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REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Fibre- optic communication subsystem test procedures – Part 4-2: Installed ~~cable~~ cabling plant – Single-mode attenuation and optical return loss measurements

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FIBRE-OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-2: Installed ~~cable~~ cabling plant – Single-mode attenuation and optical return loss measurements

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 61280-4-2:2014. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 61280-4-2 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is an International Standard.

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

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

a) addition of the equipment cord method;
b) addition of test limit adjustment related to test cord grades;
c) refinements on measurement uncertainties.

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

Draft	Report on voting
86C/1912/FDIS	86C/1916/RVD

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

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

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61280 series, published under the general title *Fibre optic communication subsystem test procedures*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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

INTRODUCTION

~~This second edition of IEC 61280-4-2 for testing single-mode cable plant follows on from the second edition of IEC 61280-4-1, dealing with multimode cable plants.~~

This document is part of a series of IEC standards for measurements of installed fibre optic cabling plants. This document is applicable for the measurement of installed single-mode fibres.

Cabling design standards such as ISO/IEC 11801-1 ~~for commercial premises, ISO/IEC 24702 for industrial premises, ISO/IEC 24764 for data centres and ISO/IEC 15018 for residential cabling contain specifications~~ provide general requirements for this type of cabling. These standards support cabling lengths of up to 2 km for commercial premises and data centres and up to 10 km for industrial premises. ISO/IEC 14763-3, which supports ~~these design standards, makes reference to the test methods of this standard~~ ISO/IEC 11801-1, normatively references IEC 61280-4-2.

Various recommendations from ITU-T have requirements for longer distance applications, including short haul (40 km), long haul (80 km), and ultra-long haul (160 km). The testing of ~~cable~~ cabling plant for these applications is covered in ITU-T Recommendation G.650.3, which refers to the test methods of this document.

FIBRE-OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-2: Installed ~~cable~~ cabling plant – Single-mode attenuation and optical return loss measurements

1 Scope

This part of IEC 61280 is applicable to the measurements of attenuation and optical return loss of an installed optical fibre ~~cable~~ cabling plant using single-mode fibre. This ~~cable~~ cabling plant can include single-mode optical fibres, connectors, adapters, splices, and other passive devices. The cabling ~~may~~ can be installed in a variety of environments including residential, commercial, industrial and data centre premises, as well as outside plant environments.

This document ~~may be applied~~ is applicable to all single-mode fibre types including those designated by IEC 60793-2-50 as Class B fibres.

The principles of this document ~~may~~ can be applied to ~~cable~~ cabling plants containing branching devices (splitters) and at specific wavelength ranges in situations where passive wavelength selective components are deployed, such as WDM, CWDM and DWDM devices.

This document is not intended to apply to ~~cable~~ cabling plants that include active devices such as fibre amplifiers or dynamic channel equalizers.

2 Normative references

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

~~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 (OFCSs)*

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

IEC 61300-3-35, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-35: Examinations and measurements* – ~~*Fibre optic cylindrical connector endface*~~ *Visual inspection of fibre optic connectors and fibre-stub transceivers*

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

IEC 61746-1:2009, *Calibration of optical time-domain reflectometers (OTDR) – Part 1: OTDR for single-mode fibres*

IEC TR 62627-01, *Fibre optic interconnecting devices and passive components – Part 01: Fibre optic connector cleaning methods*

3 Terms, definitions, graphical symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1.1
adapter
~~female part of a connector in which one or two plugs are inserted and aligned~~

~~[SOURCE: IEC TR 61931:1998, 2.6.4]~~

device that enables interconnection between terminated optical fibre cables

3.1.2
attenuation
~~measure of the reduction of optical power transmitted through the cabling under test~~

~~Note 1 to entry: Attenuation (L) is determined as the ratio of the input power (P_{in}) to output power (P_{out}) of the cabling under test, given as~~

~~$$L = 10 \times \log_{10} \times (P_{in}/P_{out})$$~~

~~Alternatively attenuation may be expressed as $L = -10 \times \log_{10} \times (P_{out}/P_{in})$. Both equations are mathematically equivalent, resulting in positive decibel values.~~

~~Note 2 to entry: Loss and attenuation are equivalent.~~

reduction of optical power induced through a medium like cabling given as A:

$$A = 10 \times \log_{10} (P_{in}/P_{out})$$

where

P_{in} and P_{out} are the power, typically measured in mW, into and out of the cabling

Note 1 to entry: Attenuation is expressed in dB.

Note 2 to entry: Alternatively, attenuation can be expressed as $A = -10 \times \log_{10} (P_{out}/P_{in})$. Both formulae are mathematically equivalent, resulting in positive decibel values.

3.1.3
bi-directional measurement
two measurements of the same optical fibre made by launching light into opposite ends of that fibre

3.1.4
configuration
form or arrangement of parts or elements such as terminations, connections, and splices

3.1.5
connector
component normally attached to an optical cable or piece of apparatus, for the purpose of providing frequent optical interconnection/disconnection of optical fibres or cables

[SOURCE: IEC TR 61931:1998, 2.6.1, modified – The words in brackets, "(optical) (fibre)", have been omitted from the term.]

