ± 0,1	µm
2	true position of fibre core	≤ 1,6	µm

All requirements of Table 7 shall be met. The attenuation requirement in Table 3 is met by design if the parameters No. 1 and 2 are met.

5.6.3.6 End-face geometry requirements for MPO and other multi-fibre connectors

The end-face geometry of single-mode MPO reference connectors shall meet the requirements of IEC 61755-3-31. The end-face geometry of the multimode MPO reference connectors shall meet the end-face geometry requirements as specified in IEC PAS 63267-3-31.

5.6.4 Reference adaptors at test interfaces

All reference adaptors used for testing are of single-mode quality and shall be equipped with ceramic alignment sleeve that, when tested in accordance with IEC 61300-3-42 with SM APC reference connectors, have an attenuation ≤ 0,2 dB. Testing multimode reference connectors in a reference adaptor shall have an attenuation < 0,1 dB.

MPO and other multi-fibre reference adaptors shall have an attenuation in accordance with Table 3 tested with reference connectors

5.7 Test cord characteristics

5.7.1 General

Each test cord should have the following characteristics:

- a) for multimode, contain an optical fibre of the same nominal characteristics (i.e. core diameter, numerical aperture) as the optical fibre under test. The optical fibre in the test cords may be BIMMF or non-BIMMF, but the tolerances of the core diameter and numerical aperture are tighter specified in order to minimize uncertainty of the measured attenuation and provide the correct launch condition. See 5.6.3 for details of the reference fibre as part of the reference connector. Test cord attenuation verification shall be in accordance with Annex A.
- b) for single-mode, contain a fibre with a selected mode field diameter of $9,2 \pm 0,1 \mu\text{m}$ at 1 310 nm as defined in IEC 61755-2-4 for single-mode PC and IEC 61755-2-5 for single-mode APC. See 5.6.3 for details of the reference fibre as part of the reference connector;
- c) be labelled by having a unique identifier with each connector labelled as indicated in Figure 3.

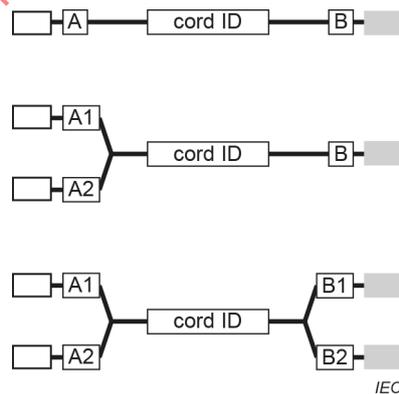


Figure 3 – An example of test cord labelling and identification

5.7.2 LSPM launch test cord

The launch test cord (LTC) shall be:

- a) terminated at one end with one or more connectors suitable for attachment to the light source;
- b) terminated at the other end with one or more reference connectors and adaptors compatible with the interface to the installed cabling;

c) 2 m to 5 m in length.

NOTE Use of test cords with reference grade connectors at both ends minimizes measurement uncertainty.

5.7.3 LSPM tail test cord

The tail test cord (TTC) shall be:

- a) terminated at one end with one or more connectors suitable for attachment to the power meter;
- b) terminated at the other end with one or more reference connectors and adaptors compatible with the interface to the installed cabling;
- c) 2 m to 5 m in length.

NOTE Use of test cords with reference grade connectors at both ends minimizes measurement uncertainty.

5.7.4 LSPM substitution test cord

The substitution test cord (STC) shall be terminated at both ends with reference connectors compatible with the interfaces to the installed cabling.

The substitution test cord shall be 2 m to 5 m in length.

5.7.5 OTDR launch test cord

The launch test cord shall be:

- a) terminated at one end with one or more connectors suitable for attachment to the OTDR;
- b) terminated at the other end with one or more reference connectors and adaptors compatible with the interface to the installed cabling;
- c) of the same type, in terms of core diameter, numerical aperture, or mode field diameter as the optical fibre within the cabling under test. Reference grade connectors should be used.

The length of the launch cord shall be longer than the dead zone created by the pulse width selected for a particular length of fibre to be measured. Suppliers of OTDR equipment should recommend lengths. In addition, these lengths shall be long enough for a reliable straight line fit of the backscatter trace that follows the attenuation dead zone with standard connector reflectance. Launch cords shall not include any splice when shorter than 15 m. If there is no recommendation for launch test cord length, the minimum length should be 100 m for multimode and 150 m for single-mode, or the minimum launch cord recommended length guidance of the OTDR manufacturer.

The OTDR launch test cord should provide the specified launch modal distribution (see 5.4.1.3). For the MM OTDR launch test cord, if the OTDR is not known to provide the specified launched modal distribution, then the launch test cord shall contain a suitable mode-controlling device to ensure that the specified launched modal distribution is maintained.

The length of optical fibres used to create OTDR launch test cords often requires that they be protected within an enclosure (see Figure 4).

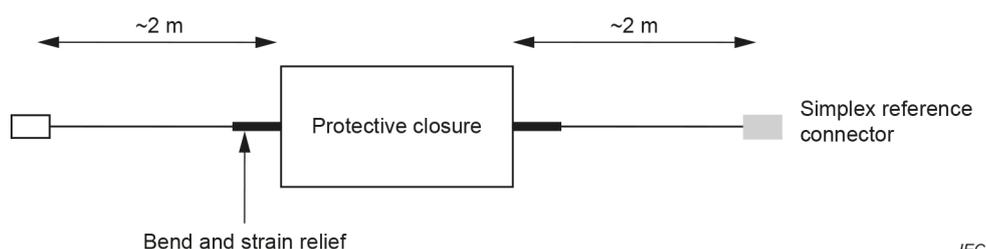


Figure 4 – OTDR launch test cord and tail test cord schematic

5.7.6 OTDR tail test cord

The tail test cord shall be:

- a) longer than the attenuation dead zone of the OTDR (see 3.1.3 and 7.3.5). If there is no recommendation for tail test cord length, the minimum length should be 100 m for multimode and 150 m for single-mode, or the minimum tail cord recommended length guidance of the OTDR manufacturer. Tail cords shall not include any splice when shorter than 15 m;
- b) long enough for a reliable straight-line fit to be made to the backscatter trace following the dead zone (C3 to C4 in Figure 31), so that reliable attenuation measurements can be carried out;
- c) terminated at one end with one or more reference connectors compatible with the interface to the installed cabling;
- d) of the same type, in terms of core diameter, numerical aperture, or mode field diameter as the optical fibre within the cabling under test. Reference grade fibre should be used.

For best practice, reference connectors should be used on both ends.

The length of optical fibres used to create OTDR tail test cords often requires that they be protected within an enclosure (see Figure 4).

5.8 Visual inspection equipment

The inspection equipment shall meet the requirements of IEC 61300-3-35.

All possible connectors in multimode and single-mode fibre configurations specified in structured cabling standards shall be inspected for contamination with a low-resolution microscope. Low resolution means that the microscope shall have a field of view of at least 250 μm . The fibre shall be a maximum 50 % of the image on the microscope in the vertical axis.

The capability of the microscope for detecting 2 μm targets and the correct field of view can be determined by use of, for example, a chrome on glass artefact with 2 μm targets and a 250 μm circle. The user should contact the equipment supplier for such an artefact. Other artefacts that determine the capability of the microscopes to detect 2 μm defects and 3 μm scratches may be used.

There are different types of microscope available on the market. Direct viewing microscopes are in general lower cost. The microscope shall contain a built-in laser safety filter to prevent accidental eye damage. Do not use direct view microscopes on live fibre systems if there is no filter. This is important during inspection of installed connector end faces where the remote end is not under control of the inspector.

The laser filter is used to control the energy which is directed into the eye from active sources emitted from the cabling. When direct viewing is used, it shall be ensured that no laser or equipment with lasers is active on the cabling. Laser safety of optical fibre communication systems shall be in accordance with IEC 60825-2.

Video microscopes contain a lens which transfers via a camera the magnified image on a display. Video microscopes provide more laser safety than direct viewing microscopes.

All microscope systems show system-to-system variability and a 100 % match between inspection results of multiple microscopes in accordance with IEC 61300-3-35 is not achievable at this moment. This is even the case when microscopes of the same brand and type are compared.

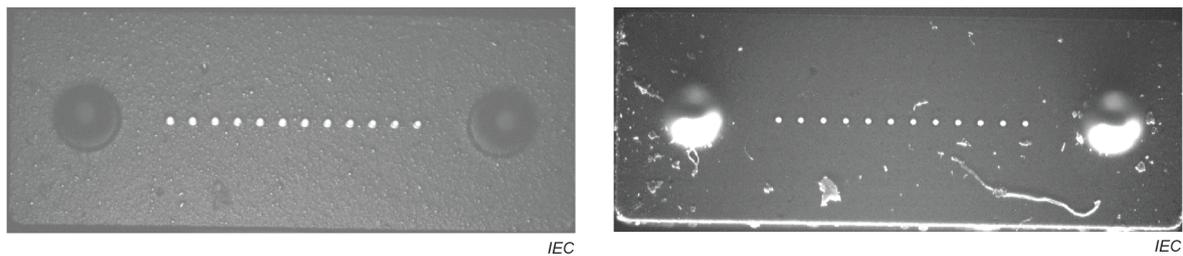


Figure 5 – Normal illumination (left) and illumination with floodlight (right)

NOTE Some microscopes are available with floodlight (side illumination); these are particularly handy when inspecting MPOs for dirt (see Figure 5).

For rectangular ferrules, the entire ferrule surface (6,4 mm × 2,5 mm) should be visible (see Figure 5) and shall be inspected for contamination. The microscope shall be fitted with suitable fixtures that retain the connector in a stable position, thereby allowing careful inspection.

Do not use direct view microscopes on live fibre systems.

6 Testing

6.1 General

Clause 6 specifies the reference planes, the visual inspection for cleanliness and the testing procedures and uncertainty for channels, links, permanent links, E2E links and MPTL measured with LSPM or OTDR.

Although permanent links are referred to in Clause 6, ISO/IEC 11801-1 has defined requirements for sub-links that can be tested in accordance with this document.

6.2 Reference planes

ISO/IEC 11801-1 and equivalent documents define transmission limits for channels, links or permanent links, E2E links and MPTL for which the representative reference planes are shown in Figure 6.

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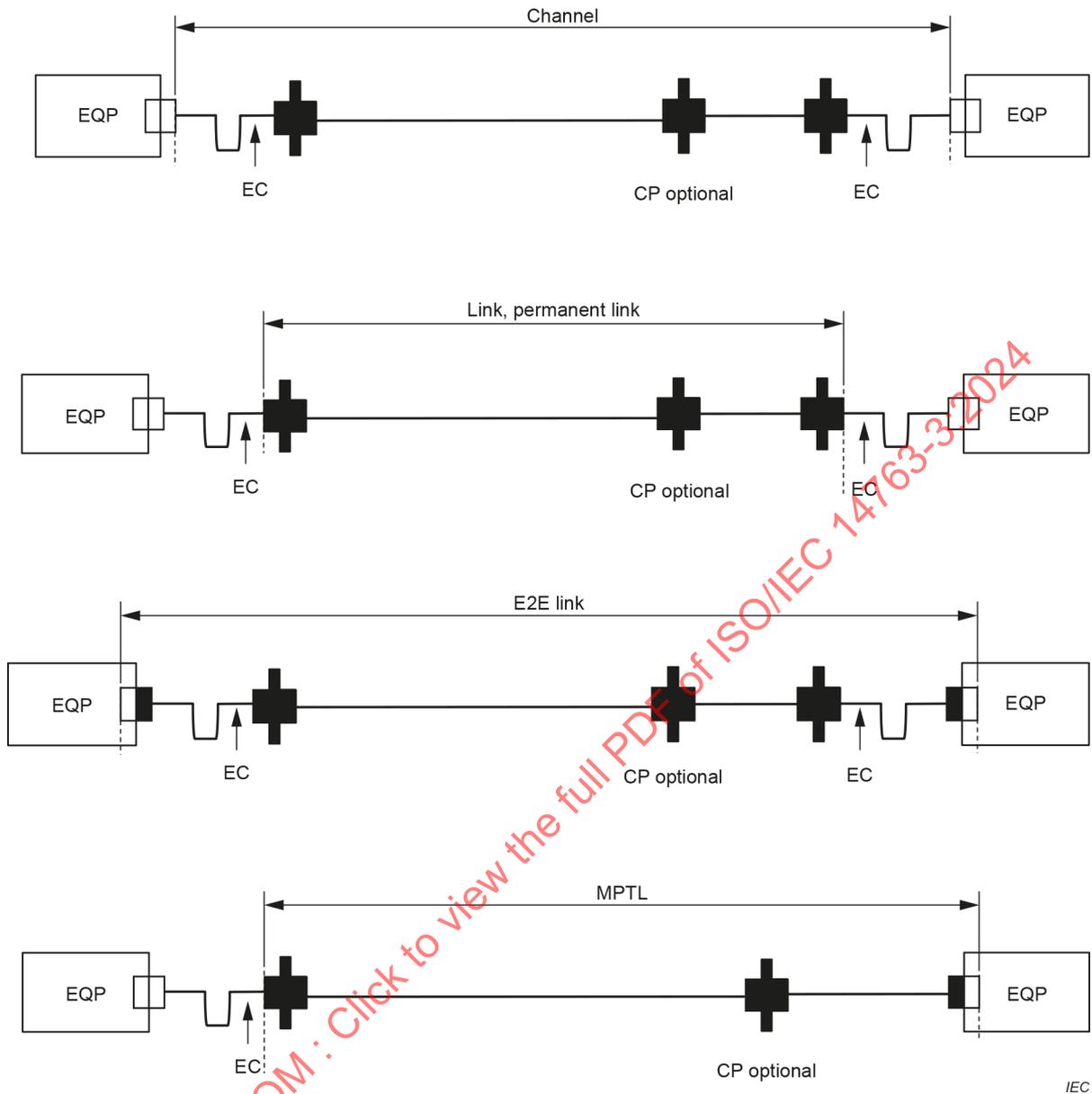
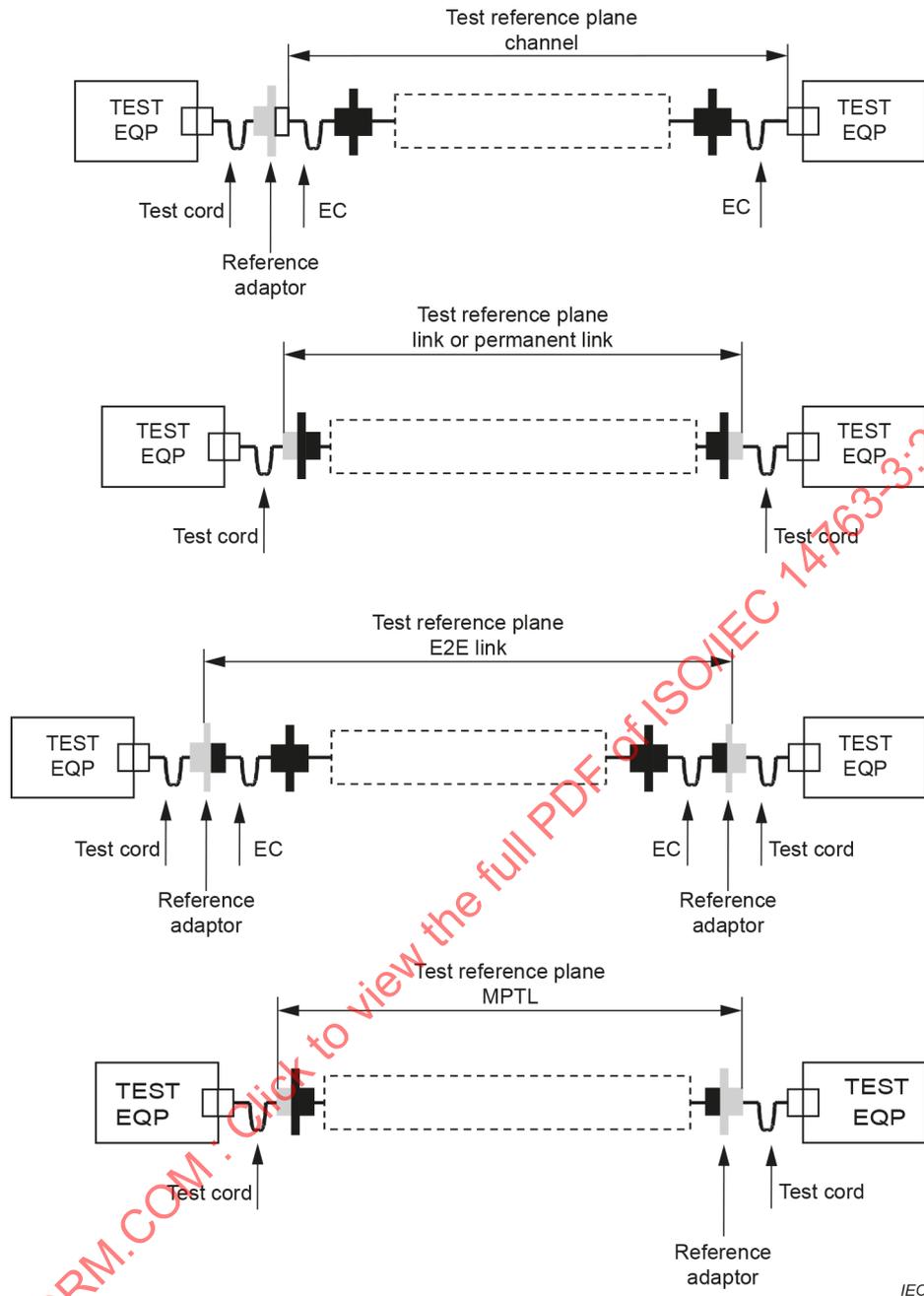


Figure 6 – Representative reference planes for channels, links, permanent links, E2E links, MPTL

The uncertainty of a test system established to measure the optical characteristics of a channel or any link is defined at its reference plane.

