INTERNATIONAL STANDARD

ISO/IEC 14763-3

First edition
2006-06

Information technology – Implementation and operation of customer premises cabling –

Part 3: Testing of optical fibre cabling



Reference number
ISO/IEC 14763-3:2006(E)

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Information technology – Implementation and operation of customer premises cabling –

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INFORMATION TECHNOLOGY – IMPLEMENTATION AND OPERATION OF CUSTOMER PREMISES CABLING –

Part 3: Testing of optical fibre cabling

FOREWORD

1) ISO (International Organization for Standardization) and IEC (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. Their preparation is entrusted to technical committees; any ISO and IEC National Committee interested in the subject dealt with may participate in this preparatory work. International governmental and non-governmental organizations liaising with ISO and IEC also participate in this preparation.

2) In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

3) All users should ensure that they have the latest edition of this publication.

4) No liability shall attach to IEC or ISO or its directors, employees, servants or agents including individual experts and members of their technical committees and IEC or ISO member bodies for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication of, use of, or reliance upon, this ISO/IEC publication or any other IEC, ISO or ISO/IEC publications.

5) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

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

This International Standard replaces ISO/IEC TR 14763-3, first edition, published in 2000, and constitutes a technical revision.

This standard incorporates innovations and recent developments including guidance in the proper use of uni-directional and bi-directional OTDR testing, the three-jumper method as default test method, fibre end-face inspection and criteria for scratches, return loss values for SC and non-SC connectors and the normative use of reference connectors. However, the most substantial change is the application of the 2 parameters which are used to determine the two repeatable multimode launch conditions “modal power distribution” and “coupled power ratio”.

This International Standard has been approved by vote of the member bodies, and the voting results can be obtained from the address given on the title page.

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

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INTRODUCTION

This document is one of three prepared in support of International Standard ISO/IEC 11801.

Figure 1 below shows the inter-relationship between ISO/IEC 11801, these associated Technical Reports/Standards and other related standards.

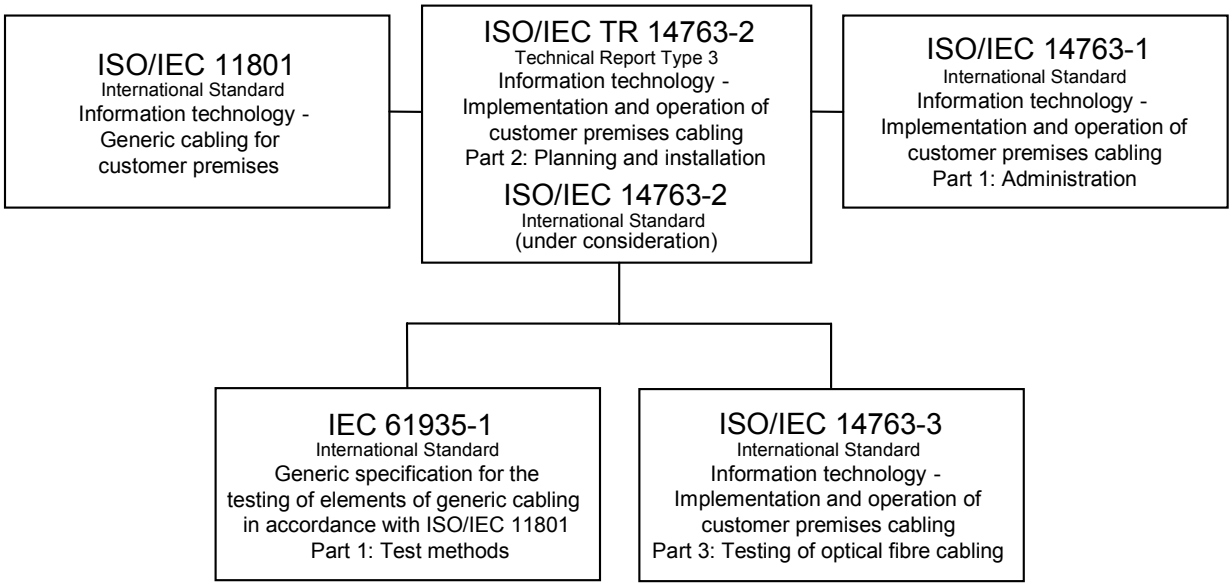


Figure 1 – Document relationships

Part 3 of ISO/IEC 14763 details inspection and test procedures for optical fibre cabling

- designed in accordance with ISO/IEC 11801 and equivalent standards and
- installed according to the requirements and recommendations of ISO/IEC 14763-2 (under consideration).

Users of this International Standard should be familiar with both ISO/IEC 11801 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 (under consideration).

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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 optical fibre cabling designed in accordance with ISO/IEC 11801 or equivalent standards. The test methods refer to existing standards-based procedures where they exist.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 11801, *Information technology – Generic cabling for customer premises*

ISO/IEC TR 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*[1]

IEC 60050-731, *International Electrotechnical Vocabulary – Chapter 731: Optical fibre communication*

IEC 60793-1-20, *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*

IEC 60793-1-45, *Optical fibres – Part 1-45: Measurement methods and test procedures – Mode field diameter*

IEC 60793-2-10, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

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

IEC 60874-14-1, *Connectors for optical fibres and cables – Part 14-1: Detail specification for fibre optic connector type SC/PC standard terminated to multimode fibre type A1a, A1b*

IEC 60874-14-2, *Connectors for optical fibres and cables – Part 14-2: Detail specification for fibre optic connector type SC/PC tuned terminated to single-mode fibre type B1*

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

IEC 60874-19, *Connectors for optical fibres and cables – Part 19: Sectional specification for fibre optic connector – Type SC-D(uplex)*

[1] ISO/IEC 14763-2 is planned to become an International Standard.

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IEC 60874-19-1, *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 60874-19-2, *Connectors for optical fibres and cables – Part 19-2: Fibre optic adaptor (duplex) type SC for single-mode fibre connectors – Detail specification*

IEC 61300-3-1, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-1: Examinations and measurements – Visual examination*

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/PAS 61300-3-43, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-43: Examination and measurements – Mode Transfer Function Measurement for fibre optic sources*

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this document the following definitions apply in addition to those of ISO/IEC 11801 and IEC 60050-731.

3.1.1
adapter
device that enables interconnection between terminated optical fibre cables

3.1.2
cabling interface adapter
test cords and other components used to connect test equipment to the cabling under test

3.1.3
connection
mated device or combination of devices including terminations connecting two cables or cable elements

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

3.1.5
coupled power ratio (CPR)
ratio of power coupled in a MMF to the power coupled in SMF which is related to the modal power distribution of the light in MMF

3.1.6
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

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3.1.7
field calibration cord
test cord used for referencing when using the 3-jumper test method

3.1.8
marginal result
measured value which differs from the specified requirement by an amount not exceeding the stated measurement uncertainty

3.1.9
multimode optical fibre (MMF)
optical fibre which supports multiple paths of light transmission

3.1.10
optical fibre
any filament made of dielectric materials that guides light

3.1.11
optical time domain reflectometer (OTDR)
instrument used to characterise optical fibre cabling by measuring the backscatter and reflection of injected light pulses as a function of time

3.1.12
pass result
measured value which meets the specified requirement and where the absolute value of the difference between the measured value and the specified requirement is greater than the stated measurement uncertainty

3.1.13
reference connector
tighter tolerances or selected connector component which is used for measuring purposes

NOTE The characteristics or selection procedures are given in the relevant connecting hardware specification.

[IEC 60874-1, 1.3.14, modified]

3.1.14
relative power distribution
metric used to determine launch conditions in terms that are relative to a light source's overall launched power

3.1.15
sheath
see cable sheath

3.1.16
single-mode optical fibre (SMF)
optical fibre which supports only one mode of light transmission

3.1.17
test cord
cable assembly used either to connect test equipment to the cabling under test or as part of a test reference measurement

3.1.18
test operator
skilled person testing in accordance with instructions provided by the test system designer

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3.1.19
test system
test equipment and cabling interface adapters necessary to undertake a given test/measurement in accordance with the requirements of this standard

3.2 Abbreviations

For the purposes of this document the following abbreviations apply in addition to those of ISO/IEC 11801 and IEC 60050-731.

APC	Angled physical contact
CPR	Coupled power ratio
IOR	Index of refraction
LMD	Launched modal distribution
LSA	Least squares average
LSPM	Light source and power meter
MMF	Multimode optical fibre
MPD	Modal power distribution
na	not applicable
OTDR	Optical time domain reflectometer
RPD	Relative power distribution
SMF	Single-mode optical fibre

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
	Joint

4 Conformance

To test installed cabling according to this International Standard:

- the general requirements of clauses 5 and 8 shall be met;
- the test equipment and test cords shall conform to the requirements of Clause 6;
- the test method, as appropriate, and treatment of results shall conform to Clauses 9 and 10;
- the test results shall be documented in accordance with 5.4;
- the requirements of IEC 60825-2 shall be met.

To inspect installed cabling according to this International Standard:

- the inspection equipment shall conform to the requirements of Clause 7;
- the inspection method, as appropriate, shall conform to Clause 11;
- the requirements of IEC 60825-2 shall be met.

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

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5 General requirements

5.1 Test system

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

The cabling interface adapters take the form of test cords together with any connecting hardware adapters that are required at the test interfaces.

The test system and, particularly the cabling interface adapters, affect the uncertainty of measurement for a given parameter.

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

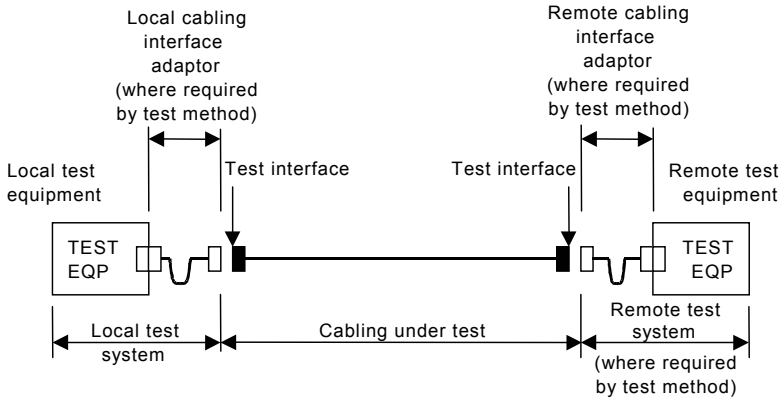


Figure 2 – The test system and the cabling under test

5.2 Normalisation and calibration

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

Test equipment should be calibrated using standardised procedures (e.g. IEC 61315 and IEC 61746), 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 undertaken.

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.

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5.3.2 Contamination

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

Materials to clean the connections (such as 98 % reagent grade alcohol, appropriate cleaning solvents, lint-free wipes and clean compressed air) shall be available and used in accordance with suppliers' instructions.

Any connecting hardware adapters used together with all connector end-faces on the test cords comprising the cabling interface adapter and the cabling under test shall be cleaned according to the instructions provided by the manufacturer of the connectors. Cleaning shall be repeated every time a test cord is connected to the cabling or component under test.

Connections should be inspected with a microscope after cleaning, to verify that they are uncontaminated.

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 as per manufacturer's specifications.

5.3.4 Relevance of measurement

Measurements shall either

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

b) have correction factors applied to the measured results in accordance with manufacturers' specifications in order to reflect the intended operating environment, or

c) 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 normalisation of the test system,

b) acceptance of all marginal results,

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

Further guidance for the treatment of marginal results is found in ISO/IEC 14763-2.

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 details (fibre core size/MFD, fibre type e.g. OM1, OM2, OM3, OS1),

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

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

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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.

6 Test equipment

6.1 LSPM

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 for link and channel attenuation measurements with an LSPM.

6.1.2 Light sources

Light sources for testing multimode optical fibre (MMF) cabling and components shall conform to the spectral characteristics of Table 1.

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.

Table 2 – SMF light source characteristics

Centre wavelength nm
1 310 ± 30
1 550 ± 30

6.1.3 Power meters

The equipment shall be capable of measuring relative or absolute optical power (such as an optical power meter) and shall be designed in such a way as to make power measurements independent of modal distribution. The equipment shall enable optical power measurements to be recorded to at least one significant digit in the decimal place (for example, −14,3 dBm, 10,1 mW).