3.1.6
light source and power meter
LSPM
test system consisting of a light source (LS), power meter (PM) and associated test cords used to measure the attenuation of an installed ~~cable~~ cabling plant

3.1.7
optical return loss
ORL
R_{ORL}
ratio of the input power, P_{in}, of the cabling under test to the backward power, P_r, reflected by the cabling under test:

~~ORL = 10 × log₁₀(Pin/Pr)~~

$$R_{ORL} = 10 \times \log_{10}(P_{in}/P_r)$$

Note 1 to entry: Optical return loss is a positive number.

Note 2 to entry: Optical return loss is expressed in dB.

3.1.8
optical time domain reflectometer
OTDR
test system consisting of an optical time-domain reflectometer and associated test cords, used to characterize and measure the attenuation and optical return loss of an installed ~~cable~~ cabling plant and specific elements within that ~~cable~~ cabling plant

3.1.9
plug
free connector
male part of a connector

[SOURCE: IEC TR 61931:1998, 2.6.2]

3.1.10
reference-grade termination
connector plug with tightened tolerances terminated onto a single-mode optical fibre with tightened tolerances such that the expected ~~loss~~ attenuation of a connection formed by mating two such assemblies is ~~less than or equal to 0,2 dB~~ lower and more repeatable than a standard-grade termination

Note 1 to entry: An adapter, required to ensure this performance, ~~may~~ can be considered to be part of the reference-grade termination where required by the test configuration.

Note 2 to entry: ~~This definition is consistent with the reference grade 2 connections defined in~~ IEC 61755-2-4 for non-angled (PC) and IEC 61755-2-5 for angled (APC) cylindrical ferrule connectors define reference-grade terminations. These standards ~~may~~ can be referenced for further information.

3.1.11
reference test method
RTM
~~test method used in the resolution of a dispute~~

test method for measuring a given characteristic strictly according to the definition of this characteristic, and giving results which are accurate, reproducible, and relatable to practical use

[SOURCE: IEC TR 61931:1998, 2.8.1, modified – The words in brackets, "(for optical fibres)", have been omitted from the term.]

3.1.12
reflectance
R_{comp}
for a discrete component in the cabling, ratio of the backward power, P_r, reflected by the component, to the input power, P_{in}, into the component:

~~Reflectance = 10 × log10(Pr / Pin)~~

$$R_{comp} = 10 \times \log_{10}(P_r / P_{in})$$

Note 1 to entry: Reflectance is a negative number.

Note 2 to entry: Alternatively, this is referred to (e.g. by IEC 61300-3-6) as the return loss of individual components and is expressed as $R_L = -10 \times \log_{10}(P_r / P_{in})$, which is a positive number.

Note 3 to entry: Reflectance is expressed in dB.

3.1.13
return loss test set
RLTS
test system consisting of a light source (LS) and internal power meter (PM), directional coupler and additional external power meter and associated test cords used to measure the optical return loss of an installed cabling plant

3.1.14
socket style connector
~~fixed connector, socket~~
connector for which the adapter, including any alignment device, is integrated with and permanently attached to the connector plug on one side of the connection

Note 1 to entry: Examples include the SG connector (see IEC 61754-19) and many harsh environment connectors.

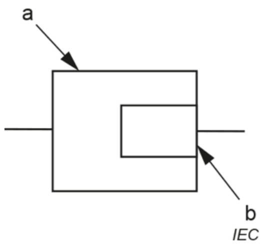
3.1.15
test cord
terminated optical fibre cord used to connect the optical source or detector to the cabling or to provide suitable interfaces to the cabling under test

Note 1 to entry: There are five types of test cords:

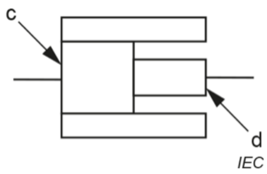
– launch cord: used to connect the light source to the cabling;
– receive cord: used to connect the cabling to the power meter (LSPM only);
– tail cord: attached to the far end of the cabling when an OTDR is used at the near end. This provides a means of evaluating attenuation and optical return loss of the whole of the cabling including the far end connection;
– adapter cord: used to transition between sockets or other incompatible connectors in a required test configuration;
– substitution cord: a test cord used within a reference measurement which is replaced during the measurement of the ~~loss~~ attenuation of the cabling under test.

3.2 Graphical symbols

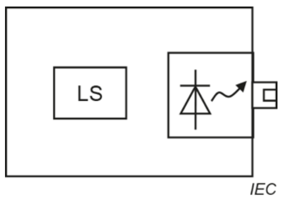
The graphical symbols shown in Figure 1 for different connection options ~~have been adapted from IEC 61930~~ are as given in IEC TR 61930:1998, except for the angled connector pair shown in Figure 1 g).