The test configuration reference planes of a channel are within the equipment cords next to, but excluding, the connections of the equipment cords into the test cords (see Figure 7). The test configuration reference planes of a link or permanent link, E2E links and MPTL are within the test cords next to, and including, the test cord connections which mate to the termination points of the link under test (see Figure 7).



NOTE 1 The dotted area contains cable and can contain splices and additional connections.

NOTE 2 Measuring the channel attenuation, one EC cord attenuation is not taken into account.

Figure 7 – Test reference planes

It is important to note the following:

- a) optical fibre and connector hardware conditions at the interface between the test cords and a permanent link or channel under test produce variations in measured results;
- b) for short lengths with low attenuation, these variations can be significant in comparison with the value being measured. This defines a minimum loss limit below which attenuation cannot be measured accurately;
- c) to reproduce a given measurement, the test conditions including the configuration of the test cords used shall be reproduced. Changing the test set-up can produce different results.

6.3 Wavelength of measurement

In order to comply with the requirements of ISO/IEC 11801-1 and equivalent standards and unless otherwise agreed, the measurements of transmission performance (attenuation, attenuation and return loss) detailed in Clause 6 and Clause 7 shall be carried out at the following nominal wavelengths:

- a) for MMF, 850 nm and 1 300 nm (see Table 1);
- b) for SMF, 1 310 nm and 1 550 nm (see Table 2).

6.4 Direction of measurement

For permanent links comprising a single fixed cable and terminating connectors, uni-directional testing may be performed. Where the permanent link is of more complex construction, or where there is a risk that components within the cabling under test cause differences in the attenuation depending on the direction of transmission, bi-directional measurements shall be carried out.

NOTE A complex construction is a link with any embedded splices or connectors.

6.5 Protection of transmission and terminal equipment

Transmission and terminal equipment shall be disconnected from the cabling under test before any testing or inspection in accordance with this document is carried out.

6.6 Use of test equipment

External effects such as temperature and humidity can affect the test equipment and thereby influence the measured results. Test equipment shall be operated in accordance with the manufacturer's specifications. Unless the manufacturer's specifications provide other information, test equipment shall be allowed to stabilize at the test environment for at least 15 minutes prior to taking readings.

6.7 Relevance of measurement

Measurements shall either:

- a) be made under environmental conditions which are representative of the intended operational environment; or
- b) be documented as being performed under non-representative conditions.

6.8 Visual inspection for cleanliness and cleaning of cabling interfaces

The inspection for cleanliness of any connector shall take place prior to any mating to another connector. For cylindrical ferrules, at least an area of 250 μm diameter shall be inspected and cleaned. Inspecting and cleaning beyond 250 μm area is recommended for cylindrical ferrules. For rectangular ferrules, the entire ferrule surface (6,4 mm \times 2,5 mm) should be inspected for cleanliness and cleaned when necessary. Use of inspection equipment with large field of view and oblique illumination eases the detection of debris on the rectangular ferrules. The flowchart in Figure 8 shows the procedure to be employed.

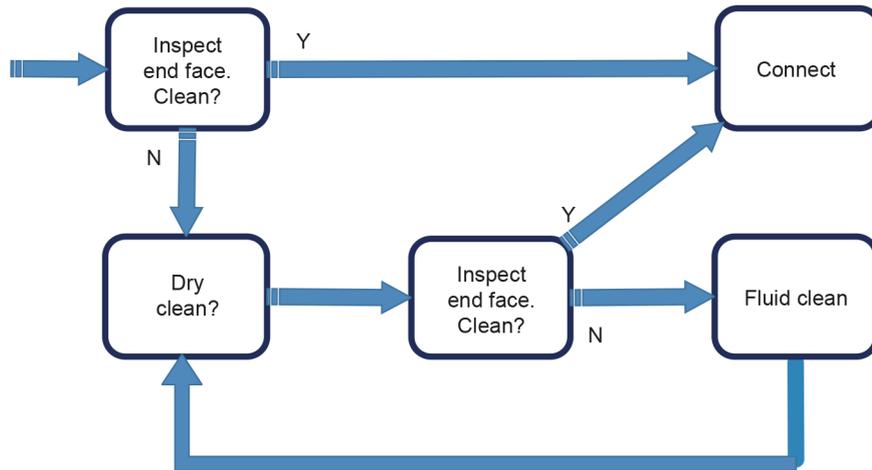


Figure 8 – Fibre end face cleaning cycle

Perform the following steps to ensure cleanliness of the cabling interfaces.

- Focus the microscope so that a crisp image of the ferrule end face (for cylindrical ferrules) or fibre end face (for rectangular ferrules) can be seen.
- For MPO connectors, inspect the entire front surface of the ferrule for debris. For single-mode ferrules, only the angled area needs to be inspected. The small flat area, if present, does not require inspection. Use of a very large field of view microscope is recommended. This microscope will show the entire surface area including bores and guide pins. A maximum of 10 particles between 10 μm and 25 μm are the recommended limit. No limit for particles below 10 μm , no particles larger than 25 μm are recommended.
- For connectors with cylindrical ferrules such as LC and SC connectors, inspect the 250 μm diameter central zone of every fibre end face for debris. A maximum of 10 particles between 5 μm and 10 μm are the recommended limit in the ring between 135 μm to 250 μm . No limit for particles smaller than 5 μm and no particles larger than 10 μm are recommended.
- If the ferrule end face fails inspection for debris, the user shall clean the ferrule end face and repeat the inspection process. Several attempts at cleaning can be required, see Annex E, or follow the supplier's instructions on cleaning methods for connectors and transceivers. Additional information can be found in IEC TR 62627-1. If the ferrule end face meets the requirements, the connectors may be mated. If they are contaminated, they shall be cleaned in accordance with Annex E and re-inspected.

6.9 Testing of installed cabling

6.9.1 General

Testing the attenuation or optical loss of installed cabling for conformance with this document may be undertaken with either LSPM or with an OTDR.

6.9.2 Attenuation of single fibre connector cabling – LSPM

6.9.2.1 General

LSPM is a common way of testing the installed cabling and obtaining numerical results.

Derived from IEC 61280-4-1 and IEC 61280-4-2, the following has been adapted specifically in support of ISO/IEC 11801-1 for permanent link and channel attenuation measurements with an LSPM.

According to ISO/IEC 11801-1, a channel does not include the connector on the equipment cords that interface with the network equipment. The optical attenuation limits specified for network equipment take into account the attenuation associated with the connections of the equipment to the installed cabling.

The testing of a channel utilizes the customer's equipment cords at both ends of the channel and these cords are left in place after testing. The channel test method is normally used to measure the attenuation of a channel at the time of service implementation or maintenance.

The channel and link test method requires a new reference for any change of connection at the light source or the power meter between tests since the connection between source and connected cord should never be disturbed after a reference measurement has been taken.

Always inspect and clean when necessary, the connector interfaces of the source, the launch test cord, the tail test cord and substitution test cord.

Allow sufficient time for light source stabilization in accordance with the light source manufacturer's recommendations.

This document does not specify which test is to be undertaken, direction of test, which wavelengths are to be tested. The testing for a specific installation shall be defined in the quality plan meeting requirements of ISO/IEC 14763-2.

6.9.2.2 Link and permanent link testing

6.9.2.2.1 General

The one-test-cord reference method is applicable for link and permanent link testing.

Link and permanent link testing is utilized to qualify the installed cabling.

Links and permanent links include a mated connector at both ends of the cabling under test.

The criteria for a link and a permanent link are based on the use of reference grade test cords at the cabling under test interface.

The use of reference grade test cords during testing reduces the impact from the introduction of customer equipment cords when creating a channel for an application. For qualification of a channel to support a specific application, channel testing is required.

The introduction of customer equipment cords to a link or permanent link to form a channel can change the attenuation value of the interface connectors by up to 0,75 dB per mated connector pair.

6.9.2.2.2 Requirements for the test system

The test system shall meet the following requirements:

- a) the launch and tail test cord termination shall be able to mate with the power meter interface and the cabling under test;
- b) test cords shall meet the requirements specified within this document and utilize reference grade connectors at the cabling under test interface;
- c) test equipment shall meet the requirements specified in Clause 5;
- d) power meters shall have interchangeable connector receptacles to suit the connector of the cabling under test.

6.9.2.2.3 Test method

The test procedure is shown below.

- a) Inspect and clean when necessary the connector interfaces of the source, the launch test cord and the cabling under test as specified within this document.
- b) Allow sufficient time for light source stabilization in accordance with the light source manufacturer's recommendations.
- c) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM) (see Figure 9).
- d) After reference setting, do not disconnect the LTC connector from the light source as the reference setting will then become invalid. In the reference setting, input connector of power meter shall match the connector used in the system under test at the end of the link where the LS is deployed.

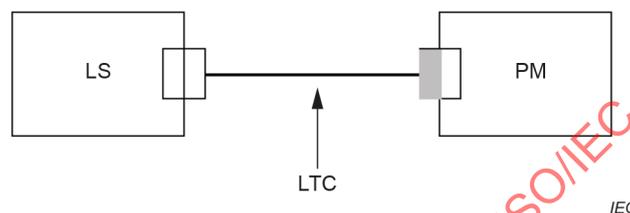


Figure 9 – Connection of LS to LTC to PM for reference setting

- e) Set the reference to 0,00 dB or record the reference measurement (P_r) in dBm or watts.
- f) Connect the LTC to the TTC using a reference adaptor and connect the other end of the TTC to the power meter (see Figure 10).

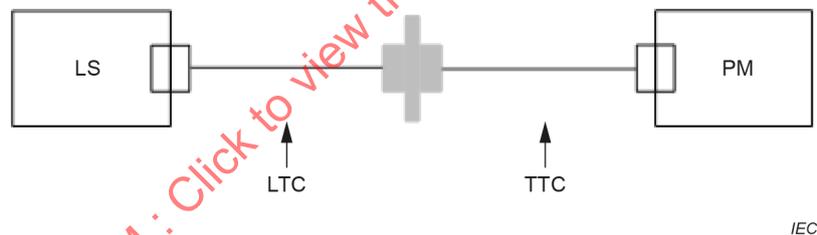


Figure 10 – Connection of LTC to TTC to verify attenuation of reference connectors

- g) Measure and record the attenuation of the LTC–TTC combination in dB.
- h) The maximum permitted attenuation shall be the value of one connection with two reference connectors (see Table 3).

If the attenuation is more than the maximum permitted value, clean all end faces, inspect then reconnect and re-test. Re-set the reference if necessary. Use alternative test cords if necessary. If the maximum permitted attenuation is not achievable, a standard's compliant link measurement cannot be made.

- i) Connect the LTC to the near end of the link. Connect the TTC to the far end of the link (see Figure 11).

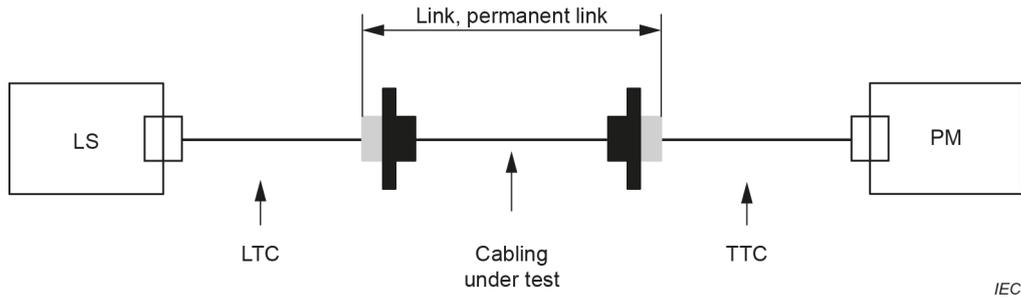


Figure 11 – Connections to link or permanent link for attenuation measurement

- j) Measure and record the power (P_1) of the link under test in dBm or watts.
- k) The optical attenuation calculation for a link or permanent link is the following:

$$A = P_r - P_1 \quad (\text{dB}) \quad (1)$$

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated as follows:

$$A = -10 \lg(P_1/P_r) \quad (\text{dB}) \quad (2)$$

6.9.2.2.4 Measurement uncertainties

For this method, the measurement uncertainties at 95 % confidence level evaluated using IEC TR 61282-14, requirements of this document and relevant data are as follows:

- a) SMF 1 310 nm: 0,33 dB for fibre length \leq 2 km;
- b) SMF 1 310 nm: 0,46 dB for fibre length from 2 km to 10 km;
- c) SMF 1 550 nm: (ffs);
- d) MMF 850 nm: 0,29 dB when measured attenuation \leq 1,9 dB;
- e) MMF 850 nm: $0,14 \times$ measured attenuation in dB, when measured attenuation $>$ 1,9 dB;
- f) MMF 1 300 nm: 0,35 dB when measured attenuation \leq 1,15 dB;
- g) MMF 1 300 nm: $0,29 \times$ measured attenuation in dB, when measured attenuation $>$ 1,15 dB.

NOTE When the uncertainty is reported with the measurement result, the reporting is: $M \pm U$, where M is the measurement and U is the uncertainty.

6.9.2.2.5 Treatment of results

The use of reference terminations on the test cords affects the calculation of limits of testing for link or permanent link attenuation. The referencing procedure involves the interconnection of reference terminations in accordance with 5.6. The measurement of the link includes connection of the test cords to non-reference terminations, which for ISO/IEC 11801-1 compliant connecting hardware are specified in Table 3.

Using the one-test-cord reference method, the calculated limit of testing link attenuation is:

- a) for MMF: $(2 \times A_{RSG}) + \sum A_{CA} + \sum A_{CON}$;
- b) for SMF: $(2 \times A_{RSG}) + \sum A_{CA} + \sum A_{CON}$.

where

A_{RSG} is reference to standard grade connection attenuation (dB);

A_{CA} is cable attenuation (dB);

A_{CON} is embedded connection attenuation (dB).

Note that where the performance of the interfaces to the cabling under test is not in accordance with ISO/IEC 11801-1, information should be sought from the manufacturers of the interfaces to determine the relevant information for Table 3.

Where bi-directional testing has been undertaken, the optical attenuation limits shall be met in both directions.

Where testing has been undertaken at more than one wavelength, the optical attenuation requirements shall be met at all wavelengths.

The treatment of results alternative to those listed in 6.9.2.2.5 shall be detailed in the quality plan meeting requirements of ISO/IEC 14763-2.

6.9.2.3 E2E link testing

6.9.2.3.1 General

The E2E link attenuation test method is applicable for E2E link attenuation testing only.

E2E link attenuation testing is utilized to qualify the installed cabling.