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

The stability of the light source contributes directly to measurement variability. A light source shall be used in such a way that any variation in output power from the normalised values (see 5.2) shall be as specified in ISO/IEC 14763-2.

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A power meter with adequate equipment temperature stability and optical power linearity to meet the desired measurement uncertainty shall be used.

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.

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

6.2.2 OTDR characterization using a launch cord only

Characterization of cabling using an OTDR with a launch cord only

- produces a characterization of the form shown in Figure 3,

  NOTE There may not be a remote interface reflection if the far end of the optical fibre is broken or terminated with an angled interface.

  - SMF may not produce a remote interface reflection if the optical fibre is broken,
  - APC connectors may not produce a discernable reflective event,
- does not provide any continuity measurement for the cabling under test,
- provides information about the general quality of the local interface to the cabling under test, the quality of the installed cable and any embedded joints within the cabling under test,
- does not allow any quantitative measurement of the local interface to the cabling under test unless the scattering characteristics of the optical fibre within the launch cord are the same as those of the optical fibre under test,
- does not allow any quantitative measurement of embedded connecting hardware joints within the cabling under test unless the scattering characteristics of the optical fibres on either side of the embedded connecting hardware are identical or unless measurements are taken in each direction,
- cannot be used for measurement of the channel or link (see 8.1) attenuation/insertion loss as it does not provide optical attenuation measurement for the remote connector and therefore cannot provide an optical attenuation measurement for the channel or permanent link under test.

6.2.3 OTDR characterization using a launch cord and a tail cord

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

- produces an unidirectional characterization of the form shown in Figure 4 (two traces need to be combined and evaluated),
- provides a continuity measurement for the cabling under test,
- 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,
- provides quantitative measurement of the local and remote interfaces to the cabling under test using measurements taken in each direction,
- provides quantitative measurement of the channel or link (see 8.1) attenuation when the measurement is taken in one direction provided that

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- the channel or link only contains a single fixed cable and terminating connectors,
- the scattering characteristics of the optical fibre within the launch and tail cords are the same,

- provides quantitative attenuation measurement of the channel, or link embedded connecting hardware (see 8.1) 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 ODTR.

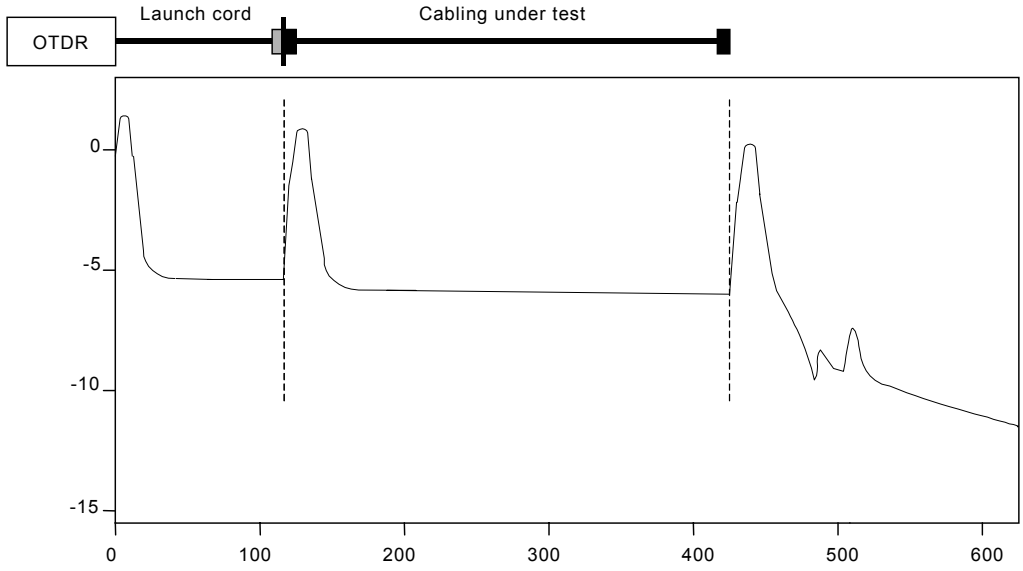


Figure 3 – OTDR characterization using a launch cord only

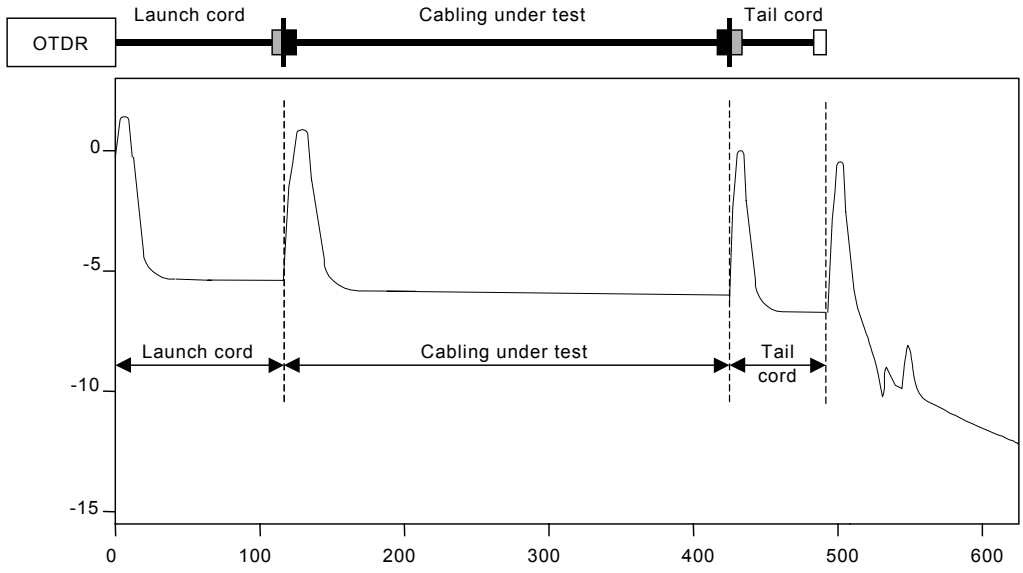


Figure 4 – OTDR characterization using a launch cord and a tail cord

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6.3 Cabling interface adapters

6.3.1 Connecting hardware at test interfaces

The connecting hardware to be connected to the cabling under test (i.e. launch cords and tail cords) together with the hardware that terminates the field calibration cords and any connecting hardware adapters used as part of the test methods specified by this international Standard shall

- have the same product specification as the hardware terminating the cabling under test,
- have a controlled end face for radius, dome offset and fibre position,
  - 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 60874-14-2,
- 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 IEC 60874-14 and IEC 60874-19),
- where used, connecting hardware adapters shall be reference adapters in accordance with the relevant IEC product specification,
  - for SC MMF (duplex) as specified in IEC 60874-19-2,
  - 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 normalisation process being undertaken.

6.3.2 Reference connector requirements

The requirements for multimode SC reference connectors are given in IEC 60874-19-1. The requirements for single-mode SC reference connectors are given in IEC 60874-14-1.

The requirements for reference connectors of other (non-SC) cylindrical and rectangular styles are given in Table 3.

Table 3 – Non-SC 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	na	na
True position of the fibre core	na	na	<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	na	na
Attenuation between 2 reference connectors	≤0,10 dB	≤0,20 dB	≤0,10 dB	≤0,20 dB

6.3.3 MMF test cords

6.3.3.1 General

Each test cord shall

- contain optical fibre of the same nominal characteristics (core/cladding diameters, numerical aperture) as the optical fibre under test,
- be labelled by having a unique identifier with each connector labelled as indicated in Figure 5.

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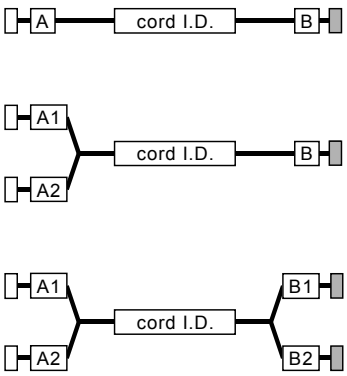


Figure 5 – Test cord labeling and identification

6.3.3.2 LSPM launch cord

The launch cord shall be

- between 1 m and 5 m in length,
- terminated at one end with one or more connectors suitable for attachment to the light source,
- terminated at the other end with one or more reference connectors compatible with the interface to the installed cabling.

If the light source is not known to provide the specified launched modal distribution (see 6.4) then the launch cord shall contain a mandrel or other mode-conditioning devices to ensure that the specified launched modal distribution is maintained.

6.3.3.3 LSPM tail cord

The tail cord shall be

- between 1 m and 5 m,
- terminated at one end with one or more connectors suitable for attachment to the power meter,
- 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/tail cord

A duplex launch/tail cord shall be

- between 1 m and 5 m in length,
- terminated at one end with one or more connectors suitable for attachment to the LSPM equipment,
- terminated at the other end with one or more reference connectors compatible with the interface to the installed cabling.

6.3.3.5 LSPM field calibration cord

The field calibration cord shall

- not exceed 2 m in length,
- be terminated at both ends with reference connectors compatible with the interfaces to the installed cabling.

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6.3.3.6 OTDR launch cord

The OTDR shall provide the specified launch modal distribution (see 6.4).

The launch cord shall be

- longer than the attenuation dead zone of the OTDR (see Annex C for further details),
- terminated at one end with one or more connectors suitable for attachment to the OTDR,
- 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 test cords often requires that they be protected within a closure (see Figure 6) which may also include any launched modal distribution devices.

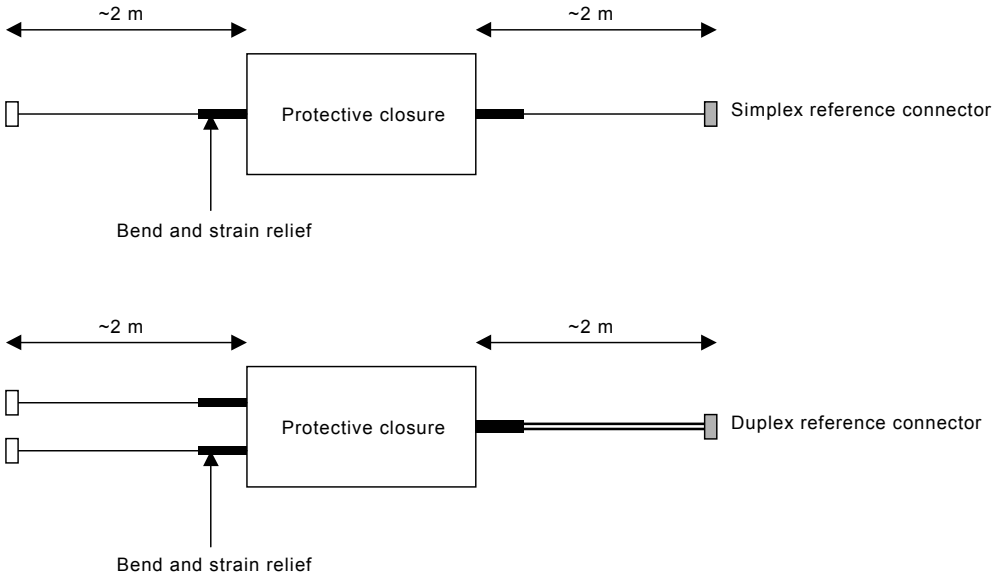


Figure 6 – OTDR launch cord schematic

Where the interface to the cabling or component under test is duplex, the launch cord shall contain two optical fibres enabling the testing of both optical fibres by switching the OTDR connections rather than re-connecting cords at the interface under test. The OTDR connections shall be uniquely identified with markers as shown in Figure 5.

6.3.3.7 OTDR tail cord

The tail cord shall be

- of a different length than the corresponding launch cord (but longer than the attenuation dead zone of the OTDR, see Annex C for further details),
- 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 test cords often requires that they be protected within a closure (see Figure 6).

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Where the interface to the cabling or component under test is duplex, the two optical fibres shall both be shorter than the corresponding launch cord (but longer than the attenuation dead zone of the OTDR) but shall be of different lengths in order to determine the maintenance of polarity in the cabling under test.

6.3.4 SMF test cords

6.3.4.1 General

Each test cord shall

- contain optical fibre of the same nominal characteristics (mode field and cladding diameters) as the optical fibre under test,
- be labelled with a unique identifier with each connector labelled as indicated in Figure 5.