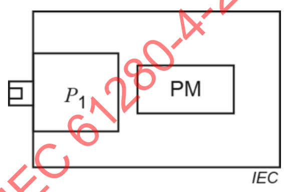
a) Socket and plug assembly



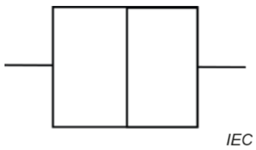
b) Connector set (plug, adapter, plug)



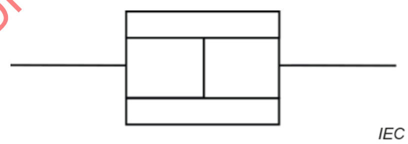
c) Light source



d) Power meter



e) Generic connection



f) Pinned-to-unpinned connection

g) Angled connector pair

Key

a socket

b plug

c plug-adapter assembly

d plug inserted into plug-adapter assembly

LS light source

PM power meter

P_1 measured power level

Figure 1 – Connector symbols

NOTE 1 In Figure 1 b) and elsewhere in this document, the plugs are shown with different sizes to indicate directionality where the cabling has adapters pre-attached, and the test cord does not, or vice versa. In Figure 1 b), the plug on the left has the adapter pre-attached.

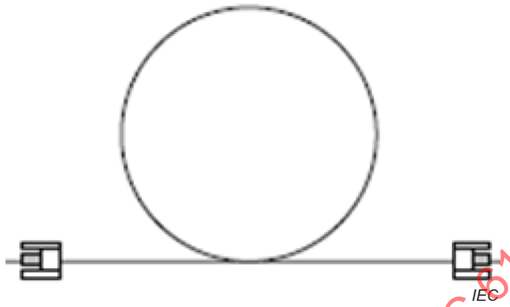
NOTE 2 Where used in all figures in this document, including those in the annexes, reference-grade terminations and adapters are shaded with grey.

NOTE 3 A simplified two-block connection used in Annex E and Annex I is shown in Figure 1 e).

NOTE 4 A simplified connection for pinned-to-unpinned and socketed connections used in Annex J is shown in Figure 1 f).

NOTE 5 An angled connector pair used in Figure 8, Annex F, and Annex G is shown in Figure 1 g).

In the figures that illustrate the measurement configurations in Annex A through Annex E, the cabling under test is illustrated by a loop, as shown in Figure 2. Although illustrated as a loop of fibre, it ~~may~~ can contain additional splices and connectors in addition to the terminal connectors. Note that for purposes of measuring the attenuation of this cabling, the ~~losses~~ attenuations associated with the terminal connectors are considered separately from the cabling itself.



NOTE The cabling is shown with adapters pre-attached, and the plugs going into them are associated with reference-grade test cord plugs.

Figure 2 – Symbol for cabling under test

3.3 Abbreviated terms

APC angled physical contact (description of connector style)

ASE amplified spontaneous emissions

ATM alternative test method

~~BBS broadband source~~

CW continuous wave

CWDM coarse wavelength division multiplexing

DWDM dense wavelength division multiplexing

FTTH fibre to the home

LED light emitting diode

LS light source

LSA least squares approximation

~~LSPM light source power meter~~

OCWR optical continuous wave reflectometer

~~ORL optical return loss~~

~~OSA optical spectrum analyser~~

~~OTDR optical time domain reflectometer~~

PC physical contact (description of connector style that is not angled)

PM power meter

~~PON passive optical network~~

~~ROADM reconfigurable optical add drop multiplexer~~

~~RLTS return loss test set~~

~~RTM reference test method~~

WDM wavelength division multiplexing

4 Measurement methods

4.1 General

4.1.1 Document structure

General requirements for apparatus, procedures, and calculations common to all methods are given in the main text of this document. Requirements that are specific to each method are documented in Annex A through Annex G. Procedures for connector end face cleaning and inspection are described in 6.9 and 7.2.

4.1.2 Attenuation

~~Four~~ Five attenuation measurement methods are described in this document. The ~~four~~ five measurement methods use test cords to interface with the ~~cable~~ cabling plant and are designated as follows:

1) one-cord reference method (see Annex A);
2) three-cord reference method (see Annex B);
3) two-cord reference method (see Annex C);
4) equipment cord method (see Annex D);
5) optical time domain reflectometer (OTDR) method (see Annex E).

The first ~~three~~ four methods use an optical light source and power meter (LSPM) to measure input and output power levels of the cabling under test to determine the attenuation. The main functional difference between these methods is the way the input power level, known as the reference power level, is measured and, hence, the inclusion or exclusion of the ~~losses~~ attenuations associated with the connections to the cabling under test, and the associated uncertainties of these connections. The process of measuring the input power level is commonly referred to as "taking the reference power level."

The use of the term "reference" in the description of the test methods refers to the process of measuring the input power, not the status of the test.

