ISO/IEC 14763-3

Edition 2.1 2018-08

CONSOLIDATED VERSION

colour inside

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

ISO/IEC 14763-3:2014-06+AMD1:2018-08 CSV(en)

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 35.200 ISBN 978-2-8322-6020-3

ISO/IEC 14763-3

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REDLINE VERSION

colour inside

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INFORMATION TECHNOLOGY – IMPLEMENTATION AND OPERATION OF CUSTOMER PREMISES CABLING –

Part 3: Testing of optical fibre cabling

FOREWORD

1) ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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This Consolidated version of ISO/IEC 14763-3 bears the edition number 2.1. It consists of the second edition (2014-06) and its corrigendum (2015-03), and its amendment 1 (2018-08). The technical content is identical to the base edition and its amendment.

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

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

This edition constitutes a technical revision.

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

– general requirements (Clause 5) have been revised and the concept of normalization has been replaced by reference measurements;
– OTDR characterization (6.2) and requirements for cabling interface adapters (6.3) and test cords have been revised and requirements for single-mode fibre test cords (6.3.4) have been removed;
– enhanced three-test-cord reference method has been introduced (9.1.1.2);
– requirements for the attenuation measurement of cords (10.6) have been revised;
– Annex A "Launched modal distribution (LMD)" has been simplified and the new title now reads "Launched modal conditions for testing multimode optical fibre cabling";
– visual inspection criteria for connectors have been reworked (Annex B);
– information on optical time domain reflectometry (Annex C) has been revised;
– examples of calculations of channel and permanent link limits (Annex G) have been revised;
– and information regarding cleaning and inspection of fibre optic connections have been added (Annex H).

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 publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

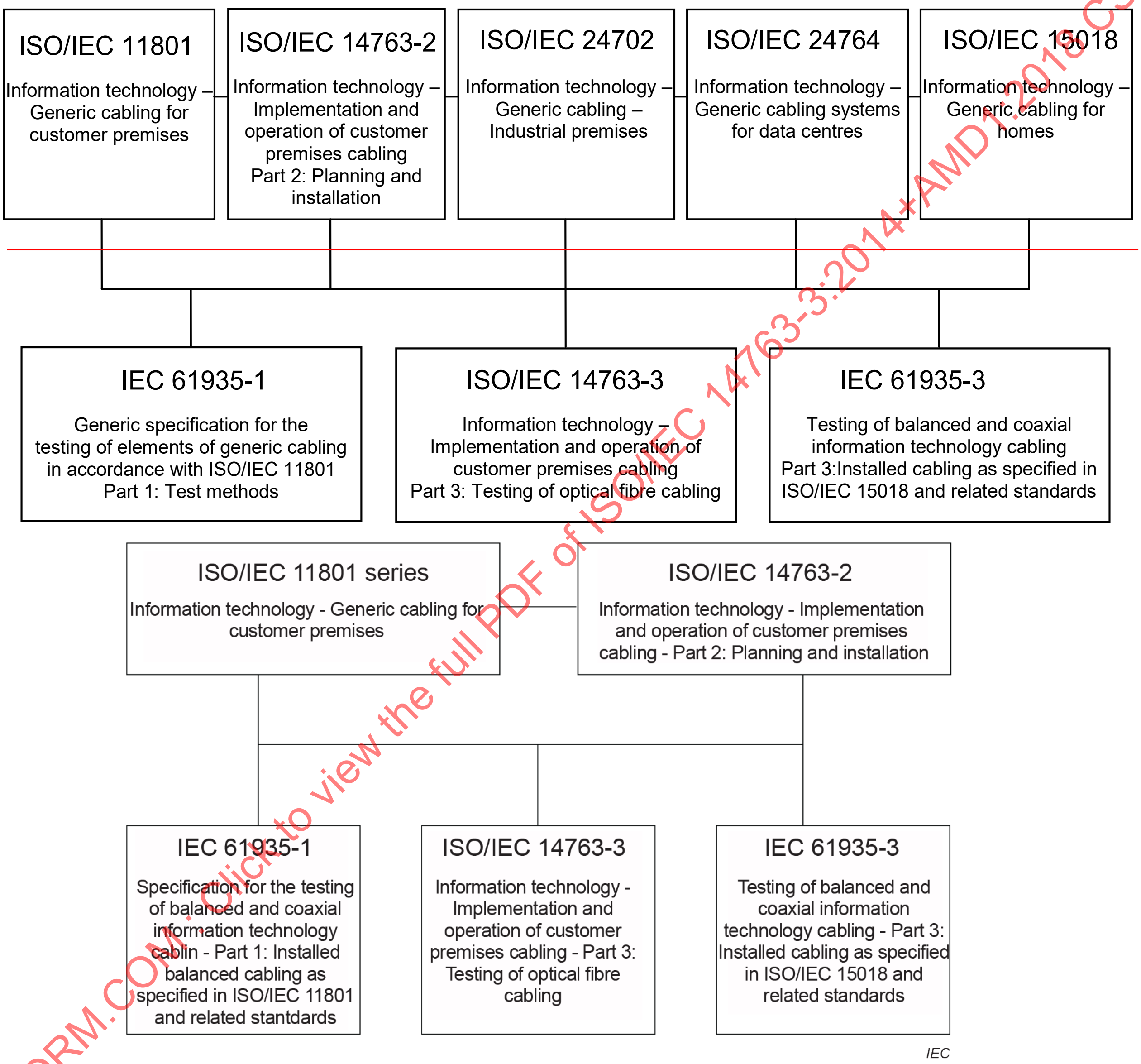
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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 International Standard ~~is one of four~~ has been prepared in support of International Standard series ISO/IEC 11801 ~~and other cabling standards~~.

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



NOTE ISO/IEC 15018 has been replaced by ISO/IEC 11801-4.

Figure 1 – Relationship of related International Standards

ISO/IEC 14763-3 details the inspection and test procedures for optical fibre cabling,

a) designed in accordance with premises cabling standards including the ISO/IEC 11801 series~~, ISO/IEC 24764, ISO/IEC 24702 and ISO/IEC 15018~~, and

b) installed according to the requirements and recommendations of ISO/IEC 14763-2.

Users of this International Standard 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 described in ISO/IEC 14763-2.

NOTE JTC 1/SC 25, in cooperation with IEC/TC 86, is currently developing an overall quantitative model to calculate total measurement uncertainty as stated in the reference planes of ISO/IEC 11801-1. When such a model has been verified, it is expected to be incorporated into this standard in form of an Amendment, thereby removing pertinent clauses currently marked “ffs” (for further study).

INTRODUCTION to the amendment

This document contains information for inspecting end faces of the different kinds of installed fibre optic cabling interfaces and connectors of test cords and recommendations for cleaning these interfaces, and replaces the normative Annex B and deletes the informative Annex H of ISO/IEC 14763-3:2014.

Additional information regarding channel and link testing is provided to Annex E.

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~~, ISO/IEC 24764, ISO/IEC 24702 and ISO/IEC 15018~~. The test methods refer to existing standards-based procedures where they exist.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 – Chapter 731: Optical fibre communication*

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

IEC 60874-14-3, *Connectors for optical fibres and cables – Part 14-3: Detail specification for fibre optic adapter (simplex) type SC for single-mode fibre*

IEC 60874-19-1, *Fibre optic interconnecting devices and passive components – Connectors for optical fibres and cables – Part 19-1: Fibre optic patch cord connector type SC-PC (floating duplex) standard terminated on multimode fibre type A1a, A1b – Detail specification*

IEC 61280-1-3, *Fibre optic communication subsystem test procedures – Part 1-3: General communication subsystems – Central Wavelength and spectral width measurement*

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 cable plant – Multimode attenuation measurement*

IEC 61280-4-2, *Fibre optic communication subsystem basic test procedures – Part 4-2: Fibre optic cable plant – Single-mode fibre optic cable plant attenuation*

IEC 61300-3-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation*

IEC 61300-3-6, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*

IEC 61300-3-35~~:2009~~, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-35: Examinations and measurements – Visual inspection of fibre optic connectors~~ endface visual~~ and~~ automated inspection~~ 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 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 62614, *Fibre optics – Launch condition requirements for measuring multimode attenuation*

IEC 62664-1-1, *Fibre optic interconnecting devices and passive components – Fibre optic connector product specifications – Part 1-1: LC-PC duplex multimode connectors terminated on IEC 60793-2-10 category A1a fibre*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
adapter
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 $A = 10 \lg(P_{out}/P_{in})$, 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
<for a reflective or non-reflective event> region 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
cable sheath
covering over the optical fibre or conductor assembly that may include one or more metallic members, strength members or jackets

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

3.1.5
3.1.5.1
connection
mated device including terminations connecting two cables or cable elements

3.1.5.2
connection
combination of devices including terminations connecting two cables or cable elements

3.1.6
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

3.1.7
event dead zone
distance in which an OTDR cannot detect a reflective event following a reflective event

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

Note 1 to entry: The fail result is for further study (ffs).

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

Note 1 to entry: The marginal result is for further study (ffs).

3.1.12
multimode optical 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 about 100 modes or more.

[SOURCE: IEC 60050-731:1991, 731-02-03, modified – definition slightly changed and note added.]

3.1.13
optical fibre
filament shaped optical waveguide made of dielectric materials

[SOURCE: IEC 60050-731:1991, 731-02-01]

3.1.14
optical time domain reflectometer
instrument used to characterise optical fibre cabling by measuring the backscatter and reflection of injected light pulses as a function of time

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

Note 1 to entry: The pass result is for further study (ffs).

3.1.16
reference adapter
adapter that ensures that the performance of reference connections can be attained

Note 1 to entry: This definition is only applicable to connectors with cylindrical ferrules.

3.1.17
reference connector
connector with tightened tolerances terminated onto an optical fibre that may 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

3.1.18
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

3.1.19
singlemode optical fibre
optical fibre which supports only one mode of light transmission

3.1.20
substitution test cord
test cord used within a reference measurement which is replaced during the measurement of the attenuation of the cabling under test

3.1.21
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

3.1.22
test cord
cable assembly used either to connect test equipment to the cabling under test or as part of a test reference measurement

3.1.23
test operator
skilled person testing in accordance with instructions provided by the test system designer

3.1.24
test system
test equipment, test cords and adapters necessary to undertake a given test in accordance with the requirements of this standard

3.1.25
defect
surface feature such as pits, chips and loose debris

3.1.26
loose debris
particles and debris on the surface that can be removed by cleaning

3.1.27
pit
permanent non-linear surface damage

3.1.28
scratch
permanent linear surface damage

3.2 Abbreviations

For the purposes of this document, the abbreviations of ISO/IEC 11801-1 as well as the following apply.

APC	Angled Physical Contact
CP	Consolidation Point
DUT	Device Under Test
EQP	Equipment
ffs	for further study
IOR	Index Of Refraction
LC	LC connector
LTC	Launch Test Cord
LS	Light Source
LSA	Least Squares Average
LSPM	Light Source And Power Meter
MMF	MultiMode optical Fibre
MPO	Multi-fibre Push- On connector (based on rectangular ferrule)
N/A	Not Applicable
OTDR	Optical Time Domain Reflectometer
PC	Physical Contact
PM	Power Meter
RL	Return Loss
SC	Subscriber Connector
SMF	Single-Mode optical 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 adapter (general)
	Optical fibre adapter imbedded in cabling
	Optical fibre reference adapter
	Splice

4 Conformance

To test installed cabling according to this International Standard

a) the general requirements of Clauses 5 and 8 shall be met,

b) the test equipment and test cords shall conform to the requirements of Clause 6,

c) the test method, as appropriate, and treatment of results shall conform to Clauses 9 and 10,

d) the test results shall be documented in accordance with 5.4,

e) the requirements of IEC 60825-2 concerning safety of laser products shall be met.

To inspect installed cabling according to this standard

1) the inspection equipment shall conform to the requirements of Clause 7,

2) the inspection method, as appropriate, shall conform to Clause 11,

3) the requirements of IEC 60825-2 concerning safety of laser products shall be met.

Relevant national and local regulations covering safe working practices shall be observed.

5 General requirements

5.1 Test system

The test systems defined in this standard comprise local test equipment and remote test equipment (where required) together with test cords and adapters which enable the connection of the test equipment to the cabling under test (see Figure 2).

Certain test methods of this standard may apply to the testing of plastic optical fibre cabling (i.e. attenuation) although no detailed information is provided. Plastic optical fibre category A4 fibres are specified in IEC 60793-2-40.

The test system and, particularly the adapters and reference connectors, affect the uncertainty of the attenuation measurement for a given component, link or channel.

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

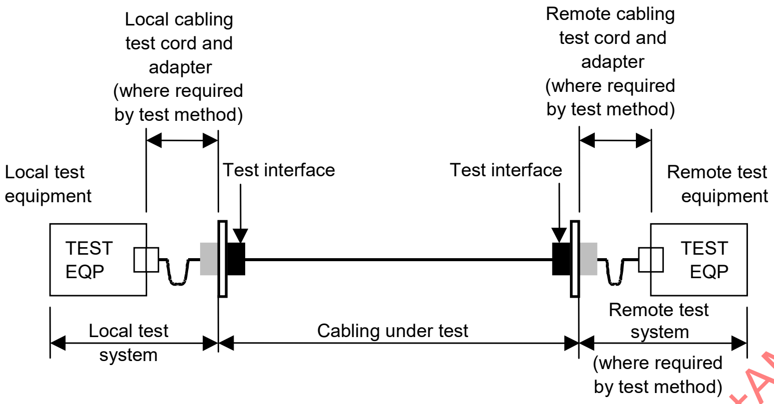


Figure 2 – Test system and the cabling under test

5.2 Reference measurement and calibration

Reference measurement processes are specified, where appropriate, to enable the test system to achieve the stated measurement uncertainty.

The test equipment shall be calibrated using standardised procedures (e.g. IEC 61315 and IEC 61746), or tester manufacturers' 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.

5.3 Environmental conditions

5.3.1 Protection of transmission and terminal equipment

Transmission and terminal equipment shall be disconnected from the cabling under test before any testing or inspection according to this standard is carried out.

5.3.2 Inspecting and cleaning connectors

Dust, dirt and other contaminants at the interfaces to the cabling under test or at interfaces of the test cords and at the interface to the test equipment may produce misleading results and in some cases damage the cabling under test.

Connector end faces on the test cords shall be inspected in accordance with Annex B. If they are dirty or contaminated they should be cleaned following the recommendations of Annex H and re-inspected. If the connectors on the test cords are damaged and/or fail to meet the requirements of Annex B, the test cords shall be replaced.

Connector end faces on the cabling under test shall be inspected in accordance with Annex B. If they are dirty or contaminated they should be cleaned following the recommendations of Annex H and re-inspected in accordance with Annex B. If the connectors on the cabling under test are damaged and/or fail to meet the requirements of Annex B, then the failure shall be reported with the recommendation that the connector be replaced.

5.3.3 Use of test equipment

External effects (for example, environmental, electromagnetic or physical) can affect the test equipment and thereby influence the measured results. Test equipment shall be operated per manufacturer's specifications. Unless manufacturer specifications provide other information, test equipment shall be allowed to stabilise at the test environment for at least 15 min prior to readings being taken.

5.3.4 Relevance of measurement

Measurements shall either

a) be made under environmental conditions which are representative of the intended operational environment,

b) be documented as being performed under non-representative conditions.

5.3.5 Treatment of marginal test results

Marginal results may be treated in a number of ways including

a) verification of the reference measurement of the test system,

b) acceptance of all marginal results,

c) repetition of the measurement using a test system with improved measurement uncertainty.

5.4 Documentation

The documentation for each parameter shall include

a) identification and details of the parameter,

b) whether channel or permanent link is being tested,

c) test equipment:

   1) type and manufacturer;

   2) serial number and calibration status;

   3) nominal wavelength,

d) optical fibre cabling details (category of cabled optical fibre performance e.g. OM2, OM3, OM4, OS1, OS2)

e) details of the cabling connector type(s),

f) the configuration of the cabling test equipment during the test,

g) the measured result,

h) the applicable requirements,

i) details of the reference numbers and direction of test,

j) the date of the test (the time may also be recorded),

k) the test operator,

l) the calculated measurement uncertainty of the test system (ffs).

6 Test equipment

6.1 Light source and power meter

6.1.1 General

Derived from IEC 61280-4-1, IEC 61280-4-2 and IEC 61300-3-4, the following has been adapted to the requirements of ISO/IEC 11801-1 for link and channel attenuation (this is sometimes called insertion loss) measurements with an LSPM.

6.1.2 Light sources

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

Light sources for testing multi-mode optical fibre (MMF) cabling and components shall conform to the spectral characteristics of Table 1 when measured in accordance with IEC 61280-1-3.

Table 1 – MMF light source characteristics

Centre wavelength nm
850 ± 30
1 300 ± 30

Light sources for testing single-mode optical fibre (SMF) shall conform to the spectral characteristics of Table 2 when measured in accordance with IEC 61280-1-3.

Table 2 – SMF light source characteristics

Centre wavelength nm
1 310 ± 30
1 550 ± 30

6.1.3 Power meters

The equipment 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)

When the test set-up (LSPM) is used for a link or channel attenuation, the measurement uncertainty shall not be greater than ±0,2 dB (ffs).

When the test set-up (LSPM) is used for a field check of the reference connectors by measuring the attenuation, the measurement uncertainty should be <0,2 dB (ffs).

If the power meter consists of an optoelectronic detector with a demountable adapter then the adapter shall be fitted to the meter in accordance with the instructions provided by the supplier of the power meter.

6.1.4 Test system stability (ffs)

The light source shall be stable to ±0,1 dB

NOTE Non-linearity between the measured and incident optical power may cause measurement errors. Also, equipment with internal waveguides may exhibit measurement variability with varying modal conditions.

6.2 OTDR

6.2.1 General

OTDR equipment for testing multimode optical fibre (MMF) cabling and components shall conform to the central wavelengths of Table 1.

OTDR equipment for testing single-mode optical fibre (SMF) shall conform to the central wavelengths of Table 2.

OTDR characterization shall be undertaken using a launch test cord and a tail test cord.

See Annex C for further information on optical fibre time domain reflectometry.

6.2.2 OTDR characterization using a launch test cord and a tail test cord

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

a) produces an unidirectional characterization of the form shown in Figure 3,

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 installed cable and any embedded connecting hardware,

d) provides a quantitative measurement of the local and remote interfaces to the cabling under test using measurements taken in each direction,

e) provides a quantitative measurement of the channel or link (see Clause 8) attenuation when the measurement is taken in one direction provided that

  – the channel or link only contains a single fixed cable and terminating connectors,

  – the scattering 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 8) 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 C.2.1).

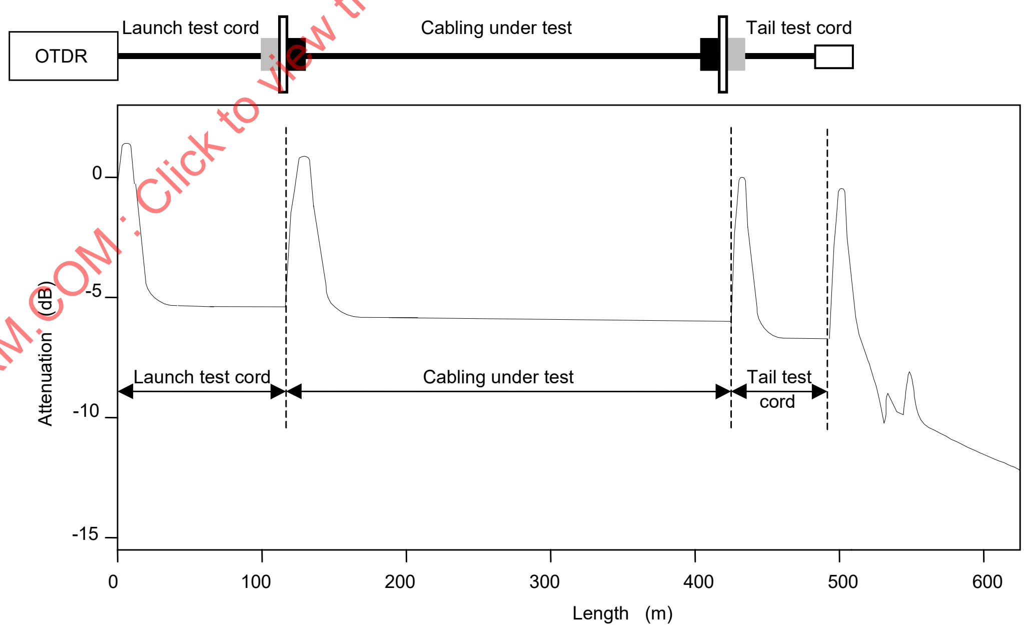


Figure 3 – OTDR characterization using a launch test cord and a tail test cord

6.3 Test cords and adapters

6.3.1 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 adapters used as part of the test methods specified by this standard:

a) should have the same or better performance specification as the hardware terminating the cabling under test;
b) should have a controlled end face for radius, dome offset and fibre position
   – for the duplex LC connector for MMF as specified in IEC 62664-1-1,
   – for the simplex LC connector for SMF as will be specified in IEC 62664-1-2[1],
   – for the duplex SC connector for MMF as specified in IEC 60874-19-1,
   – for the simplex SC connector for SMF as specified in IEC 60874-14-3;
c) should be of the same product as defined by the supplier where IEC specifications do not guarantee interoperability (the only interfaces specified to be interoperable are within the IEC 62664 series on LC connector product specifications);
d) where used, connecting hardware adapters shall be reference adapters in accordance with the relevant IEC product specification
   – for LC MMF (duplex) as specified in IEC 62664-1-1,
   – for SC SMF (simplex) as specified in IEC 60874-14-3.

The inspection and testing of test cords and connecting hardware adapters shall be done in accordance with Annex D prior to any reference measurement process being undertaken.

NOTE In the case of MPO interfaces, there is no adapter and therefore there is no influence on the final alignment of the connection.

6.3.2 Reference connector requirements

The requirements for reference connectors of cylindrical and rectangular styles are given in Table 3.

Table 3 – Non-LC reference connector requirements

	Cylindrical connector styles		Rectangular connector styles	
	MMF	SMF	MMF	SMF
Eccentricity of core centre to ferrule outer diameter	<1 µm	<0,3 µm	N/A	N/A
True position of the fibre core	N/A	N/A	<1 µm	<0,3 µm
Exit angle	≤0,2°	≤0,2°	≤0,2°	≤0,2°
Accuracy of ferrule diameter	±0,5 µm	±0,5 µm	N/A	N/A
Attenuation of 2 reference connectors in a reference adapter	≤0,10 dB	≤0,20 dB	≤0,10 dB	≤0,20 dB

LC reference adapters are specified in IEC 62664-1-1, and the attenuation of adaptors is measured according to IEC 61300-3-42.

The return loss of singlemode reference PC connectors shall be ≥45 dB.

1 Under consideration.

The return loss of singlemode reference APC connectors shall be ≥60 dB mated and ≥55 dB unmated.

Multimode reference PC connectors shall meet the conditions of Grade 3 (≥35 dB).

The geometrical data for singlemode PC connectors are specified in IEC 61755-3-1 and for singlemode APC connectors in IEC 61755-3-2.

The reference connector shall be a tuned connector which has a low attenuation-value against all other connectors measured in one batch.

6.3.3 Test cords

6.3.3.1 General

Each test cord should

a) contain an optical fibre of the same nominal characteristics (core/mode field/cladding diameters, numerical aperture) as the optical fibre under test,

b) be labelled by having a unique identifier with each connector labelled as indicated in Figure 4,

c) be no shorter than 2 m,

d) not be so long that the attenuation of the fibre has a significant effect on the measurement.

NOTE A maximum test cord length value of 10 m is considered safe for most applications. For example, 10 m of multimode fibre will have no more than 0,035 dB of attenuation at 850 nm.