6.3.4.2 LSPM launch cord

The launch cord shall be

- between 1 m and 5 m in length,
- terminated at one end with one or more connectors suitable for attachment to the light source,
- terminated at the other end with one or more single-mode reference connectors compatible with the interface to the installed cabling.

6.3.4.3 LSPM tail cord

The tail cord shall be

- between 1 m and 5 m in length,
- terminated at one end with one or more connectors suitable for attachment to the light source,
- terminated at the other end with one or more single-mode reference connectors compatible with the interface to the installed cabling.

6.3.4.4 LSPM combination launch/tail cord

A duplex launch/tail cord shall be

- between 1 m and 5 m in length,
- terminated at one end with one or more connectors suitable for attachment to the LSPM equipment,
- terminated at the other end with one or more single-mode reference connectors compatible with the interface to the installed cabling.

6.3.4.5 LSPM field calibration cord

The field calibration cord shall

- not exceed 2 m in length,
- each end shall be terminated with single-mode reference connectors compatible with the interfaces to the installed cabling.

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6.3.4.6 OTDR launch cord

The launch cord shall be

- longer than the attenuation dead zone of the OTDR,
- terminated at one end with one or more connectors suitable for attachment to the OTDR, see Annex C for further details,
- terminated at the other end with one or more single-mode reference connectors compatible with the interface to the installed cabling.

The length of optical fibres used to create test cords often requires that they be protected within a closure (see Figure 6).

Where the interface to the cabling or component under test is duplex, the launch cord shall contain two optical fibres enabling the testing of both optical fibres by switching the OTDR connections rather than re-connecting cords at the interface under test. The OTDR connections shall be uniquely identified as shown in Figure 5.

6.3.4.7 OTDR tail cord

The tail cord shall be

- of a different length than the corresponding launch cord (but longer than the attenuation dead zone of the OTDR, see Annex C for further details),
- 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 test cords often requires that they be protected within a closure (see Figure 6).

Where the interface to the cabling or component under test is duplex, the two optical fibres shall both be shorter than the corresponding launch cord (but longer than the attenuation dead zone of the OTDR), but shall be of different lengths in order to determine the maintenance of polarity in the cabling under test.

6.4 MMF launched modal distribution (LMD)

The LMD at the point of connection to the cabling under test shall be as defined in Annex A.

This required LMD shall be achieved by the use of the appropriate light source or by incorporating a mode conditioning device within the launch cord.

6.5 SMF launched modal distribution (LMD)

The provision of a single-mode launch condition requires that launch cords contain a minimum of two single air-coiled turns or mandrel wraps of 35 mm to 50 mm in diameter.

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7 Inspection equipment

7.1 Connecting hardware end-face

7.1.1 General

Microscopes used for the inspection of connector end-faces shall have a minimum capability of ×100 magnification for MMF and ×200 magnification for SMF, as shown in Table B.2.

The microscope shall be fitted with suitable fixtures that retains the connector in a stable position thereby allowing careful inspection.

7.1.2 Optical, direct vision microscope

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 the control of the inspector.

7.1.3 CCD microscope

See IEC 61300-3-35.

8 Cabling under test

8.1 Channels and permanent links

8.1.1 General

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

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8.1.2 Reference planes

ISO/IEC 11801 and equivalent standards define transmission limits for channels and permanent links for which the representative reference planes are shown in Figure 7.

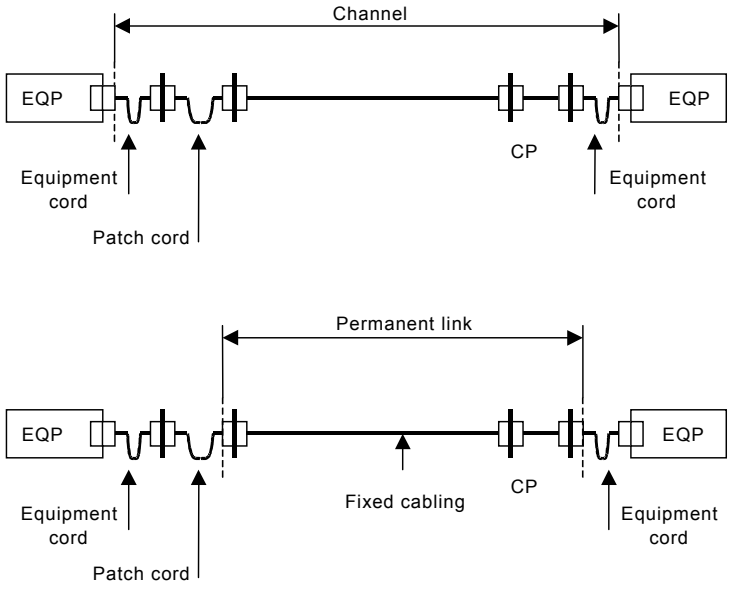


Figure 7 – Channels and permanent links in accordance with ISO/IEC 11801 and equivalent standards

The accuracy 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 plane at each end of a channel is within the equipment cable next to, but excluding, the connection of the equipment cable into the test equipment (see Figure 8). The test configuration reference plane of a permanent link is within the test cord cable next to, and including, the test cord connection which mates to the termination point of the permanent link under test (see Figure 8).

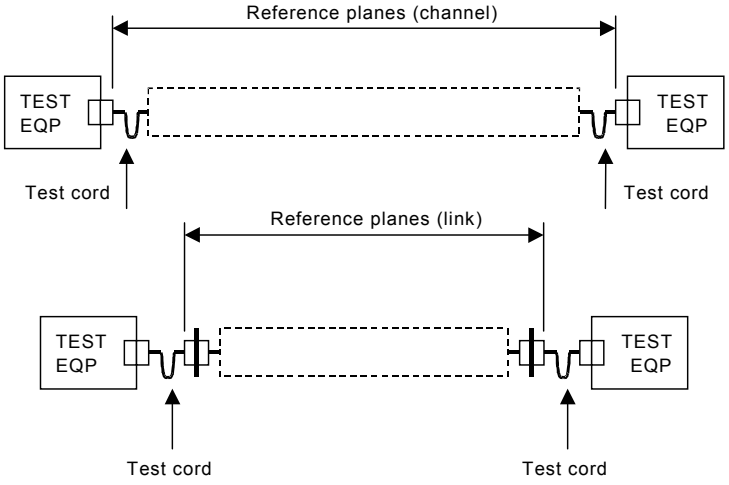


Figure 8 – Channel and permanent link test configuration

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It should be noted that

- optical fibre and connector hardware conditions at the interface between the test cords and a permanent link under test produce variations in measured results,
- for short lengths this variable factor may be significant in comparison with the value being measured. This defines a minimum length limit below which attenuation cannot be measured accurately,
- 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 inconsistent results,
- the optical signal loss of end connectors (one half of the mated pair at each end) is not taken into account in ISO/IEC 11801.

8.1.3 Wavelength of measurement

In order to comply with the requirements of ISO/IEC 11801 and equivalent standards and unless otherwise agreed, the measurements of transmission performance (attenuation/ insertion loss and return loss) detailed in clauses 9 and 10 shall be carried out at the following nominal wavelengths:

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

8.1.4 Direction of measurement

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

9 Testing of installed cabling

9.1 Attenuation/insertion loss

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 for link and channel attenuation measurements with a LSPM.

9.1.1.2 Test method

The default test method for attenuation measurement of links and channels for this standard is the 3-jumper method as shown in Figure 9. More information on this test method and the rationale for its use is given in Annex A.

For link measurements an alternative method may be used. This method is called the 1-jumper method, as shown in Figure 10. This method may only be used for simplex connecting hardware (or connecting hardware that can be tested as such) on the cabling under test and when the connector in the link is the same interface as the connector on the power meter.

For MMF, the normalisation process requires a reference measurement as shown in Figure 9 to be made between the light source and power meter by the connection of

- a launch cord in accordance with 6.3.3.2 (or 6.3.3.4),
- a field calibration cord in accordance with 6.3.3.5,
- a tail cord in accordance with 6.3.3.3 (or 6.3.3.4).

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For SMF, the normalisation process requires a reference measurement, as shown in Figure 9, to be made between the light source and power meter by the connection of

- a launch cord in accordance with 6.3.4.2 (or 6.3.4.4),
- a field calibration cord in accordance with 6.3.4.5,
- a tail cord in accordance with 6.3.4.3 (or 6.3.4.4).

The reference measurement, P_0, shall be recorded in watts or decibel metres.

The reference measurement uses two connecting hardware adapters in accordance with 6.3.1. Following the reference measurement, P_0 (dB), the field calibration cord shall be removed. If the cabling under test is a channel as defined in 8.1, these adapters shall remain connected to the launch and tail cords. If the cabling under test is a permanent link as defined in 8.1, these adapters shall remain connected to the field calibration cord.

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 field calibration cord or adapter replacement due to degradation. Sufficient time should be given for stabilization of laser sources during any repeated reference power measurement.

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

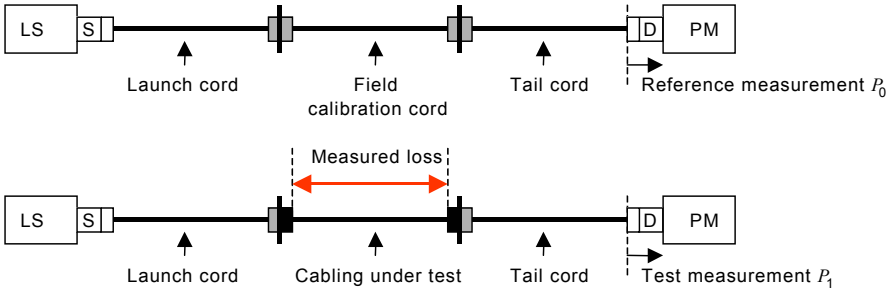
The cabling under test shall be connected between the launch and tails cords and the test measurement, P_1, shall be recorded in watts or decibel metres.

For permanent links comprising a single fixed cable and terminating connectors it is required to test in one direction only.

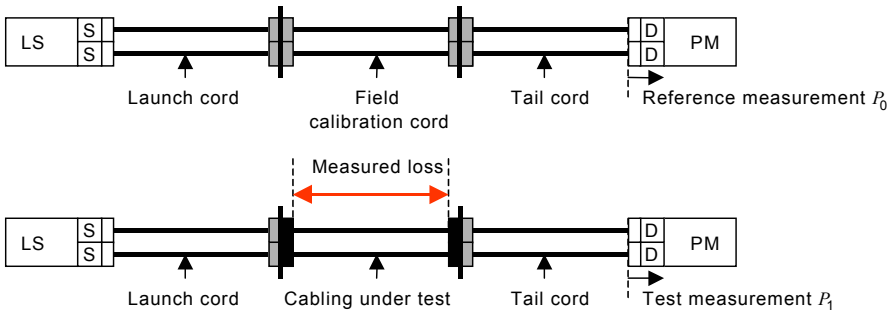
Where the permanent link or channel is of more complex construction, or where there is a risk that components within the cabling under test cause differences in the attenuation depending on the direction of transmission, bi-directional measurements shall be carried out.

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Simplex light source and power meter test configuration

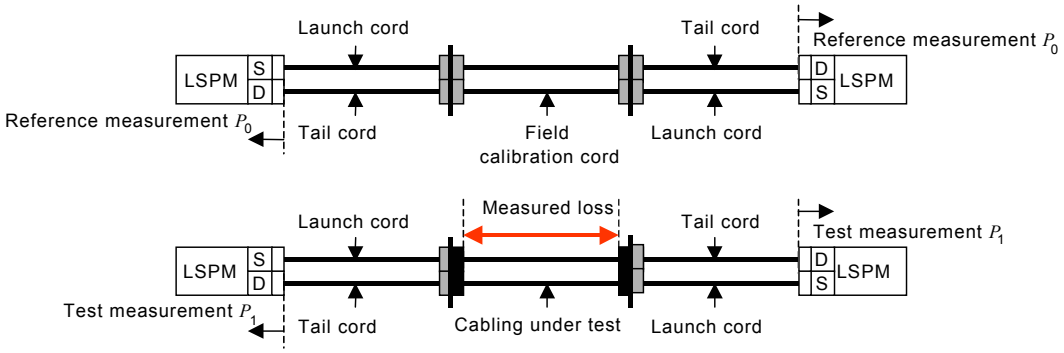


Duplex uni-directional light source and power meter test configuration



The launch and tail cords may take any of the forms shown in Figure 5.