The one-cord reference method produces results that include the attenuation associated with connections at both ends of the cabling under test. The three-cord reference method produces results that attempt to exclude the attenuation of the connections of both ends of the cabling under test. The two-cord reference method normally produces results that include the attenuation associated with one of the connections of the cabling under test. The equipment cord method includes the attenuation associated with the connections between the equipment cords and the fixed cabling, but excludes the attenuation associated with the connectors that will be connected into the equipment (i.e. transmission system).

NOTE The maximum ~~allowed~~ cabling attenuation specified for a transmission system (e.g. through an optical power budget or channel insertion loss) normally excludes the connections made to the transmission equipment. It is therefore appropriate to use the three-cord reference method where the cabling under test is intended to be connected directly to the transmission equipment.

In the OTDR method ~~emits~~, short light ~~impulses~~ pulses are injected into the cabling, and the backscattered power is measured as a function of propagation time delay or length along the fibre. This method also allows the determination of the attenuation values of individual cabling components. It does not require a separate reference measurement to be completed. Requirements for the launch and tail cords are defined in Annex E. In addition to commissioning new cabling plant, the OTDR method is useful for optical fibre cabling testing during troubleshooting and maintenance, since the cabling plant can be characterized by a detailed mapping (the OTDR trace) that can be analysed to highlight any changes.

Guidance on each attenuation measurement method is provided in Annex A through Annex E. An overview of the uncertainties for each measurement method is given in Clause 5.

4.1.3 Optical return loss

This document also defines two types of test methods that can be used for measuring the optical return loss of installed cabling:

a) OTDR based method;

b) continuous wave method using a return loss test set.

The OTDR method allows the optical return loss of the entire cabling to be measured as well as ~~providing measurements of~~ the reflectance of individual discrete components or the optical return loss of specific sections of the cabling. The measurement ~~may~~ can be carried out in one step from each end of the cabling under test. This method is described in detail in Clause E.5.

The continuous wave method described in Annex F directly measures the forward power into the cabling under test as an initial measurement step and then compares this with the reflected power measured back through a directional coupler. Additional reference or calibration measurements are required to quantify the attenuation through the directional coupler and to cancel out any internal reflections in the measurement apparatus.

~~An alternative continuous wave test method is described in Annex F. the forward power level is calculated from indirect measurements and the reflected power measured in a similar way to the method described in Annex E. Another additional reference measurement of a known reflectance termination is needed to implement this method.~~

~~Uncertainties in the specific methods are documented in respective annexes. An overview of these uncertainties is given in 4.2.~~

~~General requirements for apparatus, procedures and calculations common to all methods are given in the main text of this standard. Requirements that are specific to each particular method are documented in Annexes A through F. The main text also includes related procedures such as connector end face cleaning and inspection.~~

The continuous wave test method described in Annex G calculates the forward power level and the reflected power in a similar way to the method described in Annex F. An additional reference measurement of a known reflectance termination is required to implement this method.

4.2 Cabling configurations and applicable test methods

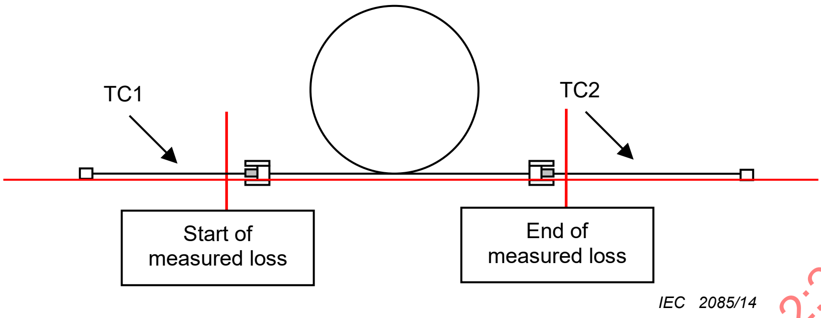
4.2.1 Cabling configurations and applicable test methods for attenuation measurements

This document assumes that the installed cabling takes one of ~~three~~ the four forms shown in Table 1. If the cabling is terminated with an adapter, the test cord shall be terminated with a plug and vice versa.

Table 1 – Cabling configurations

Configuration	Description	End connections attenuation included
A	Adapters attached to plugs or sockets attached to both ends of the cabling	Two
B	Plugs on both ends	None
C	Mixed, where one end of the cabling is terminated with an adapter and the other end is terminated with a plug	One (terminated with an adapter)
D	Plugs on both ends utilizing equipment cords	None

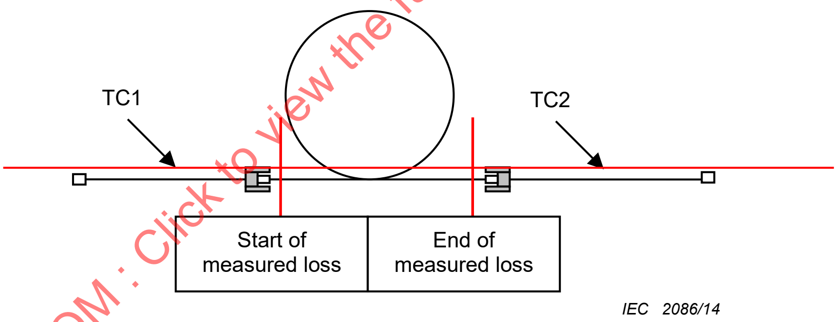
The variations in test method used to measure the cabling are dependent on the cabling configuration. For example, a common cabling configuration is that of having adapters or sockets on both ends of the cabling (e.g. within patch panels) awaiting connection to ~~electronic~~ fibre optic transmitter or receiver equipment with an equipment cord. This corresponds to configuration A. In this case, the one-cord reference method is used to include the ~~losses~~ attenuations associated with both end connectors of the cabling as illustrated in Figure 3.