E2E links include additional mated connectors at both ends of the channel. This can be a direct connected cable or a link or permanent link with attached equipment cords. The connector at the end of the E2E link can also be terminated directly at the end of the cable.

The criteria for an E2E link are based on the use of reference grade test cords at the cabling under test interface.

The use of reference grade test cords during testing utilizing the E2E link attenuation test method reduces the variation between the E2E link and channel attenuation.

The application requirements for attenuation specified within ISO/IEC 11801-1 are based on channel attenuation requirements and as such, E2E link testing is not suitable for application assessment. For qualification of a channel to support a specific application, channel testing is necessary.

The E2E link attenuation measurements should have an appropriate margin for the maximum attenuation for a given application as shown in ISO/IEC 11801-1:2017, Annex E.

6.9.2.3.2 Requirements for the test system

The test system shall meet the following requirements:

- a) the launch and tail test cord termination shall be able to mate with the power meter interface and the cabling under test;
- b) test cords shall meet the requirements specified within this document and utilize reference grade connectors at the cabling under test interface;
- c) test equipment shall meet the requirements specified in Clause 5.
- d) Power meters shall have interchangeable connector receptacles to suit the connector of the cabling under test.

6.9.2.3.3 Test method

The test procedure is shown below.

- a) Inspect and clean when necessary the connector interfaces of the source, the launch test cord and the cabling under test as specified within this document.
- b) Allow sufficient time for light source stabilization in accordance with the light source manufacturer's recommendations.
- c) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM) (see Figure 12).
- d) After reference setting, do not disconnect the launch test cord connector from the light source as the reference setting will then become invalid.

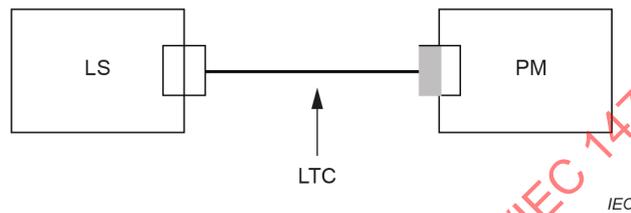


Figure 12 – Connection of LS to LTC to PM for reference setting

- e) Set the reference to 0,00 dB or record the reference measurement (P_r) in dBm or watts.
- f) Connect the LTC to the TTC using a reference adaptor and connect the other end of the TTC to the power meter (see Figure 13).

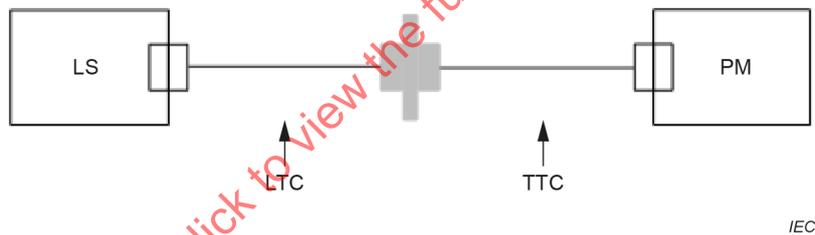
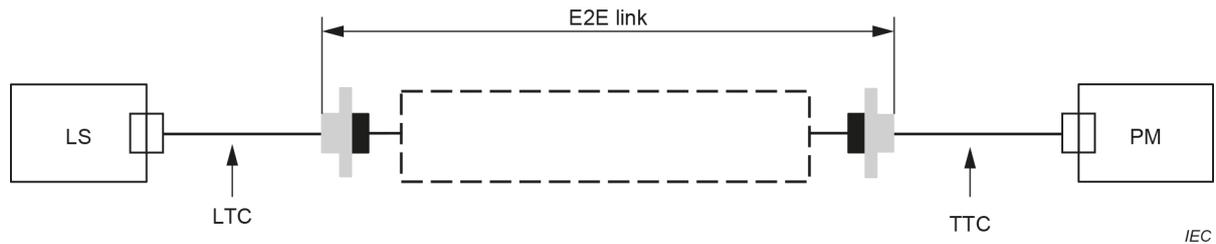


Figure 13 – Connection of LTC to TTC to verify attenuation of reference connectors

- g) Measure and record the attenuation of the LTC–TTC combination in dB.
- h) The maximum permitted attenuation shall be the value of one connection with two reference connectors (see Table 3).

NOTE If the attenuation is more than the maximum permitted value, clean all end faces, inspect then reconnect and re-test. Re-set the reference if necessary. Use alternative test cords if necessary. If the maximum permitted attenuation is not achievable, a standard's compliant E2E link measurement cannot be made.

- i) Connect the launch test cord to the near end of the link by using a reference adaptor. Connect the tail test cord to the far end of the link by using a reference adaptor (see Figure 14).



NOTE The dotted box can contain splices, connectors, cords or other components.

Figure 14 – Connections to E2E link for attenuation measurement

- j) Measure and record the power (P_1) of the link under test in dBm or watts.
- k) The optical attenuation calculation for a E2E link is the following:

$$A = P_r - P_1 \quad (\text{dB}) \quad (1)$$

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated as follows:

$$A = -10 \lg(P_1/P_r) \quad (\text{dB}) \quad (2)$$

6.9.2.3.4 Measurement uncertainties

For this method, the measurement uncertainties at 95 % confidence level evaluated using IEC TR 61282-14, requirements of this document and relevant data are as follows:

- a) SMF 1 310 nm: 0,33 dB for fibre length ≤ 2 km;
- b) SMF 1 310 nm: 0,46 dB for fibre length from 2 km to 10 km;
- c) SMF 1 550 nm: (ffs);
- d) MMF 850 nm: 0,29 dB when measured attenuation $\leq 1,9$ dB;
- e) MMF 850 nm: $0,14 \times$ measured attenuation in dB, when measured attenuation $> 1,9$ dB;
- f) MMF 1 300 nm: 0,35 dB when measured attenuation $\leq 1,15$ dB;
- g) MMF 1 300 nm: $0,29 \times$ measured attenuation in dB, when measured attenuation $> 1,15$ dB.

NOTE When the uncertainty is reported with the measurement result, the reporting is: $M \pm U$, where M is the measurement and U is the uncertainty.

6.9.2.3.5 Treatment of results

The use of reference terminations on the test cords affects the calculation of limits of testing for E2E link attenuation. The referencing procedure involves the interconnection of reference terminations in accordance with 5.6. The measurement of the link includes connection of the test cords to non-reference terminations, which for ISO/IEC 11801-1 compliant connecting hardware are specified in Table 3.

Using the E2E link attenuation test reference method, the calculated limit of testing link attenuation is:

- a) for MMF: $(2 \times A_{\text{RSG}}) + \sum A_{\text{CA}} + \sum A_{\text{CON}}$;
- b) for SMF: $(2 \times A_{\text{RSG}}) + \sum A_{\text{CA}} + \sum A_{\text{CON}}$.

where

A_{RSG} is reference to standard grade connection attenuation (dB);

A_{CA} is cable attenuation (dB);

A_{CON} is embedded connection attenuation (dB).

Where the performance of the interfaces to the cabling under test is not in accordance with ISO/IEC 11801-1, information should be sought from the manufacturers of the interfaces to determine the relevant information for Table 3.

Where bi-directional testing has been undertaken, the optical attenuation limits shall be met in both directions.

Where testing has been undertaken at more than one wavelength, the optical attenuation limits shall be met at all wavelengths.

The treatment of results alternative to those listed in 6.9.2.3 shall be detailed in the quality plan meeting requirements of ISO/IEC 14763-2.

6.9.2.4 Channel testing

6.9.2.4.1 General

The channel test method is applicable only for channel testing.

Channel testing is utilized for application implementation to confirm the optical attenuation of the channel is suitable to support the application.

Channel testing includes the customer equipment cords at both ends of the cabling under test. These customer equipment cords shall remain in place once testing has been completed.

6.9.2.4.2 Requirements for the test system

The test system shall meet the following requirements:

- a) the connector on the power meter shall be the same as the cabling under test (for reference setting);
- b) test cords shall meet the requirements specified within this document and utilize reference grade connectors at the near end equipment cord interface;
- c) test equipment shall meet the requirements specified in Clause 5;
- d) power meters shall have interchangeable connector receptacles to suit the connector of the cabling under test.

6.9.2.4.3 Test method

The test procedure is shown below.

- a) Inspect and clean when necessary all connector interfaces of the source and the launch test cord.
- b) Allow sufficient time for light source stabilization in accordance with recommendations from the manufacturer of the light source.

- c) Connect the launch test cord (LTC) to the light source (LS) at one end and to the equipment (EQP) cord at the other end. Connect equipment cord to the power meter (PM) (see Figure 15). Allow sufficient time for the light source stabilization in accordance with the light source manufacturer's recommendations. Since this reference measurement is carried out with a near end EQP cord, it is possible that the defect of near end EQP cord will not be found. When this test method is used, the quality of the near end EQP cord shall comply with the requirement (see Figure 15).

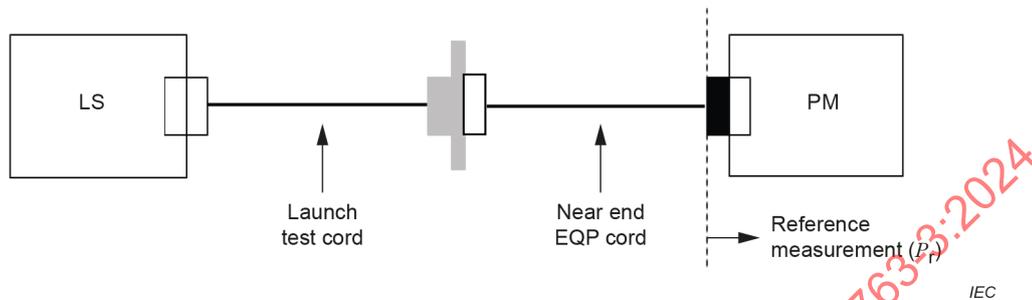


Figure 15 – Connection of LS to LTC to near end EQP cord to PM for reference setting

- d) Record the reference measurement P_r in dBm or watts.
- e) The near end EQP cord is disconnected from the power meter and the LTC-EQP cord combination is reconnected to the fixed cable of the channel under test.
- f) At the far end of the channel, connect the far end EQP cord to the power meter (see Figure 16).

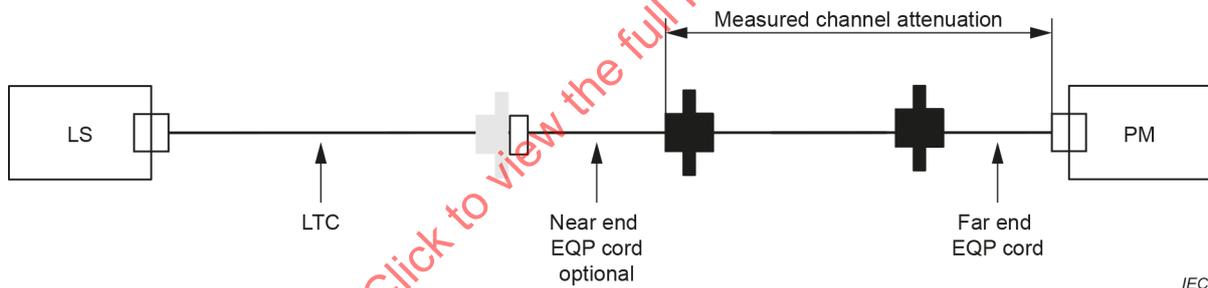


Figure 16 – Connections to channel test for attenuation measurement

NOTE Measuring the channel attenuation, one EQP cord attenuation is not taken into account.

- g) The power P_1 is measured directly at the far end EQP cord. The measurement, P_1 , shall be recorded in dBm or watts.
- h) The optical attenuation for a channel is the following:

$$A = P_r - P_1 \quad (\text{dB}) \tag{1}$$

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated as follows:

$$A = -10 \lg(P_1/P_r) \quad (\text{dB}) \tag{2}$$

The channel testing is carried out in one direction only.

6.9.2.4.4 Measurement uncertainties

For this method, the measurement uncertainties at 95 % confidence level evaluated using IEC TR 61282-14, requirements of this document and relevant data are as follows:

- a) SMF 1 310 nm: 0,16 dB for fibre length ≤ 2 km;
- b) SMF 1 310 nm: 0,35 dB for fibre length from 2 km to 10 km;
- c) SMF 1 550 nm: (ffs);
- d) MMF 850 nm: 0,17 dB when measured attenuation $\leq 1,0$ dB;
- e) MMF 850 nm: $0,17 \times$ measured attenuation in dB, when measured attenuation $> 1,0$ dB;
- f) MMF 1 300 nm: 0,29 dB when measured attenuation $\leq 0,2$ dB;
- g) MMF 1 300 nm: $0,29 \times$ measured attenuation in dB, when measured attenuation $> 0,2$ dB.

NOTE When the uncertainty is reported with the measurement result, the reporting is: $M \pm U$, where M is the measurement and U is the uncertainty.

6.9.2.4.5 Treatment of results

The optical attenuation of a channel is:

$$\sum A_{CA} + \sum A_{CON}$$

where

A_{CA} is cable attenuation (dB);

A_{CON} is embedded connection attenuation (dB).

Where compliance with a specified value is required, the measured result shall be termed a pass result, a fail result or a marginal result. Where compliance for a specific application is required, the optical attenuation of the channel shall equal or be less than that application insertion loss value specified in ISO/IEC 11801-1:2017, Table E.4.

Examples of optical attenuation calculations are shown in Annex C.

6.9.2.4.6 Test result

For a given wavelength and in a given direction, measured attenuation is calculated using Formula (1) or Formula (2).

For example, if the reference power level P_r is -20 dBm (0,01 mW) and the measured power level P_1 is -23 dBm (0,005 mW) then the attenuation is 3 dB.

In the case of bi-directional results using light source and power meter, the worst of the two measured results shall be considered as the overall measured result.

6.9.2.5 MPTL testing

6.9.2.5.1 General

The MPTL attenuation test method is applicable to MPTL attenuation testing only.

MPTL attenuation testing is utilized to qualify the installed cabling.

MPTL attenuation budget includes the two mated connectors at both ends of the link.

The criteria for an MPTL are based on the use of reference grade test cords at the cabling under test interface and the use of a reference grade adaptor at the modular plug termination end.

The use of reference grade test cords during testing utilizing the MPTL attenuation test method reduces the variation between the MPTL, the E2E link and channel attenuation.

The application requirements for attenuation specified within ISO/IEC 11801-1 are based on channel attenuation limits and as such, MPTL testing is not suitable for application assessment. For qualification of a channel to support a specific application, channel testing is necessary.

6.9.2.5.2 Requirements for the test system

The test system shall meet the following requirements:

- a) the launch and tail test cord termination shall be able to mate with the power meter interface and the cabling under test;
- b) test cords shall meet the requirements specified within this document and utilize reference grade connectors at the cabling under test interface;
- c) test equipment shall meet the requirements specified in Clause 5.

6.9.2.5.3 Test method

The test procedure is shown below:

- a) Inspect and clean when necessary the connector interfaces of the source, the launch test cord, the cabling under test, and the tail test cord as specified within this document.
- b) Allow sufficient time for light source stabilization in accordance with the light source manufacturer's recommendations.
- c) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM) (see Figure 17).
- d) After reference setting, do not disconnect the launch test cord connector from the light source as the reference setting will then become invalid.

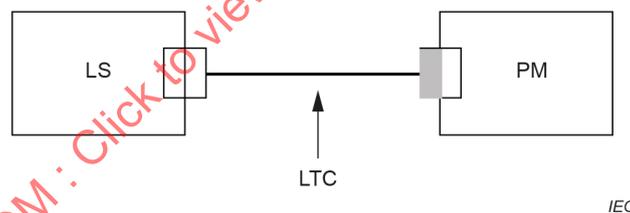


Figure 17 – Connection of LS to LTC to PM for reference setting

- e) Set the reference to 0,00 dB or record the reference measurement (P_r) in dBm or watts.
- f) Connect the LTC to the TTC using the reference adaptor and connect the other end of the TTC to the PM (see Figure 18).