Duplex bi-directional light source and power meter test configuration



The launch and tail cords may take any of the forms shown in Figure 5.

Figure 9 – LSPM 3-jumper attenuation measurement of installed cabling

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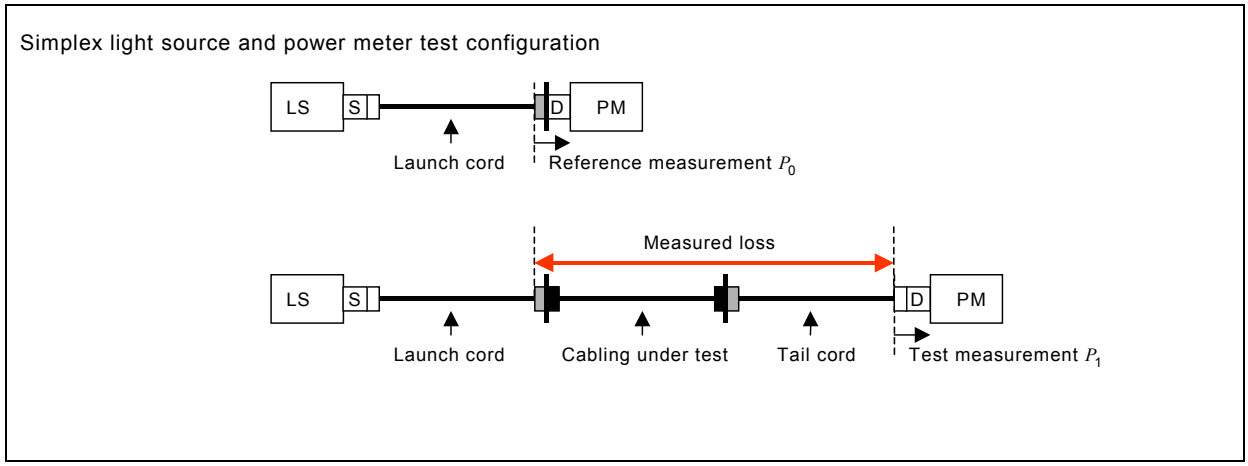


Figure 10 – LSPM 1-jumper attenuation measurement of installed link

9.1.1.3 Test result

For a given wavelength and in a given direction, measured loss is calculated using P_0 and P_1 as follows:

$$L = P_0 - P_1 \quad \text{(dB)} \tag{1}$$

where P_1 and P_0 are expressed in decibel metre.

If P_1 and P_0 are expressed in W, then the measured loss can be calculated as follows:

$$L = -10\log_{10}\left(\frac{P_1}{P_0}\right) \quad \text{(dB)} \tag{2}$$

In the case of bi-directional results the higher of the two measured results shall be considered as the overall measured result.

9.1.1.4 Test system measurement uncertainty

The measured attenuation/insertion loss of a channel or permanent link is effected by the alignment of the two optical fibres on either side of the test interfaces. The test method of 9.1.1.2 replaces the field calibration cord with the cabling under test and introduces an unavoidable measurement uncertainty that is twice that of the worst case variation for a single connection.

The use of test cords with reference connectors as required by this International 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 cabling under test:

- for MMF, the worst case insertion loss of a MMF connection against a multimode reference termination;
- for SMF, the worst case insertion loss of a SMF connection against a single-mode reference termination.

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

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Table 4 – Connecting hardware insertion loss

	MMF		SMF	
Connecting hardware	Insertion loss (random mated)	Insertion loss (mated against reference)	Insertion loss (random mated)	Insertion loss (mated against reference)
IEC 60874-19-1	0,75 dB max.	0,3 dB max.		
IEC 60874-14-2			0,75 dB max.	0,5 dB max.

6.3.2 and Table 3 define requirements for the maximum insertion loss of a connection of two reference terminations.

9.1.1.5 Treatment of channel test results

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

9.1.1.6 Treatment of permanent link test results

The use of a single test method as defined in 9.1.1.2 which excludes the permanent link connections requires the permanent link limits to be modified, as detailed in 9.1.1.6.

Comparison of the measured loss in Figure 9 and the permanent link reference planes in 8.1 shows that the attenuation/insertion loss limit defined for the permanent link in ISO/IEC 11801 or equivalent standards shall be the sum of the specified maximum attenuation values for the

- connections at the interfaces to the cabling under test, with a maximum allowance as specified when mated to a reference connector,
- embedded connections within the cabling under test,
- 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 the measured result shall be termed a pass, a fail or a marginal result.

9.1.2 OTDR

9.1.2.1 Test method

A launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) shall be connected between the OTDR and the cabling under test. A tail cord in accordance with 6.3.3.7 (MMF) or 6.3.4.7 (SMF) shall be connected to the remote end of the cabling under test.

The OTDR/optical source shall be selected for the mode/wavelength as defined in Annex C and the appropriate settings established for hockey as it is its assistance in his:

- range;
- pulse width;
- IOR;
- averaging time.

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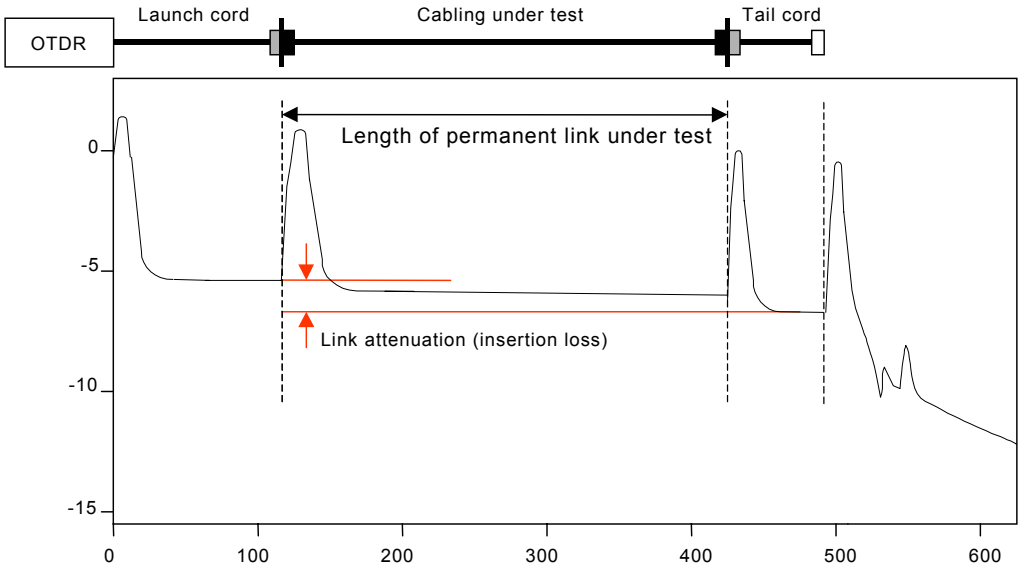


Figure 11 – OTDR measurement of installed cabling (permanent link)

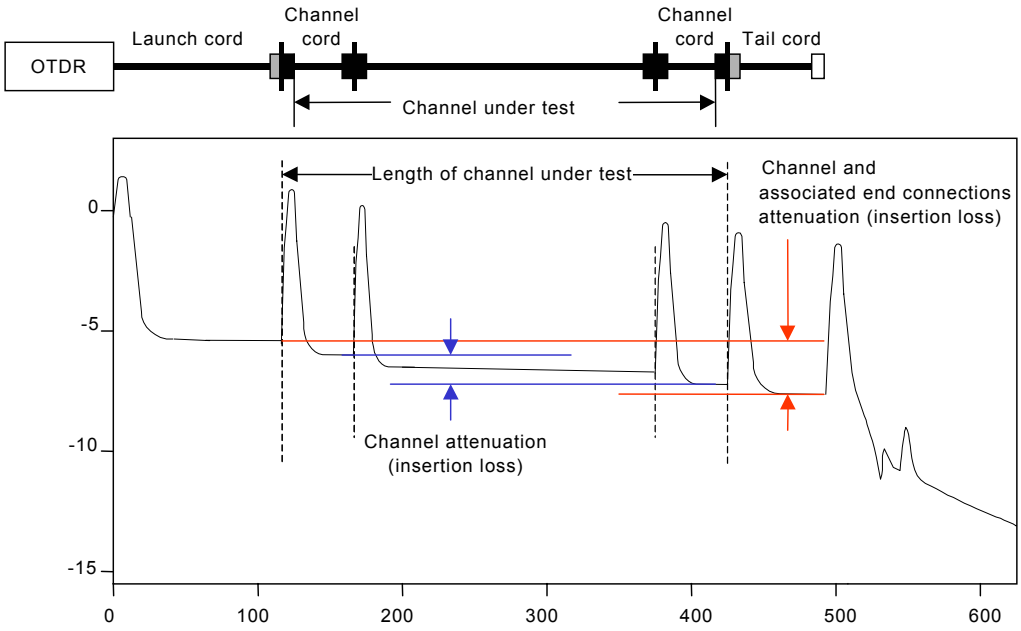


Figure 12 – OTDR measurement of installed cabling (channel)

9.1.2.2 Test system measurement uncertainty

The measured attenuation/insertion loss of a channel or permanent link to this is effected 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 cabling under test:

- for MMF, the worst case insertion loss of a MMF connection against a reference termination;

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- for SMF, the worst case insertion loss of a SMF connection against a single-mode reference termination.

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

9.1.2.3 Treatment of channel test results

Figure 12 shows the points at which the attenuation/insertion loss of the installed cabling shall be measured. It should be noted that if patch cord is shorter than attenuation dead zone, multiple events may not be individually discernable.

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.

The result for channel attenuation/insertion loss 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 and tail cords have the same scattering characteristics.

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

9.1.2.4 Treatment of permanent link test results

Figure 11 shows the points at which the attenuation/insertion loss of the installed cabling shall be measured.

The result for permanent link attenuation/insertion loss 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 and tail cords have the same scattering characteristics.

Comparison of the measured loss in Figure 9 and the permanent link reference planes in 8.1 shows that the attenuation/insertion loss limit defined for the permanent link within ISO/IEC 11801 or equivalent standards shall be the sum of the specified maximum attenuation values for the

- attenuation/insertion loss (mated against reference) for the interface connections at the interfaces to the cabling under test,
- embedded connections within the cabling under test,
- 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 or fail result should be indicated with reference to the measured result.

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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. The propagation delay can be calculated using a typical delay of 5,0 ns/m.

9.2.2 Treatment of results

Where compliance with a specified value is required a pass or fail 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 (i.e. an OTDR) (see 9.2.1).

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.

NOTE 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.

10 Testing of cabling components within installed cabling

10.1 Attenuation/insertion loss (optical fibre cable)

10.1.1 Test method

In order to test a channel or permanent link (see 8.1), a launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) shall be connected between the OTDR and the cabling under test.

In order to test an unterminated optical fibre, a launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

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

- range,
- pulse width,
- IOR,
- 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.

Alternatively, 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 13 shows the points at which the attenuation/insertion loss of the optical fibre within the cabling under test shall be measured.

The result may be provided as a simple loss value (in decibel) or as an attenuation coefficient (in decibel per kilometre).