~~**Figure 3 – Configuration A – Start and end of measured losses in reference test method**~~

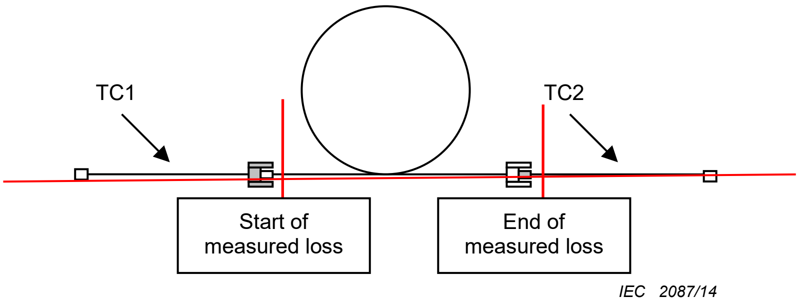
~~NOTE 1 Figure 3 is an example of cabling in configuration A with test cords TC1 and TC 2 attached, illustrating the start and end point of the measured losses when the reference test method is used (the one-cord reference method as detailed in Annex A).~~

~~Another example is a cabling configuration for which equipment cords are installed on both ends of the cabling and are awaiting connection to electronic equipment. This corresponds to configuration B. In this case, a three-cord reference method is used to exclude the loss of the end plug connections.~~



~~**Figure 4 – Configuration B – Start and end of measured losses in reference test method**~~

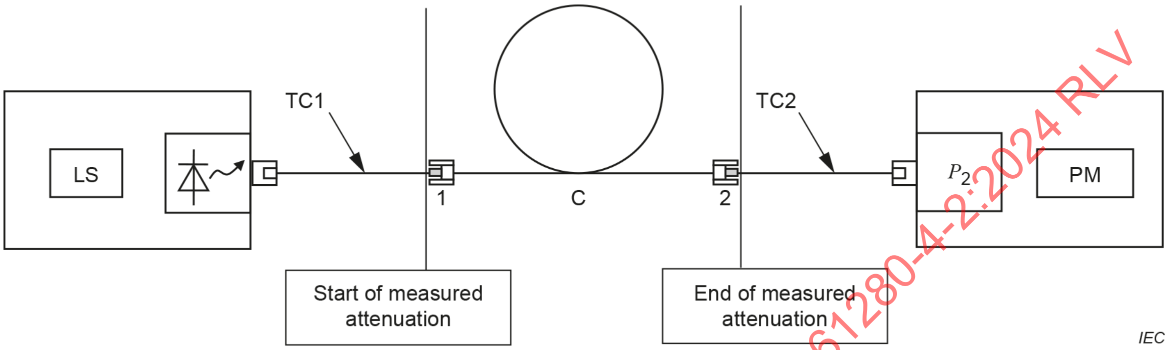
~~NOTE 2 Figure 4 is an example of cabling in configuration B with test cords attached, illustrating the start and end point of the measured losses when the reference test method is used (the three-cord reference method as detailed in Annex B).~~



~~**Figure 5 – Configuration C – Start and end of measured losses in reference test method**~~

NOTE 3 Figure 5 shows an example of cabling in configuration C with test cords attached, illustrating the start and end point of the measured losses when the reference test method is used (the two-cord reference method as detailed in Annex C).

The configuration A, B or C defines the test methods that should be applied as described in Table 2. The reference test method offers the best measurement accuracy. Alternative test methods may be called up in specific circumstances or by other standards but are subject to reduced measurement accuracy compared with the reference test method. Reference grade terminations on the test cords as described in 5.2.3, 5.3 and 5.4 shall be used for the resolution of disputes, unless otherwise agreed.