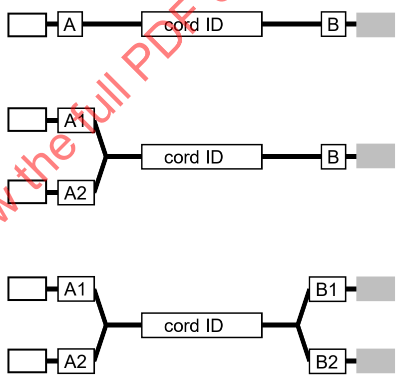


Figure 4 – An example of test cord labelling and identification

6.3.3.2 LSPM launch test cord

The launch test cord 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 compatible with the interface to the installed cabling.

For the multimode LSPM launch test cord, if the light source is not known to provide the specified launched modal distribution (see 6.4), then the launch test cord shall contain a suitable mode-controlling device to ensure that the specified launched modal distribution is maintained.

6.3.3.3 LSPM tail test cord

The tail test cord 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 compatible with the interface to the installed cabling.

6.3.3.4 LSPM combination launch test cord/tail test cord

A duplex launch test cord/tail test cord shall be

a) terminated at one end with one duplex or 2 simplex (duplexible) connectors suitable for attachment to the LSPM equipment,

b) terminated at the other end with one duplex or 2 simplex (duplexible) reference connectors compatible with the interface to the installed cabling.

6.3.3.5 LSPM substitution test cord

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

6.3.3.6 OTDR launch test cord

The OTDR should provide the specified launch modal distribution (see 6.4). For the multimode 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 launch test cord should be

a) longer than the attenuation dead zone of the OTDR (see Annex C for further details),

b) long enough for a reliable straight-line fit to be made to the backscatter trace following the dead zone (C1 to C2 in Figure 11) so that reliable attenuation measurements may be carried out. For example, in multimode fibre installations the length of the launch test cord should be at least 75 m. For single-mode fibre installations the length of the launch test cord should be at least 150 m,

c) terminated at one end with one or more connectors suitable for attachment to the OTDR,

d) terminated at the other end with one or more reference connectors compatible with the interface to the installed cabling.

The length of optical fibres used to create OTDR launch test cords often requires that they be protected within a closure (see Figure 5).

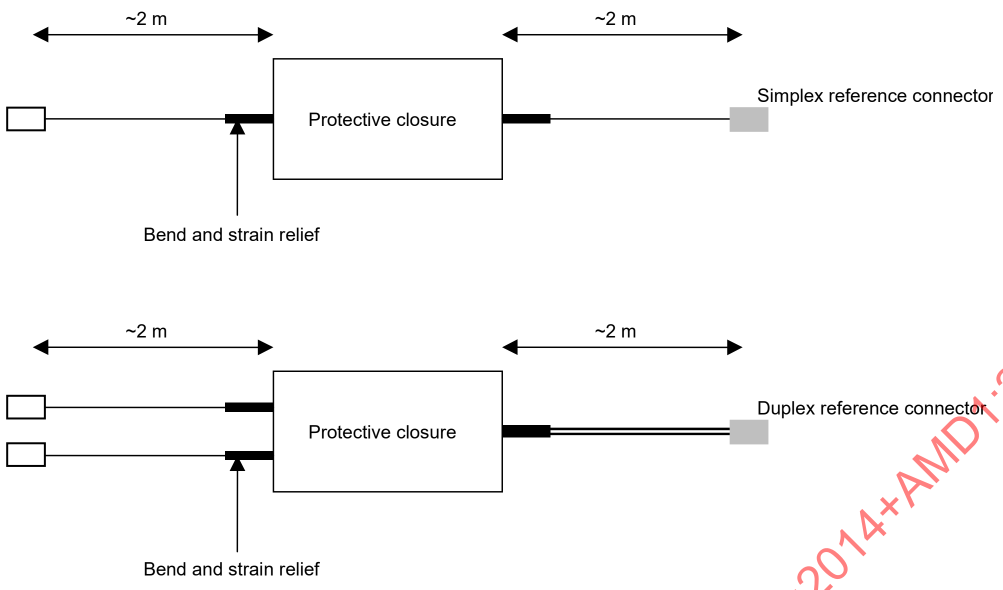


Figure 5 – OTDR launch test cord and/or tail test cord schematic

Where the interface to the cabling or component under test is duplex, the two optical fibres shall be of different lengths in order to determine the maintenance of polarity in the cable under test. The OTDR connections shall be uniquely identified with markers as shown in Figure 4.

6.3.3.7 OTDR tail test cord

The tail test cord shall be

a) longer than the attenuation dead zone of the OTDR (see Annex C for further details),

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 11), so that reliable attenuation measurements may be carried out). For example, in multimode installations the length of the tail test cord should be at least 75 m. For single-mode fibre installations the length of the tail test cord should be at least 150 m,

c) terminated at one end with one or more reference connectors compatible with the interface to the installed cabling.

The termination of the other end(s) is optional.

The length of optical fibres used to create OTDR tail test cords often requires that they be protected within a closure (see Figure 5).

6.4 MMF launched modal distribution

The launched modal distribution at the point of connection to the fibre under test shall meet the requirements in Annex A.

The required launched modal distribution shall be achieved by the use of the appropriate light source or by incorporating a mode-controlling device within the launch test cord.

6.5 SMF launch condition

The provision of a single-mode launch condition requires that launch test cords contain a minimum of two single air-coiled turns or mandrel wraps of 35 mm to 50 mm in diameter. However, this is usually provided within the test instruments and it is then not necessary to include an external wrap on a launch test cord.

7 Inspection equipment

Connecting hardware end face shall be inspected according to IEC 61300-3-35. Microscopes used for the inspection of connector end faces shall have a minimum field of view of 250 µm and have a minimum capability of ×100 magnification for MMF and ×200 magnification for SMF. The complete ferrule end face of rectangular connectors shall be inspected at low magnification for contamination. The microscope shall be fitted with suitable fixtures that retain the connector in a stable position thereby allowing careful inspection.

For direct vision viewing, the microscope shall be fitted with suitable infra-red filter mechanisms to prevent accidental eye damage. This is particularly important during the inspection of installed connector end faces where the remote end is not under control of the inspector.

Do not use direct view microscopes on live fibre systems.

For a more detailed description, see also Annex B.

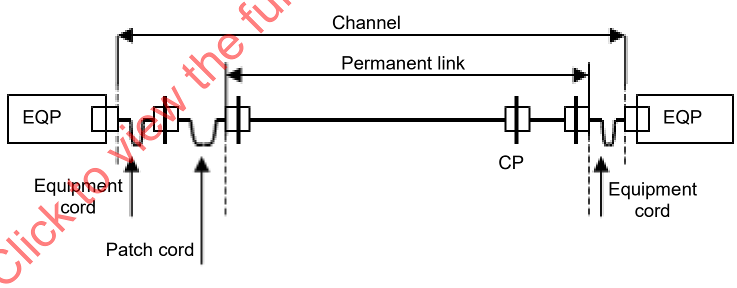
8 Cabling under test – Channels and permanent links

8.1 General

Although permanent links are referred to in this clause, ISO/IEC 11801-1 has defined requirements for sub-links that can be tested according to this standard.

8.2 Reference planes

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

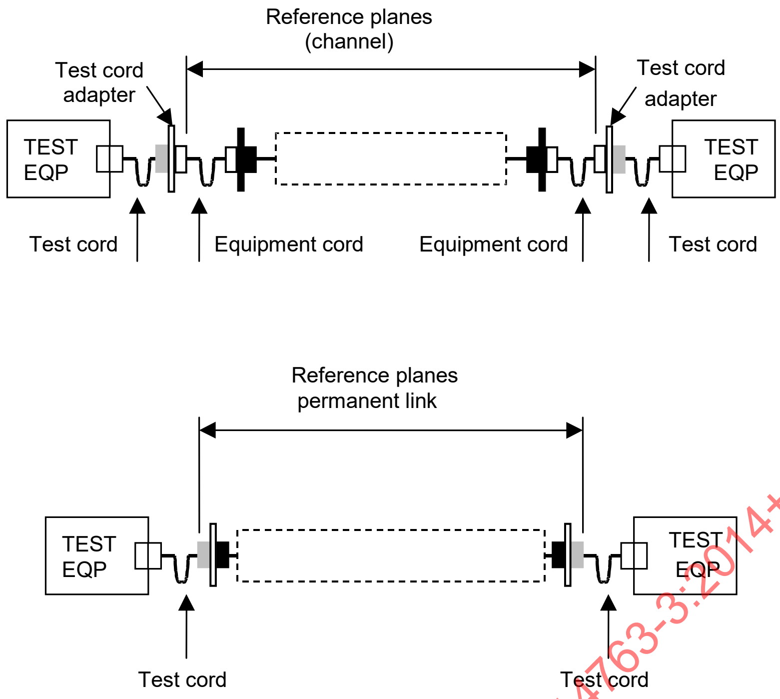


CP = consolidation point

Figure 6 – Channels and permanent links in accordance with ISO/IEC 11801-1 and equivalent standards

The uncertainty of a test system established to measure the optical characteristics of a channel and/or a permanent 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 permanent link are within the test cords next to, and including, the test cord connections which mate to the termination points of the permanent link under test (see Figure 7).



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

Figure 7 – Channel and permanent link test configuration

It should be noted that

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 may 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 it is necessary to reproduce the test conditions including the configuration of the test cords used. Changing the test set-up may produce different results.

8.3 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 Clauses 9 and 10 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).

8.4 Direction of measurement

The methods detailed in Clauses 9 and 10 specify the requirements for uni-directional or bi-directional measurements. For compliance testing of a link composed of known and unknown components bi-directional testing shall be conducted.

9 Testing of installed cabling

9.1 Attenuation

9.1.1 LSPM

9.1.1.1 General

Derived from IEC 61280-4-1, IEC 61280-4-2 and IEC 61300-3-4, the following has been adapted specifically in support of ISO/IEC 11801-1 for permanent link and channel attenuation measurements with a LSPM.

According to ISO/IEC 11801-1, a channel does not include the connector on the equipment cords that interfaces 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 and/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.

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 light source manufacturer's recommendations.

9.1.1.2 ~~Enhanced three-test-cord attenuation measurement test method of installed channels~~ Channel test method

The procedure for channel testing is as follows.

~~For both singlemode and multi-mode fibre, the process requires a reference measurement as shown in Figure 8 to be carried out between the LSPM by the connection of a launch test cord to the near end equipment cord that is to be connected to the output of the installed equipment.~~

~~The reference measurement, P_r, shall be recorded in watts (W) or decibel mW (dBm).~~

~~The near end equipment cord is disconnected from the power meter and reconnected to the installed cabling while maintaining connection to the light source.~~

~~The power P_1 is measured directly at the far end equipment cord.~~

~~The measurement, P_1, shall be recorded in watts (W) or decibel meter (dBm).~~

~~The launch test cord shall be in accordance with 6.3.3.2 (or 6.3.3.4).~~

~~The attenuation of the channel is~~

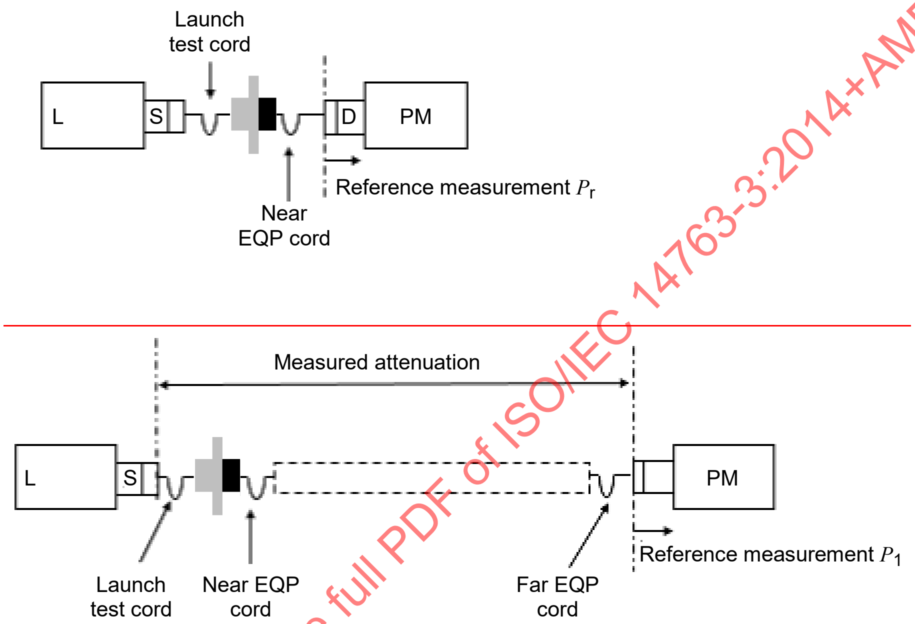
$$\cancel{A = P_r - P_1 \text{ (dB)}} \qquad \cancel{(1)}$$

~~where P_1 and P_r are expressed in dBm.~~

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

$$\cancel{A = -10\lg\left(\frac{P_1}{P_r}\right) \text{ (dB)}} \qquad \cancel{(2)}$$

~~The channel testing is carried out in one direction only.~~



~~**Figure 8 – LSPM enhanced three-test-cord attenuation measurement of installed channels**~~

a) 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). Allow sufficient time for the light source stabilization in accordance with light source manufacturer's recommendations. (See Figure 8). Since this reference measurement is carried out with a near end EQP cord, the defect of near end EQP cord may not be found. When this test method is used, the quality of the near end EQP cord shall comply with the requirement.

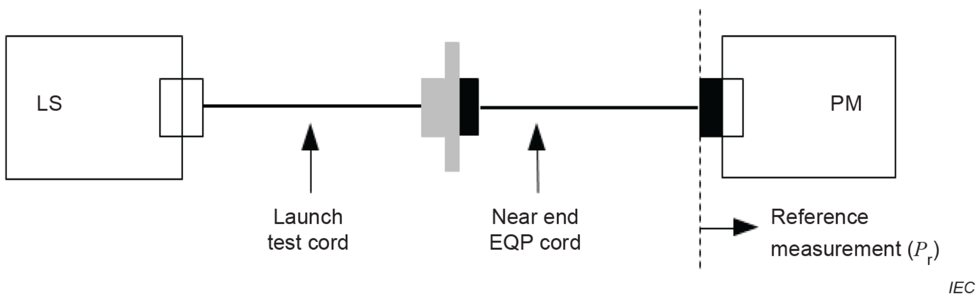


Figure 8 – Connection of LS – LTC – Near end EQP cord – PM for reference setting

b) The reference measurement, P_r, shall be recorded in watts (W) or decibel-milliwatts (dBm).

c) 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.

d) At the far end of the channel, connect the far end EQP cord to the power meter, see Figure 20).

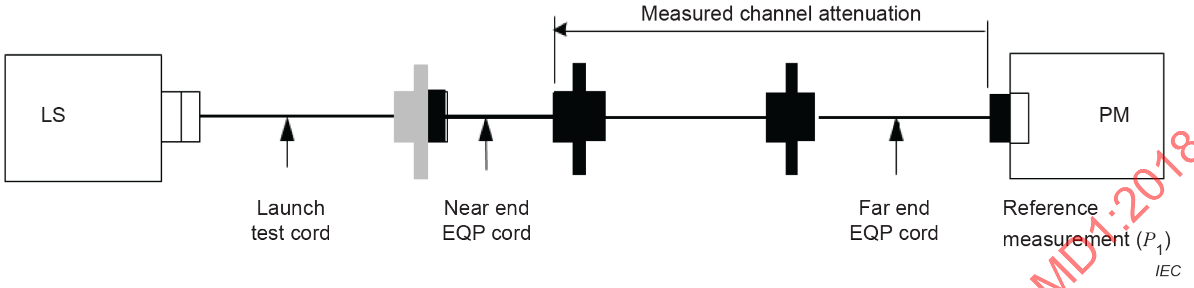


Figure 20 – Connections to channel test for attenuation measurement

e) The power P_1 is measured directly at the far end EQP cord. The measurement, P_1, shall be recorded in watts (W) or decibel-milliwatts (dBm).

f) The attenuation of the channel is:

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

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in W, 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.

For this method, the measurement uncertainties at 95 % confidence level are as follows.

SMF: ± 0,16 dB for fibre length < 2 km.

MMF: ± 0,19 dB when measured attenuation ≤ 1,4 dB.

MMF: ± 0,14 × measured attenuation when measured attenuation > 1,4 dB.

NOTE Measurement uncertainties are determined using IEC TR 61282-14 and representative system data. See IEC TR 61282-14 for more details.

9.1.1.3 ~~Test method for links using the one-test-cord reference method~~ Link test method using the one-cord method and enhanced-three-test-cord reference method

The attenuation of an installed permanent link may be measured using the Enhanced three-test-cord reference method, or the one-test-cord reference method when the connectors installed on the cabling are compatible with the connectors on the test equipment.

See Annex E for differences between the one- and enhanced three-test-cord reference methods.

The reference measurement is made between the light source and power meter by the connection of a launch test cord in accordance with 6.3.3.2, as shown in Figure 9.

The reference measurement, P_r, shall be recorded in watts (W) or decibel mW (dBm).

The launch test cord shall remain connected to the light source and the tail test cord shall be connected to the power meter.

The attenuation of the connectors on the launch test cord and tail test cord may be verified by connecting these cords together and verifying that the attenuation of this connection is no more than the expected attenuation between two reference grade connectors. See Annex D for further information on inspection and testing of test cords.

The cabling under test shall be connected between the launch test cord and tail test cord and the test measurement, P_1, shall be recorded in watts (W) or decibel mW (dBm). The attenuation shall be determined according to formulae (1) or (2), respectively.

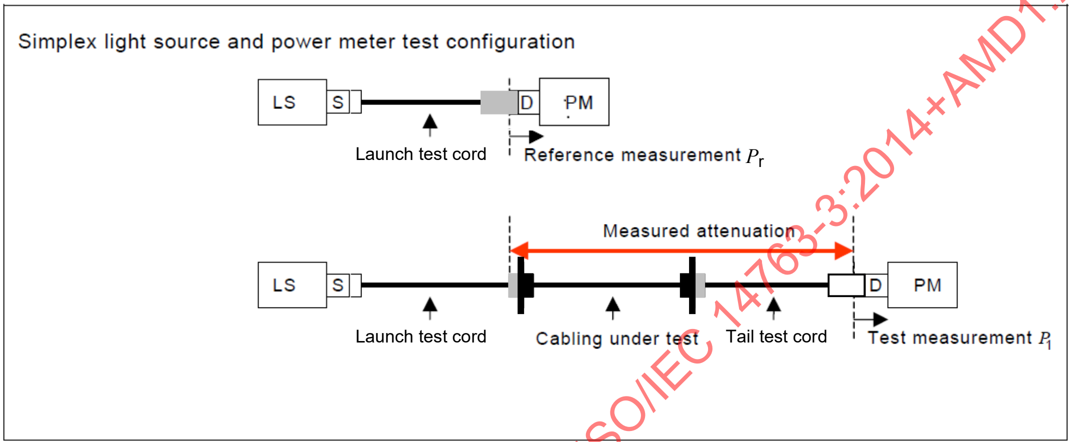


Figure 9 – LSPM one test cord attenuation measurement of installed permanent links

9.1.1.4 Unidirectional and bi-directional testing

For permanent links comprising a single fixed cable and terminating connectors, uni-directional testing may be performed. Where the permanent link or channel 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.

9.1.1.5 Test result

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

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 the worst of the two measured results shall be considered as the overall measured result.

9.1.1.6 Test system measurement uncertainty

The measured attenuation of a permanent link is affected by the alignment of the two optical fibres on either side of the test interfaces.

The use of test cords with reference connectors as required by this standard provides a reduced variation and as a result lower measurement uncertainty when compared to normal connectors.

In order to determine measurement uncertainty, the following information shall be given for the connectors terminating the cabling under test:

a) for MMF, the worst case attenuation of a MMF connection against a multimode reference termination;

b) for SMF, the worst case attenuation of a SMF connection against a single-mode reference termination.

Normative values for connecting hardware in accordance with ISO/IEC 11801-1 are stated in Table 4.

Table 4 – Connecting hardware attenuation

Connecting hardware	MMF		SMF	
	Attenuation (random mated)	**Attenuation** (mated against reference)	**Attenuation** (random mated)	**Attenuation** (mated against reference)
IEC 62664-1-1 Performance Grade B	0,30 dB max. – 50 % 0,60 dB max. – 97 %	0,50 dB max.		
In future IEC 62664-1-2 Performance Grade C[a]			0,25 dB max. – 50 % 0,50 dB max. – 97 %	0,75 dB max.
ISO/IEC 11801-1	0,75 dB max. – 100 %		0,75 dB max. – 100 %	
[a] Under consideration.				

6.3.2 and Table 3 define requirements for the maximum attenuation of a connection of two reference connectors in a reference adapter.

9.1.1.7 Treatment of channel test results

Using the enhanced three test cord reference method specified in 9.1.1.2, the limit of testing for channel attenuation is

$$\Sigma \text{ (cable attenuation)} + \Sigma \text{ (embedded connection attenuation).}$$

Examples of these calculations are shown in Annex G.

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

9.1.1.8 Treatment of permanent link test 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 reference terminations in accordance with Table 3. 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 4.

Using either the one- or the enhanced three-test-cord reference method specified in 9.1.1.2, the calculated limit of testing link attenuation is:

- for MMF: Limit = $(2 \times 0{,}5 \text{ dB}) + \Sigma$ (cable attenuation) + Σ (embedded connection attenuation);

- for SMF: Limit = (2 × 0,75 dB) + Σ (cable attenuation) + Σ (embedded connection attenuation) (for reference connector).

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 and Table 4.

NOTE When using the enhanced three-test-cord reference method, $A_{LTC/STC}$ is the measured attenuation of the reference connectors of the launch test cord and the substitution test cord.

9.1.2 OTDR

9.1.2.1 Test method

A launch test cord in accordance with 6.3.3.6 shall be connected between the OTDR and the cabling under test. A tail test cord in accordance with 6.3.3.7 shall be connected to the remote end of the cabling under test.

The output source shall be selected for the fibre type and wavelength as defined in Annex C and the appropriate settings established, as follows:

a) range;

b) pulse width;

c) IOR;

d) averaging time.

9.1.2.2 Treatment of channel test results

Prior to the measurement of the attenuation of the cabling, the reference connectors on the launch test cord and the tail test cord shall be mated and the quality shall be verified.

The attenuation of the installed cabling shall be measured either as shown in Figure 10 or as shown in Figure 11.

Figure 10 shows the 2 points at which the attenuation of the installed cabling shall be measured. If the equipment cords are very short and/or the OTDR dead zone is long, then it may reduce the accuracy of the attenuation measurement.