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

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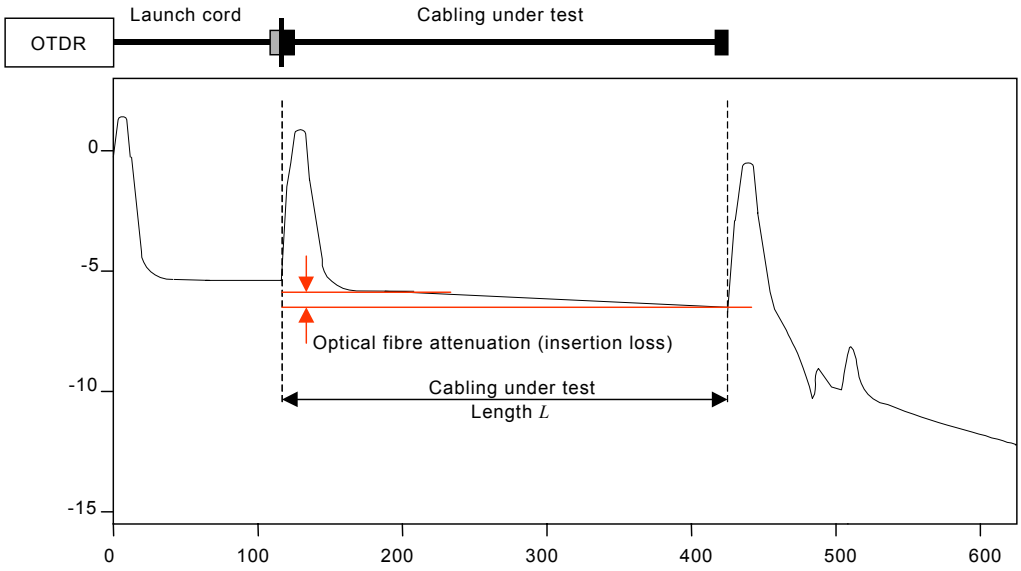


Figure 13 – OTDR measurement of optical fibre attenuation

10.2 Attenuation/insertion loss (local and remote test interfaces)

10.2.1 Test method

A launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) shall be connected between the OTDR and the cabling under test. A tail cord in accordance with 6.3.3.7 (MMF) or 6.3.4.7 (SMF) shall be connected to the remote end of the cabling under test.

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

- range,
- pulse width,
- IOR,
- averaging time.

The cabling under test shall be measured in both directions.

10.2.2 Test system measurement uncertainty

The measured attenuation/insertion loss 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 international 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

- for MMF, the worst case insertion loss of a MMF connection against a multimode reference termination,
- for SMF, the worst case insertion loss of a SMF connection against a single-mode reference termination.

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

10.2.3 Treatment of results

Figure 14 shows the points at which the attenuation/insertion loss of the interfaces to the cabling under test shall be measured. The installed cabling may be either a channel or a permanent link (see 8.1). 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.

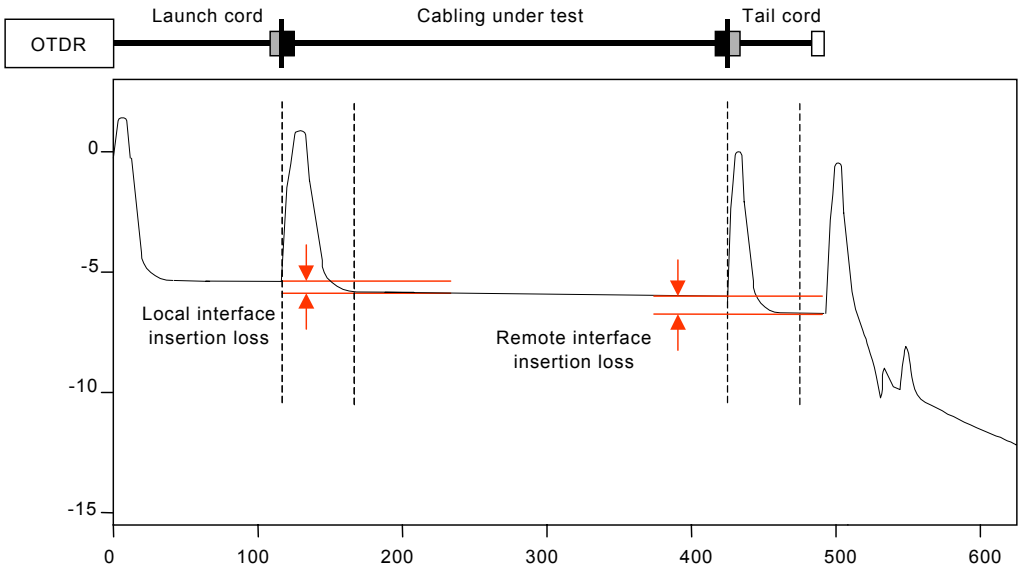


Figure 14 – OTDR measurement of interface insertion loss

The insertion loss 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 cord and the cabling under test. If the backscatter coefficient of the launch cord is higher than that of the cabling under test then the result will be overstated. If the scattering coefficient of the cabling under test is higher than that of the launch cord then the result will be understated (sometimes, but very rarely, producing an apparent amplification).

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 insertion loss (mated against reference). See Table 4.

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

10.3 Insertion loss (connecting hardware)

10.3.1 Test method

In order to test a channel or permanent link (see 8.1), a launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) shall be connected between the OTDR and the cabling under test.

In order to test connecting hardware within an unterminated optical fibre, a launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

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

- range,
- pulse width,
- IOR,
- averaging time.

The cabling under test shall be measured in both directions.

10.3.2 Treatment of results

Figure 15 shows the points at which the insertion loss of connecting hardware 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 scattering 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 marginal result should be indicated with respect to the measured result.

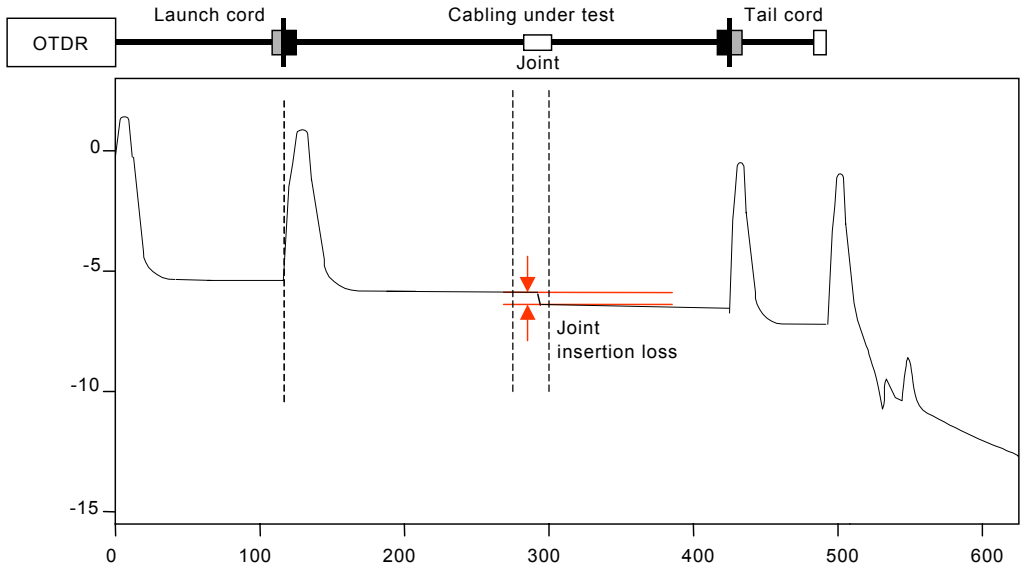


Figure 15 – OTDR measurement of joint insertion loss

10.4 Return loss (connecting hardware)

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

A launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) shall be connected between the OTDR and the cabling under test.

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If the return loss of the remote connection in the cabling under test is to be measured then a tail cord in accordance with 6.3.3.7 (MMF) or 6.3.4.7 (SMF) 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 cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) 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.

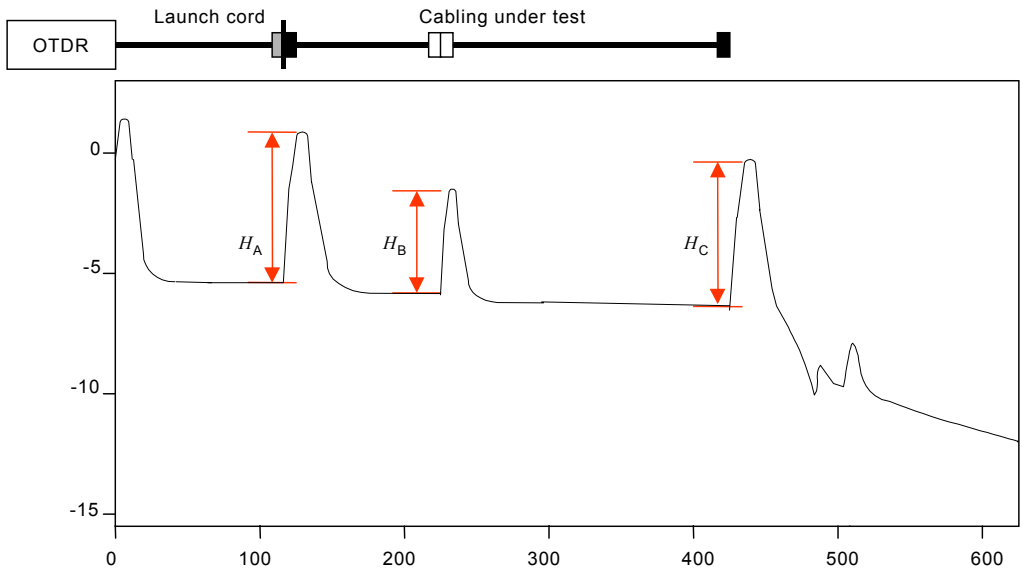


Figure 16 – OTDR measurement of return loss

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 16) as follows:

$$RL = -10 \cdot \log_{10}\left(10^{H/5} - 1\right) - 10 \cdot \log_{10} d + k \qquad \text{(dB)} \qquad (3)$$

where H > 5 dB

$$RL \approx 2 \cdot H - 10 \cdot \log_{10} d + k \qquad \text{(dB)} \qquad (4)$$

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 scattering 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.

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NOTE 2 The detector in some OTDRs saturates at large values of H (as shown in H_C in Figure 16) 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.

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

10.4.3 Measurement uncertainty

Different sources of uncertainties shall be considered in reflectance measurement.

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 directly impact the reflectance 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 8.1), a launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) shall be connected between the OTDR and the cabling under test.

In order to test an unterminated optical fibre, a launch cord in accordance with 6.3.3.6 (MMF) or 6.3.4.6 (SMF) but without a test interface connector shall be connected between the OTDR and the optical fibre under test.

The OTDR/optical source shall be selected for the mode/wavelength as Annex C and the appropriate settings established for

- range,
- pulse width,
- IOR,
- averaging time.

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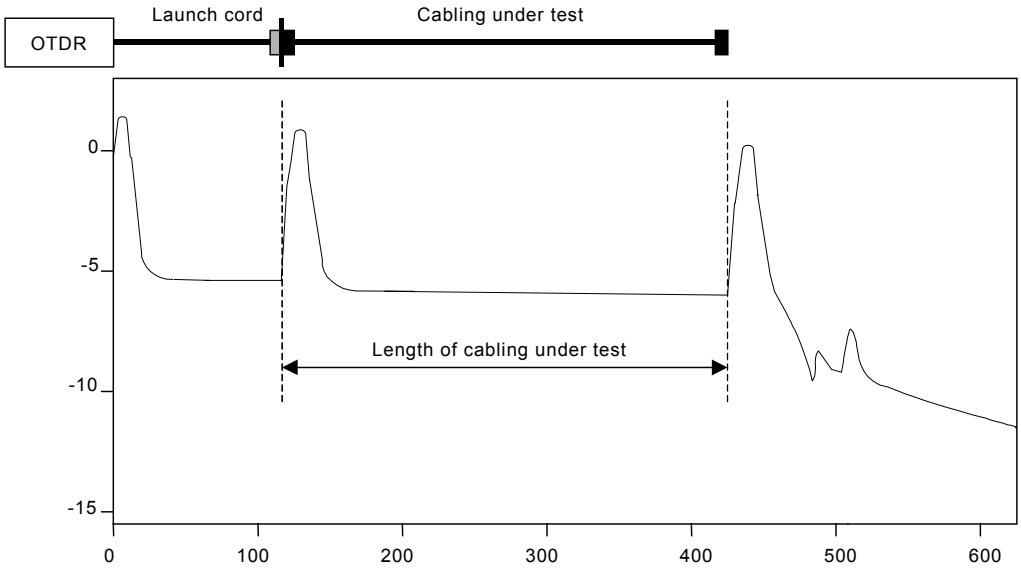


Figure 17 – Determination of length using an OTDR

Figure 17 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 8.1).

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 18, a break in a SMF may not always be characterized by a reflection peak.