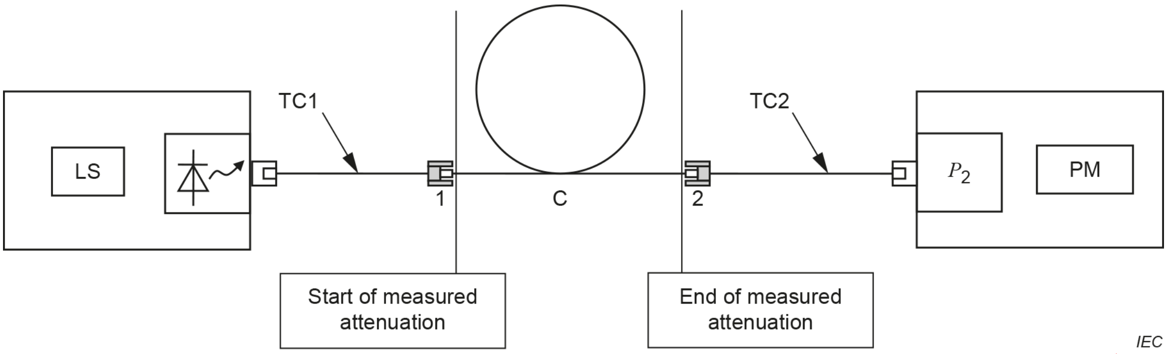
Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	measured power level

NOTE Figure 3 is an example of cabling in configuration A with test cords TC1 and TC2 attached, illustrating the start and end points of the measured attenuations when the reference test method is used (the one-cord reference method as detailed in Annex A).

Figure 3 – Configuration A – Start and end of measured attenuations in RTM

Another example is a cabling configuration where ruggedized pigtails have been spliced onto the ends of the main cable, and the connectors on the pigtails are to be directly connected into the fibre optic transmitter or receiver equipment. This corresponds to configuration B, which is illustrated in Figure 4. In this case, a three-cord reference method is used to exclude the attenuations of the end plug connections. Figure 4 illustrates the start and end points of the measured attenuations when the reference test method is used (the three-cord reference method as detailed in Annex B).



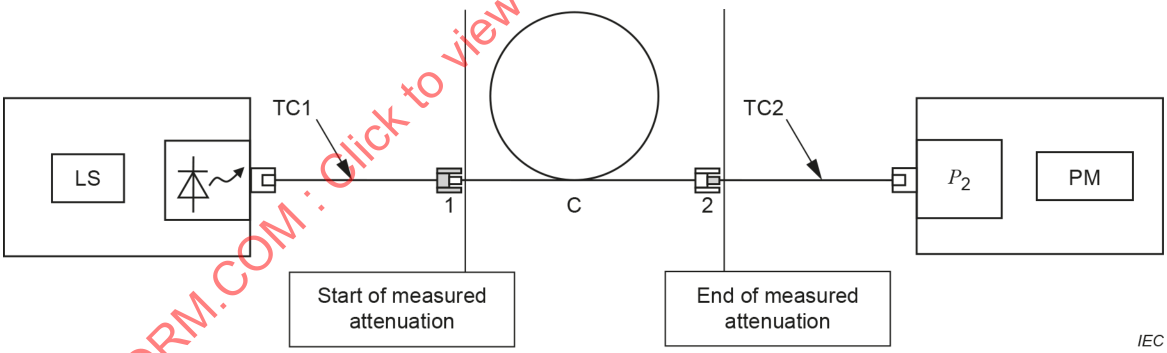
Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	measured power level

NOTE The plugs are shown with different sizes to indicate directionality where the cabling has adapters pre-attached, and the test cord does not, or vice versa.

Figure 4 – Configuration B – Start and end of measured attenuations in RTM

Figure 5 shows an example of cabling in configuration C with test cords attached, illustrating the start and end points of the measured attenuations when the reference test method is used (the two-cord reference method as detailed in Annex C).

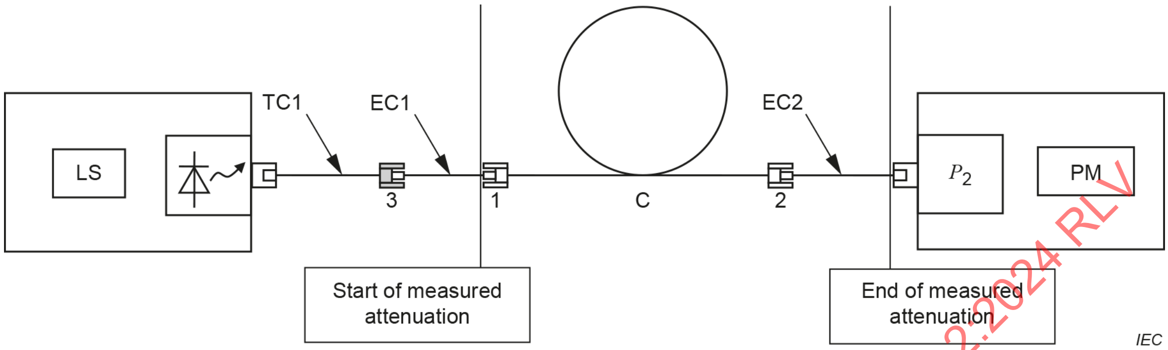


Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	measured power level

Figure 5 – Configuration C – Start and end of measured attenuations in RTM

A further example is a cabling configuration in which equipment cords are installed on both ends of the cabling and are awaiting connection to fibre optic transmitter or receiver equipment. This corresponds to configuration D, which is illustrated in Figure 6. In this case, the equipment cord method (or, when this is not practical, the three-cord method) is used to exclude the attenuation of the end plug connections.