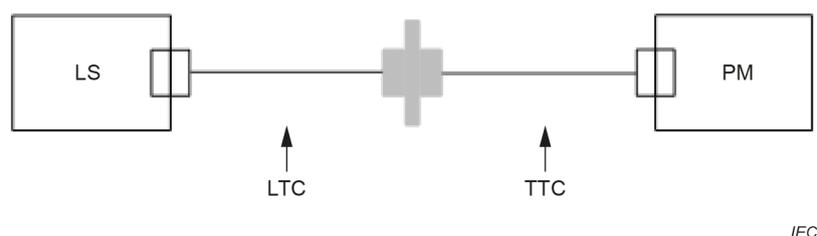


Figure 18 – Connection of LTC to TTC to verify attenuation of reference connectors

- g) Measure and record the attenuation of the LTC–TTC combination in dB.
- h) The maximum permitted attenuation shall be the value of one connection with two reference connectors (see Table 3).

NOTE If the attenuation is more than the maximum permitted value, clean all end faces, inspect then reconnect and re-test. Re-set the reference if necessary. Use alternative test cords if necessary. If the maximum permitted attenuation is not achievable, a standard's compliant MPTL measurement cannot be made.

- i) Connect the LTC to the near end of the MPTL. Connect the TTC and reference adaptor to the far end of the MPTL (see Figure 19).

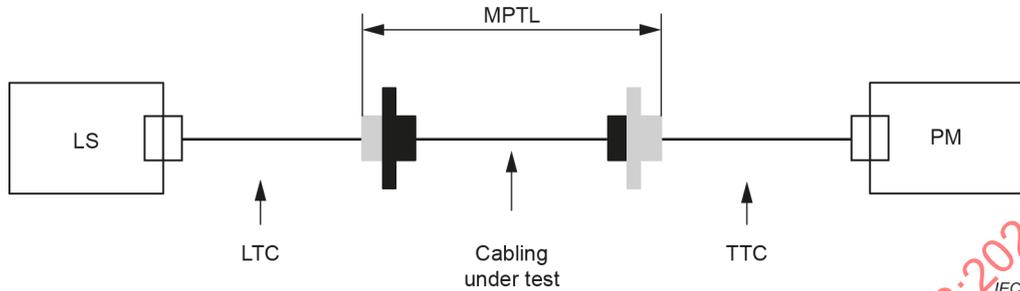


Figure 19 – Connections to MPTL for attenuation measurement

- j) Measure and record the power (P_1) of the MPTL under test in dBm or watts.
 k) The optical attenuation calculation for a MPTL is the following:

$$A = P_r - P_1 \quad (\text{dB}) \quad (1)$$

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated as follows:

$$A = -10 \lg(P_1/P_r) \quad (\text{dB}) \quad (2)$$

6.9.2.5.4 Measurement uncertainties

For this method, the measurement uncertainties at 95 % confidence level evaluated using IEC TR 61282-14, requirements of this document and relevant data are as follows:

- SMF 1 310 nm: 0,33 dB for fibre length \leq 2 km;
- SMF 1 310 nm: 0,46 dB for fibre length from 2 km to 10 km;
- SMF 1 550 nm: (ffs);
- MMF 850 nm: 0,29 dB when measured attenuation \leq 1,9 dB;
- MMF 850 nm: $0,14 \times$ measured attenuation in dB, when measured attenuation $>$ 1,9 dB;
- MMF 1 300 nm: 0,35 dB when measured attenuation \leq 1,15 dB;
- MMF 1 300 nm: $0,29 \times$ measured attenuation in dB, when measured attenuation $>$ 1,15 dB.

NOTE When the uncertainty is reported with the measurement result, the reporting is: $M \pm U$, where M is the measurement and U is the uncertainty.

6.9.2.5.5 Treatment of results

The use of reference terminations on the test cords affects the calculation of limits of testing for MPTL attenuation. The referencing procedure involves the interconnection of reference terminations in accordance with 5.6. The measurement of the MPTL includes connection of the reference test cords to non-reference terminations, which for ISO/IEC 11801-1 compliant connecting hardware are specified in Table 3.

Using the one-test-cord reference method, the calculated limit of testing MPTL attenuation is:

a) for MMF: $(2 \times A_{\text{RSG}}) + \sum A_{\text{CA}} + \sum A_{\text{CON}}$;

b) for SMF: $(2 \times A_{\text{RSG}}) + \sum A_{\text{CA}} + \sum A_{\text{CON}}$.

where

A_{RSG} is reference to standard grade connection attenuation (dB);

A_{CA} is cable attenuation (dB);

A_{CON} is embedded connection attenuation (dB).

Where the performance of the interfaces to the cabling under test is not in accordance with ISO/IEC 11801-1, information should be sought from the manufacturers of the interfaces to determine the relevant information.

Where testing has been undertaken at more than one wavelength, the optical attenuation limits shall be met at all wavelengths.

Where bi-directional testing has been undertaken, the optical attenuation limits shall be met in both directions.

In the case of bi-directional results using light source and power meter, the worst of the two measured results shall be considered as the overall measured result.

The treatment of results alternative to those listed in 6.9.2.5 shall be detailed in the quality plan meeting requirements of ISO/IEC 14763-2.

6.9.3 Attenuation of multi-fibre connector cabling – LSPM

6.9.3.1 General

Multi-fibre connectors have multiple fibres contained in a single housing, usually rectangular, that contain alignment devices, usually pins and mating holes, to ensure each fibre core aligns very precisely with its mating connector. The multi-fibre push on connector (MPO) is a widely used connecting device.

NOTE With MPO cabling different adaptors, polarities and matings are possible. Documentation of the complete system is useful.

6.9.3.2 MPO to MPO link or permanent link testing – One-test-cord reference method LSPM

6.9.3.2.1 General

The one-test-cord reference method is acceptable for link and permanent links with MPO when the pin assignment of the fibre test cords used can be altered.

Annex F specifies cabling alternatives where the one-test-cord reference method is not possible.

Link and permanent link testing is utilized to qualify the installed cabling.

Link and permanent links include a mated connector at both ends of the cabling under test. Any matings made in this test procedure shall involve the use of a pinned and a unpinned connector.

The criteria for a link or permanent link are based on the use of reference grade test cords at the cabling under test interface. Test cords are defined in Table 6 and Table 7.

The introduction of customer equipment cords to a link or permanent link to form a channel can change the attenuation value of the interface connectors by up to 0,75 dB per connector.

6.9.3.2.2 Requirements for the test system

The test system shall meet the following requirements:

- a) the interface connector of the launch test cord shall be a multi-fibre connector;
- b) the connector of the power meter shall be a multi-fibre connector;
- c) the light source launch test cord requires the use of a pin conversion test cord;
- d) the interface connector of the power meter test cord shall use a pin conversion test cord;
- e) test cords shall meet the limits specified within this document and utilize low loss connectors at the cabling under test interface; and
- f) test equipment shall meet the requirements specified in Clause 5.

6.9.3.2.3 Test method

The test procedure is shown below.

- a) Inspect and clean when necessary the connector interfaces of the source and the launch test cord.
- b) Allow sufficient time for light source stabilization in accordance with recommendations from the manufacturer of the light source.
- c) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM) (see Figure 20).
- d) After reference setting, do not disconnect the LTC connector from the light source as the reference setting will then become invalid.

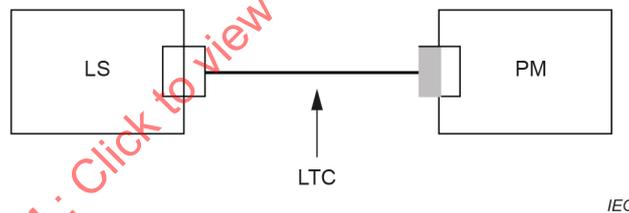


Figure 20 – Connection of LS to LTC to PM for reference setting

- e) Set the reference to 0,00 dB or record the reference measurement (P_r) in dBm or watts.
- f) Connect the LTC to the TTC using an MPO adaptor (see Figure 21). This arrangement is used for verification of both low loss connections and not as a reference measurement.

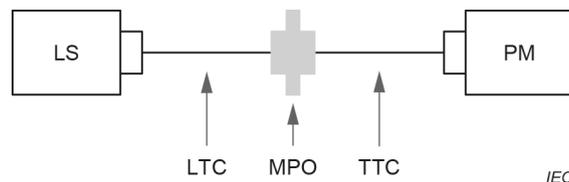


Figure 21 – Connection of LTC to TTC for test-cord verification

- g) Measure and record the attenuation of all cores of the LTC–TTC combination (where no pin conversion is required on the test cords) or the PCTC–TTC (when the pin conversion is required on the test cords) combination in dB.

- h) The maximum permitted attenuation for verification shall be the value of one connection with two reference connectors (see Table 3) for the LTC–TTC or PCTC–TTC combination.

NOTE If the attenuation is more than the maximum permitted value, clean all end faces, inspect then reconnect and re-test. Re-set the reference if necessary. Use alternative test cords if necessary. If the maximum permitted attenuation is not achievable, a standards compliant permanent link measurement cannot be made.

- i) Remove the MPO adaptor, connect the LTC to the near end of the MPO link and connect the TTC to the far end of the MPO link (see Figure 22). Where pin conversion is required on the test cords, remove the MPO adaptor connected to the TTC, and convert by means of the pin altering feature on the test cords, the TTC or LTC – whichever is required to form connection to the MPO link under test.

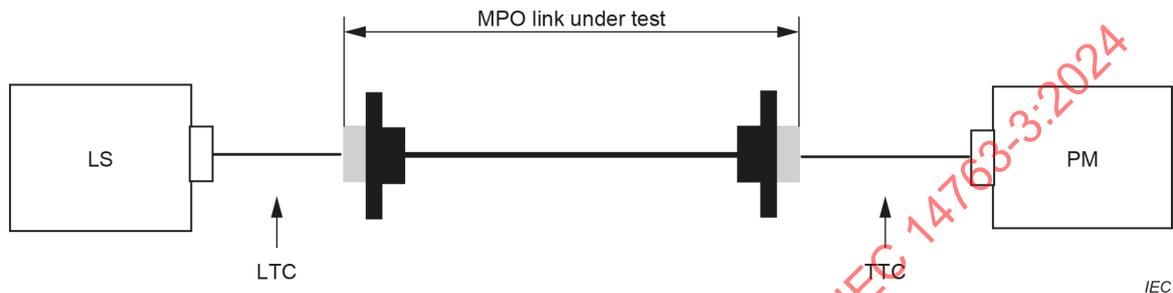


Figure 22 – Connections to link or permanent link attenuation

- j) Measure and record the power (P_1) of all cores of the MPO link under test in dBm or watts.
 k) The optical attenuation calculation for a core of the MPO link is the following:

$$A = P_r - P_1 \text{ (dB)} \quad (1)$$

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated as follows:

$$A = -10 \lg(P_1/P_r) \text{ (dB)} \quad (2)$$

6.9.3.2.4 Measurement uncertainties

For this method, the measurement uncertainties at 95 % confidence level evaluated using IEC TR 61282-14, requirements of this standard and relevant data are as follows:

- SMF 1 310 nm: 0,54 dB for fibre length \leq 2 km;
- SMF 1 310 nm: 0,79 dB for fibre length from 2 km to 10 km;
- SMF 1 550 nm: (ffs);
- MMF 850 nm: 0,40 dB when measured attenuation \leq 2,0 dB;
- MMF 850 nm: 0,50 dB when measured attenuation from 2,0 dB to 3dB.
- MMF 1 300 nm: (ffs);

NOTE When the uncertainty is reported with the measurement result, the reporting is: $M \pm U$, where M is the measurement and U is the uncertainty.

6.9.3.2.5 Treatment of results

The use of reference terminations on the test cords affects the calculation of limits of testing for permanent link attenuation. The referencing procedure involves the interconnection of low loss terminations in accordance with 5.6. The measurement of the link includes connection of the test cords to non-reference terminations, which for ISO/IEC 11801-1 compliant connecting hardware are specified in Table 3.

Using the one-test-cord reference method, the calculated limit of testing link attenuation is:

- a) for MMF: $(2 \times A_{\text{RSG}}) + \sum A_{\text{CA}} + \sum A_{\text{CON}}$;
- b) for SMF: $(2 \times A_{\text{RSG}}) + \sum A_{\text{CA}} + \sum A_{\text{CON}}$.

where

A_{RSG} is reference to standard grade connection attenuation (dB);

A_{CA} is cable attenuation (dB);

A_{CON} is embedded connection attenuation (dB).

When MPO PCTC is used, add an allowance for the connection with two reference connectors (see Figure 24):

- 1) for MMF: MPO mated connectors 0,15 dB;
- 2) for SMF: MPO mated connectors 0,35 dB.

Where the performance of the interfaces to the cabling under test is not in accordance with ISO/IEC 11801-1, information should be sought from the manufacturers of the interfaces to determine the relevant information for Table 3.

Where bi-directional testing has been undertaken, the optical attenuation limits shall be met in both directions.

Where testing has been undertaken at more than one wavelength, the optical attenuation limits shall be met at all wavelengths.

The treatment of results alternative to those listed in 6.9.3.2 shall be detailed in the quality plan meeting requirements of ISO/IEC 14763-2.

6.9.3.3 MPO E2E link testing – enhanced-three-test-cord reference method LSPM

6.9.3.3.1 General

The MPO E2E link test method is applicable for E2E links with MPO connectors.

E2E link testing is utilized to qualify the installed cabling.

E2E links include a mated connector at both ends of the channel. This can be a direct connected cable or a (permanent) link with attached equipment cords. The connector at the end of the E2E link can also be terminated directly at the end of the cable.

The criteria for an E2E link are based on the use of reference grade test cords at the cable under test interface.

The use of reference grade test cords during testing reduces the impact from the introduction of customer equipment cords when creating a channel for an application.

The introduction of customer equipment cords to a (permanent) link to form a channel can change the attenuation value of the interface connectors by up to 0,75 dB per connector.

6.9.3.3.2 Requirements for the test system

The test system shall meet the following requirements:

- a) the interface connector of the light source test cord shall be a multi-fibre connector;
- b) the interface connector of the power meter shall be a multi-fibre connector;

- c) the interface connector of the launch test cord shall be the opposite to that of the cabling under test;
- d) the interface connector of the power meter test cord shall be the opposite to that of the cabling under test;
- e) test cords shall meet the limits specified within this document and utilize reference grade connectors at the cabling under test interface; and
- f) test equipment shall meet the requirements specified in Clause 5.

6.9.3.3.3 Test method

The test procedure is shown below.

- a) Inspect and clean when necessary the connector interfaces of the source and the launch test cord.
- b) Allow sufficient time for light source stabilization in accordance with recommendations from the manufacturer of the light source.
- c) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM) (see Figure 23).

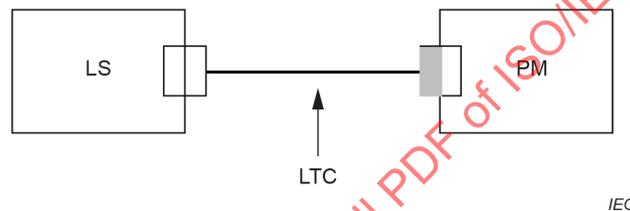


Figure 23 – Connection of LS to LTC to PM for reference setting

- d) Set the reference to 0,00 dB or record the reference measurement (P_r) in dBm or watts.
- e) Connect the LTC to the TTC using MPO adaptors (see Figure 24) using a substitution test cord (STC) with reference connectors each end to ensure the pin configuration is correct. The STC shall be pinned the same as the MPO link under test. This arrangement is used for verification of both reference grade connections and not as a reference measurement.

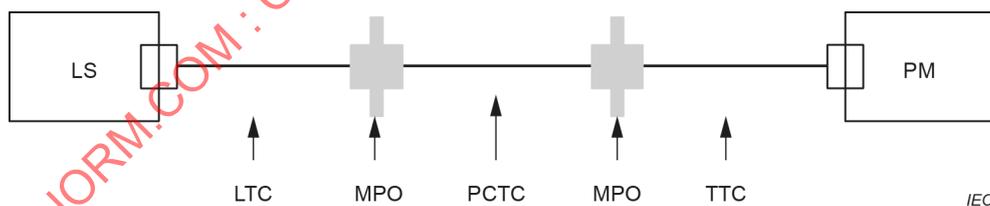


Figure 24 – Connection of LTC to PCTC to TTC to verify the attenuation of reference connectors

- f) Measure and record the attenuation of all cores of the LTC–STC–TTC combination in dB.
- g) The maximum permitted attenuation for verification shall be the value of two connections each with two reference connectors (see Table 6 and Table 7) for the LTC–STC–TTC combination.