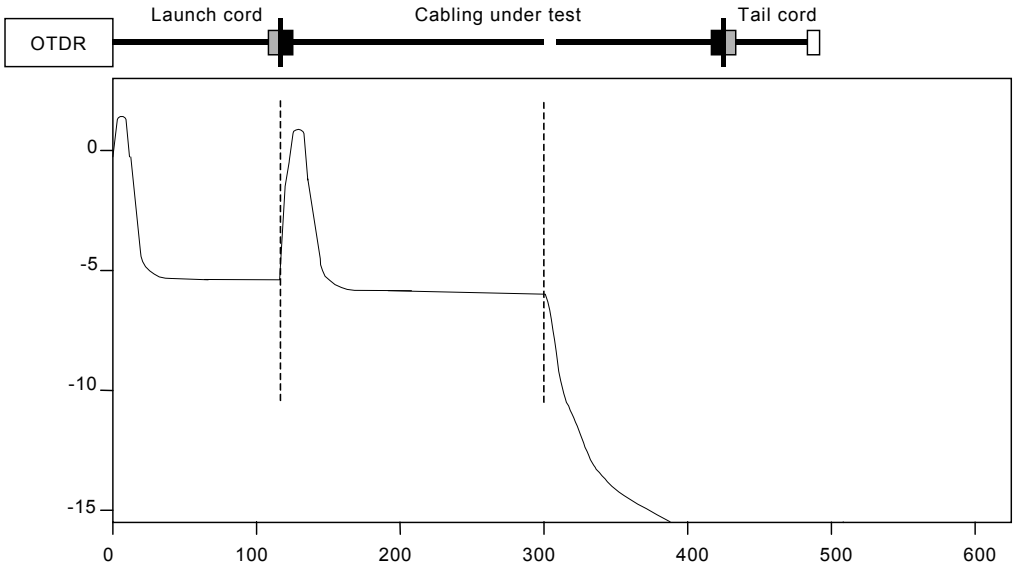


Figure 18 – OTDR characterization of a SMF permanent link containing a break

An installation error (e.g an installed cable bend radius below 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 an step change in attenuation on the OTDR trace (see Figure 19).

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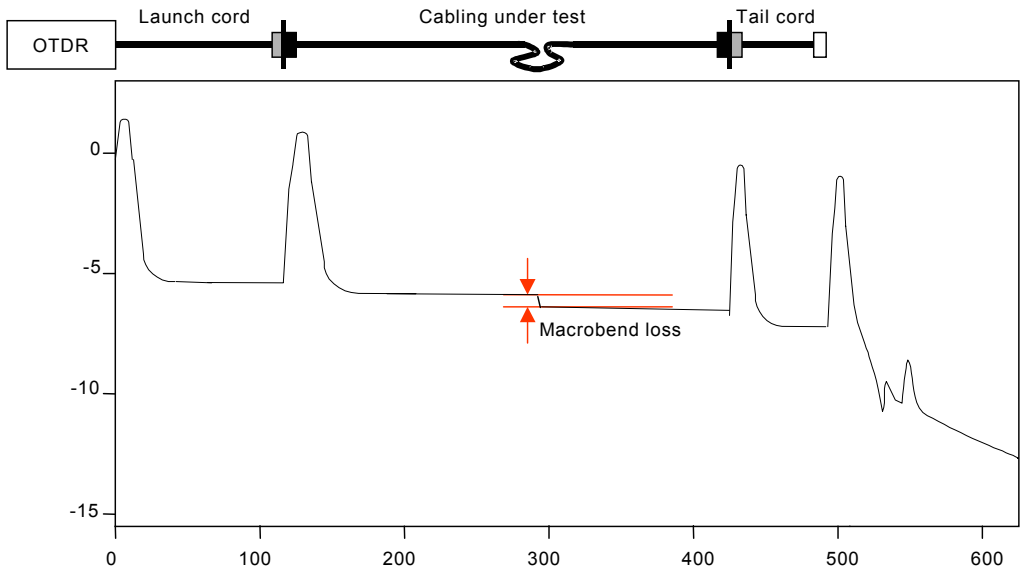


Figure 19 – OTDR characterization of an permanent link containing a macrobend

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).

NOTE 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/insertion loss (cords)

10.6.1 Test method

For MMF, the normalisation process requires a reference measurement as shown in Figure 20 to be made between the light source and power meter by the connection of a launch cord in accordance with 6.3.3.2 (or 6.3.3.4).

For SMF, the normalisation process requires a reference measurement as shown in Figure 20 to be made between the light source and power meter by the connection of a launch cord in accordance with 6.3.4.2 (or 6.3.4.4).

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

The reference measurement, P_0, shall be recorded in watts or decibel metres.

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 field calibration cord or adapter replacement due to degradation. Sufficient time should be given for stabilization of laser sources during any repeated reference power measurement.

The launch cord shall remain connected to the light source.

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

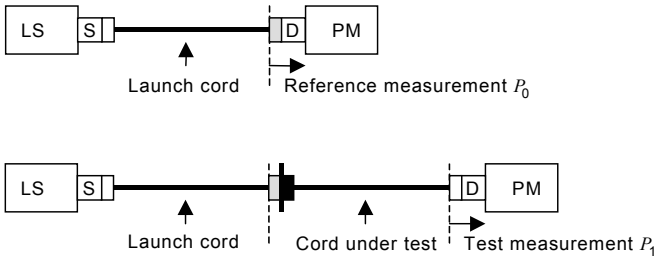


Figure 20 – Measurement of cord interface attenuation/insertion loss

10.6.2 Treatment of results

For a given wavelength, the measured loss is calculated using P_0 and P_1 as follows:

$$L = P_0 - P_1 \quad \text{(dB)} \tag{5}$$

where P_1 and P_0 are expressed in decibel metre.

If P_1 and P_0 are expressed in watts, then the measured loss can be calculated as follows:

$$L = -10\log_{10}\left(\frac{P_1}{P_0}\right) \quad \text{(dB)} \tag{6}$$

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

10.7 Return loss (cords)

See IEC 61300-3-6, method 1.

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 cord is used. Verification of continuity of an optical fibre shall be documented using a visible light source.

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11.2 Cabling polarity

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

11.3 Optical fibre cable length

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.

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Annex A
(normative)

Launched modal distribution (LMD)

A.1 Distribution of optical power within a MMF

Optical power is transmitted along a MMF in distinct paths called modes. Modes are arranged in Mode Groups ranging from Mode Group 01 to XX where the total number of mode groups (XX) depends upon

- the design of the optical fibre,
- the wavelength of transmission,
- the number of modes per mode group is proportional to the mode group number.

The relative amount of power in each mode at the point of connection of the test source to the cabling or component under test is critical to the consistency and uncertainty of the measurements.

There are two independent metrics used within this standard for determining the launch condition. The first one is based upon a measurement of the mode transfer function (see A.2) and is called the Modal Power Distribution (MPD) as defined in A.3, the second is called the Coupled Power Ratio (CPR) and is defined in A.4. Requirements of both metrics shall be fulfilled.

These are measured at the output end of a launch cord attached to the test source. The launch cord contains optical fibre of the same type used in the cabling or component under test.

The mode transfer function (presented as MPD) is the definitive metric for determining the compliance of the launch condition. MPD is measured with near-field measurement equipment, usually under laboratory conditions. The CPR should only be considered as a simple means of checking the launch in the field to get an approximate indication of its launch condition.

A.2 Modal transfer function

The near field radiation pattern of the output end of a patch cord attached to the source shall be measured according to the procedure defined in IEC 60793-1-20. The derivative of the near field with respect to radial position shall be calculated as defined in IEC/PAS 61300-3-43, but without dividing the result by a reference data set. The resultant Mode Transfer Function (MTF) indicates the power distribution amongst all the modes, m.

A sample MTF is shown in Figure A.1. The information is normalised to display on vertical and horizontal scales that span from 0 to 1.

This information is converted to MPD in order to establish compliance limits in a way that is meaningful to loss measurements while affording flexibility in meeting the requirements with various launch conditions.

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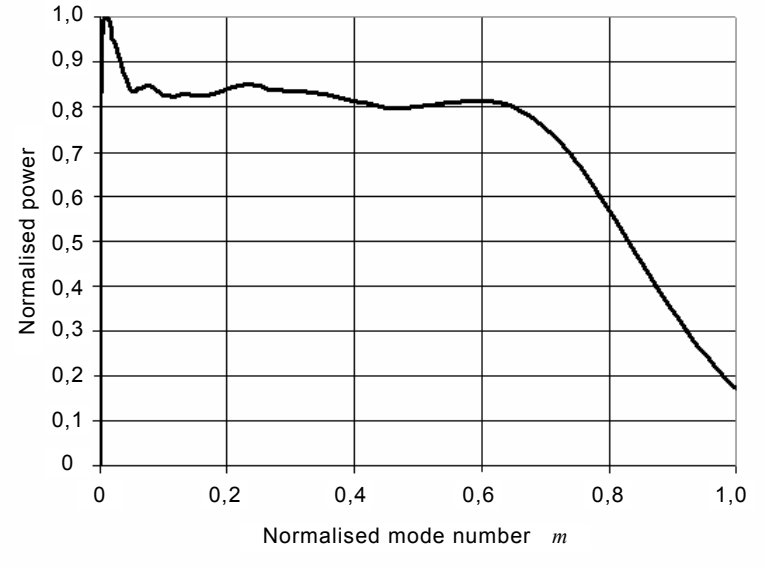


Figure A.1 – Example of a characteristic MTF

A.3 MPD (modal power distribution)

A.3.1 General

The MPD is a graphical representation of the relative power in each of the mode groups within a MMF as shown in Figure A.2.

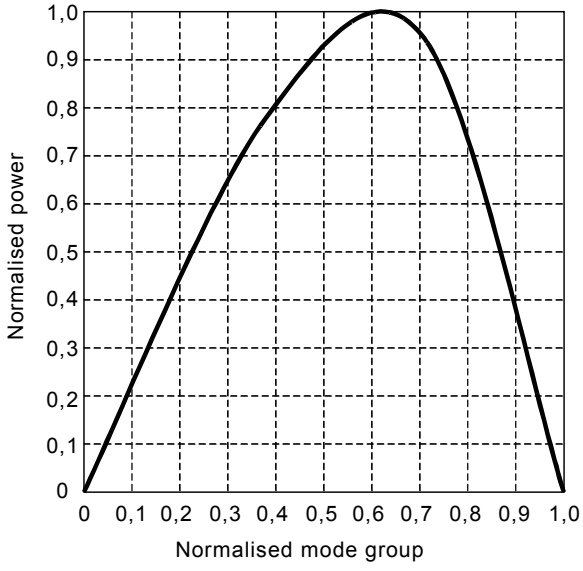


Figure A.2 – Example of a characteristic MPD

The normalised mode group (x-axis) represents the mode group as a fraction of the highest mode group number.

For a 50/125 μm OM2 MMF (as defined in ISO/IEC 11801):

- at 850 nm there are approximately 19 mode groups, for example a NMG value of 0,42 represents a mode group number of 08,

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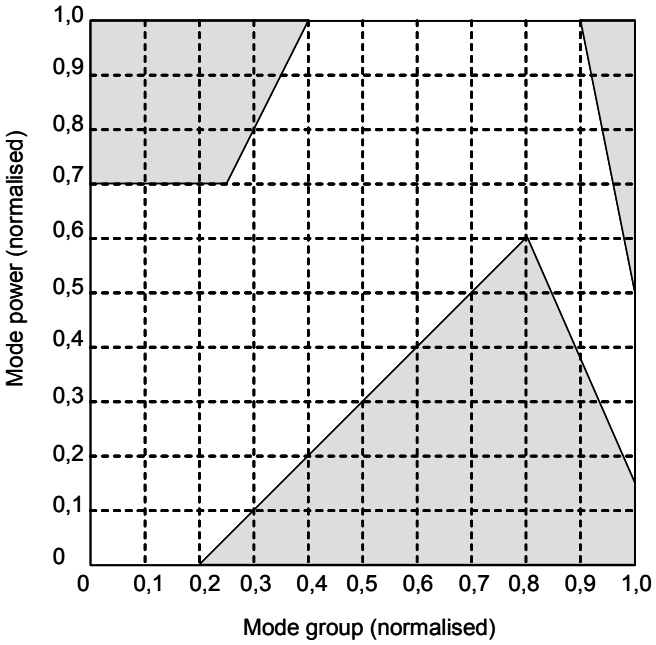
- at 1 300 nm there are approximately 12 mode groups, for example a NMG value of 0,42 represents a mode group number of 05.