It should be noted that

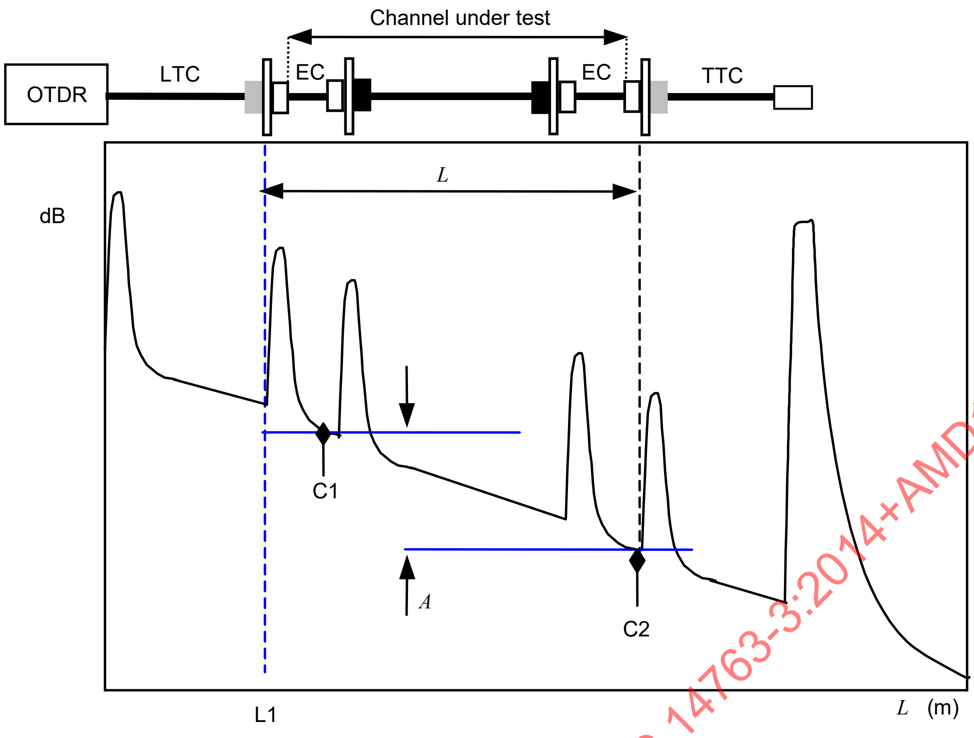
a) it is not possible to carry out the more accurate five point attenuation measurement where two reflective events are in close proximity as there is unlikely to be sufficient length of optical fibre in the equipment cords to obtain a linear fit to these sections around C1 and C2,

b) if the equipment cords are very short and/or the OTDR dead zone is long then it may not be possible to measure the channel attenuation.

Figure 11 shows the alternative approach where the attenuation of the channel is measured plus the attenuation of the equipment connectors.

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 comprises 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 pass, fail or a marginal result.



Key

LTC	Launch test cord
TTC	Tail test cord
EC	Equipment cord
C1, C2	Cursors for 2-point channel attenuation measurement
A	Attenuation of channel
L	Length of channel

Figure 10 – OTDR measurement of installed cabling (channel): 2 point attenuation measurement method

9.1.2.3 Treatment of permanent link test results

Figure 10 shows the points at which the attenuation of the installed cabling shall be measured.

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

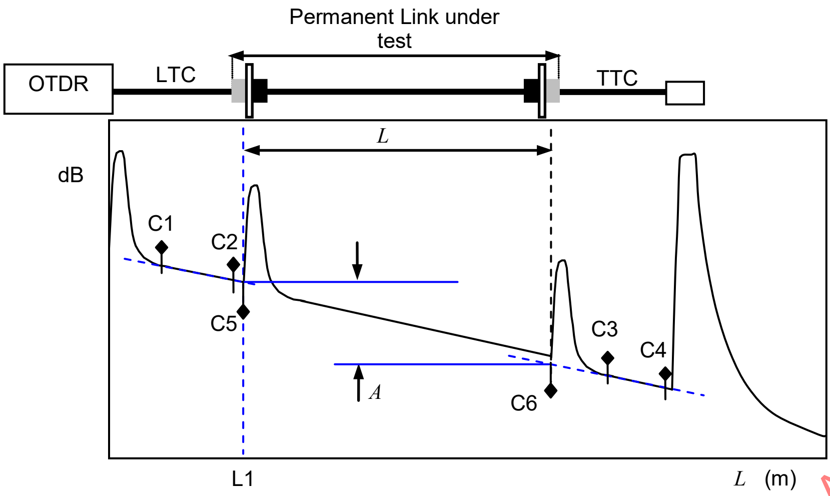
Comparison of the measured attenuation in Figure 8 and the permanent link reference planes in 8.2 shows that the attenuation limit defined for the permanent link within ISO/IEC 11801-1 or equivalent standards shall be the sum of the specified maximum attenuation values for the

a) attenuation (mated against reference) for the interface connections at the interfaces to the cabling under test,

b) embedded connections within the cabling under test,

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, fail or a marginal test result shall be indicated with reference to the measured result.



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 11 – OTDR measurement of installed cabling (permanent link)

9.1.2.4 Test system measurement uncertainty

NOTE The test system measurement uncertainty is for further study (ffs).

The measured attenuation of a channel or permanent link to this is affected by the alignment of the two optical fibres on either side of the test interfaces.

The use of test cords with reference connectors as required by this standard provides a reduced variation and as a result a more accurate result.

In order to determine measurement uncertainty, the following information shall be given for the connectors terminating the link under test:

a) for MMF, the worst case attenuation of a MMF connection against a multimode reference termination;

b) for SMF, the worst case attenuation of a SMF connection against a single-mode reference termination.

Normative values in order to connect hardware in accordance with ISO/IEC 11801-1 are shown in Table 4.

9.2 Propagation delay

9.2.1 Test method

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/optical power meter equipment. This type of equipment also supplies calculations of length.

Propagation delay may be calculated as follows:

$$T = L_{OF} \times n/c \tag{4}$$

where

T is the propagation delay

L_{OF} is the optical fibre length

c is the approximated speed of light in a vacuum (3×10^8 m/s)

n is the group refractive index of the optical fibre

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

9.2.2 Treatment of results

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

9.3 Length

9.3.1 Test method

The optical fibres should be tested using equipment capable of measuring propagation delay (e.g. an OTDR) (see 9.2.1). For determination of the optical fibre cable length see 11.3.

9.3.2 Measurement uncertainty

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 may differ from the physical length of the cable. Within a given length of cable containing multiple optical fibres each individual optical fibre may 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.

9.3.3 Treatment of results

The limits and restrictions indicated in 9.3.2 shall be included within the statement of measurement uncertainty.

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

The propagation velocity or the group refractive index, provided by the manufacturer of the optical fibre cable 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 (e.g. the verification of unknown cabling), the impact of any errors introduced should be recognised and agreed between the installer and the user. For default group refractive index values see Table C.1.

10 Testing of cabling components within installed cabling

10.1 Attenuation of optical fibre cable

10.1.1 Test method

In order to test a channel or permanent link (see Clause 8), a launch test cord in accordance with 6.3.3.6 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 6.3.3.6 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 mode/wavelength as defined in Annex C and the appropriate settings established for

a) range,

b) pulse width,

c) IOR,

d) averaging time.

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.

10.1.2 Measurement uncertainty

The measurement shall be over a section of the optical fibre away from the attenuation dead zone of the OTDR (see Annex C) 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.

For example, if the distance is 50 m, a loss uncertainty of ±0,05 dB leads to an attenuation coefficient uncertainty of ±1 dB/km. For this reason the attenuation coefficient should not be determined for short distances of fibre.

Preferably, the attenuation coefficient can be calculated using a linear regression over the backscattering signal (LSA method).

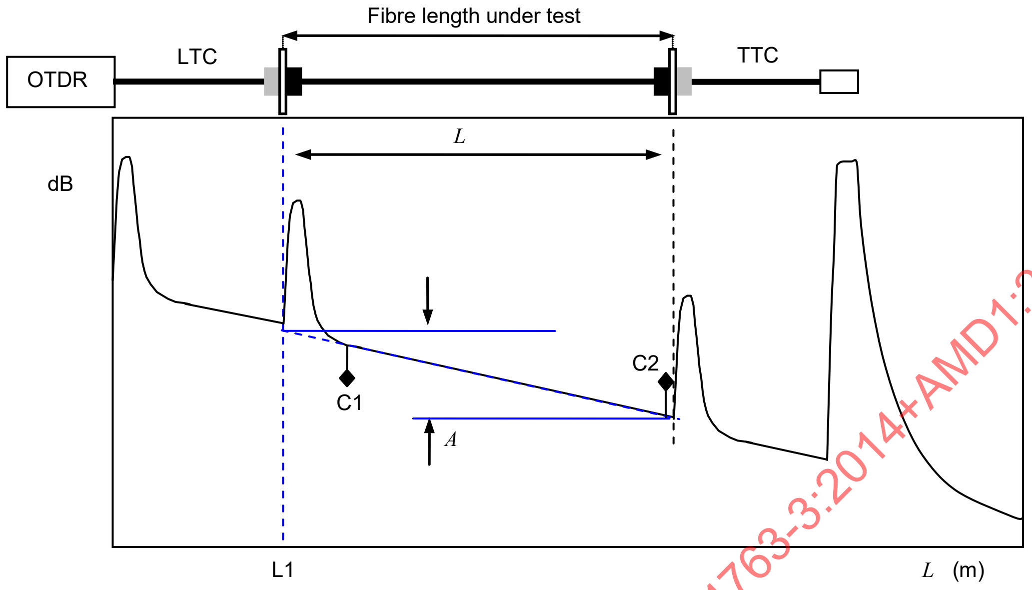
The minimum fibre lengths will differ for MMF and SMF measurements and for the operating wavelengths used. The OTDR manufacturer shall be consulted to determine their recommendations for the minimum fibre lengths over which the attenuation coefficient may be measured reliably.

10.1.3 Treatment of results

Figure 12 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
A	Attenuation of optical fibre
L	Length of optical fibre

Figure 12 – OTDR measurement of optical fibre attenuation

10.2 Attenuation of local and remote test interfaces

10.2.1 Test method

A launch test cord in accordance with 6.3.3.6 shall be connected between the OTDR and the cabling under test. A tail test cord in accordance with 6.3.3.7 shall be connected to the remote end of the cabling under test.

The OTDR output shall be selected for the mode/wavelength as defined in Annex C and the appropriate settings established for

a) range,

b) pulse width,

c) IOR,

d) averaging time.

The cabling under test shall be measured in both directions.

10.2.2 Test system measurement uncertainty

NOTE The test system measurement uncertainty is for further study (ffs).

The measured attenuation of a channel or permanent link depends upon the alignment of the two optical fibres on either side of the test interfaces.

The use of test cords with reference connectors as required by this standard provides reduced variation thereby generating a more accurate result.

In order to determine measurement uncertainties, the following information shall be stated for the connectors terminating the cabling under test

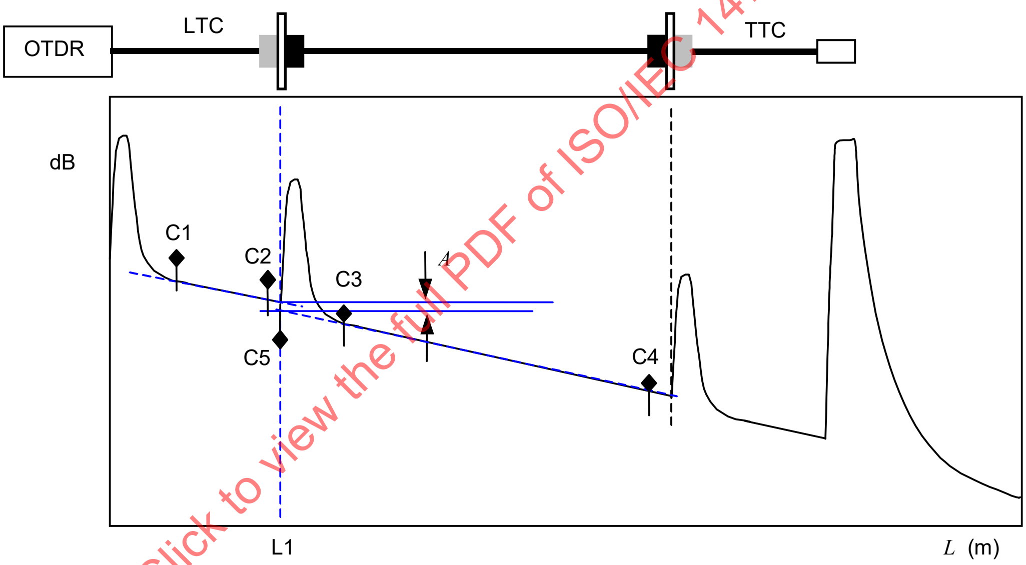
a) for MMF, the worst case attenuation of a MMF connection against a multimode reference termination,

b) for SMF, the worst case attenuation of a SMF connection against a single-mode reference termination.

Normative values for connecting hardware in accordance with ISO/IEC 11801-1 are shown in Table 4.

10.2.3 Treatment of results

Figure 13 shows the points at which the attenuation of the interfaces to the cabling under test shall be measured. The installed cabling may be either a channel or a permanent link (see Clause 8). However, where the channel contains short equipment cords at one or more ends, it may be impossible to make a measurement since the connections of the cords to the permanent link will be disguised within the end interface reflections.



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 13 – OTDR measurement of connection attenuation

The attenuation of the local interface is shown as the interface loss (dB). However, this is not a true measurement since the backscatter coefficient (k) may be different in the launch test cord and the cabling under test. If the backscatter coefficient of the launch test cord is higher than that of the cabling under test then the result will be overstated. If the backscattering coefficient of the cabling under test is higher than that of the launch test cord then the result will be understated (sometimes producing an apparent gain).

For this reason the result shall be the mean of the measurements in each direction.

The limiting constraint for the interface shall be the maximum attenuation (mated against reference). See Table 4.

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

10.3 Attenuation of connecting hardware

10.3.1 Test method

In order to test a channel or permanent link (see Clause 8), a launch test cord in accordance with 6.3.3.6 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 6.3.3.6 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 mode/wavelength as defined in Annex C and the appropriate settings established for

a) range,
b) pulse width,
c) IOR,
d) averaging time.

The cabling under test shall be measured in both directions.

10.3.2 Treatment of results

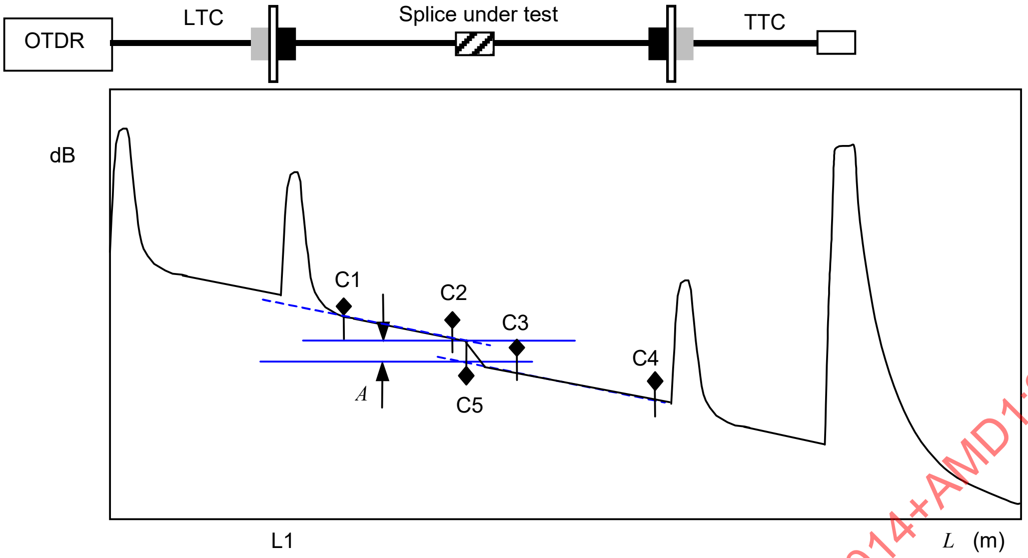
Figure 14 shows the points at which the attenuation of connecting hardware and/or splices within the cabling under test shall be measured.

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.

If the backscattering coefficients of the optical fibres on either side of the embedded connecting hardware are different then the results of measurement in each direction will differ (sometimes producing an apparent amplification in one direction).

For this reason, the result shall be the mean of the measurements in each direction.

Where compliance with a specified value is required a pass, fail or a marginal test 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 14 – OTDR measurement of joint attenuation

10.4 Return loss of connecting hardware

10.4.1 Test method (in accordance with IEC 61300-3-6, method 2)

A launch test cord in accordance with 6.3.3.6 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 6.3.3.7 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 6.3.3.6 but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

An attenuator at the OTDR receiver input may be required to reduce the optical power to a level that does not saturate the OTDR receiver.

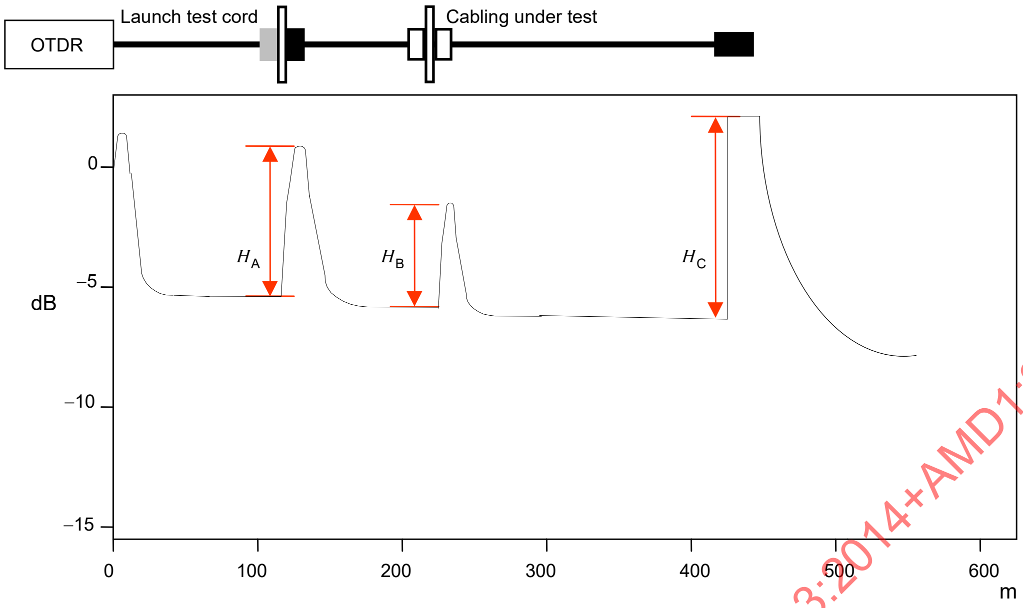


Figure 15 – OTDR measurement of return loss

10.4.2 Treatment of results

The return loss of a cabling component under test is calculated from the height of the reflected peak (H_A or H_B in Figure 15) as follows:

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

where H > 5 dB

$$RL \approx -2H - 10\lg d + k \quad \text{(dB)} \tag{6}$$

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 Annex C.

NOTE 1 Most OTDRs automatically measure RL using instrument settings set by the manufacturer. However, in this case, it is also important to pay attention to the measurement uncertainty consideration as set out in 10.4.3.

NOTE 2 The detector in some OTDRs saturates at large values of H (as shown in H_C in Figure 15) so that measurement uncertainty is lost in measuring small values of return loss. This type of signal saturation is avoided by adding a variable attenuator between the OTDR and the cabling component under test.

NOTE 3 The term "return loss" is sometimes expressed by some OTDR manufacturers as "reflectance" with a negative sign.

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

10.4.3 Measurement uncertainty

Different sources of uncertainties shall be considered when measuring the return loss.

Instrument related uncertainties such as errors on the pulse amplitude or uncertainties on the shape or on the true value of the pulse width shall be considered if they are not corrected by the instrument, otherwise, the maximum uncertainty value provided by the manufacturer shall be taken into account.

Fibre related uncertainties have a direct impact on the return loss uncertainties (e.g. ±2 dB uncertainty on the backscattering coefficient leads to exactly ±2 dB uncertainty on the reflectance). Typical uncertainty values included in Annex C may be used.

10.5 Optical fibre length

10.5.1 Test method

In order to test a channel or permanent link (see Clause 8), a launch test cord in accordance with 6.3.3.6 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 6.3.3.6 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 mode/wavelength as described in Annex C and the appropriate settings established for

a) range,

b) pulse width,

c) IOR,

d) averaging time.

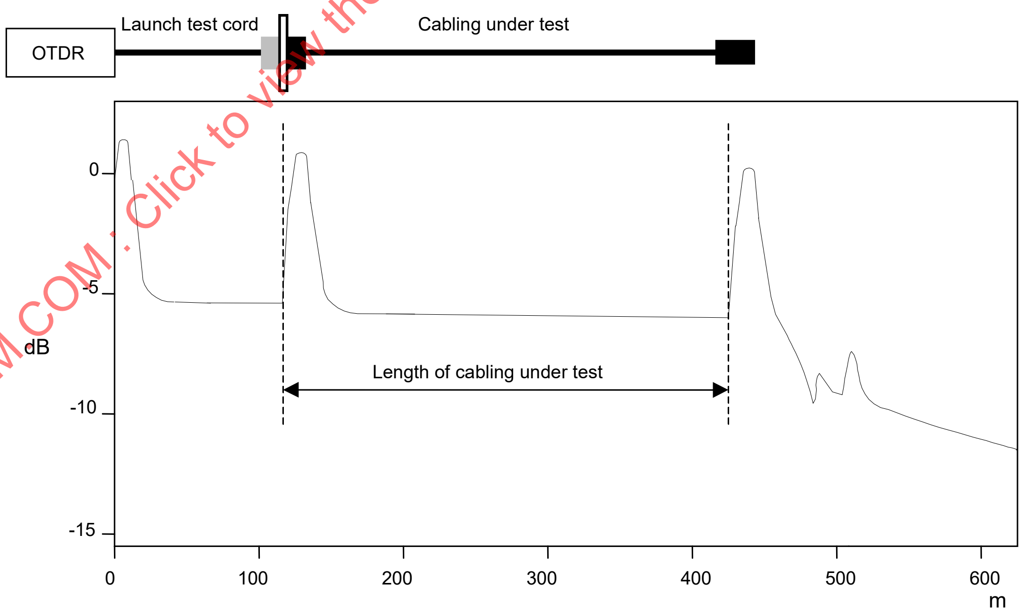


Figure 16 – Determination of length using an OTDR

Figure 16 shows the points at which the length of the transmission path contained within the installed cabling shall be measured (SMF may not produce a remote interface reflection). The installed cabling may be either a channel or a permanent link (see Clause 8).

A break in a MMF permanent link would also be characterized by the presence of the reflection peak. However, unlike MMF and as shown in Figure 17, a break in a SMF may not always be characterized by a reflection peak.

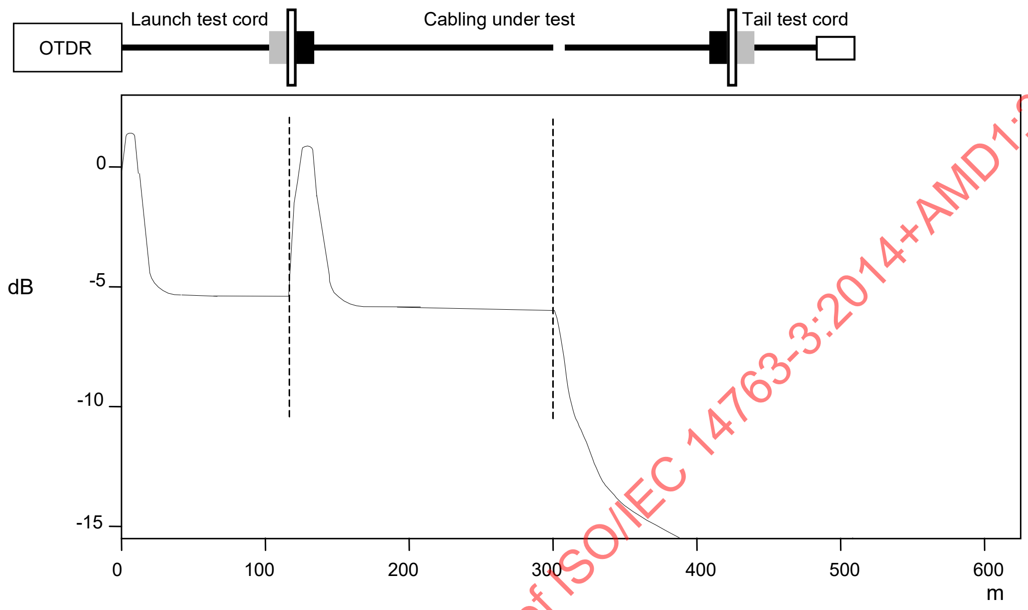


Figure 17 – OTDR characterization of a SMF permanent link containing a break

An installation error (e.g. an installed cable bend radius less than that specified in the relevant product standard or manufacturers/supplier 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 may show as a step change in attenuation on the OTDR trace (see Figure 18).