If the attenuation is more than the maximum permitted value, clean all end faces, inspect then reconnect and re-test. Re-set the reference if necessary. Use alternative test cords if necessary. If the maximum permitted attenuation is not achievable, a standards compliant permanent link measurement cannot be made.

- h) Remove the MPO adaptors, connect the LTC to the near end of the MPO link and connect the TTC to the far end of the MPO link (see Figure 25).

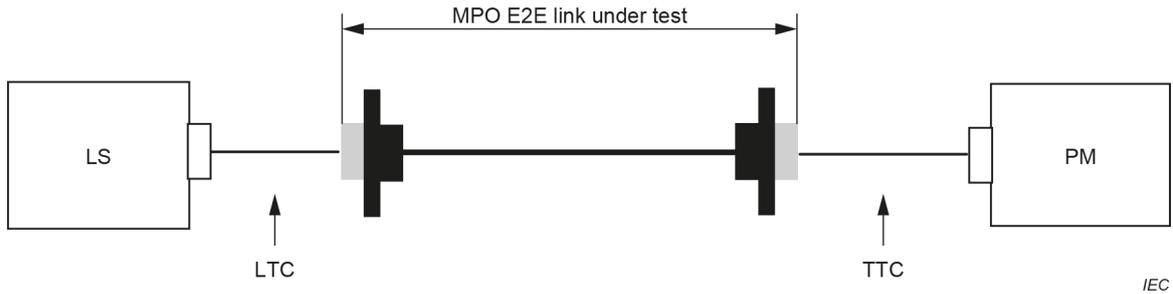


Figure 25 – Connections to E2E link for attenuation measurement

- i) Measure and record the power (P_1) of all cores of the MPO E2E link under test in dBm or watts.
- j) The optical attenuation calculation for a core of the MPO E2E link is the following:

$$A = P_r - P_1 \quad (\text{dB}) \quad (1)$$

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated as follows:

$$A = -10 \lg(P_1/P_r) \quad (\text{dB}) \quad (2)$$

6.9.3.3.4 Measurement uncertainties

For this method, the measurement uncertainties at 95 % confidence level evaluated using IEC TR 61282-14, requirements of this document and relevant data are as follows:

- a) SMF 1 310 nm: 0,54 dB for fibre length ≤ 2 km;
- b) SMF 1 310 nm: 0,79 dB for fibre length from 2 km to 10 km;
- c) SMF 1 550 nm: (ffs);
- d) MMF 850 nm: 0,40 dB when measured attenuation $\leq 2,0$ dB;
- e) MMF 850 nm: 0,50 dB when measured attenuation is from 2,0 dB to 3 dB;
- f) MMF 1 300 nm: (ffs).

NOTE When the uncertainty is reported with the measurement result, the reporting is: $M \pm U$, where M is the measurement and U is the uncertainty.

6.9.3.3.5 Treatment of results

The use of reference terminations on the test cords affects the calculation of limits of testing for permanent link attenuation. The referencing procedure involves the interconnection of low loss terminations in accordance with 5.6. The measurement of the link includes connection of the test cords to non-reference terminations, which for ISO/IEC 11801-1 compliant connecting hardware are specified in Table 3.

Using the enhanced-three-test-cord reference method, the calculated limit of testing link attenuation is:

- a) for MMF: $(2 \times A_{RSG}) + \sum A_{CA} + \sum A_{CON}$;
- b) for SMF: $(2 \times A_{RSG}) + \sum A_{CA} + \sum A_{CON}$.

where

A_{RSG} is reference to standard grade connection attenuation (dB);

A_{CA} is cable attenuation (dB);

A_{CON} is embedded connection attenuation (dB).

Where the performance of the interfaces to the cabling under test is not in accordance with ISO/IEC 11801-1, information should be sought from the manufacturers of the interfaces to determine the relevant information for Table 3.

Where bi-directional testing has been undertaken, the optical attenuation limits shall be met in both directions.

Where testing has been undertaken at more than one wavelength, the optical attenuation limits shall be met at all wavelengths.

The treatment of results alternative to those listed in 6.9.3.3 shall be detailed in the quality plan meeting requirements of ISO/IEC 14763-2.

6.9.3.4 MPO to single-fibre connector E2E link testing

6.9.3.4.1 General

The MPO E2E link test method is applicable for E2E links with multi-fibre connectors at one interface end, and single-fibre connectors at the other interface end.

6.9.3.4.2 Requirements for the test system

For testing in accordance with multi light source E2E link testing, the use of a fanout MPO-SFC is required. The test system shall meet the following requirements:

- a) the MPO gender shall match the MPO at the other end of the link;
- b) the interface connector of the light source test cord shall be able to mate with the power meter interface;
- c) the interface connector of the light source can use a pin conversion test cord;
- d) the interface connector of the power meter test cord shall be the same as the cabling under test;
- e) test cords and pin conversion test cords shall meet the limits specified within this document and utilize low loss connectors at the cabling under test interface;
- f) test equipment shall meet the requirements specified in Clause 5.

6.9.3.4.3 Test method

The test procedure is shown below.

- a) Inspect and clean when necessary the connector interfaces of the source and the launch test cord.
- b) Connect the single fibre connectors of the fanout test cord (FTC) to the cable link under test, ensuring the MPO of the FTC is the same as the MPO of the cabling under test. Correct polarity shall be implemented.
- c) Allow sufficient time for light source stabilization in accordance with recommendations from the manufacturer of the light source.
- d) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM) (see Figure 26).

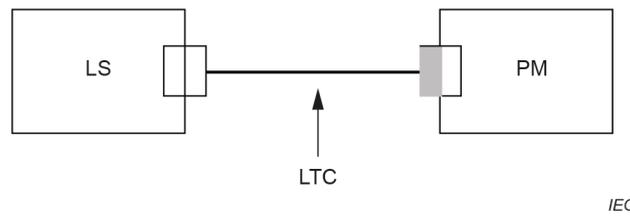


Figure 26 – Connection of LS to LTC to PM for reference setting

- e) Set the reference to 0,00 dB or record the reference measurement (P_r) in dBm or watts.
- f) Connect the LTC to the TTC using MPO adaptors (see Figure 27) where no pin conversion is required on the test cords, or connect the LTC to the PCTC and connect the TTC to the PCTC using MPO adaptors (see Figure 28). This arrangement is used for verification of both low loss connections and not as a reference measurement.

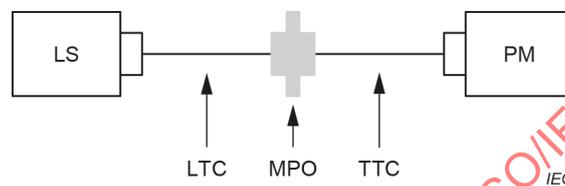


Figure 27 – Connection of LTC to TTC for test-cord verification

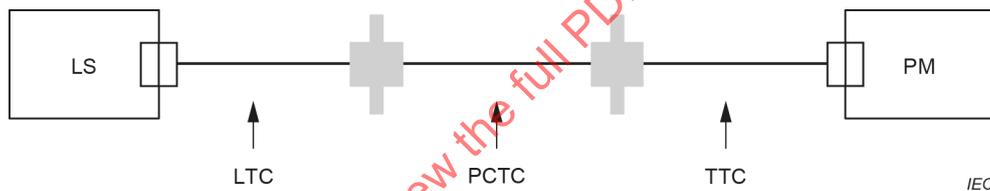


Figure 28 – Connection of LTC to PCTC to TTC for enhanced-three-test-cord verification

- g) Measure and record the attenuation of all cores of the LTC–TTC combination (where no pin conversion is required on the test cords) or the LTC–PCTC–TTC combination in dB.
 - 1) The maximum permitted attenuation for verification shall be the value of one connection with two reference connectors (see Table 3) for the LTC–TTC combination or shall be the value of two connections each with two reference connectors (see Table 3) for the LTC–PCTC–TTC combination.

NOTE If the attenuation is more than the maximum permitted value, clean all end faces, inspect then reconnect and re-test. Re-set the reference if necessary. Use alternative test cords if necessary. If the maximum permitted attenuation is not achievable, a standards compliant permanent link measurement cannot be made.

- h) Where no pin conversion is required on the test cords, disconnect the TTC from the MPO adaptor to which the LTC is connected, and replace the TTC multi-fibre with the TTC single-fibre, and connect the MPO adaptor to which the LTC is connected to the near end of the MPO to single fibre link and connect the TTC single-fibre to the far end of the MPO to single fibre link using a single reference adaptor (see Figure 29). Where pin conversion is required on the test cords, disconnect the TTC from the MPO adaptor to which the PCTC is connected, and replace the TTC multi-fibre with the TTC single-fibre, and connect the MPO adaptor to which the PCTC is connected to the near end of the MPO to single fibre link and connect the TTC single-fibre to the far end of the MPO to single fibre link using a single reference adaptor (see Figure 30).

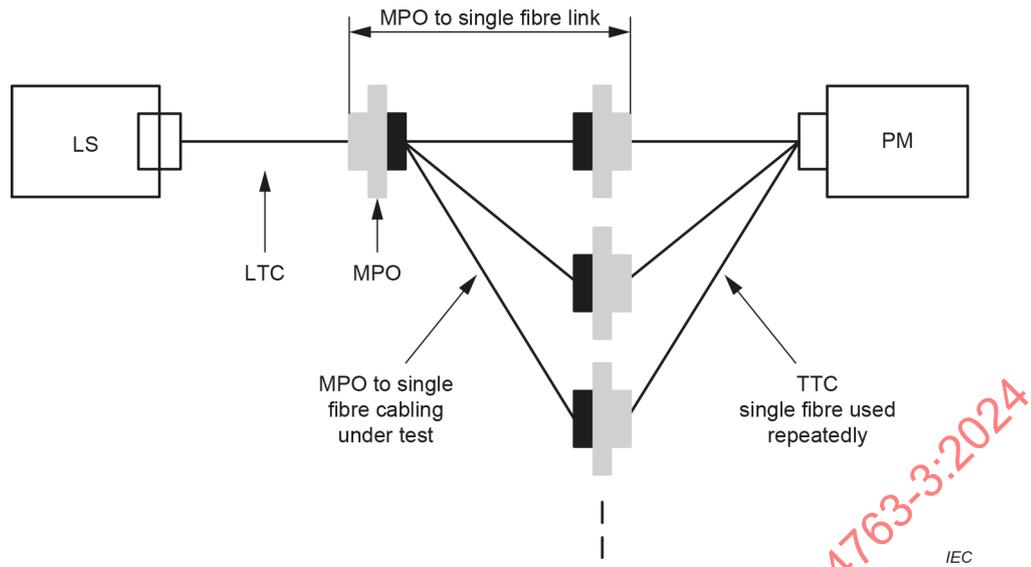


Figure 29 – MPO to single fibre link attenuation testing where no pin conversion is required on launch test cord

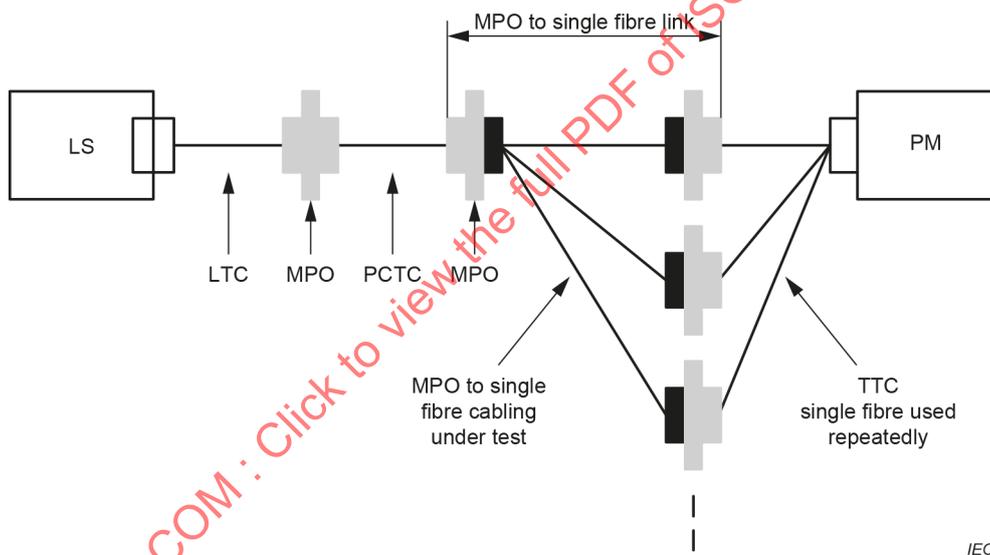


Figure 30 – MPO to single fibre link attenuation testing where pin conversion is required on LTC

- i) Measure and record the power (P_1) of all cores of the MPO to single fibre link under test in dBm or watts.
- j) The optical attenuation calculation for a core of the MPO to single fibre link is the following:

$$A = P_r - P_1 \quad (\text{dB}) \tag{1}$$

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated as follows:

$$A = -10 \lg(P_1/P_r) \quad (\text{dB}) \tag{2}$$

6.9.3.4.4 Measurement uncertainties

For this method, the measurement uncertainties at 95 % confidence level evaluated using IEC TR 61282-14, requirements of this document and relevant data are as follows:

- a) SMF 1 310 nm: 0,54 dB for fibre length \leq 2 km;
- b) SMF 1 310 nm: 0,79 dB for fibre length from 2 km to 10 km;
- c) SMF 1 550 nm: (ffs);
- d) MMF 850 nm: 0,40 dB when measured attenuation \leq 2,0 dB;
- e) MMF 850 nm: 0,50 dB when measured attenuation is from 2,0 dB to 3dB;
- f) MMF 1 300 nm: (ffs).

NOTE When the uncertainty is reported with the measurement result, the reporting is: $M \pm U$, where M is the measurement and U is the uncertainty.

6.9.3.4.5 Treatment of results

The use of reference terminations on the test cords affects the calculation of limits of testing for permanent link attenuation. The referencing procedure involves the interconnection of low loss terminations in accordance with 5.6. The measurement of the link includes connection of the test cords to non-reference terminations, which for ISO/IEC 11801-1 compliant connecting hardware are specified in Table 3.

Using the enhanced-three-test-cord reference method, the calculated limit of testing link attenuation is:

- a) for MMF: $(2 \times A_{RSG}) + \sum A_{CA} + \sum A_{CON}$;
- b) for SMF: $(2 \times A_{RSG}) + \sum A_{CA} + \sum A_{CON}$.

where

A_{RSG} is reference to standard grade connection attenuation (dB);

A_{CA} is cable attenuation (dB);

A_{CON} is embedded connection attenuation (dB).

When PCTC is used, add an allowance for the reference connector to the reference connector (see Figure 31):

- 1) for MMF: MPO mated connectors 0,15 dB;
- 2) for SMF: MPO mated connectors 0,35 dB.

Where the performance of the interfaces to the cabling under test is not in accordance with ISO/IEC 11801-1, information should be sought from the manufacturers of the interfaces to determine the relevant information for Table 3.

Where bi-directional testing has been undertaken, the optical attenuation limits shall be met in both directions.

Where testing has been undertaken at more than one wavelength, the optical attenuation limits shall be met at all wavelengths.

The treatment of results alternative to those listed in 6.9.3.4 shall be detailed in the quality plan meeting requirements of ISO/IEC 14763-2.

6.9.4 Attenuation of link and channel by means of OTDR testing

6.9.4.1 General

The OTDR testing shall be capable of measuring optical attenuation, optical return loss, length and propagation delay. Where bi-directional testing is undertaken, the OTDR should be capable of reporting the attenuation result as the mean result of both directions. The correct setup of the OTDR is essential to obtaining meaningful and reliable results.

An OTDR is capable of testing the complete link or permanent link, MPTL, E2E link or channel as well as any included individual components and events.

6.9.4.2 Test equipment requirements

An OTDR apparatus in accordance with 5.5 shall be capable of measuring and reporting the required results. A launch test cord in accordance with 5.7 shall be longer than the dead zone of the OTDR, with an interface connector that will mate with the cabling under test. The launch test cord shall be the same category as the cabling under test.