For a 62,5/125 µm OM1 MMF (as defined in ISO/IEC 11801):

- at 850 nm there are approximately 31 mode groups, for example a NMG value of 0,42 represents a mode group number of 13.
- at 1 300 nm there are approximately 19 mode groups, for example a NMG value of 0,42 represents a mode group number of 08.

A.3.2 Requirements

The MPD shall meet the requirements of Figure A.3, based on IEC/PAS 61300-3-43.



Template (x,y) coordinates
Upper left keepout: (0,0; 1,0) (0,4; 1,0) (0,25; 0,7) (0,0; 0,7)
Lower keepout: (0,2; 0,0) (0,8; 0,6) (1,0; 0,15) (1,0; 0,0)
Upper right keepout: (0,9; 1,0) (1,0; 1,0) (1,0; 0,5)

Figure A.3 – MPD (modal power distribution) specification

A.4 CPR (coupled power ratio)

A.4.1 General

The CPR coefficient is a measure of the relative power contained in mode group 01 as a fraction of the total power at the point of connection to the cabling or component under test. CPR measurements are easy to perform and give quantitative, repeatable results.

The CPR measurement may be applied either to a light source, via a test cord as detailed in A.4.3 or to a launch cord attached to a light source in accordance with 6.3.3.2, 6.3.3.4 or 6.3.3.6.

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A.4.2 Test system

A.4.2.1 Power meter

The preferred power meter parameters for multimode detectors type D1 are given in IEC 61300-3-4.

A.4.2.2 MMF CPR test cord

Each test cord shall

- contain optical fibre of the same nominal characteristics (core/cladding diameters, numerical aperture) as the optical fibre for which CPR is to be determined,
- be approximately 2 m in length,
- be terminated at one end with one or more connectors suitable for attachment to the light source for which CPR is to be determined,
- be terminated at the other end with one or more reference connectors compatible with the interface to the SMF CPR tail cord,
- have coatings that strip cladding light,
- be labelled with a unique identifier with each connector labelled as indicated in Figure 5.

A.4.2.3 SMF CPR tail cords

Each test cord shall

- be approximately 2 m in length,
- terminated at one end with one or more connectors suitable for attachment to the power meter,
- terminated at the other end with a single-mode connector compatible with the launch cord (or MMF CPR test cord, as appropriate),
- have coatings that strip cladding light,
- be labelled with a unique identifier with each connector labelled as indicated in Figure 5.

The cords shall contain optical fibre that has single-mode behaviour at the wavelength at which the CPR is to be determined. These fibres should have a mode field diameter of 9,0 μm ±1,0 μm for 1 300 nm (in accordance with IEC 60793-1-45 Type B1.1) and 5,0 μm ± 0,5 μm for 850 nm.

A.4.2.4 Connecting hardware

It is assumed that the connecting hardware will provide an insertion loss <0,5 dB in the relevant wavelength band (λ = 1 300 nm and λ = 850 nm), as measured by IEC 61300-3-4, insertion method (B).

A.4.3 Test method

A.4.3.1 Pre-conditioning

Any connecting hardware adapters used together with all connector end-faces on the test cords and the cabling under test shall be cleaned according to the instructions provided by the manufacturer of the interfaces. This shall be repeated every time a test cord is connected to the cabling or component under test.

Suitable materials for the cleaning of connectors (such as 98 % reagent grade alcohol and clean compressed air) shall be available and shall be used in accordance with suppliers' instructions.

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A.4.3.2 Measurements

The light source and power meter shall be connected by either the launch cord for which the determination of the CPR is to be made or a MMF CPR test cord in accordance with A.4.2.2. The cord shall be deployed in such a way as to minimize changes in deployment during the test which could affect the modal power distribution. Bend radii of less than 50 mm shall be avoided.

The measurement, P_0 , shall be recorded in watts or decibel metres.

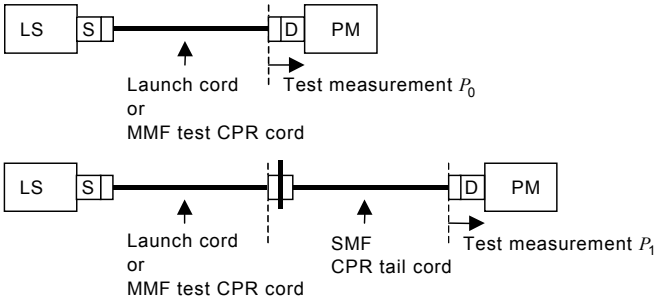


Figure A.4 – CPR measurement method

The cord shall be disconnected from the power meter and the SMF CPR tail cord inserted. The SMF cord shall be deployed with two loops of between 35 mm to 50 mm in diameter.

The measurements, P_0 and P_1, shall be recorded in watts or decibel metres.

For a given wavelength and in a given direction, the measured CPR is calculated using P_0 and P_1 as follows:

$$CPR = P_0 - P_1 \quad \text{(dB)} \tag{A.6}$$

where P_1 and P_0 are expressed in decibel metres.

If P_1 and P_0 are expressed in watts, then the measured loss can be calculated as follows:

$$CPR = -10\log_{10}\left(\frac{P_1}{P_0}\right) \quad \text{(dB)} \tag{A.7}$$

A.4.3.3 Requirements for 62,5/125 MMF

In the 850 nm wavelength region defined in Table 1 the LMD shall meet the following requirements:

- a *CPR* of 25,5 dB ±0,5 dB;

In the 1 300 nm wavelength region defined in Table 1 the LMD shall meet the following requirements:

- *CPR* of 21,5 dB ± 0,5 dB.

A.4.3.4 Requirements for 50/125 MMF

In the 850 nm wavelength region defined in Table 1 the LMD shall meet the following requirements:

- a *CPR* of 20,5 dB ±0,5 dB.

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In the 1 300 nm wavelength region defined in Table 1 the LMD shall meet the following requirements

- *CPR* of 16,5 dB ± 0,5 dB.

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Annex B
(normative)

Visual inspection criteria for connectors

B.1 Connector end-face definitions

B.1.1 General

The condition of the connector end-faces is a significant factor in the long term operation of the network. This annex defines recommended requirements for the inspection of terminated optical fibres.

B.1.2 End-face zone definitions

With reference to Figure B.1 the connector end-face is subdivided into a core region and a cladding region.

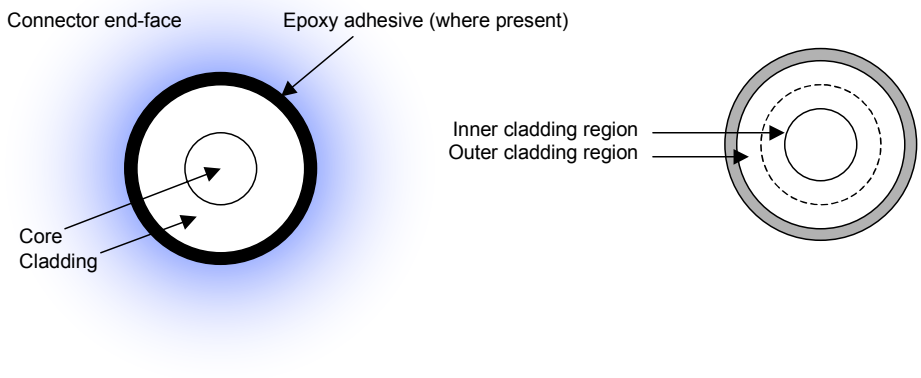


Figure B.1 – Connector end-face region definitions

For inspection purposes the cladding region is further sub-divided into imaginary inner and outer regions as shown in Figure B.1 and as defined in Table B.1.

Table B.1 – Connector end-face regions

Optical fibre design µm	Core diameter µm	Inner cladding diameter µm	Outer cladding diameter µm
SM	8 to 10	58	125
50/125	50	88	125
62,5/125	62,5	94	125

B.1.3 Modified inspection criteria

The subdivision of cladding regions defined in B.1.2 reflects a basic industry specification that has been proven to provide products of satisfactory operational lifetime. Modified standards may be adopted following their definition within an installation specification and quality plan.

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B.2 Inspection of terminated optical fibre

B.2.1 General

The connector end-faces shall be subjected to visual inspection using a microscope as defined in 7.1 and shall meet the following visual standards providing a finished product capable of meeting the specified system lifetime. See IEC 61300-3-1 for details of visual inspection.

B.2.2 Scratch and pit defects

Inspection shall be carried out under front illumination conditions.

The core region shall not exhibit scratches and pits that exceed the requirements of Table B.2 while using the surface finishing techniques recommended by the manufacturers of the connectors used.

Table B.2 – Requirements for visual end-face inspection

	MMF (100× magnification)	SMF (200× magnification)
Number of scratches (max.)	10 (between 2,0 µm and 5,0 µm)	2 (≤3,0 µm)
	0 (>5,0 µm)	0 (>3,0 µm)
Number of pits/chips (max.)	10 (between 2,0 µm and 5,0 µm)	2 (≤3,0 µm)
	0 (>5,0 µm)	0 (>3,0 µm)

Note It is assumed that, at the required magnification, phenomena within the size ranges in Table B.2 are easily visible. The size of the phenomenon can be approximated by comparison to the visible core diameter.

B.2.3 Chip defects

Inspection for chip defects shall be carried out under front illumination conditions.

The core region and the inner cladding region shall be free from defects (either as flaws within the fibre or cracks intersecting the surface).

The outer cladding region shall be free from defects that extend for more than 25 % of the cladding circumference (either as flaws within the fibre or cracks intersecting the surface). Refer to Figure B.2.

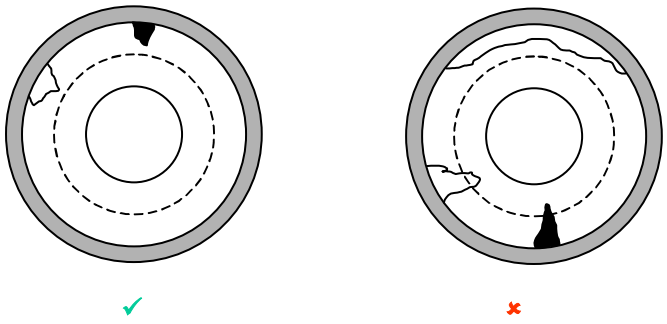


Figure B.2 – Polishing defects and cracks

B.2.4 Cracks

Where possible, inspection shall be carried out using both front and rear illumination conditions. Cracks are not permitted in the core or clad.

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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

- the dynamic range,
- the averaging duration,
- the laser pulse width.

These parameters define respectively

- the capability of an OTDR to display a large attenuation of cabling,
- the number of fibre links that can be characterised in a given period of time,
- the minimum distance between two characterised evens 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

- when the laser pulse power increases
- when the effective pulse width increases,
- when the noise level decreases (e.g. when the measurement duration 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.

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C.2 Limitations of OTDR capability

C.2.1 Minimum lengths of operation

C.2.1.1 Attenuation dead zone

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

Figure C.1 shows the same permanent link tested using a 3 m (upper diagram) and a 500 m (lower diagram) launch 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 cord is linear. This latter factor suggests that an effective characterization of the local interface loss may be made.