Key

LS	light source
TC1	launch cord
EC1	equipment launch cord
C	cabling under test
EC2	equipment receive cord
PM	power meter
1, 2, 3	connector sets
P_2	measured power level

Figure 6 – Configuration D – Start and end of measured attenuations in RTM

The specific configuration used in the attenuation measurement (i.e. A, B, C, or D) defines the test method (or test methods) that should be applied, as described in Table 2. The reference test method (RTM) offers the best measurement accuracy. Alternative test methods (ATM) may be called up in specific circumstances, or by other standards, but are subject to reduced measurement accuracy compared with the reference test method. Unless otherwise agreed, resolutions of dispute shall employ the appropriate RTM in conjunction with the applicable reference-grade terminations and adapters, as described in 6.3, 6.4, 6.5, and 6.10.

Table 2 – Test methods and configurations

Configuration	RTM	ATM
A	Annex A (1-cord)	Annex B (3-cord)[a], Annex C (2-cord), Annex E (OTDR)
B	Annex B (3-cord)	Annex E (OTDR)
C	Annex C (2-cord)	Annex B (3-cord), Annex E (OTDR)
D	Annex D (equipment cord)	Annex B (3-cord), Annex E (OTDR)

NOTE The configurations, RTMs, and annexes are ordered according to the frequency in which different configurations are typically encountered.

[a] For situations where pinned-to-unpinned or plug-to-socket style connectors are used, such as MTRJ, SG or another harsh environment connector, where the power meter does not accept the unpinned or plug connector of the launch cord, the method illustrated in Figure C.3 ~~may~~ can be used.

Where information is required about the discrete components installed within the cabling under test, Annex E is the only one of these test methods that provides this information.

4.2.2 Cabling configurations and applicable test methods for optical return loss measurements

Any of the cabling configurations described in 4.2.1 can be measured using any of the three defined ORL test methods described in Annex E, Annex F, and Annex G.

The OTDR ORL test method described in Clause E.5 requires no separate reference measurements to be taken and is least likely to be affected by measurement errors. When the cabling is tested using suitable launch and tail cords, it is easy to define the start and end points of the ORL measurement as shown in Figure E.5.

The continuous wave ORL test methods described in ~~Annex E is likely to provide the most accurate ORL results, provided that reference measurements are carried out correctly and that unwanted reflections are suppressed~~ Annex F and Annex G offer a way to measure ORL. The method described in Annex G is more applicable for field measurements because it uses the same light source and power meter. Particular care ~~needs to~~ shall be taken if a short (< 10 km) length of cable is tested with a PC (non-angled) connector at the far end. If this connector is left open, the unwanted reflection from this glass-to-air interface will dominate the total ORL. Hence the use of a tail cord with PC connection at one end and APC connection at the other end, as shown in Figure F.1, helps to suppress the glass-to-air reflection whilst providing a contribution from a representative reflectance from a connector pair at the far end of the system.

The ~~alternative configuration~~ test method of continuous wave (CW) ORL measurement, as described in Annex G, does not include a direct measurement of the forward power going into the system under test, and requires reference measurements on known reflectance terminations.

5 Overview of uncertainties for attenuation measurements

5.1 General

~~The uncertainties are affected by the type of fibre, the terminations of the cabling and the measurement method used. See Annex G for some more detailed considerations.~~

The measurement uncertainties should be determined using the calculations provided in IEC TR 61282-14.

Even if a calculation spreadsheet is provided, the full calculation of measurement uncertainties is relatively complex due to the large number of considered parameters. Subclauses 5.2 to 5.8 provide an alternative to this calculation.

5.2 Sources of significant uncertainties

For typical conditions, calculations using IEC TR 61282-14 show that significant sources of uncertainties are limited to those generated by source instability, measurement method, and connector mating reproducibility.

Other sources of uncertainties, such as source wavelength, measurement resolution, power meter linearity, are less significant and do not impact measurements, because the accumulation of uncertainties is a quadratic summation.

5.3 Consideration of the power meter

The power meter (PM) should have a detector large enough to capture the entire incident light. In this way, the attenuation and uncertainty associated with coupling the receive cord to the power meter is minimal.

5.4 Consideration of test cord and connector grade

5.4.1 General

~~A main source of uncertainty involves the connection of the terminated cabling to the test equipment.~~ The attenuation and reflectance associated with the test cord connections ~~may~~ can be different from the attenuation and reflectance present when the cabling is connected to other cords or transmission equipment. The use of reference-grade terminations on the test cords reduces this uncertainty and improves reproducibility of the measurement, but the allocation of acceptable attenuation is ~~changed~~ different, as listed in Table H.1.

Test cords can be reference-grade or standard-grade, so that two different measurement conditions shall be considered. Using reference-grade connectors on test cords reduces measurement uncertainty but changes the test limits that should be applied when a pass or fail assessment is required, whereas using standard-grade connectors implies a much higher measurement uncertainty, which sometimes exceeds the actual attenuation measurement (see Table 3 and Annex H) although no adjustment of test limits is necessary.