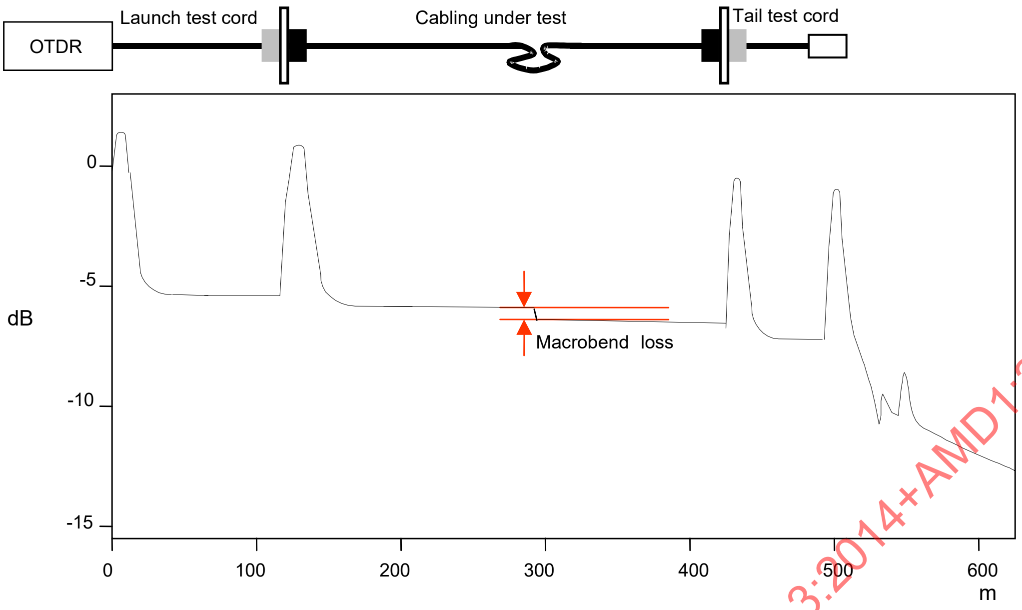


Figure 18 – OTDR characterization of a permanent link containing a macrobend

10.5.2 Measurement uncertainty

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 may differ from the physical length of the cable. Within a given length of cable containing multiple optical fibres each individual optical fibre may 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.

10.5.3 Treatment of results

The limits and restrictions indicated in 10.5.2 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 cable 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 recognised and agreed between the installer and the user.

10.6 Attenuation of cords

10.6.1 Test method

The reference measurement is made between the light source and the power meter by the connection of a launch test cord in accordance with 6.3.3.2 (or 6.3.3.4), as shown in Figure 19.

Launch test cords should be tested at both ends to verify that they meet manufacturer's specifications.

The reference measurement, P_r, shall be recorded in W or dBm.

The cord under test shall be connected between the launch test cord and the power meter and the test measurement, P_1, shall be recorded in W or dBm.

The launch test cord shall remain connected to the light source.

The cord under test shall be connected between the launch test cord and the power meter and the test measurement, P_1, shall be recorded in W or dBm.

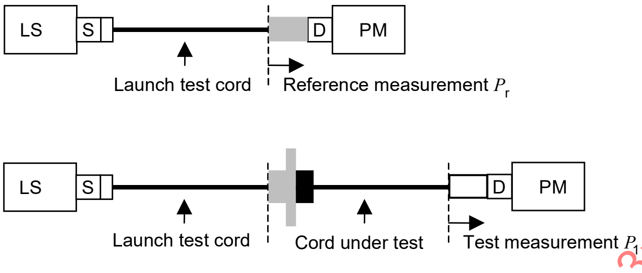


Figure 19 – Measurement of cord interface attenuation

The attenuation measurement method is detailed in IEC 61300-3-4.

10.6.2 Treatment of results

For a given wavelength and in a given direction, the measured loss is calculated using P_r and P_1 as stated in formula (1).

If P_1 and P_r are expressed in watts, then the measured attenuation can be calculated according to formula (2).

The measured result for a connection shall be recorded and may be termed as pass, fail or a marginal result against the limit defined in the relevant IEC product specification in comparison to a reference connector (see Table 4 for SC connecting hardware).

11 Inspection of cabling and cabling components

11.1 Optical fibre continuity

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

11.2 Cabling polarity

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

11.3 Optical fibre cable length

The optical fibre cable length may be obtained from cable sheath markings.

This may not agree with any measurement of optical fibre length carried out using an OTDR or equipment having the functions of an OTDR. The differences may be due to the nature of the cable construction and any error in the determination of the effective group IOR of the optical fibre.

11.4 Inspection of optical fibre end faces

See Annex B.

11.5 Optical fibre core size

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

Annex A
(normative)

Launch modal conditions for testing multimode optical fibre cabling

The launch modal condition at the point of measurement, at the output of launch test cords, shall meet the requirements of IEC 62614 and IEC 61280-4-1. The launch modal condition at the point of measurement, the light emitted by the core of the reference connector may be achieved in several ways.

The correct encircled flux modal condition can be achieved by

a) use of certified equipment which includes a matched test cord and mode conditioner,
b) use of equipment with unknown modal condition but use of a certified modal conditioning device in the launch test cord,
c) 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.

The launch test cord shall include reference grade connectors per IEC 61280-4-1.

The following launch conditions are considered normative:

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

Annex B
(normative)

Visual inspection ~~criteria for connectors~~ and cleaning of optical fibre cabling interface

~~The visual inspection criteria for connectors shall be performed in accordance with IEC 61300-3-35.~~

~~This annex applies the requirements of IEC 61300-3-35 (Clause 4 and Clause 5) to the inspection of endfaces of connectors in accordance with ISO/IEC premises cabling standards and any associated test cords subject to the following variation.~~

~~Singlemode PC optical fibre connecting hardware in accordance with ISO/IEC 11801, ISO/IEC 24764 and ISO/IEC 24702 are required to provide return loss of 35 dB (minimum). IEC 61300-3-35:2009 does not contain inspection requirements which support this return loss specification. Pending the inclusion of these requirements at a later date, the content of Table 5 of IEC 61300-3-35:2009 is applicable.~~

B.1 Specified optical fibre cabling interfaces

The different international cabling standards specify the following optical fibre cabling interfaces:

a) LC connector simplex and duplex connectors both in multimode and single-mode PC and single mode APC configuration and adapters;

b) MPO connectors (male and female) in multimode PC and single-mode APC configuration and adapters.

Since different configurations are possible, Annex B explains the visual inspection criteria and cleaning recommendations for each configuration of the LC and MPO cabling interface.

B.2 The inspection equipment

The inspection equipment that shall be used is specified in IEC 61300-3-35.

All possible connectors in multimode and single-mode fibre configurations specified in structured cabling standards shall be inspected with a low-resolution microscope.

Low resolution means that the microscope shall have a field of view of at least 250 microns. The fibre shall be 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/scratches may be used.

There are different types of microscopes available on the market.

Direct viewing microscopes are in general lower cost. Very important with this type of equipment is that the microscope shall contain a built-in laser safety filter.

The laser filter is to control the energy which is directed into the eye from active sources in the cabling. When direct viewing is used one should ensure that no laser or equipment with lasers is active on the cabling. See IEC 60825-2 for regulations regarding laser safety of optical fibre communication systems.

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.

Low resolution microscopes as specified in IEC 61300-3-35 with automated analysis are available on the market.

All microscope systems show system-to-system variability and a 100 % match between inspection results of multiple microscopes according to 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.

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

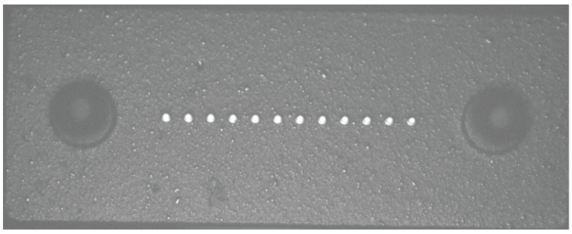


Figure B.1 – Normal illumination of male MPO

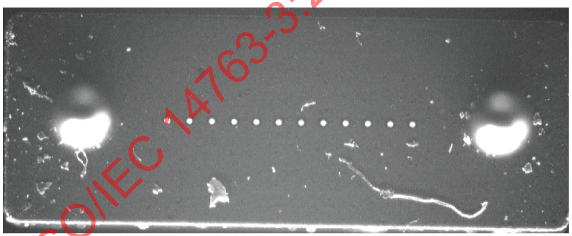


Figure B.2 – Same ferrule with floodlight

B.3 Return loss requirements for cabling interfaces

B.3.1 General

Cabling interfaces have 3 major sets of requirements:

a) multimode 20 dB for cylindrical (LC) and rectangular ferrules (MPO);
b) single-mode 35 dB PC for cylindrical ferrules only (LC);
c) single-mode 60 dB APC for cylindrical (LC) and rectangular ferrules (MPO).

For each of these 3 sets, Annex B shows the requirements, and the cleaning recommendations both as free connector (channel) and connector inside an adapter (link).

B.3.2 Multimode cylindrical and rectangular ferrules (20 dB return loss)

B.3.2.1 General requirements

The following inspection zones and requirements shall be followed when the end faces of multimode connectors are inspected. The inspection shall be carried out in accordance with IEC 61300-3-35.

The contact zones of all connector types shall be inspected for dirt and loose particles, for MPO cabling interfaces the contact zone is the complete ferrule end face. This inspection becomes very easy when microscopes with very low resolution with floodlight are used, see Figure B.1 and Figure B.2. Inspection for dirt shall always be followed by low-resolution inspection of the polished fibres for scratches and defects according to Table B.1. Scratches and defects are counted separately.

The inspection requirements of IEC 61300-3-35 apply. For the convenience of the user, Table B.1 contains the requirements of IEC 61300-3-35:2015 (which is the current standard at the time of publication of this document). At the time of inspection, users of this document shall verify if Table B.1 is in line with the requirements of the then valid IEC 61300-3-35.

Table B.1 – Inspection requirements for cabling interfaces with 20 dB return loss

Zone (diameter)	**Scratches** (maximum number of a given dimension)	**Defects** (maximum number of a given dimension)
A: core 0 µm to 65 µm	No limit ≤ 3 µm None[a] > 3 µm	3 ≤ 5 µm None[a] > 5 µm
B: cladding 65 µm to 115 µm	No limit ≤ 5 µm None[a] > 5 µm	10 ≤ 5 µm None[a] > 5 µm

NOTE 1 Outside the core and cladding zone there are only cleanliness requirements.

The recommended inspection area for cylindrical ferrules is limited to 250 µm diameter. Ten particles of ≤ 5µm diameter are allowed. There are no requirements for the area outside the 250 µm zone. Cleaning loose debris beyond this region is recommended good practice.

For rectangular ferrules, it is recommended to inspect the entire ferrule surface for cleanliness.

Ten particles of ≤ 10 µm diameter are allowed.

NOTE 2 For multiple-fibre rectangular-ferrule connectors, the criteria apply to all fibres in the array.

NOTE 3 The zone size for multimode fibres has been set at 65 µm to accommodate both 50 µm and 62,5 µm core size fibres. This is done to simplify the grading process.

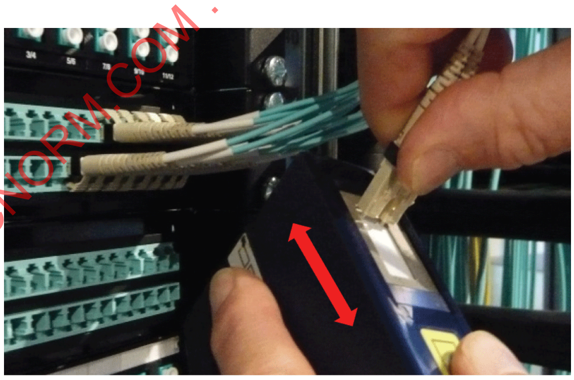
[a] None detected with low resolution microscope capable of detecting 2 µm defects/scratches.

When dirt (loose contamination) is found, the ferrule end face shall be cleaned.

The cleaning methods as described are recommended.

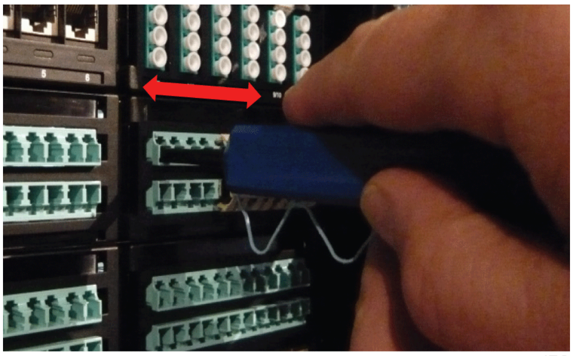
B.3.2.2 Cleaning procedure for LC multimode cabling interface

Figure B.3 and Figure B.4 show the cleaning procedure for LC multimode cabling interface.



IEC

Figure B.3 – Example of multimode LC channel interface



IEC

Figure B.4 – Example of multimode LC link interface

a) Dry cleaning is preferred. In general, two strokes on the tape in the cassette or two push/clicks of the pen cleaner are sufficient to remove the loose contaminant.

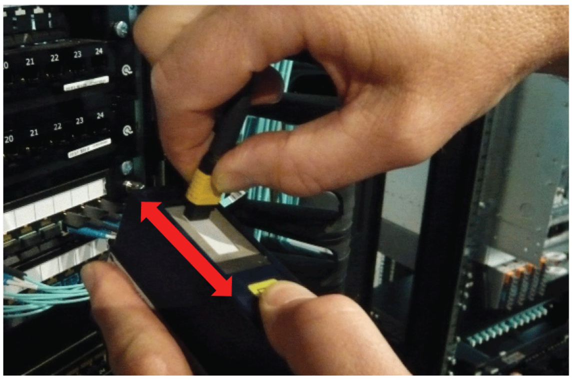
b) When dirt is difficult to remove, use of an appropriate cleaning liquid (quick evaporating) is allowed when it is followed by dry cleaning. Otherwise a residue might be left behind on connector surface.

   Put a drop of cleaning fluid on the tape of the cassette, use two strokes on the wet tape followed by two strokes on the dry tape. This is a recommended cleaning method when simple dry cleaning is not sufficient.

This cleaning procedure is in general the same for all types of cabling interface.

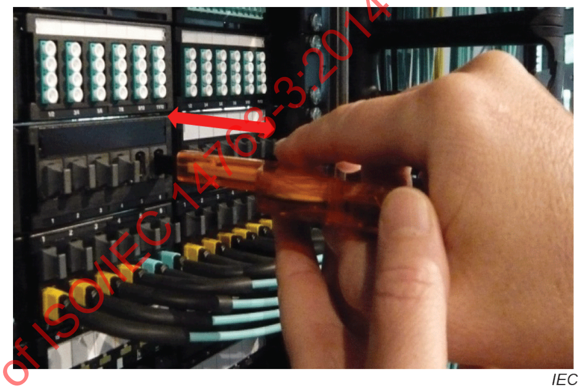
B.3.2.3 Cleaning procedure for MPO cabling interface

Figure B.5 and Figure B.6 show the cleaning procedure for the MPO multimode cabling interface.



IEC

Figure B.5 – Example of MPO channel interface



IEC

Figure B.6 – Example of MPO link interface

Special attention should be given to cleaning of male MPO channel interfaces because the pins prohibit the use of female MPO cassette cleaners. It is recommended to use special MPO male cassettes available on the market which allow cleaning of the fibres between the pins or one should use an MPO generic cleaner that works for male and female connector types.

It is recommended to inspect the entire ferrule surface of the MPO connector for loose contaminants by means of a microscope with very low resolution with floodlight illumination. Due to the ferrule surface structure of the MPO connector it is more difficult to differentiate between loose particles and the ferrule surface. Use of the floodlight illumination solves this as loose contamination appears as white particles on a dark surface (see Figure B.1 and Figure B.2).

NOTE The floodlight illumination inspection is in addition to inspecting core/cladding defects.

B.3.3 Single mode PC cylindrical ferrules (35 dB return loss)

B.3.3.1 General requirements

The following inspection zones and requirements shall be followed when the end faces of multimode connectors are inspected. The inspection shall be carried out in accordance with IEC 61300-3-35.

Inspection for dirt shall always be followed by low-resolution inspection of the polished fibres for scratches and defects according to Table B.1. Scratches and defects are counted separately.

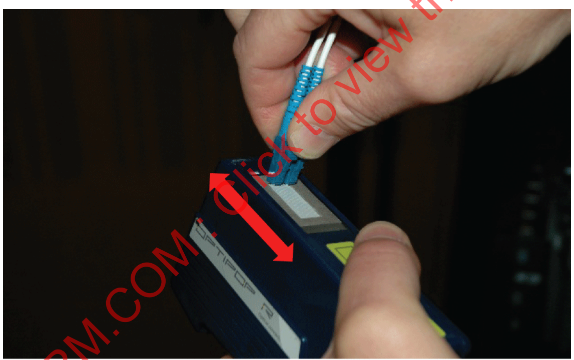
The inspection requirements of IEC 61300-3-35 apply. For the convenience of the user, Table B.2 contains the requirements of IEC 61300-3-35:2015 (which is the current standard at the time of publication of this document). At the time of inspection, users of this document shall verify if Table B.2 is in line with the requirements of the then valid IEC 61300-3-35.

Table B.2 – Inspection requirements for cabling interfaces with 35 dB return loss

Zone (diameter)	**Scratches** (maximum number of given dimension)	**Defects** (maximum number of as given dimension)
A: core 0 µm to 15 µm	1 ≤ 3 µm None[a] > 3 µm	None[a]
B: cladding 15 µm to 115 µm	No limit ≤ 5 µm None[a] > 5 µm	10 ≤ 3 µm None[a] > 3 µm
NOTE Outside the core and cladding zone there are only cleanliness requirements. The recommended inspection area for cylindrical ferrules is limited to 250 µm. Ten particles of ≤ 5 µm diameter are allowed. There are no requirements for the area outside the 250 µm zone. Cleaning loose debris beyond this region is recommended. Ten particles of ≤ 5 µm diameter are allowed.		
[a] None detected with low resolution microscope capable of detecting 2 µm defects/scratches.		

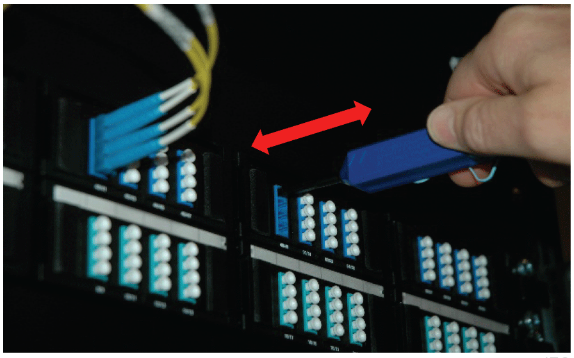
B.3.3.2 Cleaning procedure for the LC single-mode cabling interfaces

Figure B.7 and Figure B.8 show the cleaning procedure for the LC single-mode cabling interface.



IEC

Figure B.7 – Example of single-mode LC channel interface



IEC

Figure B.8 – Example of single-mode LC link interface

The single-mode LC cabling interfaces have the same shape as the multimode LC cabling interfaces. The distinct difference is the colour: blue for the single-mode LC connector housing and beige or aqua for the multimode connector housing.

B.3.4 Single-mode APC cylindrical and rectangular ferrules (60 dB return loss)

B.3.4.1 General requirements

The single-mode angled polished LC and MPO cabling interfaces are used in applications where very high return loss is required. Angled polished connectors are in general used in telecommunication applications or as connection to the telecommunication networks.

The angled polished LC and MPO cabling interfaces have the same shape as the multimode LC cabling interfaces. The distinct difference is the colour: green for the angled polished single-mode LC and MPO connector housing and beige or aqua for the multimode connector housing.

The following inspection zones and requirements shall be followed when the end faces of single-mode angle polished cylindrical connectors are inspected. The inspection shall be carried out in accordance with IEC 61300-3-35.

For ferrules of MPO connectors it is recommended to inspect first the entire ferrule end face for loose particles and dirt and not only the fibre area. This inspection becomes very easy when microscopes with very low resolution with floodlight are used, see Figure B.1 and Figure B.2. Inspection for dirt shall always be followed by low-resolution inspection of the polished fibres for scratches and defects according to Table B.1. Scratches and defects are counted separately.

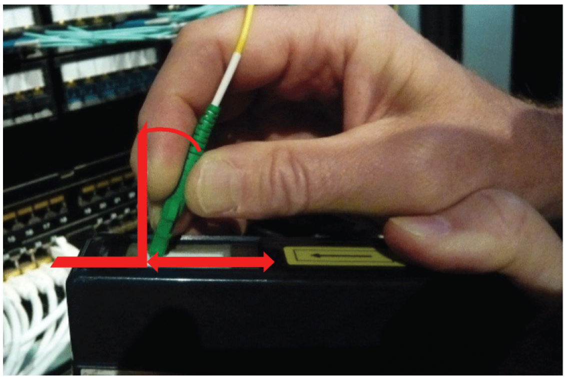
The inspection requirements of IEC 61300-3-35 apply. For the convenience of the user, Table B.3 contains the requirements of IEC 61300-3-35:2015 (which is the current standard at the time of publication of this document). At the time of inspection, users of this document shall verify if Table B.3 is in line with the requirements of the then valid IEC 61300-3-35.

Table B.3 – Inspection requirements for cabling interfaces with 60 dB return loss

Zone (diameter)	**Scratches** (maximum number of a given dimension)	**Defects** (maximum number of a given dimension)
A: core 0 µm to 15 µm	4 ≤ 3 µm	None[a]
B: cladding 15 µm to 115 µm	No limit ≤ 5 µm None[a] > 5 µm	5 ≤ 3 µm 10 > 3 µm
NOTE 1 Outside the core and cladding zone there are only cleanliness requirements. The recommended inspection area for cylindrical ferrules is limited to 250 µm. Ten particles of ≤ 5 µm diameter are allowed. There are no requirements for the area outside the 250 µm zone. Cleaning loose debris beyond this region is recommended. For rectangular ferrules, it is recommended to inspect the entire ferrule surface for cleanliness. Ten particles of ≤ 10 µm are allowed. NOTE 2 For multiple-fibre rectangular-ferrule connectors, the criteria apply to all fibres in the array.		
[a] None detected with low resolution microscope capable of detecting 2 µm defects/scratches.		

B.3.4.2 Cleaning procedure for the LC/APC single-mode cabling interfaces

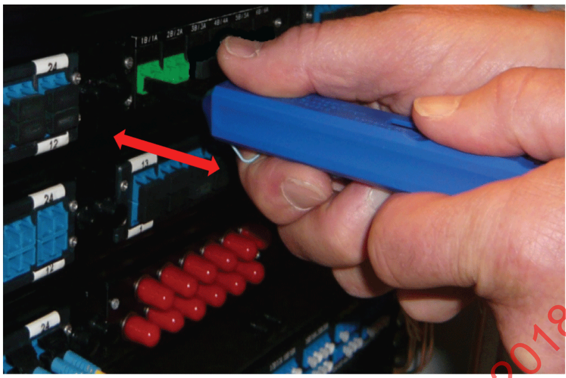
Figure B.9 and Figure B.10 show the cleaning procedure for the LC/APC single-mode cabling interface.



IEC

NOTE The angle of the connector is exaggerated for indicating purposes.

Figure B.9 – Example of single-mode LC/APC channel interface



IEC

Figure B.10 – Example of single-mode LC/APC link interface

Cleaning of the angled LC is slightly more complex than of the LC PC connector because the ferrule front face is under an 8° angle. When the LC/APC channel cabling connector is cleaned, it is recommended to clean a single connector and not a duplex connector which allows a tilt of the connector such that the ferrule surface is in complete planar contact with the cleaning cloth.

For cleaning the LC/APC link cabling interface, neither the plug nor the cleaning probe can be tilted. Repeated push and click operations might be needed for effective cleaning.