A tail test cord in accordance with 5.7 shall be longer than the dead zone of the OTDR, with an interface connector that will mate with the cabling under test. The tail test cord shall be the same category as the cabling under test.

The use of adaptor cords attached to the launch or tail test cord at the interface to the cabling under test will make the OTDR test result invalid for conformance.

6.9.4.3 Test method for link or permanent link, E2E link, MPTL

6.9.4.3.1 General

A launch test cord in accordance with 5.7.5 shall be connected between the OTDR and the cabling under test.

A tail test cord in accordance with 5.7.6 shall be connected at the end of the cabling under test.

The OTDR output shall be selected for the wavelength as defined in 5.4.1.4 and the OTDR shall be configured using the following rules:

- a) use the shortest pulse width possible (see 7.3.9);
- b) use the averaging time no greater than 3 min per trace. However, as short averaging times (i.e. < 10 s) generally provide poor results, 30 s averaging time is recommended.

For a better understanding of the relations between OTDR parameters and OTDR capabilities, see 7.3.

Single-mode cabling under test shall be measured in both directions, unless the optical fibres of the launch test cord and the tail test cord have the same scattering characteristics.

6.9.4.3.2 Measurement uncertainties

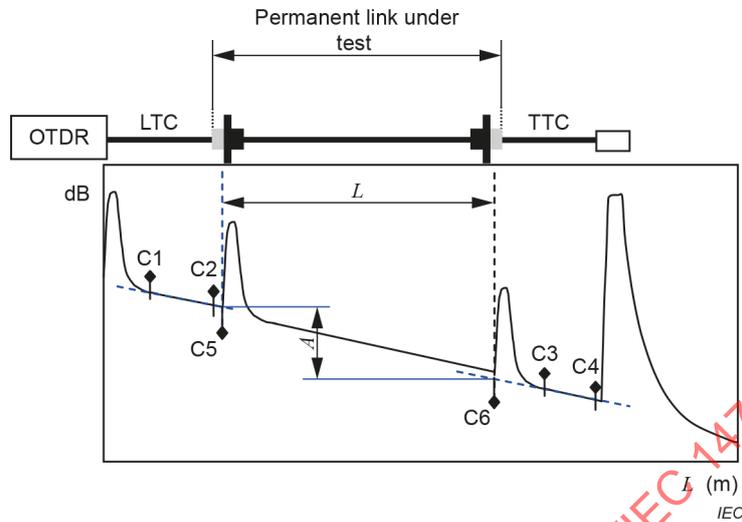
The measurement shall be over a section of the optical fibre away from the attenuation dead zone of the OTDR (see 7.3.5) and shall not contain connecting hardware.

Assuming a minimum dynamic margin of 5 dB, the uncertainty at 95 % confidence level of the attenuation is:

- a) SMF 1 550 nm: 0,45 dB (measurement in both directions, otherwise 0,55 dB);
- b) MMF: ffs.

6.9.4.3.3 Treatment of results

Figure 31 shows the points at which the attenuation of the installed cabling shall be measured.



Key

- LTC launch test cord
- TTC tail test cord
- C1, C2, C3, C4 cursors for linear regression definition
- C5, C6 cursors at attenuation location
- A attenuation of permanent link
- L length of permanent link

Figure 31 – OTDR measurement of installed cabling (permanent link) – linear regression measurement method

To obtain the total attenuation result for a (permanent) link, it is sufficient to carry out a unidirectional measurement only when the optical fibres of the launch test cord and the tail test cord have the same scattering characteristics, or, if not the case, it shall be measured in both directions and the mean of the two results calculated.

When measurement in both directions is used, the result shall be calculated using Formula (5) in 7.4.

Comparison of the measured attenuation in Figure 31 and the reference planes in Figure 7 shows that the attenuation limit defined for the permanent link within ISO/IEC 11801-1 or equivalent standards shall be the sum of:

- a) the specified maximum attenuation values for the attenuation (mated against reference) of the two interface connections at the interfaces to the cabling under test;
- b) embedded connections and splices within the cabling under test, if any;
- c) cable(s) within the cabling under test (where the attenuation of a length of optical fibre cable is calculated from its attenuation coefficient multiplied by its length).

Where compliance with a specified value is required, a pass result, a fail result or a marginal result shall be indicated with reference to the measured result.

6.9.4.4 Test method for channel

6.9.4.4.1 Test method

A launch test cord in accordance with 5.7.2 shall be connected between the OTDR and the cabling under test.

A tail test cord in accordance with 5.7.3 shall be connected at the end of the cabling under test.

The OTDR output shall be selected for the wavelength as defined in 5.4.1.4 and the OTDR shall be configured using the following rules:

- a) the shortest pulse width possible should be selected that is consistent with acquiring a trace in a reasonable timescale that is sufficiently smooth (i.e. with sufficient signal-to-noise ratio having the dynamic margin greater than 5 dB) to allow effective analysis;
- b) the averaging time should not need to be any greater than 3 min per trace. However, as short averaging times (e.g. < 10 s) generally provide poor results, 30 s averaging time should be considered.

For a better understanding of the relations between OTDR parameters and OTDR capabilities, see 7.3.

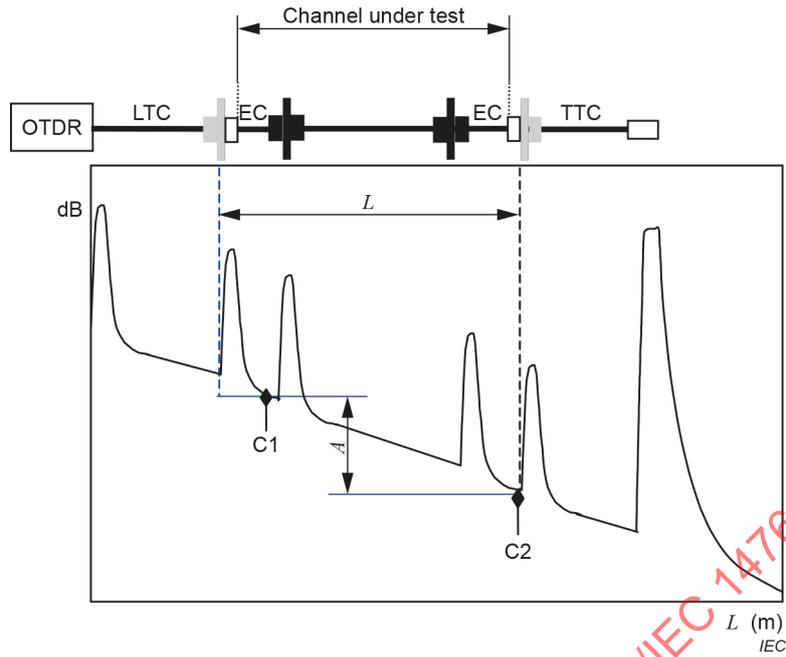
6.9.4.4.2 Measurement uncertainties

This measurement configuration (Figure 32) does not respect hypothesis for uncertainties calculation. Therefore, uncertainties cannot be calculated because the equipment cords are too short.

6.9.4.4.3 Treatment of results

Figure 32 shows the two points at which the attenuation of the installed cabling shall be measured.

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Key

- LTC launch test cord
- TTC tail test cord
- EC equipment cord
- C1, C2 cursors for two-point channel attenuation measurement
- A* attenuation of channel
- L* length of channel

Figure 32 – OTDR measurement of installed cabling (channel): two-point attenuation measurement method

Note that:

- a) it is not possible to carry out the more accurate linear regression attenuation measurement where two reflective events are in close proximity as there is unlikely to be sufficient length of optical fibre in the equipment cords to obtain a linear fit to the locations around C1 and C2;
- b) if the equipment cords are very short and the OTDR dead zone is long, then it might not be possible to measure the channel attenuation.

The result for channel attenuation is obtained by carrying out the measurement in both directions and calculating the mean of the two results. This is not necessary where the optical fibres of the cabling under test comprise a single length of fixed cabling with terminating connectors and where the optical fibre of the launch test cord and the tail test cord have the same scattering characteristics.

Where compliance with a specified value is required, the measured result shall be indicated as a pass result, a fail result or a marginal result.

6.9.5 Propagation delay

6.9.5.1 General

Propagation delay is utilized for time sensitive and real-time applications such as sound reinforcement, process control, sensors, industrial automation and autonomous movement control.

Propagation delay can be established by use of pulse echo or time of flight test equipment.

6.9.5.2 Test equipment requirements

Optical fibres shall be tested using equipment capable of measuring optical signal propagation in the time domain such as optical time domain reflectometers and certain types of optical power source and optical power meter equipment.

6.9.5.3 Test method for propagation delay

6.9.5.3.1 General

Connect the OTDR to the cabling under test via a launch cord. Set the instrument to allow the reading of the distance between two cursors. Calculate the propagation delay from the length measurement provided by the OTDR using Formula (3):

$$T = L_{OF} \times n / c \quad (3)$$

where

T is the propagation delay in seconds;

L_{OF} is the measured length in metres;

c is the speed of light in a vacuum (299 792 458 m/s);

n is the group refractive index set on the instrument for the measurement.

6.9.5.3.2 Measurement uncertainty

Use guidance of the OTDR manufacturer for the measurement uncertainty.

6.9.5.4 Treatment of results

Propagation delay is not a pass/fail criterion; however, it may be called up by the quality plan in accordance with ISO/IEC 14763-2 or by the network application.

Where compliance with a specified value is required, a pass result, a fail result or a marginal result should be indicated with reference to the measured result.

6.9.6 Length

6.9.6.1 General

The optical fibre length is required for the determination of pass/fail criteria including insertion loss (attenuation) and what applications the link can support, and additionally propagation delay if required.

Determination of length can be made using one of the following methods:

- a) time of flight (preferred);
- b) pulse echo (preferred);
- c) propagation delay;
- d) cable sheath markings;
- e) physical measurement.

6.9.6.2 Test equipment requirements

Any one of the following may be used to determine length:

- a) a light source power meter or other test equipment with time of flight or pulse echo functionality;
- b) an OTDR;
- c) a measuring device (wheel, tape or other appropriate device) that is capable of measuring physical length.

6.9.6.3 Test method for length

6.9.6.3.1 General

For time of flight and pulse echo, ensure the instrument is set to the correct IOR and measure length in accordance with the tester manufacturer's instructions.

For OTDR, use the set-up and measurement of length for link or permanent link, MPTL, E2E link or channel (see Figure 35 and Figure 36).

Length can be determined from propagation delay using Formula (4):

$$L_{\text{OF}} = T / (n / c) \quad (4)$$

where

T is the propagation delay in seconds;

L_{OF} is the optical fibre length in metres;

c is the approximated speed of light in a vacuum (299 792 458 m/s);

n is the group refractive index of the optical fibre.

NOTE As $n \rightarrow 1,5$ for all optical fibres, the formula can be approximated to $L_{\text{OF}} = T / 5$ m.

When reporting the optical fibre cable sheath length as the optical fibre length, it is recommended to add to the report that the measured value is the optical fibre cable sheath length.

When calculating optical fibre cable sheath length based on cable markings, be aware of any sheath marking of 0 m that is present, and take this into account when calculating the cable sheath length.

Physical measurement shall follow the measurement instrument manufacturer's instructions.

6.9.6.3.2 Measurement uncertainties

The optically measured length of an optical fibre can differ from the physical length of the cable. Within a given length of cable containing multiple optical fibres, each individual optical fibre can have a different length.

The measured length of the transmission path contained within the cabling under test is the accepted length of the optical fibre (assuming that the correct effective group IOR has been used) rather than the physical length of the cable.

The optical fibre length will always be equal to or greater than that of the cable itself. The difference between the two lengths is dependent upon cable construction. The cable manufacturer should be consulted if specific information is required.

6.9.6.4 Treatment of results

Length is not a pass/fail criterion; however, it may be called up by the quality plan in accordance with ISO/IEC 14763-2 or by the network application.

Where compliance with a specified value is required, a pass result or fail result shall be indicated with respect to the measured result.

The propagation velocity or the group refractive index, provided by the manufacturer of the optical fibre cabling under test, is required by the test equipment in order to calculate optical fibre length. If another value is used because no value was indicated by the manufacturer (i.e. the verification of unknown cabling), the impact of any errors introduced should be recognized and agreed between the installer and the user. For default group refractive index values, see Table 8.

6.9.7 Optical fibre continuity

Continuity of an optical fibre between two interfaces can be verified using LSPM equipment or with an OTDR if a tail test cord is used. Continuity of an optical fibre can also be verified using a visible light source.

6.9.8 Cabling polarity

The desired polarity of the cabling system can be verified using LSPM equipment, or with an OTDR if a tail test cord is used. The polarity of the cabling system can also be verified using a visible light source.

6.9.9 Optical fibre core size

The inspection of the optical fibre end faces under conditions of front illumination (see Clause 5) allows the optical fibre core size to be determined by consideration of the relative diameters of the core and cladding.

7 Performance assessment of installed cabling components using OTDR

7.1 General

Performance assessment of installed cabling components is based on the attenuation measurement of each individual component such as the test interface, the splices or the connections and the fibre itself. This is based on an extensive use of an OTDR. It is important to have a full understanding of the OTDR basis, described in 7.2.

Measurement uncertainty values provided after are based on the used measurement methods and commonly observed uncertainty values.

7.2 OTDR basis

The OTDR operates by injecting a short pulse of light into one end of the fibre optic system under test and monitoring as a function of time delay the returning signal coming back out of the same end of the optical fibre.

This returning signal comes from two sources:

- a) scattered light from within the optical fibre itself. This is due to Rayleigh scattering caused by minute variations in the molecular structure of the silica causing some of the light pulse's energy to be scattered in all directions. A very small proportion of this is scattered back in the direction it came from – this is known as "backscatter";
- b) reflections from interfaces and changes in refractive index at discrete points along the length of the system. These are known as Fresnel reflections.

The graph of returning signal power as a function of time delay is the raw data that the OTDR works with. Usually, this raw data is processed by the OTDR such that the returning signal power is plotted on a logarithmic scale to give loss in decibels on the vertical scale. On the horizontal scale, the time delay for the round trip is converted into a one-way distance along the system, by providing the OTDR with a figure for the group index (effective refractive index) of the optical fibre under test.

This resultant graph of loss on the vertical scale against distance on the horizontal scale is known as a backscatter trace. Analysis of this backscatter trace can yield much information about the cabling under test including:

- 1) total attenuation of the link or channel under test;
- 2) length (and propagation delay) of the link or channel under test;
- 3) attenuation coefficient of the optical fibre in the cabling under test;
- 4) attenuation of connections (splices and connector pairs);
- 5) return loss (reflectance) of reflective features such as connector pairs and mechanical splices;
- 6) distance information between features on the trace.

However, successful and comprehensive characterization of the cabling under test is dependent upon a number of factors, including:

- the optical performance of the OTDR being used, dynamic margin, pulse width, averaging time, dead zone, group index, measurement range and distance sampling (see 7.3);
- the correct set up of the OTDR's measurement parameters;
- the correct measurement configuration including appropriate length launch cords and tail cords;
- measurement good practices – cleanliness of connectors, etc.;
- the use of bi-directional measurement (see 7.4).

7.3 Fundamental parameters that define the operational capability of an OTDR

7.3.1 Dynamic range

The capability of an OTDR to measure a large amount of attenuation, the dynamic range is the difference between the maximum backscatter level near 0 m and the noise floor. The dynamic range increases when the laser pulse width increases, and when the noise level decreases by averaging.

See IEC 61746-1 for a formal definition of dynamic range.

7.3.2 Dynamic margin

The difference between the minimum backscattered level at the end of the fibre and the noise floor. The dynamic margin varies the same way as the dynamic range. The estimation of the dynamic margin can be used to determine the noise amplitude on the backscatter signal which defines a large part of the measurement uncertainty. When the dynamic margin is low, the noise on the backscattered signal become asymmetrical, leading to an underestimation of the backscattered signal. To limit this underestimation to 0,1 dB, it is recommended to keep the dynamic margin higher than 5 dB.

7.3.3 Pulse width

The pulse width and laser peak power define the energy level launched into the optical fibre. This determines the amount of scattering signal returning. As pulse width increases, dynamic range increases; however, dead zones increase.