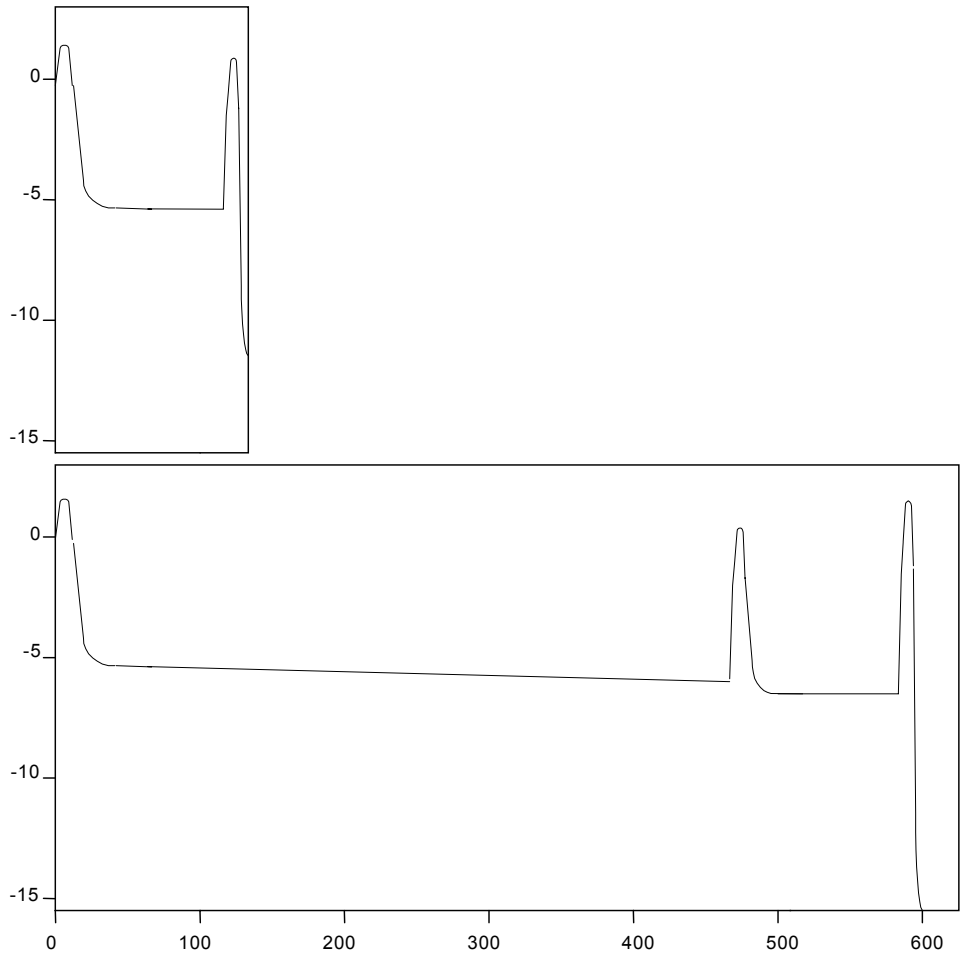


Figure C.1 – OTDR characterization using different length launch cords

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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.

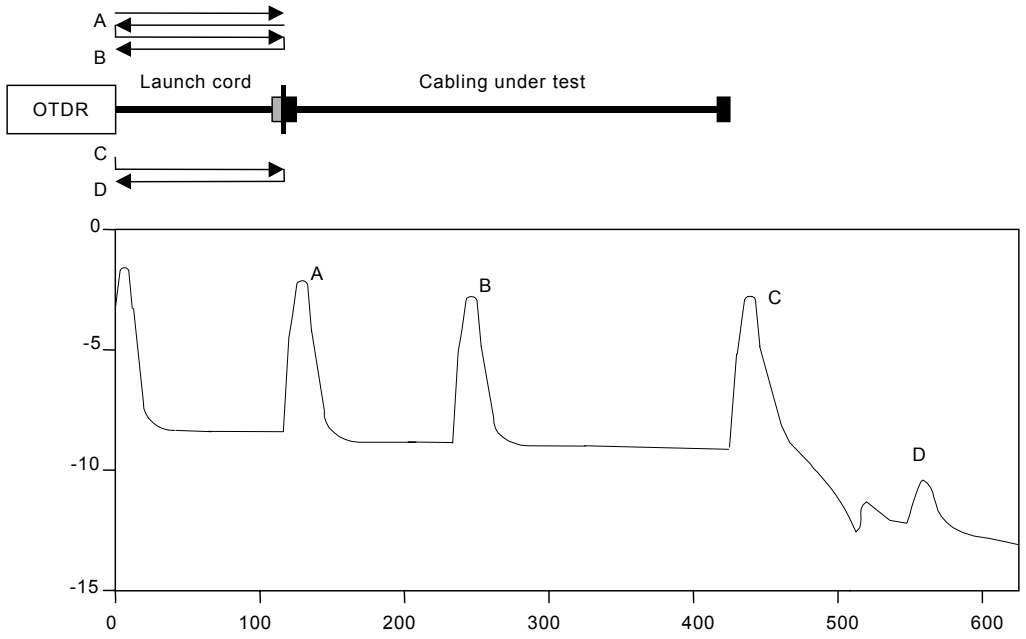


Figure C.2 – OTDR characterization showing ghost effects

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 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.

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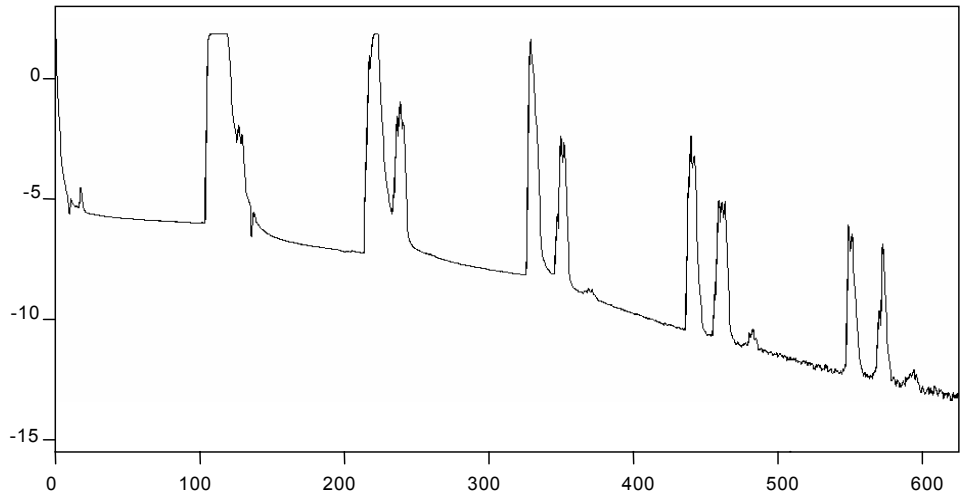


Figure C.3 – OTDR characterization showing complex ghost effects

C.2.3 Effective group index of refraction (IOR)

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 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 Scattering coefficient

The use of the correct scattering coefficient is important for the accurate measurement of return loss. Where the scattering coefficient is not automatically measured and used by the OTDR the values shown in Table C.2 may be considered as typical.

Table C.2 – Default scattering 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	–	–

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Annex D
(normative)

Inspection and testing of test and field calibration cords

D.1 General requirements

A launch, field calibration or tail cord is functioning properly provided that

- the connector end-faces meet the inspection requirement of Annex B,
- the reference connector(s) at the end of the cord perform(s) according to specification,
- the cordage performs according to its specification.

D.2 Insertion loss (test and field calibration cord reference connections)

For MMF, the normalisation 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 cord in accordance with 6.3.3.2 (or 6.3.3.4).

For SMF, the normalisation 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 cord in accordance with 6.3.4.2 (or 6.3.4.4).

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 field calibration cord or adapter replacement due to degradation. Sufficient time should be given for stabilization of laser sources during any repeated reference power measurement.

The measurement, P_0 shall be recorded in watts or decibel metres.

The launch cord shall remain connected to the light source. The reference connector on the field calibration, tail or other launch cord under test shall be connected between the launch cord and the power meter and the test measurement, P_1, shall be recorded in watts or decibel metres.

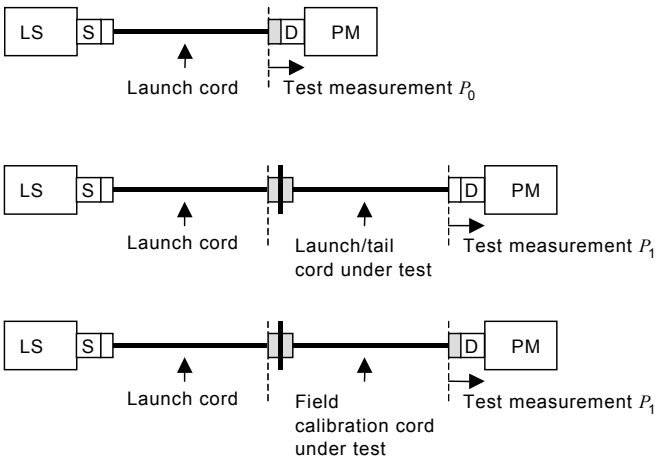


Figure D.1 – Measurement of field calibration cord interface attenuation/insertion loss

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For a given nominal wavelength, the measured loss is calculated using P_0 and P_1 as follows:

$$L = P_0 - P_1 \quad \text{(dB)} \tag{D.1}$$

where P_1 and P_0 are expressed decibel metres.

If P_1 and P_0 are expressed in watts, then the measured loss can be calculated as follows:

$$L = -10\log_{10}\left(\frac{P_1}{P_0}\right) \quad \text{(dB)} \tag{D.2}$$

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.

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Annex E
(informative)

3-jumper method for link and channel attenuation

The 3-jumper method constitutes the default test method for the attenuation measurement of links and channels.

This method is generic and can be used for measuring the attenuation of both channels and links regardless of the type of connector interface on cabling and equipment.

Although the correct connector types on the equipment side of the launch and tail cords may be chosen, the connector type on the connector interface of the light source and power meter may be different from each other and/or from the connector on the installed cabling.

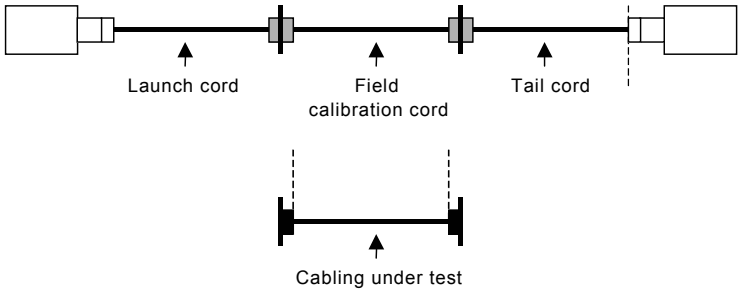


Figure E.1 – Example of cabling and test cord configuration with 3-jumper test method

Even in those cases where there are different connector interfaces on each end of the installed cabling, use of the 3-jumper method enables attenuation measurement by choosing the same connectors used on the field calibration cord. Care should be taken to ensure that the connectors on the field calibration cord are of reference quality.

This test method can also facilitate the testing of links and channels containing duplex connector interfaces.

This document permits the use of the 1-jumper method for link and channel measurements only when the connector type on the cabling under test is the same as the connector type on the power meter.

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Annex F
(informative)

Quality planning

F.1 Inspection and test schedules

This International Standards defines two test stages:

- stage 1, tests applied to cabling components prior to installation of permanent links;
- stage 2, tests applied to installed channels and permanent links.

Stage 2 tests are grouped into

- basic tests,
- 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 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:

- optical fibre attenuation/insertion loss in accordance with 10.1;
- optical fibre length (and/or propagation delay) in accordance with 10.5;
- inter-component length in accordance with 10.5;
- embedded connecting hardware attenuation/insertion loss in accordance with 10.3;
- embedded connecting hardware return loss in accordance with 10.4;
- cord characteristics in accordance with 10.6 and 10.7;
- continuity in accordance with 11.1;
- maintenance of polarity in accordance with 11.2.

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

- optical fibre cable length in accordance with 11.2;
- continuity in accordance with 11.1;
- maintenance of polarity in accordance with 11.2.

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F.3 Stage 2 testing

F.3.1 Basic test group

Tests included in the basic test group are:

- channel or permanent link attenuation/insertion loss in accordance with 9.1.1;
- channel or permanent link propagation delay in accordance with 9.2;
- channel or permanent link length in accordance with 9.3;
- continuity in accordance with 11.1;
- maintenance of polarity in accordance with 11.2.

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:

- channel or permanent link attenuation/insertion loss in accordance with 9.1.2;
- channel or permanent link propagation delay in accordance with 9.2;
- optical fibre length in accordance with 10.5;
- optical fibre attenuation/insertion loss in accordance with 10.1;
- local and remote interface attenuation/insertion loss in accordance with 10.2;
- local and remote interface return loss in accordance with 10.4;
- embedded connecting hardware attenuation/insertion loss in accordance with 10.3;
- embedded connecting hardware return loss in accordance with 10.4;
- continuity in accordance with 11.1;
- maintenance of polarity in accordance with 11.2.

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ISBN 2-8318-8693-7



ICS 35.200

Typeset and printed by the IEC Central Office
GENEVA, SWITZERLAND

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