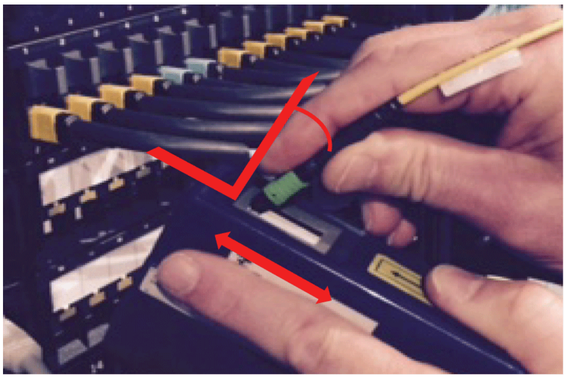
B.3.4.3 Cleaning procedure for single-mode (SM) MPO/APC cabling interface

Special attention should be given to cleaning of male MPO channel interfaces because the pins prohibit the use of female MPO cassette cleaners. It is recommended to use special MPO male cassettes available on the market which allow cleaning of the fibres between the pins or one should use an MPO generic cleaner that works for male and female connector types.

Cleaning of the angled MPO is slightly more complex than of the regular MPO connector because the ferrule front face is under an 8° angle.

It is recommended to inspect the entire ferrule surface of the MPO connector for loose contaminants by means of a microscope with very low resolution with floodlight illumination. Due to the ferrule surface structure of the MPO connector it is more difficult to differentiate between loose particles and the ferrule surface. Use of the floodlight illumination solves this as loose contamination appears as white particles on a dark surface.

Figure B.11 and Figure B.12 show the cleaning procedure for the single-mode MPO/APC cabling interface.



NOTE The angle of the connector is exaggerated for indicating purposes.

Figure B.11 – Example of SM MPO/APC channel interface

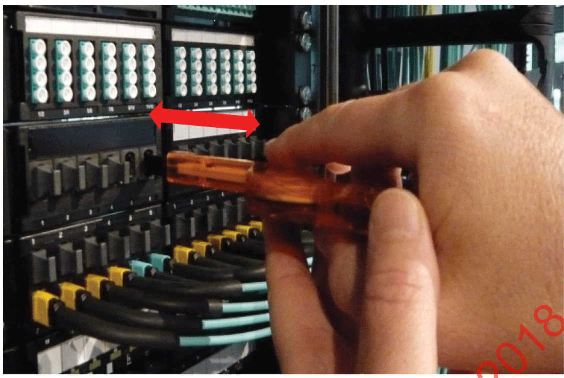


Figure B.12 – Example of SM MPO/APC link interface

Annex C
(informative)

Optical time domain reflectometry

C.1 Operational capability

C.1.1 Effective characterization

The fundamental parameters that define the operational capability of an OTDR are

a) the dynamic range,

b) the averaging duration,

c) the laser pulse width.

These parameters define respectively

1) the capability of an OTDR to display a large attenuation of cabling,

2) the number of fibre links that can be characterised in a given period of time,

3) the minimum distance between two characterised events on the fibre.

NOTE These parameters are inter-related. The minimum configuration will differ for MMF and SMF and from one wavelength to another.

C.1.2 Dynamic range

The dynamic range is the amount of fibre that causes the backscatter signal to equal the noise level.

For a given fibre the dynamic range increases

a) when the laser pulse power increases

b) when the effective pulse width increases,

c) when the noise level decreases (e.g. when the signal averaging increases, when the pulse width increases and when the bandwidth can be reduced).

C.1.3 Pulse width

The pulse width of an OTDR defines, in conjunction with the peak power, the level of energy launched into the fibre. As explained in C.1.2, the larger the pulse, the larger the dynamic range. However, all the reflections (e.g. the input connector, the fibre end and any other connectors) hide the backscattering signal and have at least the same duration as the pulse width. So the pulse width limits the resolution because it is not possible to separate two events within a reflected pulse.

The selection of the pulse width should be the minimum value providing access to the overall link.

C.1.4 Integration or sample count

In order to obtain the best characterization trace it is preferable to use a large number of samples (or integrations) of the reflected light. The higher the integration count, the longer it takes to obtain the trace. There is generally a law of diminishing returns. The selection made should be the minimum value that provides an effective characterization.

C.2 Limitations of OTDR capability

C.2.1 Minimum lengths of operation – Attenuation dead zone

The non-linear end effects caused by the OTDR launching into the launch test cord together with the achievable resolution of the OTDR prevent a sensible assessment of the local interface (or any other event) unless the launch test cord is of a minimum length.

It is recommended that the OTDR be capable of using a short pulse (<20 ns) and have sufficient dynamic range (>20 dB) to achieve a measurement typically in lengths of up to 2 000 m. The OTDR should have an attenuation dead zone less than 10 m following standard connectors (i.e. return loss of 35 dB for multimode connectors and 45 dB for single-mode connectors).

NOTE The attenuation dead zone is typically specified by OTDR suppliers with the shortest available pulse width.

Figure C.1 shows the same permanent link tested using a 3 m (upper diagram) and a 500 m (lower diagram) launch test cord. The local interface cannot be seen in the upper diagram. In the lower diagram the loss through the local interface is clearly shown and the loss of the cable in the launch test cord is linear. This latter factor suggests that an effective characterization of the local interface loss may happen.

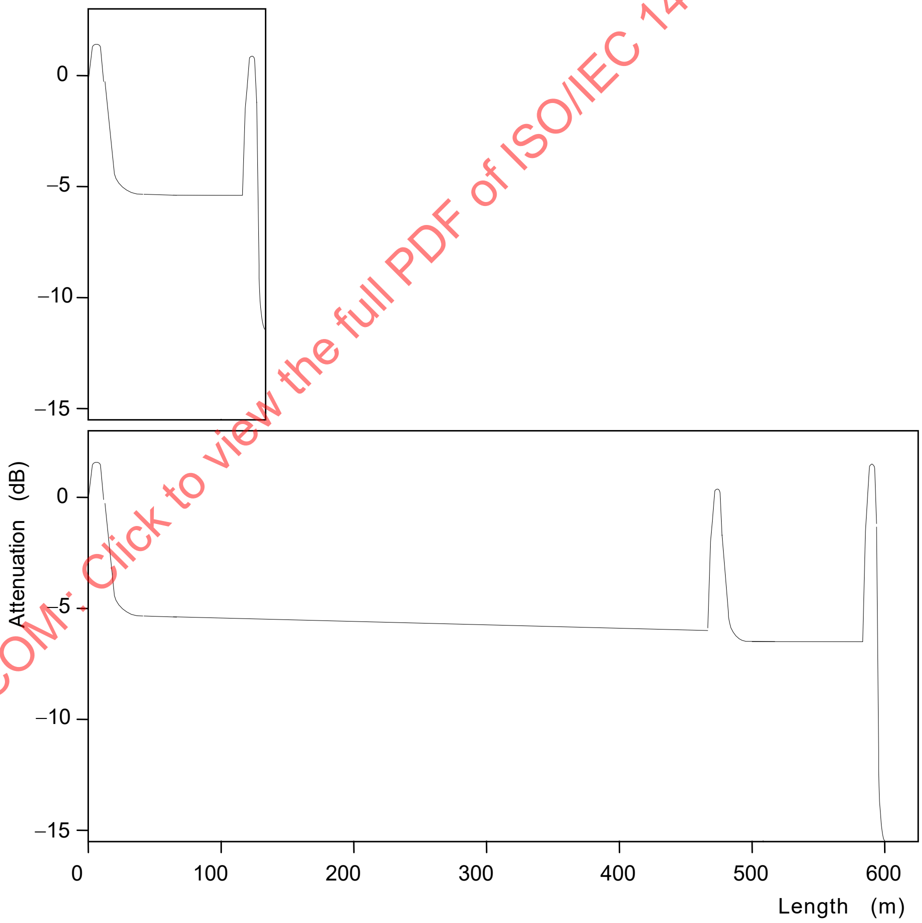


Figure C.1 – OTDR characterization using different length launch test cords

C.2.2 Ghosting

Ghosting, the presence of multiple peaks in the OTDR characterization due to repeated harmonic reflections, is a restricting factor when permanent links containing multiple interfaces are measured. The ghost is produced by a second (or third) harmonic reflection from a given event.

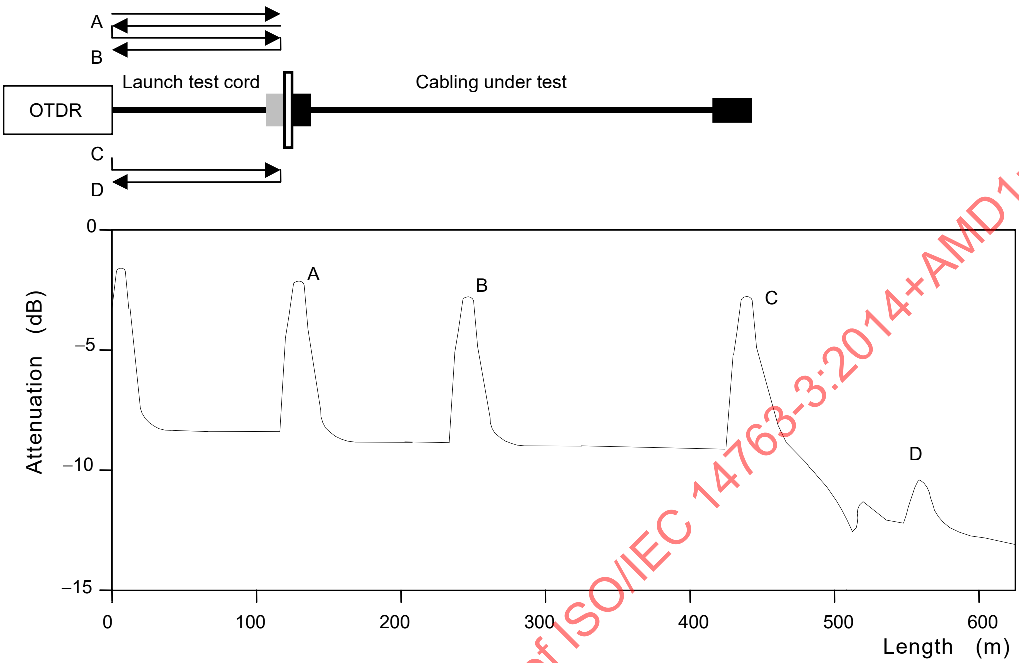


Figure C.2 – OTDR characterization showing ghost effects

A simple example is shown in Figure C.2. The reflective peaks B and D are artefacts produced by multiple reflections. Ghosts appear at pre-determined points (i.e. the distance from the datum to B is twice the distance from the datum to A. The distance from the datum to D is the distance from the datum to C plus the distance from the datum to A). Ghosts do not add or subtract significant optical power from the characterization (which allows them to be easily identified in Figure C.2).

However, if the cabling configuration under test becomes too complex the number of ghosts becomes excessive and the traces become impossible to interpret, even by experts. An example is shown in Figure C.3.

Some OTDR equipment may remove ghosts through the use of a software analysis tool. Another way to remove ghosts is to use launch test cords that are longer than the permanent links to be tested. However, the simplest method to manage ghost effects is to plan ahead and restrict the allowed test configurations.

In general, it is recommended good practise to clean the exit port connector and the launch test cord connector.

NOTE Ghosts are primarily due to open, dirty, contaminated, or damaged connectors and are indicated on an OTDR as a saturated pulse with tailing.

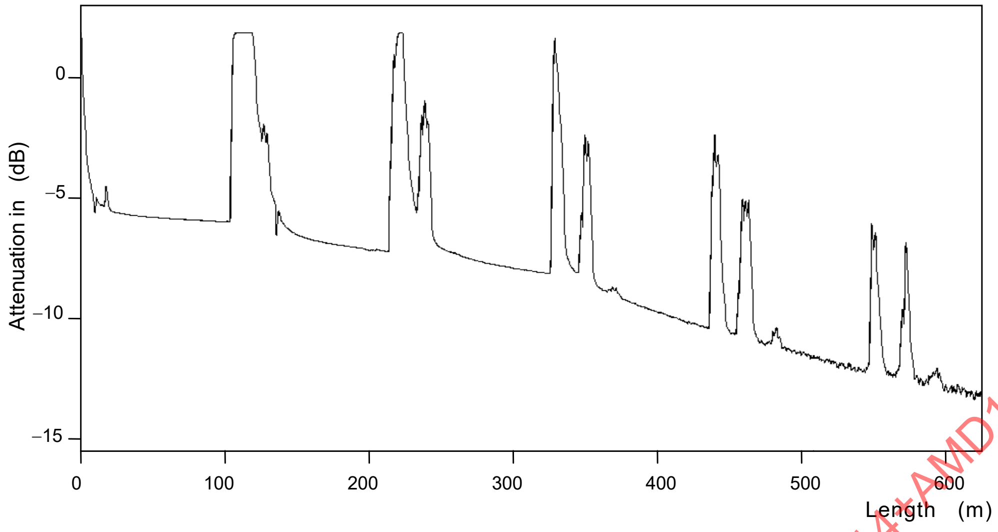


Figure C.3 – OTDR characterization showing complex ghost effects

C.2.3 Effective group index of refraction

The use of the correct effective group index of refraction is important for the accurate measurement of length only. It has no other impact. Where the group IOR is known, it shall be used. Where no information is available the values shown in Table C.1 shall be used.

Table C.1 – Default effective group IOR values

	850 nm	1 300 nm	1 310 nm	1 550 nm
SMF	–	–	1,467	1,468
MMF (50/125) µm	1,490	1,486	–	–
MMF (62,5/125) µm	1,496	1,491	–	–

C.2.4 Backscattering coefficient

The use of the correct backscattering coefficient (as stated in IEC 61300-3-6) is important for the accurate measurement of return loss. Where the backscattering coefficient is not automatically measured and used by the OTDR the values shown in Table C.2 may be considered typical.

Table C.2 – Default backscattering coefficient values

	850 nm	1 300 nm	1 310 nm	1 550 nm
SMF	–	–	80 dB	82 dB
MMF (50/125) µm	66 dB	72 dB	–	–
MMF (62,5/125) µm	67 dB	74 dB	–	–

Annex D
(normative)

Inspection and testing of launch test cords, tail test cords and substitution test cords

D.1 General requirements

A launch test cord, substitution test cord or tail test cord is functioning properly provided that

a) the connector end faces meet the inspection requirement of Annex B,

b) the reference connector(s) at the end of the cord perform(s) according to specification,

c) the cordage performs according to its specification.

Prior to start of the attenuation measurement the performance of the reference cords shall be verified in agreement with Annex D.

D.2 Attenuation (test and substitution test cord reference connections)

For MMF, the reference measurement process requires a reference measurement, as shown in Figure D.1, to be made between the light source and power meter by the connection of a launch test cord in accordance with a LSPM launch test cord in accordance with 6.3.3.2 (or 6.3.3.4).

For SMF, the reference measurement process requires a reference measurement, as shown in Figure D.1, to be made between the light source and power meter by the connection of a launch test cord in accordance with 6.3.3.2 (or 6.3.3.4).

Reference power measurements shall be repeated periodically, as necessary. Situations requiring the re-establishment of reference conditions include optical power changes, temperature fluctuations, a move to a different location, powering off and substitution test cord or adapter replacement due to degradation. Sufficient time should be given for stabilization of laser sources during any repeated reference power measurement.

The reference measurement, P_r, shall be recorded in W or dBm.

The launch test cord shall remain connected to the light source. The reference connector on the substitution, tail or other launch test cord under test shall be connected between the launch test cord and the power meter and the test measurement, P_1, shall be recorded in W or dBm.

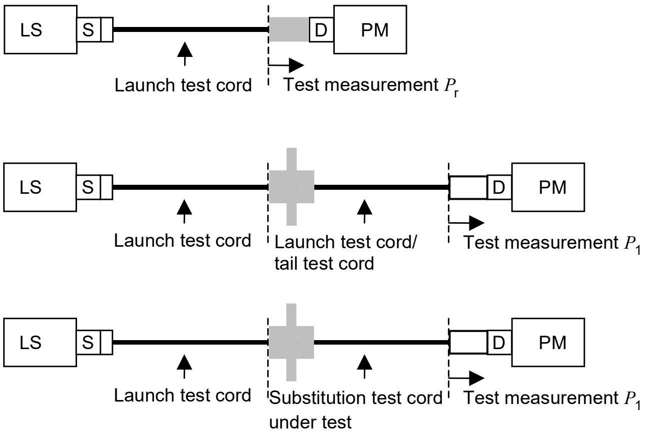


Figure D.1 – Measurement of launch test cord, tail test cord and substitution test cord interface attenuation

For a given nominal wavelength, the measured attenuation is calculated using P_r and P_1 as according to formulae (1) or (2), respectively.

The calculated result shall be recorded and shall be indicated as pass or fail with respect to the limits defined in 6.3.2 and Table 3.

Annex E
(informative)

Enhanced three-test-cord and one-test-cord reference methods for link and channel attenuation

E.1 Reference methods for link attenuation

This annex provides guidelines and selection information for the use of the one-test-cord and the enhanced three-test-cord reference measurement methods for the measurement of attenuation of optical fibre cabling links as stated in ISO/IEC 11801-1. The enhanced three-test-cord reference method is to be used for measuring the attenuation ~~of channels as well as for measuring the attenuation~~ of permanent links. The one-test-cord reference method can be used only for measuring the attenuation of permanent links.

Even in those cases where there are different connector interfaces on each end of the installed permanent link, use of the enhanced three-test-cord reference method enables the attenuation measurement by choosing the same connectors used on the substitution test cord. Care should be taken to ensure that the connectors on the substitution test cord are of reference quality.

The test limits for the attenuation measurement of links and the expected measurement uncertainty are the same for both the one-test-cord reference and the enhanced three-test-cord reference methods.

E.2 One-test-cord ~~reference~~ method ~~for~~ link attenuation

E.2.1 General

The ~~one-test-cord reference~~ one-cord test method may only be applied in the following specific circumstances:

a) the interface to the cabling under test is the same as the interface on the power meter; and

b) where the cabling under test has simplex interfaces (or interfaces that can be tested as such).

E.2.2 Test method

Inspect and clean when necessary the connector interfaces of the source and the launch test cord.

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

b) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM). (See Figure E.1.)

c) Never disconnect the launch test cord connector from the light source.

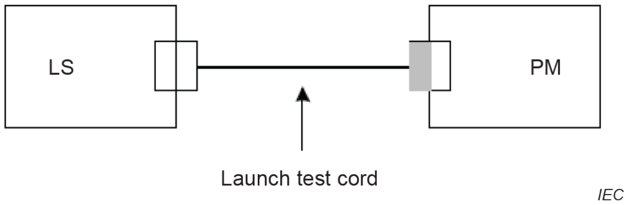


Figure E.1 – Connection of LS – LTC – PM for reference setting

d) Set the reference to 0,0 dB or record the reference measurement (P_r) in dBm or watts.

e) Connect the launch test cord to the near end of the link. Connect the tail test cord (TTC) to the far end of the link. (See Figure E.2.)

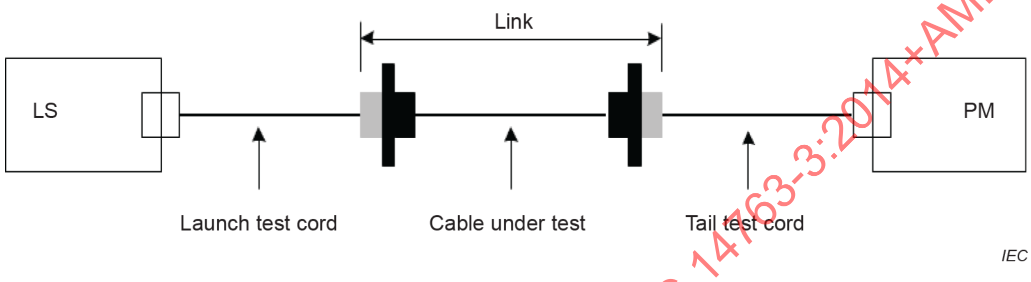


Figure E.2 – Connections to link for attenuation measurement

f) Measure and record the attenuation (P_1) of the link under test in dB.

For this method, the measurement uncertainties at 95 % confidence level are as follows.

SMF: ± 0,24 dB for fibre length < 2 km.

MMF: ± 0,27 dB when measured attenuation ≤ 1,9 dB.

MMF: ± 0,14 × measured attenuation when measured attenuation > 1,9 dB.

NOTE Measurement uncertainties are determined using IEC TR 61282-14 and representative system data. See IEC TR 61282-14 for more details.

E.3 ~~Test method for channel attenuation~~ Enhanced three-test-cord reference method for link attenuation

~~According to ISO/IEC 11801, a channel does not include the connector on the equipment cords that interfaces with the network equipment. The optical attention 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.~~

E.3.1 General

The enhanced three-test-cord reference method to test a link may be used when the connectors on each end of the link are different from each other and if a verification of the reference connections is needed.

E.3.2 Test method

Inspect and clean when necessary the connector interfaces of the source and the launch test cord.

a) Allow sufficient time for light source stabilization in accordance with recommendations from the manufacturer of the light source.

b) Connect the launch test cord (LTC) to the light source (LS) and to the power meter (PM). (See Figure E.3.)

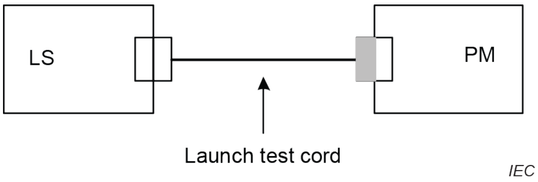


Figure E.3 – Connection of LS – LTC – PM for reference setting

c) Set the reference to 0,0 dB or record the reference measurement (P_r) in dBm or watts.

d) Connect the launch test cord to the substitution test cord (STC) and connect the tail test cord (TTC) to the STC using reference adapters. (See Figure E.4.) This arrangement is used for verification of both reference connections and not as a reference measurement.

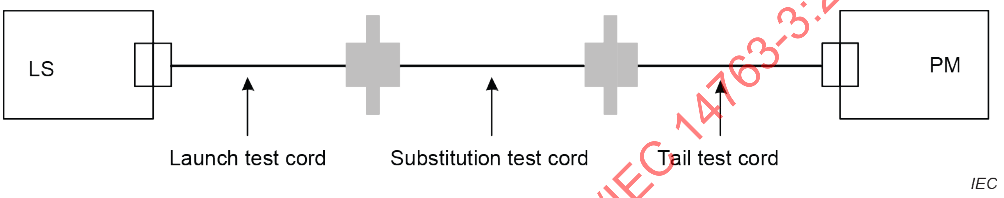


Figure E.4 – Connection of LTC – STC – TTC for enhanced three-test-cord verification

e) Measure and record the attenuation of the LTC-STC-TTC combination in dB.

The maximum permitted attenuation for verification shall be the value of two concatenated sets of reference connections (0,2 dB multimode and 0,4 dB single-mode).

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 alternate test cords if necessary. If the maximum permitted attenuation is not achievable, a standards compliant permanent link measurement cannot be made.

f) Remove the substitution test cord and reference adapters. Connect the launch test cord to the near end of the link. Connect the tail test cord to the far end of the link. (See Figure E.5.)

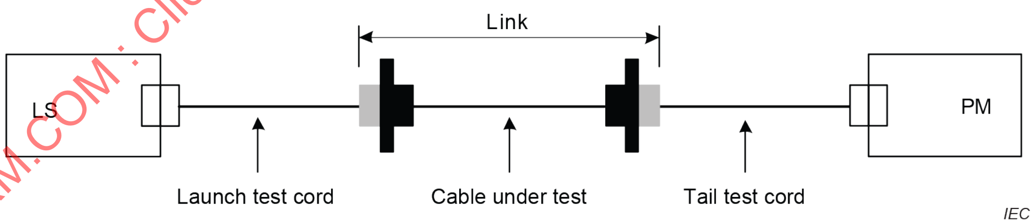


Figure E.5 – Connections to link for attenuation measurement

g) Measure and record the attenuation (P_1) of the link under test in dB.