7.3.4 Averaging time

The averaging time defines the duration to sum and average a large number of data samples. Best signal characterization is preferable yet takes the longest averaging time. The greatest benefit to averaging time occurs during the first 30 s of averaging. Generally, a dynamic range increase of 0,75 dB occurs when doubling the number of averages.

7.3.5 Dead zone

There are several orders of magnitude difference between the very small signal level received from the backscattered light within the optical fibre and the relatively large signal level received from Fresnel reflections at reflective interfaces at connectors. It takes a finite time for the detector in the OTDR to recover from the Fresnel reflection such that it can measure the backscattered light levels again. During this time, it is not possible for the OTDR to measure any variation in the backscattered signal level (such as splice losses for example) and so the section of optical fibre following a reflection is referred to as the "dead zone".

The length of this dead zone will depend upon the response time of the detector, the magnitude of the Fresnel reflection and its duration, which is determined by the pulse width.

For most applications the most significant dead zone is the attenuation dead zone. This is the distance after a reflective event at which the backscatter level has returned to be within a certain tolerance (ΔF) of a linear fit to the backscatter trace and attenuation measurements can be made.

7.3.6 Group index

The group index is used to set up the scale factor of the horizontal scale. This allows fault location and attenuation coefficient calculation.

On a general basis, the index of refraction is not known, while the length of the optical fibre is known. In this case, the real index of refraction can be determined.

When the index of refraction is known, it shall be used; otherwise, use the values of Table 8.

Table 8 – Default group index values

Type of fibre	Centre wavelength			
	850 nm	1 300 nm	1 310 nm	1 550 nm
OM1	1,496	1,491		
OM2, OM3, OM4, OM5	1,484	1,479		
OS1a, OS2			1,467	1,468

If fibre types other than type of Table 8 are being used and if accurate length measurements are required, the fibre manufacturer should be consulted for appropriate refractive index figures.

7.3.7 Measurement range

The measurement range or measurement span is the distance that is covered by the OTDR time base. The measurement range shall be set to be greater than the length of the optical fibre to be tested. Note that on some OTDRs, when testing systems with strongly reflective connectors, it can be desirable to set the measurement range to be greater than twice the length of the system under test in order to reduce ghosting effects.

7.3.8 Distance sampling

The distance sampling (or sampling resolution) is the distance between two points of the horizontal scale. This distance can be coupled to the measurement range (i.e. the number of data points is a constant).

When adjustable, the sampling resolution should be set to a small enough interval to ensure that all features of the link are well resolved. In any case, it should be ten times lower than the pulse width. Note that the size of the data file generated will be proportional to the measurement range divided by the sampling resolution.

7.3.9 Event threshold

Sometimes OTDR traces are unusable due to a high noise level as a result of incorrect parameter selection.

OTDR manufacturers typically set the event threshold to 0,1 dB. Lower values can increase trace clutter. Higher values can miss identifying valid events.

7.4 Bi-directional measurement

For cabling containing splices or additional connectors, OTDR testing is carried out from both ends of the cabling under test. This allows any inaccuracy in the measurement of component attenuation due to variations in the optical fibre backscattering characteristics to be cancelled out by averaging the component attenuation measurements taken from both ends of the system.

In order to accurately measure the first and last connection for bi-directional averaging, one should keep the launch and tail cords in their initial measurement positions. Thus, the launch cord of the first direction becomes the tail cord of the opposite direction. This will ensure that identical optical fibres are mated so that the effects of mode field mismatch between the test cords and cabling can be averaged out.

An individual attenuation is defined as the half sum of the attenuation recorded from each end:

$$A = \frac{A_{oe} + A_{eo}}{2} \text{ (dB)} \quad (5)$$

where A_{oe} is the attenuation measured in the direction from the origin to the extremity and A_{eo} is the attenuation measured in the direction from the extremity to the origin.

7.5 Attenuation of optical fibre cable

7.5.1 Test method

7.5.1.1 General

In order to test a channel or permanent link (see Clause 5), a launch test cord in accordance with 5.7.5 shall be connected between the OTDR and the cabling under test.

In order to test an unterminated optical fibre, a launch test cord in accordance with 5.7.5 but without a test interface connector shall be connected between the OTDR and the optical fibre under test by means of a splice or a connector.

The OTDR output shall be selected for the wavelength as defined in 5.4.1.4 and the OTDR shall be configured using the following rules:

- a) the shortest pulse width possible should be selected that is consistent with acquiring a trace in a reasonable timescale that is sufficiently smooth (e.g. with sufficient signal-to-noise ratio having the dynamic margin greater than 5 dB) to allow effective analysis;
- b) the averaging time should not need to be any greater than 3 min per trace. However, as short averaging times (i.e. < 10 s) generally provide poor results, 30 s averaging time should be considered.

For a better understanding of the relations between OTDR parameters and OTDR capabilities, see 7.3.

This method may also be used to assess the uniformity of attenuation of cabled optical fibres in accordance with IEC 60793-2-10 (MMF) and IEC 60793-2-50 (SMF).

The cabling under test shall be measured in one direction.

7.5.1.2 Measurement uncertainties

The measurement shall be over a section of the optical fibre away from the attenuation dead zone of the OTDR (see 7.3.5) and shall not contain connecting hardware.

The attenuation coefficient is calculated by the OTDR by dividing the difference of backscattering power between any two points (the loss) by the distance between the two points. For short values of distance, the calculation can produce huge uncertainties of the attenuation coefficient, even if the uncertainties of the loss are small.

Assuming a minimum dynamic margin of 5 dB, the uncertainty at 95 % confidence level of the attenuation is:

- SMF 1 550 nm: 0,55 dB;
- MMF: ffs.

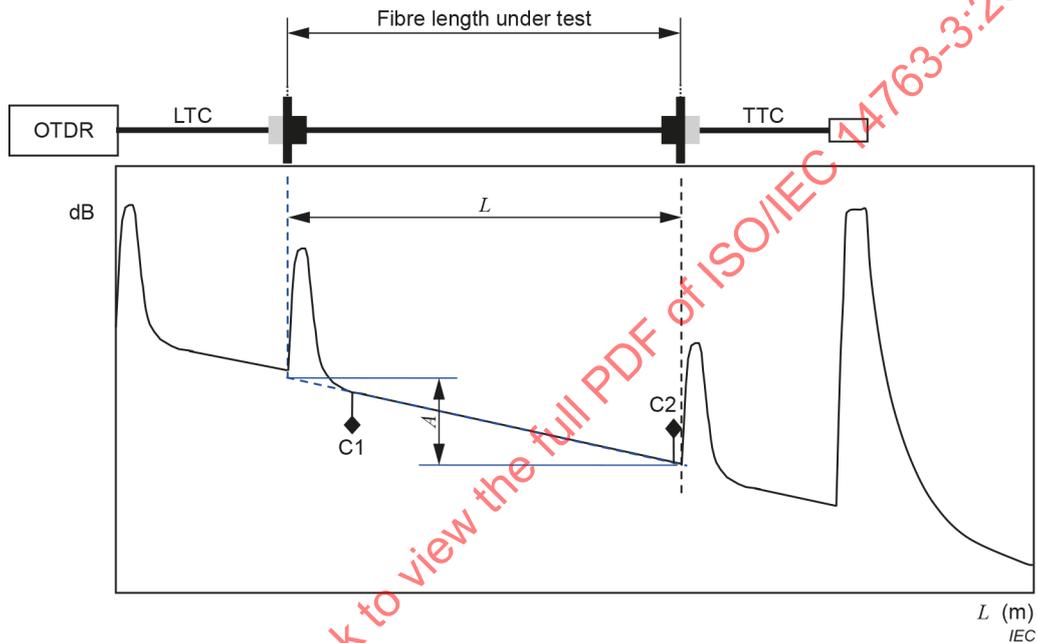
Divide previous values by the length of the fibre to get the uncertainty of the attenuation coefficient.

7.5.2 Treatment of results

Figure 33 shows the points at which the attenuation of the optical fibre within the cabling under test shall be measured.

The result may be provided as a simple loss value (in dB) or as an attenuation coefficient (in dB/km).

Where compliance with a specified value is required, a pass or fail result should be indicated with respect to the measured result.



Key	
LTC	launch test cord
TTC	tail test cord
C1, C2	cursors for linear regression definition
Δ	attenuation of optical fibre
L	length of optical fibre

Figure 33 – OTDR measurement of optical fibre attenuation

7.6 Attenuation of local and remote test interfaces

7.6.1 Test method

A launch test cord in accordance with 5.7.5 shall be connected between the OTDR and the cabling under test. A tail test cord in accordance with 5.7.6 shall be connected to the remote end of the cabling under test.

The OTDR output shall be selected for the wavelength as defined in 5.4.1.4 and the OTDR shall be configured using the following rules:

- a) the shortest pulse width possible should be selected that is consistent with acquiring a trace in a reasonable timescale that is sufficiently smooth (e.g. with sufficient signal-to-noise ratio having the dynamic margin greater than 5 dB) to allow effective analysis;
- b) the averaging time should not need to be any greater than 3 min per trace. However, as short averaging times (i.e. < 10 s) generally provide poor results, 30 s averaging time should be considered.

For a better understanding of the relations between OTDR parameters and OTDR capabilities, see 7.3.

The cabling under test shall be measured in both directions.

NOTE The pass/fail criteria for an interface connector and associated splice will be the sum of both components.

7.6.2 Test system measurement uncertainties

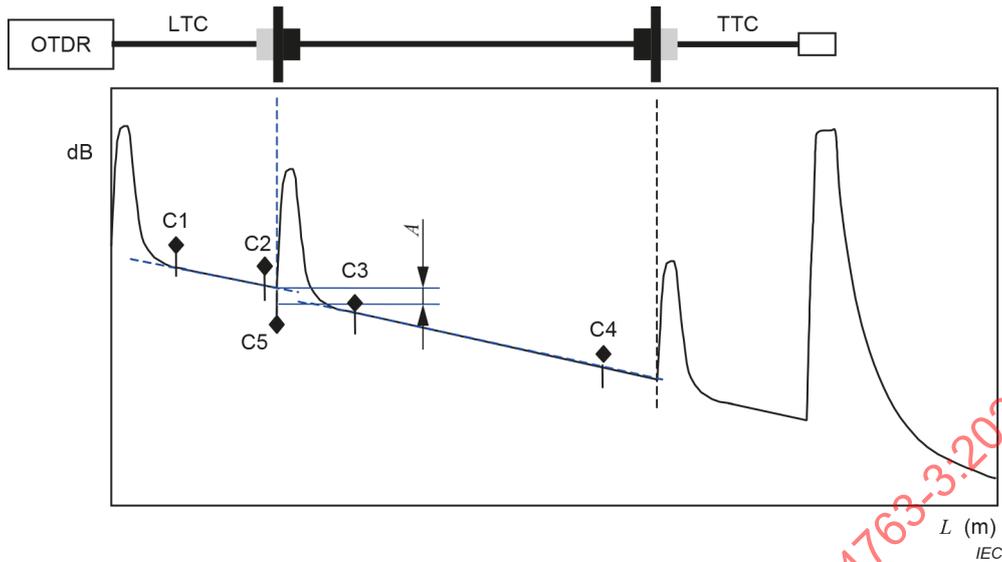
Assuming bi-directional measurement and a minimum dynamic margin of 10 dB, and OTDR linear regression of 100 m and 1 m between points (100 points), the uncertainty at 95 % confidence level is:

- a) SMF: ffs;
- b) MMF: ffs.

7.6.3 Treatment of results

Figure 34 shows the points at which the attenuation of the interfaces to the cabling under test shall be measured. The installed cabling can be either a channel or a permanent link (see Clause 5). However, where the channel contains short equipment cords at one or more ends, it can be impossible to make a measurement since the connections of the cords to the permanent link will be disguised within the end interface reflections.

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Key	
LTC	launch test cord
TTC	tail test cord
C1, C2, C3, C4	cursors for linear regression definition
C5	cursor at attenuation location
A	attenuation of measured connection

Figure 34 – OTDR measurement of connection attenuation

The attenuation of the local interface is shown as the interface loss (dB). To eliminate effects of difference of optical fibre backscattering characteristics, the result shall be the mean of the measurements in each direction (see also 7.4).

Where compliance with a specified value is required, a pass result, a fail result or a marginal result should be indicated with respect to the measured result.

7.7 Attenuation of connecting hardware

7.7.1 Test method

In order to test a channel or permanent link (see Clause 5), a launch test cord in accordance with 5.7.5 shall be connected between the OTDR and the cabling under test.

In order to test connecting hardware within an unterminated optical fibre, a launch test cord in accordance with 5.7.5 but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

The OTDR output shall be selected for the wavelength as defined in 5.4.1.4 and the OTDR shall be configured using the following rules:

- a) the shortest pulse width possible should be selected that is consistent with acquiring a trace in a reasonable timescale that is sufficiently smooth (e.g. with sufficient signal-to-noise ratio having the dynamic margin greater than 5 dB) to allow effective analysis;
- b) the averaging time should not need to be any greater than 3 min per trace. However, as short averaging times (i.e. < 10 s) generally provide poor results, 30 s averaging time should be considered.

For a better understanding of the relations between OTDR parameters and OTDR capabilities, see 7.3.

The cabling under test shall be measured in both directions.

7.7.2 Test system measurement uncertainties

Assuming bi-directional measurement and a minimum dynamic margin of 10 dB, and OTDR linear regression of 100 m and 1 m between points (100 points), the uncertainty at 95 % confidence level is:

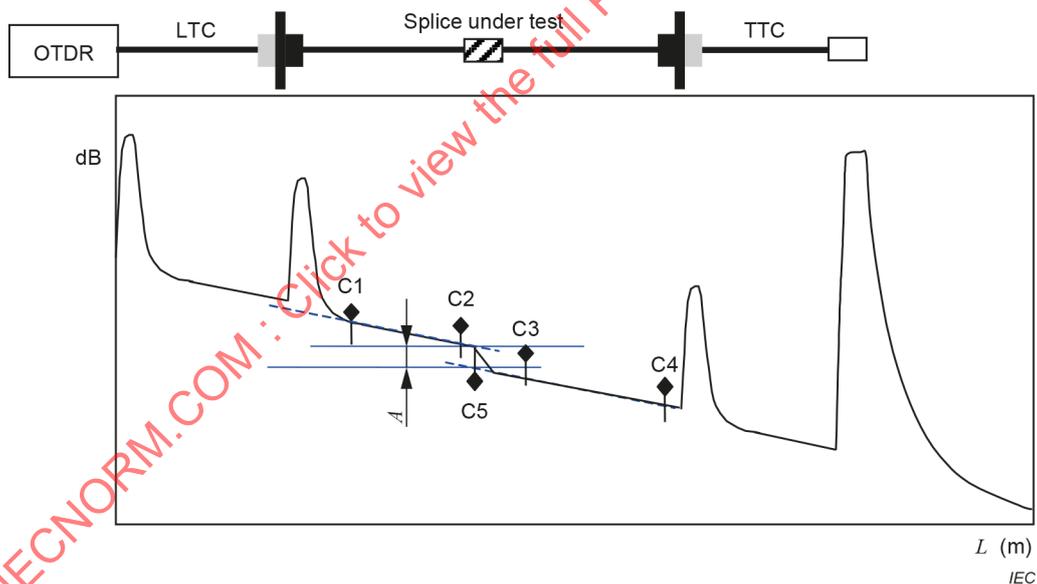
- a) SMF: 0,06 dB;
- b) MMF: ffs.

7.7.3 Treatment of results

Figure 35 shows the points at which the attenuation of connecting hardware or splices within the cabling under test shall be measured.

A joint, particularly a fusion splice, should not contain an air-gap so reflective peaks are not normally seen. Instead, the optical power received simply displays a "drop" or "step" at the joint position.

Where compliance with a specified value is required, a pass result, a fail result or a marginal result should be indicated with respect to the measured result.



Key

- LTC launch test cord
- TTC tail test cord
- C1, C2, C3, C4 cursors for linear regression definition
- C5 cursor at attenuation location
- A attenuation of non-reflective event under test

Figure 35 – OTDR measurement of joint attenuation

7.8 Return loss of connecting hardware

7.8.1 General

The return loss of a passive component is the ratio of the power reflected back by that component to the power input to that component. On the OTDR trace, this is related to the height of the peak (H_B on Figure 36) that represents the amount of light reflected back from that component, but it is also a function of the backscatter coefficient of the fibre under test and the pulse width used for the measurement.