For this method, the measurement uncertainties at 95 % confidence level are as follows.

SMF: ± 0,24 dB for fibre length < 2 km.

MMF: ± 0,27 dB when measured attenuation ≤ 1,9 dB.

MMF: ± 0,14 × measured attenuation when measured attenuation > 1,9 dB.

NOTE Measurement uncertainties are determined using IEC TR 61282-14 and representative system data. See IEC TR 61282-14 for more details.

Annex F
(informative)

Quality planning

F.1 Inspection and test schedules

This standard defines two test stages:

a) stage 1, tests applied to cabling components prior to installation of permanent links;

b) stage 2, tests applied to installed channels and permanent links.

Stage 2 tests are grouped into

1) basic tests,

2) extended tests.

The tests included in the basic test group are sufficient to determine the conformance of channels and permanent links with the requirements of the ISO/IEC 11801-1 and equivalent standards. The measurements can be performed using light source and power meter equipment.

Where measured results do not comply with the applicable limits, it is recommended that the channel or permanent link be subjected to investigation using the extended test group to identify the non-compliant component(s).

The tests in the extended test group supplement those of the basic test group with component-based measurements made possible by the use of an OTDR. Such a measurement may be used where a graphical representation of localised events is required (for troubleshooting/poor installation) or where graphical records are required for documentation and administration purposes.

F.2 Stage 1 inspection and testing

The following tests may be included in a stage 1 test schedule:

a) optical fibre attenuation in accordance with 10.1;

b) optical fibre length (and/or propagation delay) in accordance with 10.5.

The following may be inspected within a stage 1 inspection schedule:

c) optical fibre cable length in accordance with 11.3;

d) continuity in accordance with 11.1.

F.3 Stage 2 testing

F.3.1 Basic test group

Tests included in the basic test group are

a) channel or permanent link attenuation in accordance with 9.1.1,

b) channel or permanent link propagation delay in accordance with 9.2,

c) channel or permanent link length in accordance with 9.3,

d) continuity in accordance with 11.1,

e) maintenance of polarity in accordance with 11.2,

f) visual inspection of polished end faces for dirt in accordance with Annex B.

If the LSPM equipment is unable to measure propagation delay then channel or permanent link length may be added to the inspection criteria.

F.3.2 Extended test group

Tests included in the extended test group are

a) channel or permanent link attenuation in accordance with 9.1.2,

b) channel or permanent link propagation delay in accordance with 9.2,

c) optical fibre length in accordance with 10.5,

d) optical fibre attenuation in accordance with 10.1,

e) local and remote interface attenuation in accordance with 10.2,

f) local and remote interface return loss in accordance with 10.4,

g) embedded connecting hardware attenuation in accordance with 10.3,

h) embedded connecting hardware return loss in accordance with 10.4,

i) continuity in accordance with 11.1,

j) maintenance of polarity in accordance with 11.2.

Annex G
(informative)

Examples of calculations of channel and permanent link limits

G.1 Channel measurement

The following examples are based on Table 4.

Example 1

Consider a cabling channel comprising:

– cabled optical fibre conforming to OM4 of ISO/IEC 11801-1;
– a total length including equipment cords of 100 m;
– two panel connections in accordance with ISO/IEC 11801-1;
– equipment cords terminated with connectors in accordance with ISO/IEC 11801-1.

The channel limit at 850 nm would be: (0,1 × 3,5) + (2 × 0,75 dB) = 1,85 dB

The channel limit at 1 300 nm would be: (0,1 × 1,5) + (2 × 0,75 dB) = 1,65 dB

Example 2

Consider a cabling channel comprising:

– cabled optical fibre conforming to OS1 of ISO/IEC 11801-1;
– a total length including equipment cords of 500 m;
– two panel connections in accordance with ISO/IEC 11801-1;
– two optical fibre splices in accordance with ISO/IEC 11801-1;
– equipment cords terminated with connectors in accordance with ISO/IEC 11801-1.

The channel limit at 1 310 nm would be: (0,5 × 1,0) + (2 × 0,75) + (2 × 0,3) dB = 2,6 dB

The channel limit at 1 550 nm would be: (0,5 × 1,0) + (2 × 0,75) + (2 × 0,3) dB = 2,6 dB

G.2 Permanent link measurement

The following examples are based on Table 4.

Example 1

Consider a permanent link comprising

– cabled optical fibre conforming to OM3 of ISO/IEC 11801-1,
– a total length of 100 m,
– two panel connections in accordance with ISO/IEC 11801-1.

Using the one test cord reference method the limit would be as follows:

– at 850 nm:(2 × 0,5 + 0,1 × 3,5) dB = 1,35 dB;
– at 1 300 nm: (2 × 0,5 + 0,1 × 1,5) dB = 1,15 dB.

Example 2

Consider a permanent link comprising

– cabled optical fibre conforming to OS1 of ISO/IEC 11801-1,
– a total length of 500 m,
– two panel connections in accordance with ISO/IEC 11801-1,
– two optical fibre splices in accordance with ISO/IEC 11801-1.

Using the enhanced three-test-cord or one-test-cord reference method the limit would be as follows:

– at 1 310 nm: (2 × 0,65) + (0,5 × 1,0) + (2 × 0,3) dB = 2,4 dB;
– at 1 550 nm: (2 × 0,65) + (0,5 × 1,0) + (2 × 0,3) dB = 2,4 dB.

~~Annex H~~
~~(informative)~~

~~Cleaning and inspection of fibre optic connections~~

~~Cleaning and inspection of fibre optic connections shall be done in accordance with IEC/TR 62627-01:2010, Clauses 3 to 5 with the following addition:~~

- ~~a low resolution microscope shall be used for the inspection of plugs and adapters;~~
- ~~this applies to test equipment and test cords as well as network components.~~

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2 Withdrawn.

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3 Under consideration.

ISO/IEC 14763-3

Edition 2.1 2018-08

FINAL VERSION

colour inside

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

ISO/IEC 14763-3:2014-06+AMD1:2018-08 CSV(en)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INFORMATION TECHNOLOGY – IMPLEMENTATION AND OPERATION OF CUSTOMER PREMISES CABLING –

Part 3: Testing of optical fibre cabling

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DISCLAIMER
This Consolidated version is not an official IEC Standard and has been prepared for user convenience. Only the current versions of the standard and its amendment(s) are to be considered the official documents.

This Consolidated version of ISO/IEC 14763-3 bears the edition number 2.1. It consists of the second edition (2014-06) and its corrigendum (2015-03), and its amendment 1 (2018-08). The technical content is identical to the base edition and its amendment.

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

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

This edition constitutes a technical revision.

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

– general requirements (Clause 5) have been revised and the concept of normalization has been replaced by reference measurements;
– OTDR characterization (6.2) and requirements for cabling interface adapters (6.3) and test cords have been revised and requirements for single-mode fibre test cords (6.3.4) have been removed;
– enhanced three-test-cord reference method has been introduced (9.1.1.2);
– requirements for the attenuation measurement of cords (10.6) have been revised;
– Annex A "Launched modal distribution (LMD)" has been simplified and the new title now reads "Launched modal conditions for testing multimode optical fibre cabling";
– visual inspection criteria for connectors have been reworked (Annex B);
– information on optical time domain reflectometry (Annex C) has been revised;
– examples of calculations of channel and permanent link limits (Annex G) have been revised;
– and information regarding cleaning and inspection of fibre optic connections have been added (Annex H).

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 publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

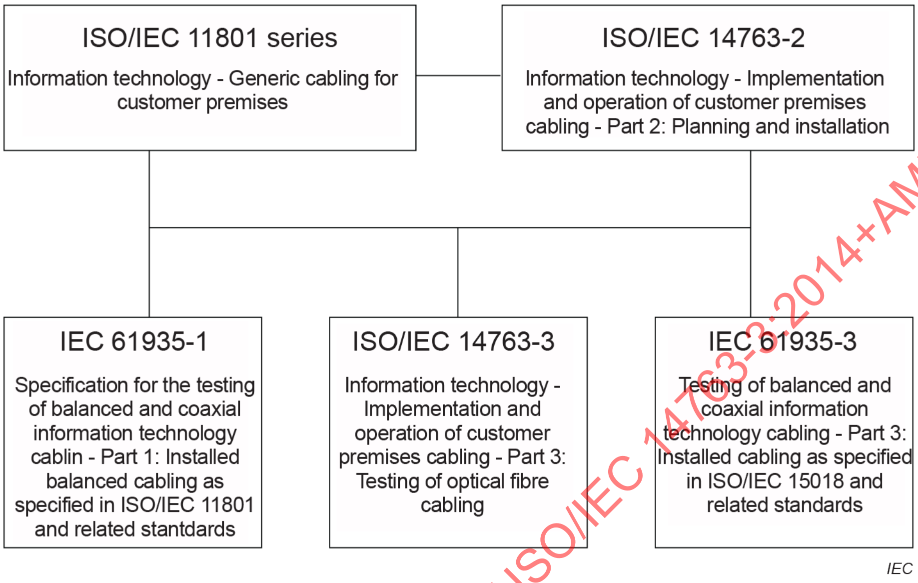
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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 International Standard has been prepared in support of International Standard series ISO/IEC 11801.

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



NOTE ISO/IEC 15018 has been replaced by ISO/IEC 11801-4.

Figure 1 – Relationship of related International Standards

ISO/IEC 14763-3 details the inspection and test procedures for optical fibre cabling,

a) designed in accordance with premises cabling standards including the ISO/IEC 11801 series, and

b) installed according to the requirements and recommendations of ISO/IEC 14763-2.

Users of this International Standard 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 described in ISO/IEC 14763-2.

NOTE JTC 1/SC 25, in cooperation with IEC/TC 86, is currently developing an overall quantitative model to calculate total measurement uncertainty as stated in the reference planes of ISO/IEC 11801-1. When such a model has been verified, it is expected to be incorporated into this standard in form of an Amendment, thereby removing pertinent clauses currently marked “ffs” (for further study).

INTRODUCTION to the amendment

This document contains information for inspecting end faces of the different kinds of installed fibre optic cabling interfaces and connectors of test cords and recommendations for cleaning these interfaces, and replaces the normative Annex B and deletes the informative Annex H of ISO/IEC 14763-3:2014.

Additional information regarding channel and link testing is provided to Annex E.

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, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 – Chapter 731: Optical fibre communication*

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

IEC 60874-14-3, *Connectors for optical fibres and cables – Part 14-3: Detail specification for fibre optic adapter (simplex) type SC for single-mode fibre*

IEC 60874-19-1, *Fibre optic interconnecting devices and passive components – Connectors for optical fibres and cables – Part 19-1: Fibre optic patch cord connector type SC-PC (floating duplex) standard terminated on multimode fibre type A1a, A1b – Detail specification*

IEC 61280-1-3, *Fibre optic communication subsystem test procedures – Part 1-3: General communication subsystems – Central Wavelength and spectral width measurement*

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 cable plant – Multimode attenuation measurement*

IEC 61280-4-2, *Fibre optic communication subsystem basic test procedures – Part 4-2: Fibre optic cable plant – Single-mode fibre optic cable plant attenuation*

IEC 61300-3-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation*

IEC 61300-3-6, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*

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 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 62614, *Fibre optics – Launch condition requirements for measuring multimode attenuation*

IEC 62664-1-1, *Fibre optic interconnecting devices and passive components – Fibre optic connector product specifications – Part 1-1: LC-PC duplex multimode connectors terminated on IEC 60793-2-10 category A1a fibre*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
adapter
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 $A = 10\ \lg(P_{out}/P_{in})$, 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
<for a reflective or non-reflective event> region 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
cable sheath
covering over the optical fibre or conductor assembly that may include one or more metallic members, strength members or jackets

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

3.1.5
3.1.5.1
connection
mated device including terminations connecting two cables or cable elements

3.1.5.2
connection
combination of devices including terminations connecting two cables or cable elements

3.1.6
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

3.1.7
event dead zone
distance in which an OTDR cannot detect a reflective event following a reflective event

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

Note 1 to entry: The fail result is for further study (ffs).

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

Note 1 to entry: The marginal result is for further study (ffs).

3.1.12
multimode optical 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 about 100 modes or more.

[SOURCE: IEC 60050-731:1991, 731-02-03, modified – definition slightly changed and note added.]

3.1.13
optical fibre
filament shaped optical waveguide made of dielectric materials

[SOURCE: IEC 60050-731:1991, 731-02-01]

3.1.14
optical time domain reflectometer
instrument used to characterise optical fibre cabling by measuring the backscatter and reflection of injected light pulses as a function of time

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

Note 1 to entry: The pass result is for further study (ffs).

3.1.16
reference adapter
adapter that ensures that the performance of reference connections can be attained

Note 1 to entry: This definition is only applicable to connectors with cylindrical ferrules.

3.1.17
reference connector
connector with tightened tolerances terminated onto an optical fibre that may 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

3.1.18
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

3.1.19
singlemode optical fibre
optical fibre which supports only one mode of light transmission

3.1.20
substitution test cord
test cord used within a reference measurement which is replaced during the measurement of the attenuation of the cabling under test

3.1.21
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

3.1.22
test cord
cable assembly used either to connect test equipment to the cabling under test or as part of a test reference measurement

3.1.23
test operator
skilled person testing in accordance with instructions provided by the test system designer

3.1.24
test system
test equipment, test cords and adapters necessary to undertake a given test in accordance with the requirements of this standard

3.1.25
defect
surface feature such as pits, chips and loose debris

3.1.26
loose debris
particles and debris on the surface that can be removed by cleaning

3.1.27
pit
permanent non-linear surface damage

3.1.28
scratch
permanent linear surface damage

3.2 Abbreviations

For the purposes of this document, the abbreviations of ISO/IEC 11801-1 as well as the following apply.

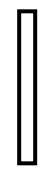
APC	Angled Physical Contact
CP	Consolidation Point
DUT	Device Under Test
EQP	Equipment
ffs	for further study
IOR	Index Of Refraction
LC	LC connector
LTC	Launch Test Cord
LS	Light Source
LSA	Least Squares Average
LSPM	Light Source And Power Meter
MMF	MultiMode optical Fibre
MPO	Multi-fibre Push On connector (based on rectangular ferrule)
N/A	Not Applicable
OTDR	Optical Time Domain Reflectometer
PC	Physical Contact
PM	Power Meter
RL	Return Loss
SC	Subscriber Connector
SMF	Single-Mode optical 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 adapter (general)
	Optical fibre adapter imbedded in cabling
	Optical fibre reference adapter
	Splice

4 Conformance

To test installed cabling according to this International Standard

a) the general requirements of Clauses 5 and 8 shall be met,

b) the test equipment and test cords shall conform to the requirements of Clause 6,

c) the test method, as appropriate, and treatment of results shall conform to Clauses 9 and 10,

d) the test results shall be documented in accordance with 5.4,

e) the requirements of IEC 60825-2 concerning safety of laser products shall be met.

To inspect installed cabling according to this standard

1) the inspection equipment shall conform to the requirements of Clause 7,

2) the inspection method, as appropriate, shall conform to Clause 11,

3) the requirements of IEC 60825-2 concerning safety of laser products shall be met.

Relevant national and local regulations covering safe working practices shall be observed.

5 General requirements

5.1 Test system

The test systems defined in this standard comprise local test equipment and remote test equipment (where required) together with test cords and adapters which enable the connection of the test equipment to the cabling under test (see Figure 2).

Certain test methods of this standard may apply to the testing of plastic optical fibre cabling (i.e. attenuation) although no detailed information is provided. Plastic optical fibre category A4 fibres are specified in IEC 60793-2-40.

The test system and, particularly the adapters and reference connectors, affect the uncertainty of the attenuation measurement for a given component, link or channel.

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

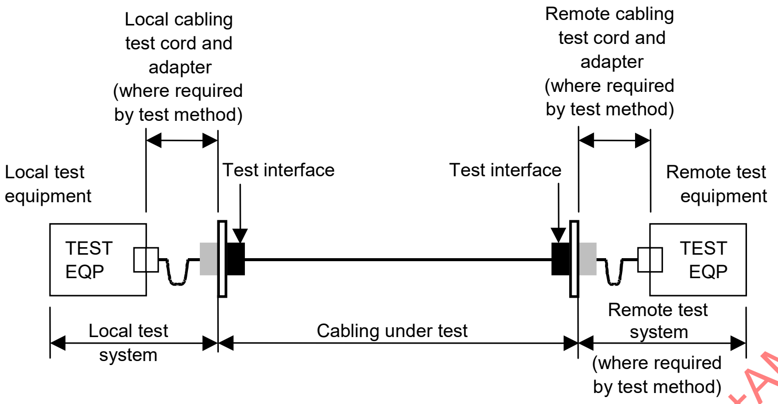


Figure 2 – Test system and the cabling under test

5.2 Reference measurement and calibration

Reference measurement processes are specified, where appropriate, to enable the test system to achieve the stated measurement uncertainty.

The test equipment shall be calibrated using standardised procedures (e.g. IEC 61315 and IEC 61746), or tester manufacturers' 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.

5.3 Environmental conditions

5.3.1 Protection of transmission and terminal equipment

Transmission and terminal equipment shall be disconnected from the cabling under test before any testing or inspection according to this standard is carried out.

5.3.2 Inspecting and cleaning connectors

Dust, dirt and other contaminants at the interfaces to the cabling under test or at interfaces of the test cords and at the interface to the test equipment may produce misleading results and in some cases damage the cabling under test.

Connector end faces on the test cords shall be inspected in accordance with Annex B. If they are dirty or contaminated they should be cleaned following the recommendations of Annex H and re-inspected. If the connectors on the test cords are damaged and/or fail to meet the requirements of Annex B, the test cords shall be replaced.

Connector end faces on the cabling under test shall be inspected in accordance with Annex B. If they are dirty or contaminated they should be cleaned following the recommendations of Annex H and re-inspected in accordance with Annex B. If the connectors on the cabling under test are damaged and/or fail to meet the requirements of Annex B, then the failure shall be reported with the recommendation that the connector be replaced.

5.3.3 Use of test equipment

External effects (for example, environmental, electromagnetic or physical) can affect the test equipment and thereby influence the measured results. Test equipment shall be operated per manufacturer's specifications. Unless manufacturer specifications provide other information, test equipment shall be allowed to stabilise at the test environment for at least 15 min prior to readings being taken.

5.3.4 Relevance of measurement

Measurements shall either

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

5.3.5 Treatment of marginal test results

Marginal results may be treated in a number of ways including

a) verification of the reference measurement of the test system,
b) acceptance of all marginal results,
c) repetition of the measurement using a test system with improved measurement uncertainty.

5.4 Documentation

The documentation for each parameter shall include

a) identification and details of the parameter,
b) whether channel or permanent link is being tested,
c) test equipment:
   1) type and manufacturer;
   2) serial number and calibration status;
   3) nominal wavelength,
d) optical fibre cabling details (category of cabled optical fibre performance e.g. OM2, OM3, OM4, OS1, OS2)
e) details of the cabling connector type(s),
f) the configuration of the cabling test equipment during the test,
g) the measured result,
h) the applicable requirements,
i) details of the reference numbers and direction of test,
j) the date of the test (the time may also be recorded),
k) the test operator,
l) the calculated measurement uncertainty of the test system (ffs).

6 Test equipment

6.1 Light source and power meter

6.1.1 General

Derived from IEC 61280-4-1, IEC 61280-4-2 and IEC 61300-3-4, the following has been adapted to the requirements of ISO/IEC 11801-1 for link and channel attenuation (this is sometimes called insertion loss) measurements with an LSPM.

6.1.2 Light sources

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

Light sources for testing multi-mode optical fibre (MMF) cabling and components shall conform to the spectral characteristics of Table 1 when measured in accordance with IEC 61280-1-3.

Table 1 – MMF light source characteristics

Centre wavelength nm
850 ± 30
1 300 ± 30

Light sources for testing single-mode optical fibre (SMF) shall conform to the spectral characteristics of Table 2 when measured in accordance with IEC 61280-1-3.

Table 2 – SMF light source characteristics

Centre wavelength nm
1 310 ± 30
1 550 ± 30

6.1.3 Power meters

The equipment 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)

When the test set-up (LSPM) is used for a link or channel attenuation, the measurement uncertainty shall not be greater than ±0,2 dB (ffs).

When the test set-up (LSPM) is used for a field check of the reference connectors by measuring the attenuation, the measurement uncertainty should be <0,2 dB (ffs).

If the power meter consists of an optoelectronic detector with a demountable adapter then the adapter shall be fitted to the meter in accordance with the instructions provided by the supplier of the power meter.

6.1.4 Test system stability (ffs)

The light source shall be stable to ±0,1 dB

NOTE Non-linearity between the measured and incident optical power may cause measurement errors. Also, equipment with internal waveguides may exhibit measurement variability with varying modal conditions.

6.2 OTDR

6.2.1 General

OTDR equipment for testing multimode optical fibre (MMF) cabling and components shall conform to the central wavelengths of Table 1.

OTDR equipment for testing single-mode optical fibre (SMF) shall conform to the central wavelengths of Table 2.

OTDR characterization shall be undertaken using a launch test cord and a tail test cord.

See Annex C for further information on optical fibre time domain reflectometry.

6.2.2 OTDR characterization using a launch test cord and a tail test cord

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

a) produces an unidirectional characterization of the form shown in Figure 3,

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 installed cable and any embedded connecting hardware,

d) provides a quantitative measurement of the local and remote interfaces to the cabling under test using measurements taken in each direction,

e) provides a quantitative measurement of the channel or link (see Clause 8) attenuation when the measurement is taken in one direction provided that

   – the channel or link only contains a single fixed cable and terminating connectors,

   – the scattering 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 8) 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 C.2.1).

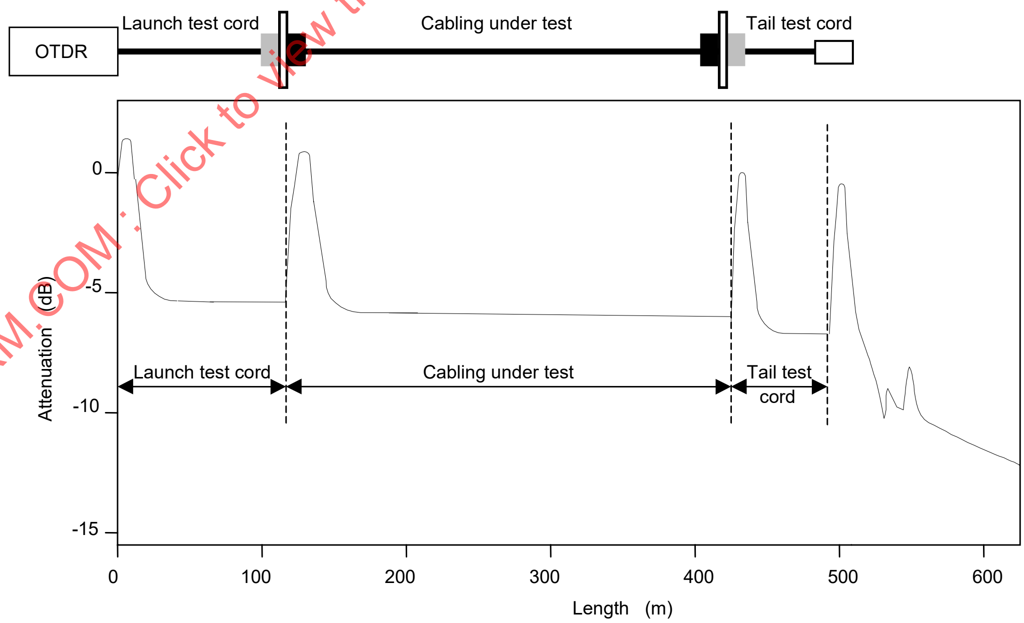


Figure 3 – OTDR characterization using a launch test cord and a tail test cord

6.3 Test cords and adapters

6.3.1 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 adapters used as part of the test methods specified by this standard:

a) should have the same or better performance specification as the hardware terminating the cabling under test;
b) should have a controlled end face for radius, dome offset and fibre position
   – for the duplex LC connector for MMF as specified in IEC 62664-1-1,
   – for the simplex LC connector for SMF as will be specified in IEC 62664-1-2[1],
   – for the duplex SC connector for MMF as specified in IEC 60874-19-1,
   – for the simplex SC connector for SMF as specified in IEC 60874-14-3;
c) should be of the same product as defined by the supplier where IEC specifications do not guarantee interoperability (the only interfaces specified to be interoperable are within the IEC 62664 series on LC connector product specifications);
d) where used, connecting hardware adapters shall be reference adapters in accordance with the relevant IEC product specification
   – for LC MMF (duplex) as specified in IEC 62664-1-1,
   – for SC SMF (simplex) as specified in IEC 60874-14-3.

The inspection and testing of test cords and connecting hardware adapters shall be done in accordance with Annex D prior to any reference measurement process being undertaken.

NOTE In the case of MPO interfaces, there is no adapter and therefore there is no influence on the final alignment of the connection.

6.3.2 Reference connector requirements

The requirements for reference connectors of cylindrical and rectangular styles are given in Table 3.

Table 3 – Non-LC reference connector requirements

	Cylindrical connector styles		Rectangular connector styles	
	MMF	SMF	MMF	SMF
Eccentricity of core centre to ferrule outer diameter	<1 µm	<0,3 µm	N/A	N/A
True position of the fibre core	N/A	N/A	<1 µm	<0,3 µm
Exit angle	≤0,2°	≤0,2°	≤0,2°	≤0,2°
Accuracy of ferrule diameter	±0,5 µm	±0,5 µm	N/A	N/A
Attenuation of 2 reference connectors in a reference adapter	≤0,10 dB	≤0,20 dB	≤0,10 dB	≤0,20 dB

LC reference adapters are specified in IEC 62664-1-1, and the attenuation of adaptors is measured according to IEC 61300-3-42.

The return loss of singlemode reference PC connectors shall be ≥45 dB.

[1] Under consideration.

The return loss of singlemode reference APC connectors shall be ≥60 dB mated and ≥55 dB unmated.

Multimode reference PC connectors shall meet the conditions of Grade 3 (≥35 dB).

The geometrical data for singlemode PC connectors are specified in IEC 61755-3-1 and for singlemode APC connectors in IEC 61755-3-2.

The reference connector shall be a tuned connector which has a low attenuation-value against all other connectors measured in one batch.

6.3.3 Test cords

6.3.3.1 General

Each test cord should

a) contain an optical fibre of the same nominal characteristics (core/mode field/cladding diameters, numerical aperture) as the optical fibre under test,

b) be labelled by having a unique identifier with each connector labelled as indicated in Figure 4,

c) be no shorter than 2 m,

d) not be so long that the attenuation of the fibre has a significant effect on the measurement.

NOTE A maximum test cord length value of 10 m is considered safe for most applications. For example, 10 m of multimode fibre will have no more than 0,035 dB of attenuation at 850 nm.

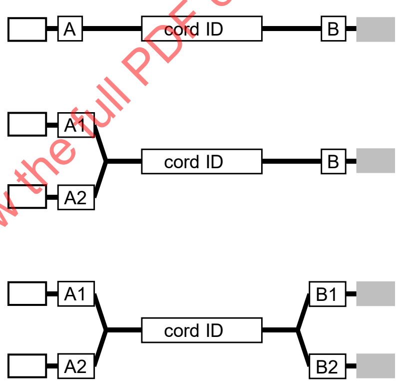


Figure 4 – An example of test cord labelling and identification

6.3.3.2 LSPM launch test cord

The launch test cord 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 compatible with the interface to the installed cabling.

For the multimode LSPM launch test cord, if the light source is not known to provide the specified launched modal distribution (see 6.4), then the launch test cord shall contain a suitable mode-controlling device to ensure that the specified launched modal distribution is maintained.

6.3.3.3 LSPM tail test cord

The tail test cord 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 compatible with the interface to the installed cabling.

6.3.3.4 LSPM combination launch test cord/tail test cord

A duplex launch test cord/tail test cord shall be

a) terminated at one end with one duplex or 2 simplex (duplexible) connectors suitable for attachment to the LSPM equipment,

b) terminated at the other end with one duplex or 2 simplex (duplexible) reference connectors compatible with the interface to the installed cabling.

6.3.3.5 LSPM substitution test cord

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

6.3.3.6 OTDR launch test cord

The OTDR should provide the specified launch modal distribution (see 6.4). For the multimode 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 launch test cord should be

a) longer than the attenuation dead zone of the OTDR (see Annex C for further details),

b) long enough for a reliable straight-line fit to be made to the backscatter trace following the dead zone (C1 to C2 in Figure 11) so that reliable attenuation measurements may be carried out. For example, in multimode fibre installations the length of the launch test cord should be at least 75 m. For single-mode fibre installations the length of the launch test cord should be at least 150 m,

c) terminated at one end with one or more connectors suitable for attachment to the OTDR,

d) terminated at the other end with one or more reference connectors compatible with the interface to the installed cabling.

The length of optical fibres used to create OTDR launch test cords often requires that they be protected within a closure (see Figure 5).

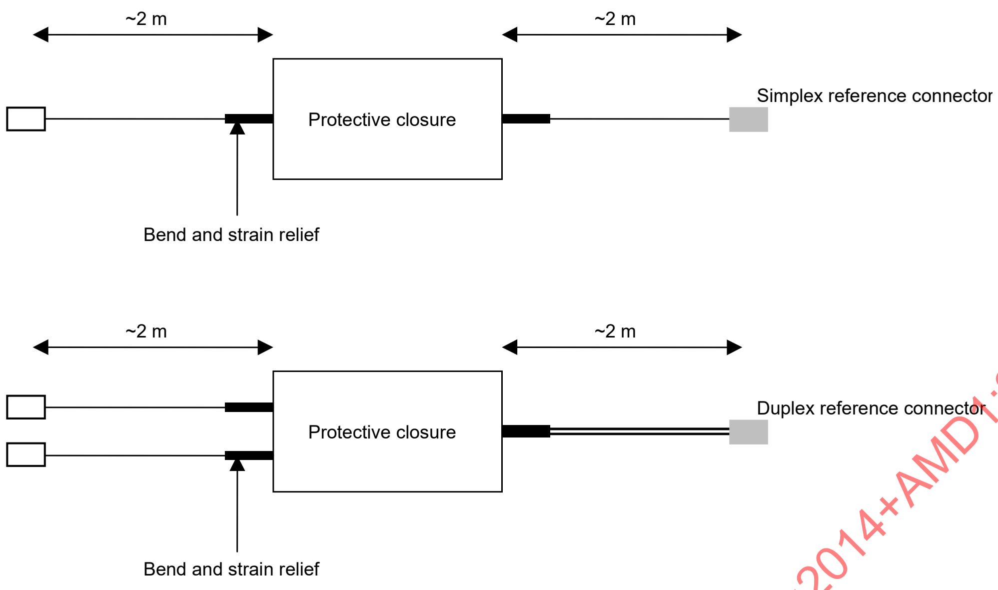


Figure 5 – OTDR launch test cord and/or tail test cord schematic

Where the interface to the cabling or component under test is duplex, the two optical fibres shall be of different lengths in order to determine the maintenance of polarity in the cable under test. The OTDR connections shall be uniquely identified with markers as shown in Figure 4.

6.3.3.7 OTDR tail test cord

The tail test cord shall be

a) longer than the attenuation dead zone of the OTDR (see Annex C for further details),

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 11), so that reliable attenuation measurements may be carried out). For example, in multimode installations the length of the tail test cord should be at least 75 m. For single-mode fibre installations the length of the tail test cord should be at least 150 m,

c) terminated at one end with one or more reference connectors compatible with the interface to the installed cabling.

The termination of the other end(s) is optional.

The length of optical fibres used to create OTDR tail test cords often requires that they be protected within a closure (see Figure 5).

6.4 MMF launched modal distribution

The launched modal distribution at the point of connection to the fibre under test shall meet the requirements in Annex A.

The required launched modal distribution shall be achieved by the use of the appropriate light source or by incorporating a mode-controlling device within the launch test cord.

6.5 SMF launch condition

The provision of a single-mode launch condition requires that launch test cords contain a minimum of two single air-coiled turns or mandrel wraps of 35 mm to 50 mm in diameter. However, this is usually provided within the test instruments and it is then not necessary to include an external wrap on a launch test cord.

7 Inspection equipment

Connecting hardware end face shall be inspected according to IEC 61300-3-35. Microscopes used for the inspection of connector end faces shall have a minimum field of view of 250 µm and have a minimum capability of ×100 magnification for MMF and ×200 magnification for SMF. The complete ferrule end face of rectangular connectors shall be inspected at low magnification for contamination. The microscope shall be fitted with suitable fixtures that retain the connector in a stable position thereby allowing careful inspection.

For direct vision viewing, the microscope shall be fitted with suitable infra-red filter mechanisms to prevent accidental eye damage. This is particularly important during the inspection of installed connector end faces where the remote end is not under control of the inspector.

Do not use direct view microscopes on live fibre systems.

For a more detailed description, see also Annex B.

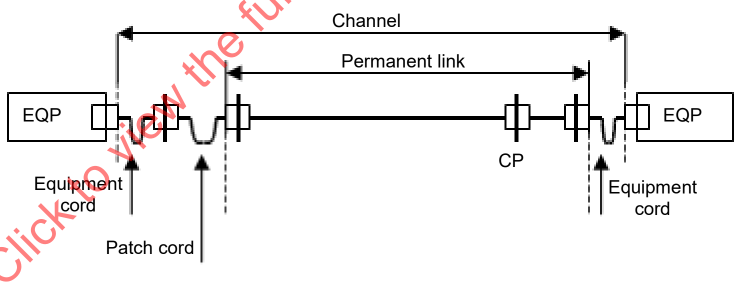
8 Cabling under test – Channels and permanent links

8.1 General

Although permanent links are referred to in this clause, ISO/IEC 11801-1 has defined requirements for sub-links that can be tested according to this standard.

8.2 Reference planes

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

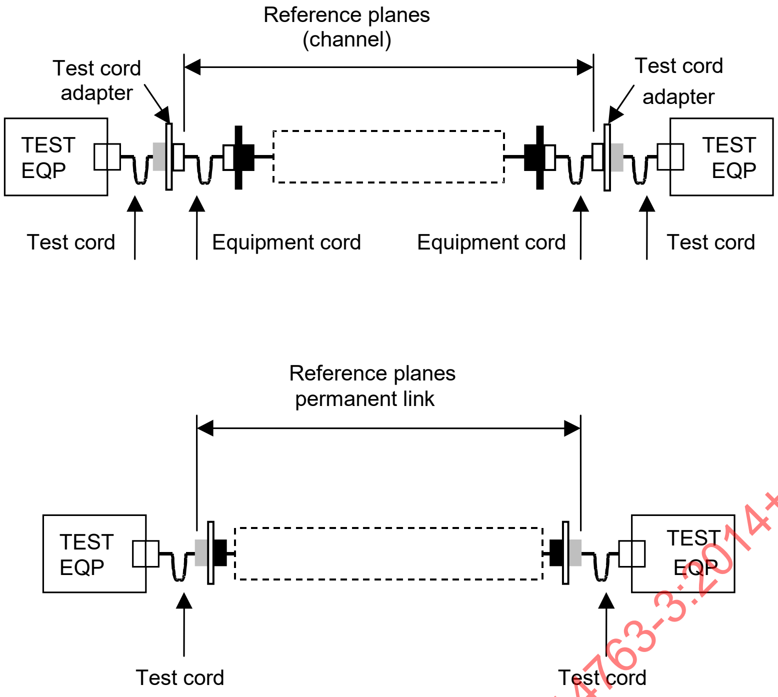


CP = consolidation point

Figure 6 – Channels and permanent links in accordance with ISO/IEC 11801-1 and equivalent standards

The uncertainty of a test system established to measure the optical characteristics of a channel and/or a permanent 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 permanent link are within the test cords next to, and including, the test cord connections which mate to the termination points of the permanent link under test (see Figure 7).



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

Figure 7 – Channel and permanent link test configuration

It should be noted that

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 may 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 it is necessary to reproduce the test conditions including the configuration of the test cords used. Changing the test set-up may produce different results.

8.3 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 Clauses 9 and 10 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).

8.4 Direction of measurement

The methods detailed in Clauses 9 and 10 specify the requirements for uni-directional or bi-directional measurements. For compliance testing of a link composed of known and unknown components bi-directional testing shall be conducted.

9 Testing of installed cabling

9.1 Attenuation

9.1.1 LSPM

9.1.1.1 General

Derived from IEC 61280-4-1, IEC 61280-4-2 and IEC 61300-3-4, the following has been adapted specifically in support of ISO/IEC 11801-1 for permanent link and channel attenuation measurements with a LSPM.

According to ISO/IEC 11801-1, a channel does not include the connector on the equipment cords that interfaces 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 and/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.

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 light source manufacturer's recommendations.

9.1.1.2 Channel test method

The procedure for channel testing is as follows.

a) 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). Allow sufficient time for the light source stabilization in accordance with light source manufacturer's recommendations. (See Figure 8). Since this reference measurement is carried out with a near end EQP cord, the defect of near end EQP cord may not be found. When this test method is used, the quality of the near end EQP cord shall comply with the requirement.

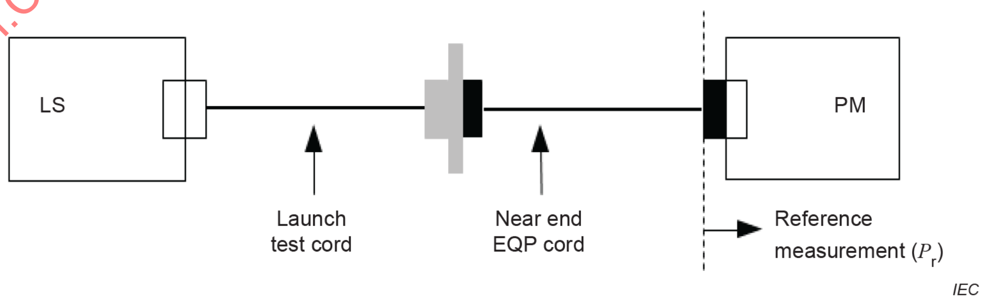


Figure 8 – Connection of LS – LTC – Near end EQP cord – PM for reference setting

b) The reference measurement, P_r, shall be recorded in watts (W) or decibel-milliwatts (dBm).

c) 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.

d) At the far end of the channel, connect the far end EQP cord to the power meter, see Figure 20).

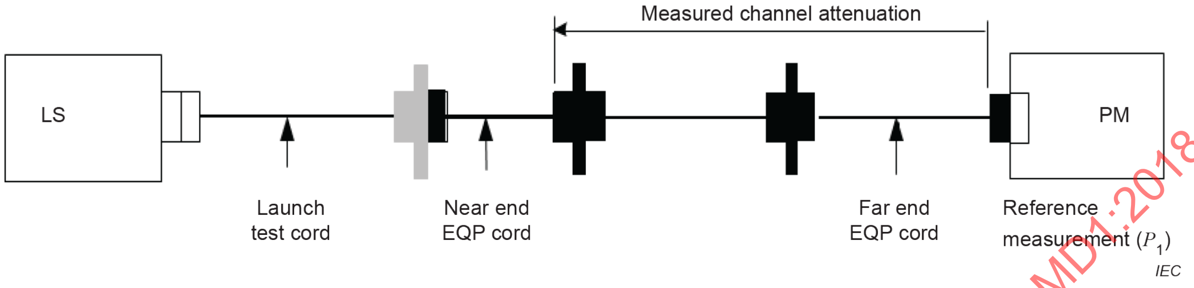


Figure 20 – Connections to channel test for attenuation measurement

e) The power P_1 is measured directly at the far end EQP cord. The measurement, P_1, shall be recorded in watts (W) or decibel-milliwatts (dBm).

f) The attenuation of the channel is:

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

where P_1 and P_r are expressed in dBm.

If P_1 and P_r are expressed in W, 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.

For this method, the measurement uncertainties at 95 % confidence level are as follows.

SMF: ± 0,16 dB for fibre length < 2 km.

MMF: ± 0,19 dB when measured attenuation ≤ 1,4 dB.

MMF: ± 0,14 × measured attenuation when measured attenuation > 1,4 dB.

NOTE Measurement uncertainties are determined using IEC TR 61282-14 and representative system data. See IEC TR 61282-14 for more details.

9.1.1.3 Link test method using the one-cord method and enhanced-three-test-cord reference method

The attenuation of an installed permanent link may be measured using the Enhanced three-test-cord reference method, or the one-test-cord reference method when the connectors installed on the cabling are compatible with the connectors on the test equipment.

See Annex E for differences between the one- and enhanced three-test-cord reference methods.

The reference measurement is made between the light source and power meter by the connection of a launch test cord in accordance with 6.3.3.2, as shown in Figure 9.

The reference measurement, P_r, shall be recorded in watts (W) or decibel mW (dBm).

The launch test cord shall remain connected to the light source and the tail test cord shall be connected to the power meter.

The attenuation of the connectors on the launch test cord and tail test cord may be verified by connecting these cords together and verifying that the attenuation of this connection is no more than the expected attenuation between two reference grade connectors. See Annex D for further information on inspection and testing of test cords.

The cabling under test shall be connected between the launch test cord and tail test cord and the test measurement, P_1, shall be recorded in watts (W) or decibel mW (dBm). The attenuation shall be determined according to formulae (1) or (2), respectively.

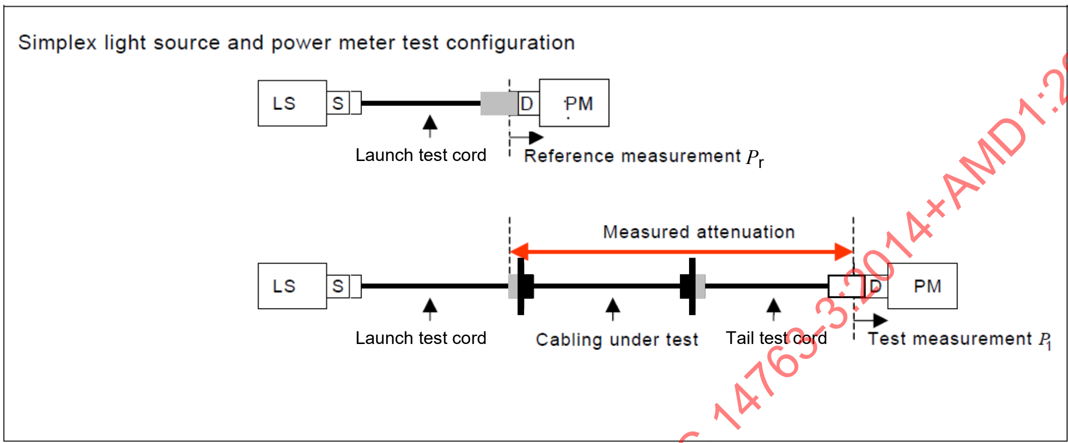


Figure 9 – LSPM one test cord attenuation measurement of installed permanent links

9.1.1.4 Unidirectional and bi-directional testing

For permanent links comprising a single fixed cable and terminating connectors, uni-directional testing may be performed. Where the permanent link or channel 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.

9.1.1.5 Test result

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

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 the worst of the two measured results shall be considered as the overall measured result.

9.1.1.6 Test system measurement uncertainty

The measured attenuation of a permanent link is affected by the alignment of the two optical fibres on either side of the test interfaces.

The use of test cords with reference connectors as required by this standard provides a reduced variation and as a result lower measurement uncertainty when compared to normal connectors.

In order to determine measurement uncertainty, the following information shall be given for the connectors terminating the cabling under test:

a) for MMF, the worst case attenuation of a MMF connection against a multimode reference termination;

b) for SMF, the worst case attenuation of a SMF connection against a single-mode reference termination.

Normative values for connecting hardware in accordance with ISO/IEC 11801-1 are stated in Table 4.

Table 4 – Connecting hardware attenuation

Connecting hardware	MMF		SMF	
	Attenuation (random mated)	Attenuation (mated against reference)	Attenuation (random mated)	Attenuation (mated against reference)
IEC 62664-1-1 Performance Grade B	0,30 dB max. – 50 % 0,60 dB max. – 97 %	0,50 dB max.		
In future IEC 62664-1-2 Performance Grade C[a]			0,25 dB max. – 50 % 0,50 dB max. – 97 %	0,75 dB max.
ISO/IEC 11801-1	0,75 dB max. – 100 %		0,75 dB max. – 100 %	

[a] Under consideration.

6.3.2 and Table 3 define requirements for the maximum attenuation of a connection of two reference connectors in a reference adapter.

9.1.1.7 Treatment of channel test results

Using the enhanced three test cord reference method specified in 9.1.1.2, the limit of testing for channel attenuation is

$$\Sigma \text{ (cable attenuation)} + \Sigma \text{ (embedded connection attenuation).}$$

Examples of these calculations are shown in Annex G.

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

9.1.1.8 Treatment of permanent link test 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 reference terminations in accordance with Table 3. 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 4.

Using either the one- or the enhanced three-test-cord reference method specified in 9.1.1.2, the calculated limit of testing link attenuation is:

- for MMF: Limit = (2 × 0,5 dB) + Σ (cable attenuation) + Σ (embedded connection attenuation);
- for SMF: Limit = (2 × 0,75 dB) + Σ (cable attenuation) + Σ (embedded connection attenuation) (for reference connector).

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 and Table 4.

NOTE When using the enhanced three-test-cord reference method, $A_{\mathrm{LTC/STC}}$ is the measured attenuation of the reference connectors of the launch test cord and the substitution test cord.

9.1.2 OTDR

9.1.2.1 Test method

A launch test cord in accordance with 6.3.3.6 shall be connected between the OTDR and the cabling under test. A tail test cord in accordance with 6.3.3.7 shall be connected to the remote end of the cabling under test.

The output source shall be selected for the fibre type and wavelength as defined in Annex C and the appropriate settings established, as follows:

a) range;

b) pulse width;

c) IOR;

d) averaging time.

9.1.2.2 Treatment of channel test results

Prior to the measurement of the attenuation of the cabling, the reference connectors on the launch test cord and the tail test cord shall be mated and the quality shall be verified.

The attenuation of the installed cabling shall be measured either as shown in Figure 10 or as shown in Figure 11.

Figure 10 shows the 2 points at which the attenuation of the installed cabling shall be measured. If the equipment cords are very short and/or the OTDR dead zone is long, then it may reduce the accuracy of the attenuation measurement.