IEC 61300-3-6 covers measuring the related parameter of return loss of passive components.

NOTE The optical return loss of a link or channel is the ratio of the power input to the cabling under test to the sum of the power reflected and scattered back by the cabling under test.

7.8.2 Test method

A launch test cord in accordance with 5.7.5 shall be connected between the OTDR and the cabling under test.

If the return loss of the remote connection in the cabling under test is to be measured, then a tail test cord in accordance with 5.7.6 shall be connected to the remote end of the cabling under test.

In order to test embedded connecting hardware within an unterminated optical fibre, a launch test cord in accordance with 5.7.5 but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

The OTDR output shall be selected for the wavelength as defined in 5.4.1.4 and the OTDR shall be configured using the following rules:

- a) the shortest pulse width possible should be selected that is consistent with acquiring a trace in a reasonable timescale that is sufficiently smooth (e.g. with sufficient signal-to-noise ratio having the dynamic margin greater than 5 dB) to allow effective analysis;
- b) the averaging time should not need to be any greater than 3 min per trace. However, as short averaging times (i.e. < 10 s) generally provide poor results, 30 s averaging time should be considered;
- c) the detector in some OTDRs saturates at large values of H (as shown in H_C in Figure 36);
- d) this type of signal saturation can be avoided by adding a variable attenuator between the OTDR and the cabling component under test.

For a better understanding of the relations between OTDR parameters and OTDR capabilities, see 7.3.

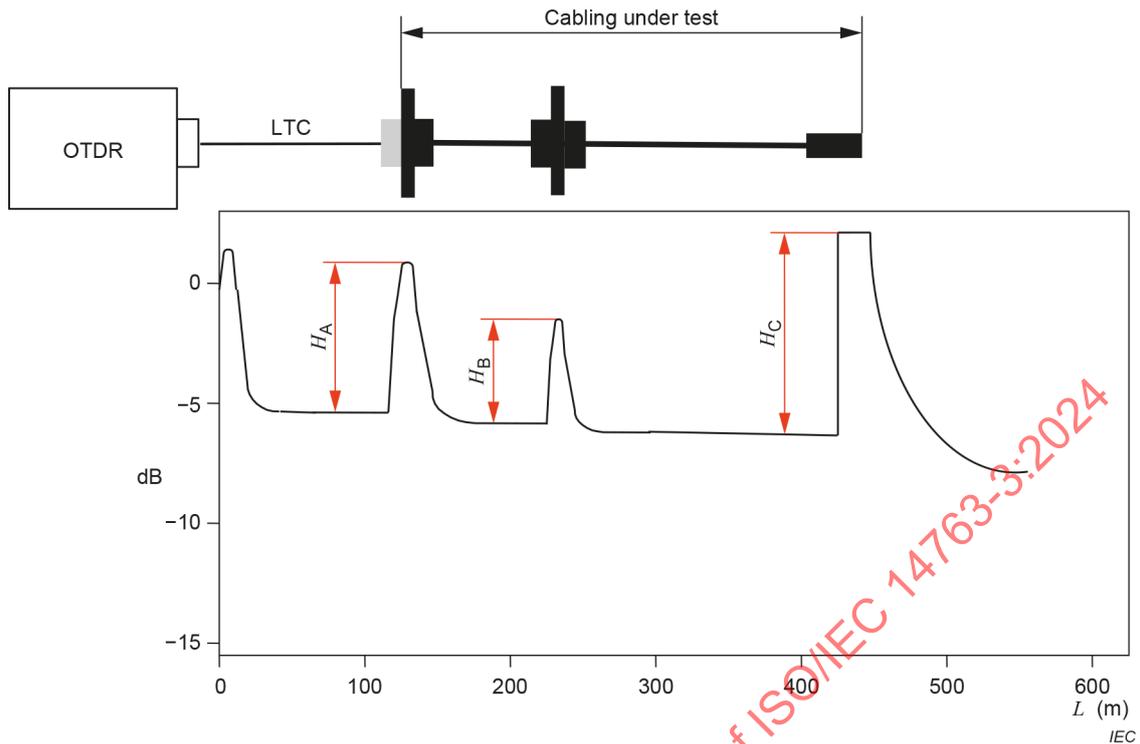


Figure 36 – OTDR measurement of return loss

7.8.3 Test system measurement uncertainties

Fibre related uncertainties have a direct impact on the return loss uncertainties. Assuming a minimum dynamic margin of 3 dB, the uncertainty at 95 % confidence level is:

- a) SMF: 2 dB;
- b) MMF: 2 dB.

7.8.4 Treatment of results

The return loss of a cabling component under test is calculated from the height of the reflection peak (H_A or H_B in Figure 36) as follows:

$$RL = -10 \lg \left(10^{H/5} - 1 \right) - 10 \lg d + k \quad (\text{dB}) \quad (6)$$

with $H > 5$ dB

$$RL \approx -2H - 10 \lg d + k \quad (\text{dB}) \quad (7)$$

where:

- H is the height of peak (H_A or H_B) (dB);
- d is the pulse width (ns);
- k is the backscatter coefficient of the optical fibre (dB).

Typical values of backscattering coefficient for MMF and SMF are included in Table 9.

Table 9 – Default backscattering coefficient values

Type of fibre	Centre wavelength			
	850 nm dB/ns	1 300 nm dB/ns	1 310 nm dB/ns	1 550 nm dB/ns
OM1	66	72	-	-
OM2...OM5	67	74	-	-
OS1a, OS2	-	-	80	82

NOTE 1 Most OTDRs automatically measure RL using instrument default settings. In this case, the measurement uncertainty remains as defined in 7.8.3.

NOTE 2 The greater the height of the reflection peak H , the worse the return loss result is.

NOTE 3 OTDRs often report reflectance, r , rather than return loss, RL; the relationship is r (dB) = -RL (dB).

Where compliance with a specified value is required, a pass result, a fail result or a marginal result should be indicated with respect to the measured result.

7.9 Optical fibre length

7.9.1 Test method

In order to test a channel or permanent link (see Clause 5), a launch test cord in accordance with 5.7.5 shall be connected between the OTDR and the cabling under test.

In order to test connecting hardware within an unterminated optical fibre, a launch test cord in accordance with 5.7.5 but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

The OTDR output shall be selected for the wavelength as defined in 5.4.1.4 and the OTDR shall be configured using the following rules:

- a) the shortest pulse width possible should be selected that is consistent with acquiring a trace in a reasonable timescale that is sufficiently smooth (e.g. with sufficient signal-to-noise ratio having the dynamic margin greater than 5 dB) to allow effective analysis;
- b) the averaging time should not need to be any greater than 3 min per trace. However, as short averaging times (i.e. < 10 s) generally provide poor results, 30 s averaging time should be considered.

For a better understanding of the relations between OTDR parameters and OTDR capabilities, see 7.3.

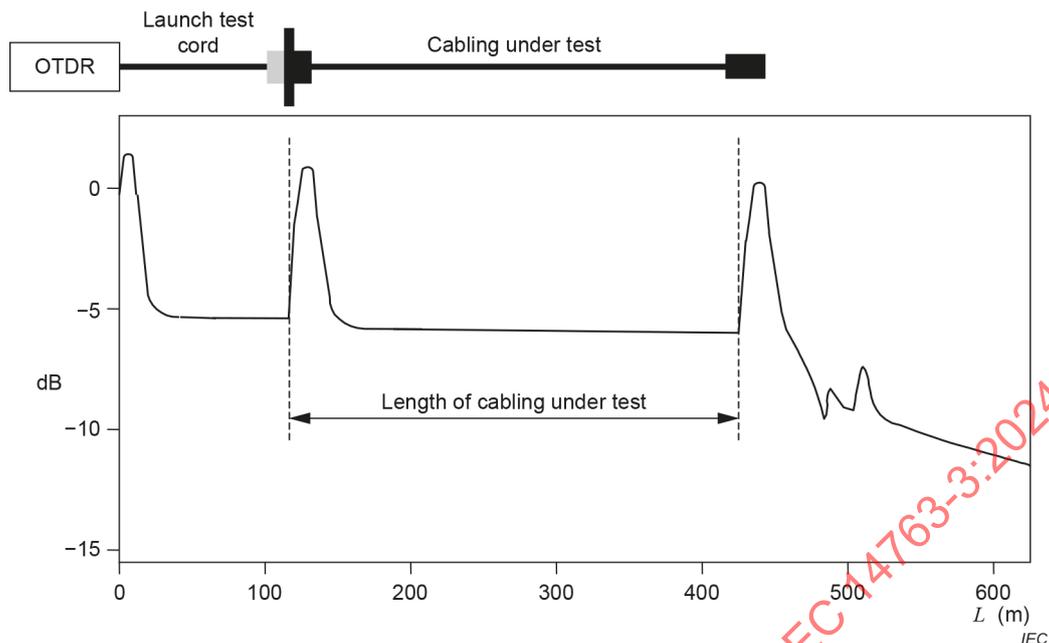


Figure 37 – Determination of length using an OTDR

Figure 37 shows the points at which the length of the transmission path contained within the installed cabling shall be measured (SMF possibly does not produce a remote interface reflection). The installed cabling can be either a channel or a permanent link (see Clause 5).

A break in a multimode fibre permanent link would also be characterized by the presence of the reflection peak. However, unlike multimode fibre and as shown in Figure 38, a break in a single-mode fibre is not always characterized by a reflection peak.

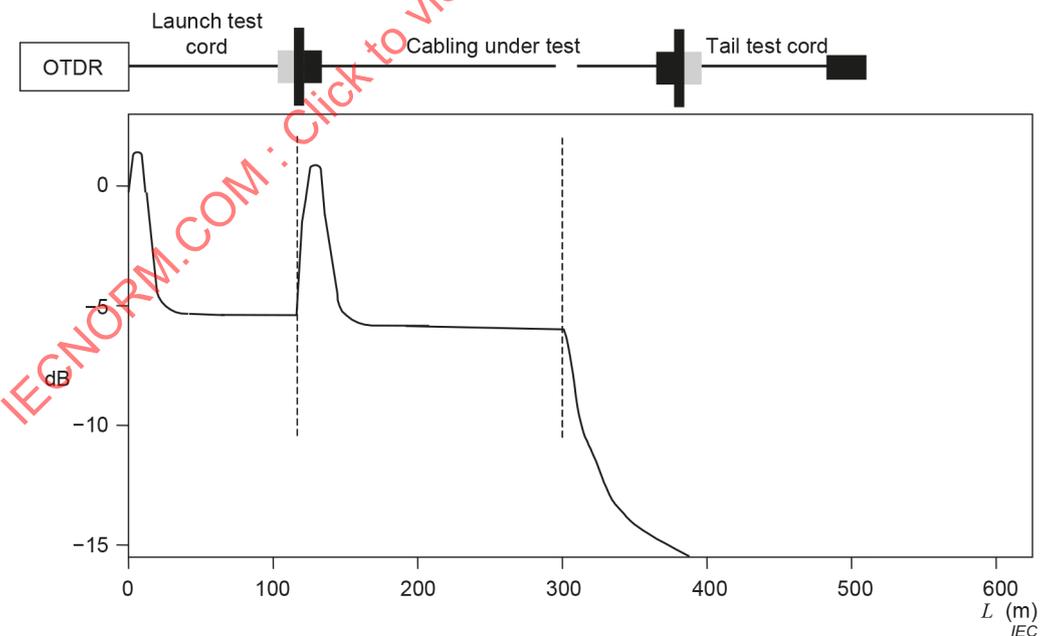


Figure 38 – OTDR characterization of a SMF permanent link containing a break

An installation error (e.g. an installed cable bend radius less than that specified in the relevant product standard or manufacturer's or supplier's information) causes a macrobend in the optical fibre in the cable. This macrobend introduces an attenuation of the transmitted light in the optical fibre and can show as a step change in attenuation on the OTDR trace (see Figure 39).

NOTE An attenuation difference between 1 310 nm and 1 550 nm greater than 0,5 dB can be an indication of macrobends.

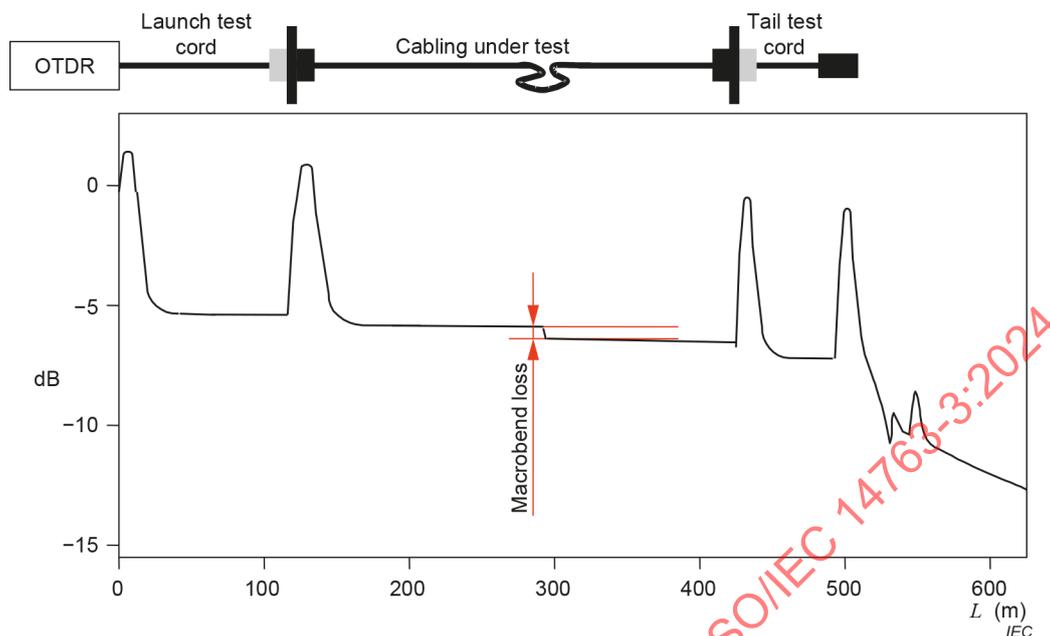


Figure 39 – OTDR characterization of a permanent link containing a macrobend

7.9.2 Measurement uncertainties

The measured length of the transmission path contained within the cabling under test is the length of the optical fibre (assuming that the correct effective group IOR has been used) rather than the physical length of the cable. The optically measured length of an optical fibre can differ from the physical length of the cable. Within a given length of cable containing multiple optical fibres, each individual optical fibre can have a different length.

The optical fibre length will always be equal to or greater than that of the cable itself. The difference between the two lengths is dependent upon cable construction. The cable manufacturer should be consulted if specific information is required.

7.9.3 Treatment of results

The limits and restrictions indicated in 7.9.2 should be included within the statement of measurement uncertainty.

The lengths measured shall be checked for consistency with the optical fibres supplied and installed (subject to the uncertainty of the measurement).

The propagation velocity or the group refractive index, provided by the manufacturer of the optical fibre cabling under test, is required by the test equipment to calculate optical fibre length. If another value is used due to lack of information (e.g. the verification of unknown cabling), the impact of any errors introduced should be recognized and agreed between the installer and the user.

8 Test result documentation

The documentation for each parameter (such as length, attenuation, propagation delay) shall include:

- a) identification and details of the test;
- b) whether channel, permanent link, E2E link or MPTL is being tested;
- c) test equipment:
 - 1) type, model and manufacturer,
 - 2) serial number and calibration status,
 - 3) nominal wavelength;
- d) optical fibre cabling details (category of cabled optical fibre performance, e.g. OM3, OM4, OM5, OS1a, OS2);
- e) details of the cabling connector type(s);
- f) details of the test cords used for the measurements including:
 - 1) the performance grade of the fibre in the test cords,
 - 2) if MMF, whether the fibre in the test cords is BIMMF (OMxb),
 - 3) the length of the test cords;
- g) the test procedure and method;
- h) the configuration of the cabling test equipment during the test;
- i) the measured result;
- j) the applicable requirements;
- k) details of the reference numbers and direction of test;
- l) the date of the test (the time can also be recorded);
- m) the test operator name.

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