It should be noted that

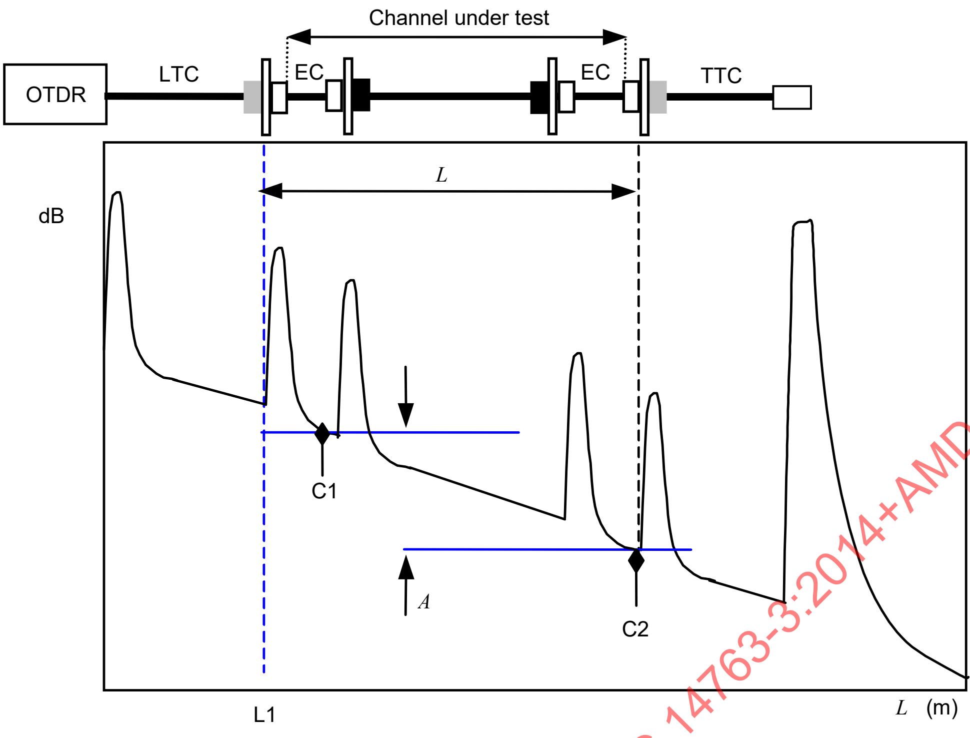
a) it is not possible to carry out the more accurate five point attenuation measurement where two reflective events are in close proximity as there is unlikely to be sufficient length of optical fibre in the equipment cords to obtain a linear fit to these sections around C1 and C2,

b) if the equipment cords are very short and/or the OTDR dead zone is long then it may not be possible to measure the channel attenuation.

Figure 11 shows the alternative approach where the attenuation of the channel is measured plus the attenuation of the equipment connectors.

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 comprises 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 pass, fail or a marginal result.



Key

LTC	Launch test cord
TTC	Tail test cord
EC	Equipment cord
C1, C2	Cursors for 2-point channel attenuation measurement
A	Attenuation of channel
L	Length of channel

Figure 10 – OTDR measurement of installed cabling (channel): 2 point attenuation measurement method

9.1.2.3 Treatment of permanent link test results

Figure 10 shows the points at which the attenuation of the installed cabling shall be measured.

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

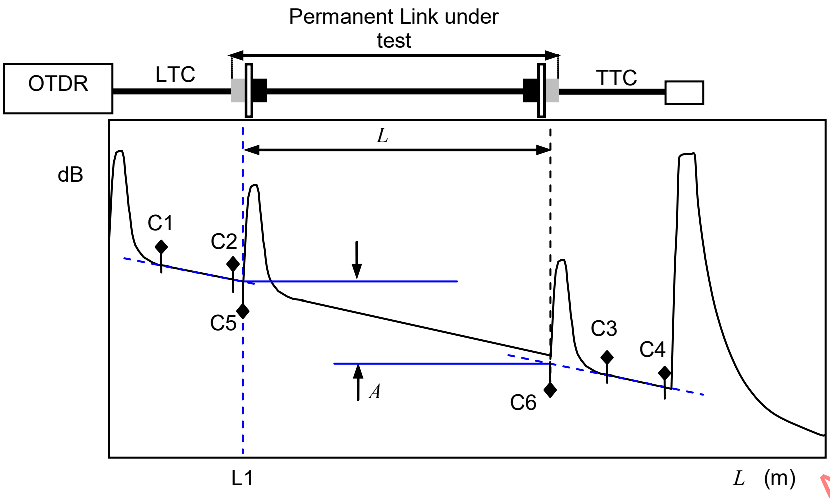
Comparison of the measured attenuation in Figure 8 and the permanent link reference planes in 8.2 shows that the attenuation limit defined for the permanent link within ISO/IEC 11801-1 or equivalent standards shall be the sum of the specified maximum attenuation values for the

a) attenuation (mated against reference) for the interface connections at the interfaces to the cabling under test,

b) embedded connections within the cabling under test,

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, fail or a marginal test result shall be indicated with reference to the measured result.



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 11 – OTDR measurement of installed cabling (permanent link)

9.1.2.4 Test system measurement uncertainty

NOTE The test system measurement uncertainty is for further study (ffs).

The measured attenuation of a channel or permanent link to this is affected by the alignment of the two optical fibres on either side of the test interfaces.

The use of test cords with reference connectors as required by this standard provides a reduced variation and as a result a more accurate result.

In order to determine measurement uncertainty, the following information shall be given for the connectors terminating the link under test:

a) for MMF, the worst case attenuation of a MMF connection against a multimode reference termination;

b) for SMF, the worst case attenuation of a SMF connection against a single-mode reference termination.

Normative values in order to connect hardware in accordance with ISO/IEC 11801-1 are shown in Table 4.

9.2 Propagation delay

9.2.1 Test method

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/optical power meter equipment. This type of equipment also supplies calculations of length.

Propagation delay may be calculated as follows:

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

where

T is the propagation delay

L_{OF} is the optical fibre length

c is the approximated speed of light in a vacuum (3×10^8 m/s)

n is the group refractive index of the optical fibre

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

9.2.2 Treatment of results

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

9.3 Length

9.3.1 Test method

The optical fibres should be tested using equipment capable of measuring propagation delay (e.g. an OTDR) (see 9.2.1). For determination of the optical fibre cable length see 11.3.

9.3.2 Measurement uncertainty

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 may differ from the physical length of the cable. Within a given length of cable containing multiple optical fibres each individual optical fibre may 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.

9.3.3 Treatment of results

The limits and restrictions indicated in 9.3.2 shall be included within the statement of measurement uncertainty.

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

The propagation velocity or the group refractive index, provided by the manufacturer of the optical fibre cable 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 (e.g. the verification of unknown cabling), the impact of any errors introduced should be recognised and agreed between the installer and the user. For default group refractive index values see Table C.1.

10 Testing of cabling components within installed cabling

10.1 Attenuation of optical fibre cable

10.1.1 Test method

In order to test a channel or permanent link (see Clause 8), a launch test cord in accordance with 6.3.3.6 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 6.3.3.6 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 mode/wavelength as defined in Annex C and the appropriate settings established for

a) range,

b) pulse width,

c) IOR,

d) averaging time.

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.

10.1.2 Measurement uncertainty

The measurement shall be over a section of the optical fibre away from the attenuation dead zone of the OTDR (see Annex C) 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.

For example, if the distance is 50 m, a loss uncertainty of ±0,05 dB leads to an attenuation coefficient uncertainty of ±1 dB/km. For this reason the attenuation coefficient should not be determined for short distances of fibre.

Preferably, the attenuation coefficient can be calculated using a linear regression over the backscattering signal (LSA method).

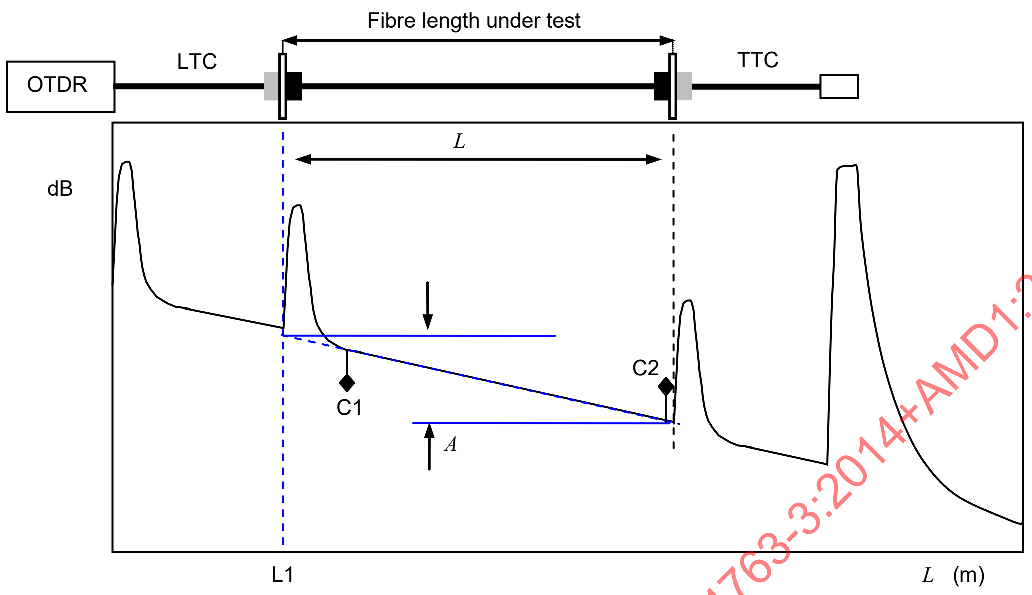
The minimum fibre lengths will differ for MMF and SMF measurements and for the operating wavelengths used. The OTDR manufacturer shall be consulted to determine their recommendations for the minimum fibre lengths over which the attenuation coefficient may be measured reliably.

10.1.3 Treatment of results

Figure 12 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
A	Attenuation of optical fibre
L	Length of optical fibre

Figure 12 – OTDR measurement of optical fibre attenuation

10.2 Attenuation of local and remote test interfaces

10.2.1 Test method

A launch test cord in accordance with 6.3.3.6 shall be connected between the OTDR and the cabling under test. A tail test cord in accordance with 6.3.3.7 shall be connected to the remote end of the cabling under test.

The OTDR output shall be selected for the mode/wavelength as defined in Annex C and the appropriate settings established for

a) range,

b) pulse width,

c) IOR,

d) averaging time.

The cabling under test shall be measured in both directions.

10.2.2 Test system measurement uncertainty

NOTE The test system measurement uncertainty is for further study (ffs).

The measured attenuation of a channel or permanent link depends upon the alignment of the two optical fibres on either side of the test interfaces.

The use of test cords with reference connectors as required by this standard provides reduced variation thereby generating a more accurate result.

In order to determine measurement uncertainties, the following information shall be stated for the connectors terminating the cabling under test

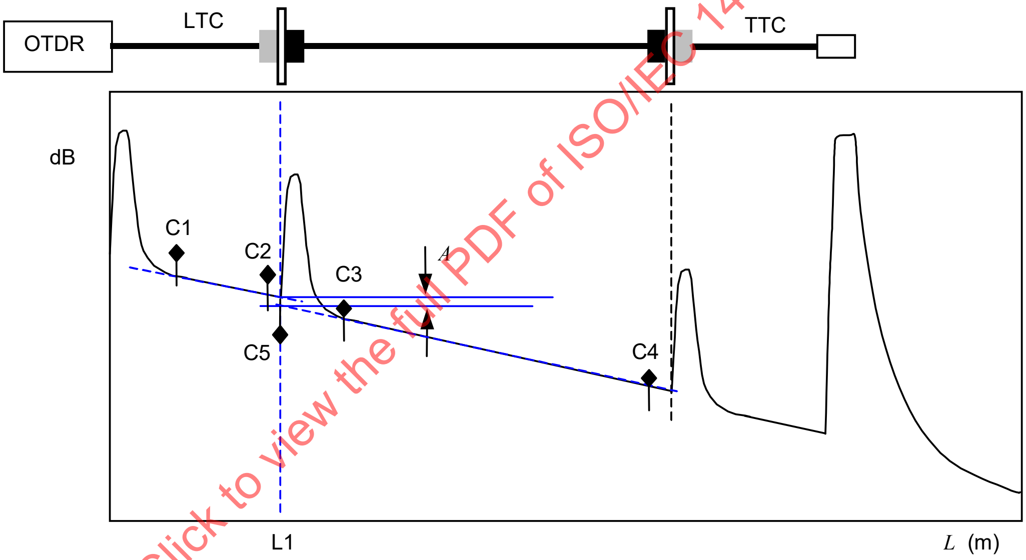
a) for MMF, the worst case attenuation of a MMF connection against a multimode reference termination,

b) for SMF, the worst case attenuation of a SMF connection against a single-mode reference termination.

Normative values for connecting hardware in accordance with ISO/IEC 11801-1 are shown in Table 4.

10.2.3 Treatment of results

Figure 13 shows the points at which the attenuation of the interfaces to the cabling under test shall be measured. The installed cabling may be either a channel or a permanent link (see Clause 8). However, where the channel contains short equipment cords at one or more ends, it may be impossible to make a measurement since the connections of the cords to the permanent link will be disguised within the end interface reflections.



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 13 – OTDR measurement of connection attenuation

The attenuation of the local interface is shown as the interface loss (dB). However, this is not a true measurement since the backscatter coefficient (k) may be different in the launch test cord and the cabling under test. If the backscatter coefficient of the launch test cord is higher than that of the cabling under test then the result will be overstated. If the backscattering coefficient of the cabling under test is higher than that of the launch test cord then the result will be understated (sometimes producing an apparent gain).

For this reason the result shall be the mean of the measurements in each direction.

The limiting constraint for the interface shall be the maximum attenuation (mated against reference). See Table 4.

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

10.3 Attenuation of connecting hardware

10.3.1 Test method

In order to test a channel or permanent link (see Clause 8), a launch test cord in accordance with 6.3.3.6 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 6.3.3.6 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 mode/wavelength as defined in Annex C and the appropriate settings established for

a) range,

b) pulse width,

c) IOR,

d) averaging time.

The cabling under test shall be measured in both directions.

10.3.2 Treatment of results

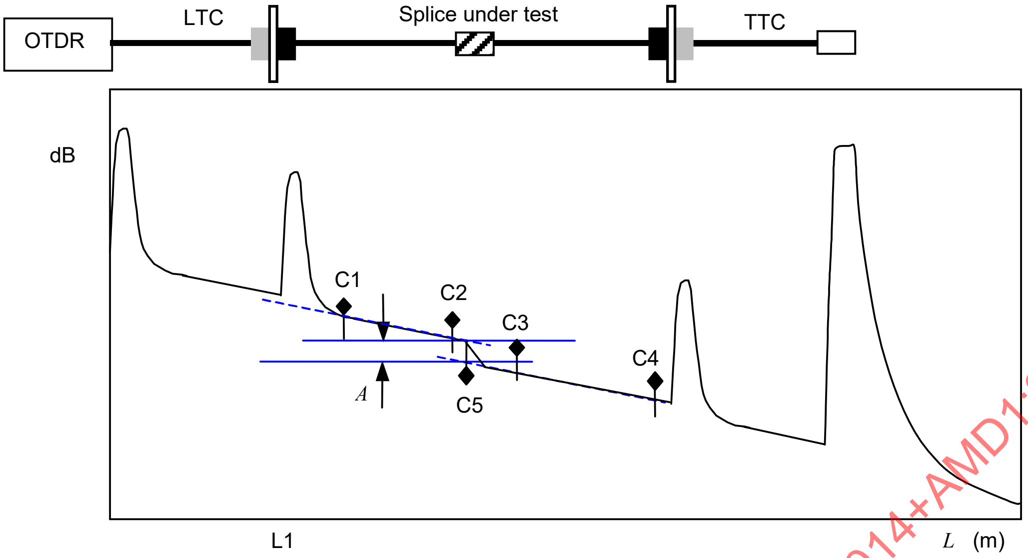
Figure 14 shows the points at which the attenuation of connecting hardware and/or splices within the cabling under test shall be measured.

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.

If the backscattering coefficients of the optical fibres on either side of the embedded connecting hardware are different then the results of measurement in each direction will differ (sometimes producing an apparent amplification in one direction).

For this reason, the result shall be the mean of the measurements in each direction.

Where compliance with a specified value is required a pass, fail or a marginal test 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 14 – OTDR measurement of joint attenuation

10.4 Return loss of connecting hardware

10.4.1 Test method (in accordance with IEC 61300-3-6, method 2)

A launch test cord in accordance with 6.3.3.6 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 6.3.3.7 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 6.3.3.6 but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

An attenuator at the OTDR receiver input may be required to reduce the optical power to a level that does not saturate the OTDR receiver.

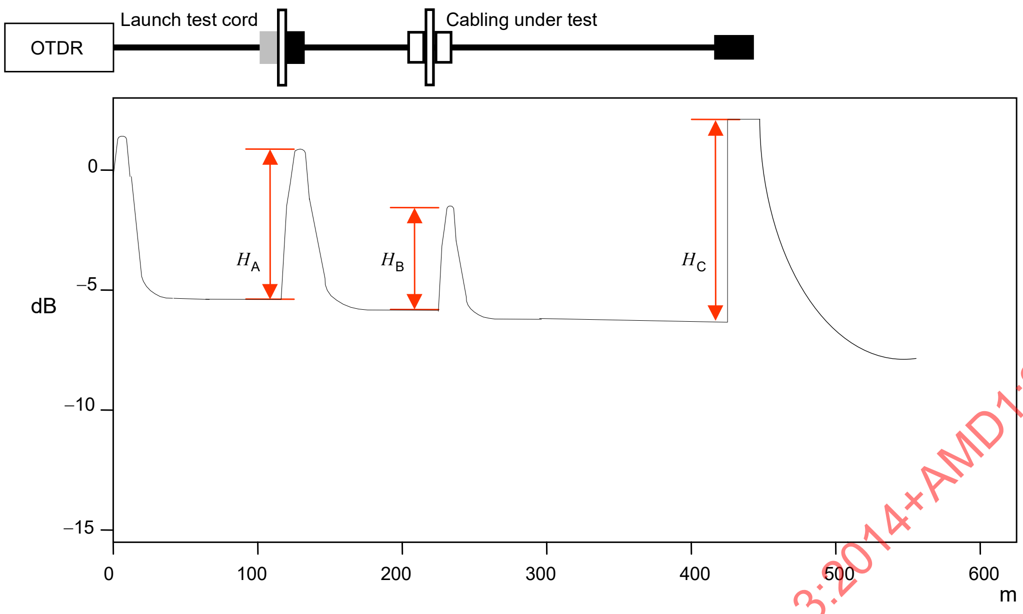


Figure 15 – OTDR measurement of return loss

10.4.2 Treatment of results

The return loss of a cabling component under test is calculated from the height of the reflected peak (H_A or H_B in Figure 15) as follows:

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

where H > 5 dB

$$RL \approx -2H - 10\lg d + k \quad \text{(dB)} \tag{6}$$

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 Annex C.

NOTE 1 Most OTDRs automatically measure RL using instrument settings set by the manufacturer. However, in this case, it is also important to pay attention to the measurement uncertainty consideration as set out in 10.4.3.

NOTE 2 The detector in some OTDRs saturates at large values of H (as shown in H_C in Figure 15) so that measurement uncertainty is lost in measuring small values of return loss. This type of signal saturation is avoided by adding a variable attenuator between the OTDR and the cabling component under test.

NOTE 3 The term "return loss" is sometimes expressed by some OTDR manufacturers as "reflectance" with a negative sign.

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

10.4.3 Measurement uncertainty

Different sources of uncertainties shall be considered when measuring the return loss.

Instrument related uncertainties such as errors on the pulse amplitude or uncertainties on the shape or on the true value of the pulse width shall be considered if they are not corrected by the instrument, otherwise, the maximum uncertainty value provided by the manufacturer shall be taken into account.

Fibre related uncertainties have a direct impact on the return loss uncertainties (e.g. ±2 dB uncertainty on the backscattering coefficient leads to exactly ±2 dB uncertainty on the reflectance). Typical uncertainty values included in Annex C may be used.

10.5 Optical fibre length

10.5.1 Test method

In order to test a channel or permanent link (see Clause 8), a launch test cord in accordance with 6.3.3.6 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 6.3.3.6 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 mode/wavelength as described in Annex C and the appropriate settings established for

a) range,
b) pulse width,
c) IOR,
d) averaging time.

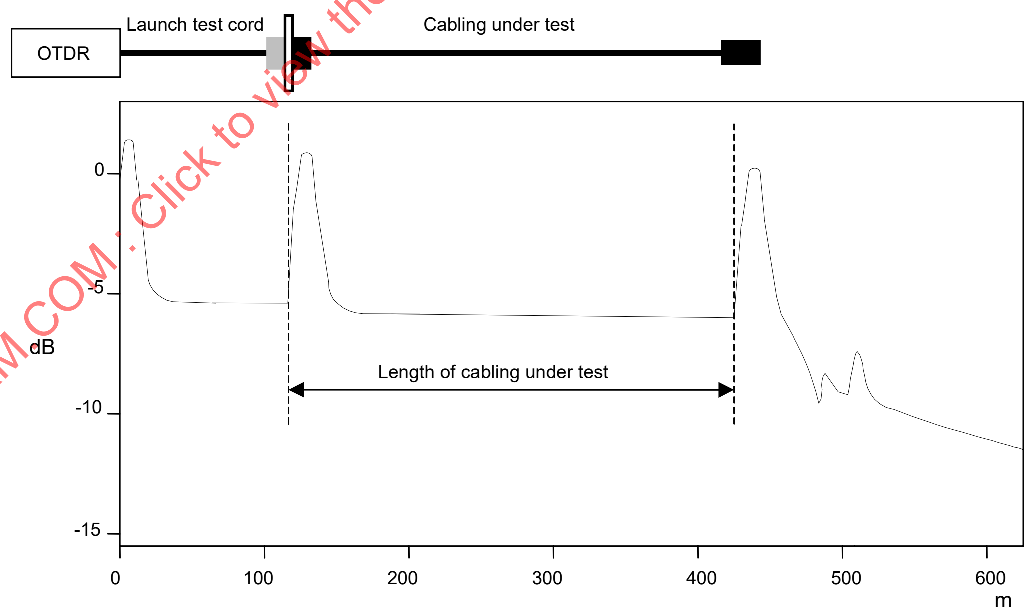


Figure 16 – Determination of length using an OTDR

Figure 16 shows the points at which the length of the transmission path contained within the installed cabling shall be measured (SMF may not produce a remote interface reflection). The installed cabling may be either a channel or a permanent link (see Clause 8).

A break in a MMF permanent link would also be characterized by the presence of the reflection peak. However, unlike MMF and as shown in Figure 17, a break in a SMF may not always be characterized by a reflection peak.

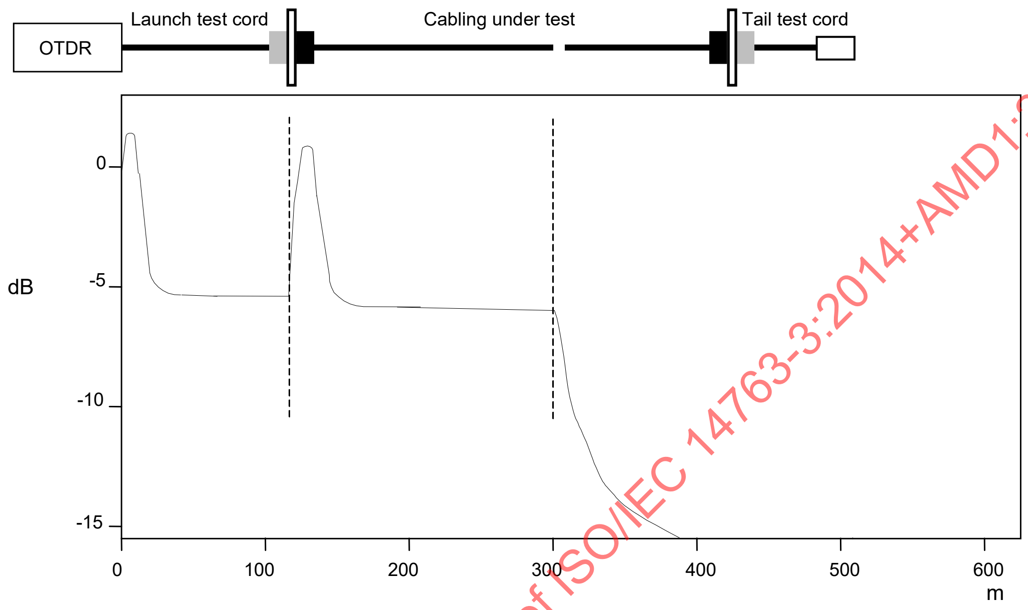


Figure 17 – OTDR characterization of a SMF permanent link containing a break

An installation error (e.g. an installed cable bend radius less than that specified in the relevant product standard or manufacturers/supplier 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 may show as a step change in attenuation on the OTDR trace (see Figure 18).