Table 3 – Test limit adjustment and uncertainty related to test cord connector grade

Test cord termination grade	Cabling and equipment cord termination grade	Test limit adjustment	Total uncertainty
SM reference-grade	SM standard-grade	A lower test limit is required for most measurements, including the one-test cord reference method and OTDR testing. However, the 3-test cord reference method requires a higher test limit. See Annex H for more details and examples.	Can be estimated using IEC TR 61282-14 default values
SM standard-grade	SM standard-grade	None	Uncertainty values are higher than the values estimated using the IEC TR 61282-14 default values (see Table 4)

5.4.2 Mode field diameter variation

If the test interfaces ~~have~~ employ fibres with significant differences in mode field diameter, additional attenuation ~~may~~ can be introduced that will affect the measurement accuracy. ~~The single-mode~~ Optical interface standards ~~give~~ developed for single-mode fibres provide details of the attenuation introduced by mode field diameter mismatches, see for example IEC 61755-2-1 for non-angled interfaces and IEC 61755-2-2 for 8-degree angled interfaces.

5.5 Reflections from other interfaces

When conducting optical return loss measurements, reflections from other interfaces can be a significant cause of measurement uncertainty, particularly for the continuous wave method. It is important to configure the cabling under test such that unwanted reflections are suppressed. For example, when testing a short length of cable, a test cord should be coupled to the far end of the cabling under test with an angled connector at the remote end of the test cord. Usually, the connector interface to the return loss test set has an angled connector.

For the OTDR based return loss method, the use of suitably long launch and tail ~~leads can be used~~ cords helps to eliminate the effect of unwanted reflections.

5.6 Optical source

The following sources of uncertainties are relevant to the attenuation measurements:

- wavelength of the light source ~~– causes fibre attenuation variations between source wavelength and cabling system transmitter wavelength~~, because the fibre attenuation can be different at the source wavelength and at the transmitter wavelength of the cabling system ;
- spectral width of the light source ~~– wider spectral widths cause fibre attenuation variations between the source wavelength and the cabling system transmitter wavelength; narrower spectral widths can introduce coherent interference effects~~, because spectrally wider light sources can measure different fibre attenuation values than spectrally narrower light sources, whereas optical sources with overly narrow spectral width can introduce undesired coherent interference effects .

5.7 Output power reference

For methods using a light source and power meter (LSPM), one of the main sources of uncertainty is the variable coupling efficiency of the light source to the launch cord due to mechanical tolerances. To minimize this uncertainty, a reference power reading should be made whenever the connection is disturbed by stress on the connector or by disconnection.

For LSPM methods, a reference measurement shall be made to determine the output power of the launch cord which will be coupled to the cable or ~~cable~~ cabling plant under test. This measurement should be made each time the launch cord is attached to the source, as the coupling ~~may~~ can be slightly different each time it is carried out.

~~4.3.6 Received power reference~~

~~If the power meter has a detector large enough to capture all incident light, then the coupling of the receive cord to the power meter is minimal and shall be discounted. In other circumstances (which may include the use of pigtailed detectors), the uncertainty introduced shall be included in the overall measurement uncertainty.~~

5.8 Bi-directional measurements

For the LSPM methods of measuring attenuation, the test results from each end of the cabling should be very similar. A good practice for assessing the validity of the measurement results is to compare the measurement results from each end and to make sure that they are within a certain tolerance (for example 0,5 dB) of each other, thus making sure that no additional uncertainty is present due to measurement errors.

5.9 Typical uncertainties for attenuation methods A, B, C, and D

Typical uncertainties for attenuation measurements are shown in Table 4. These values were calculated using IEC TR 61282-14 and assuming the following conditions:

- PM: use of the same photodetector in the power meter for the reference power measurement and attenuation power measurement; the polarity of the reference measurement is the same as the cabling under test;
- source centroidal wavelength, reference IEC 61280-1-3: 1 310 nm and 1 550 nm ± 30 nm;
- source level: ≥ −7 dBm (0,2 mW);
- source stability: ±0,10 dB (k = 2);
- optical fibre: IEC 60793-2-50, B-652 and B-657;
- R2 reference-grade PC connectors: ≤ 0,2 dB attenuation, reference IEC 61755-2-4;
- repeatability of connection: 0,05 dB.

NOTE At the time of writing, it was expected that the designation "R2" for single-mode reference grade connectors with 0,2 dB attenuation will be replaced by a new designation "R_{s1-2}" in the future Edition 2 of IEC 61755-2-4 and also referred to as "Rs1-Grade 2" in Edition 3 of ISO/IEC 14763-3[1].

Table 4 – Uncertainty for given fibre length and attenuation at 1 310 nm, 1 550 nm and 1 625 nm

				Uncertainty values at 95 % at 1 310 nm			
Distance km	**Attenuation** dB	**IEEE 802.3 designation**	**ITU span type designation**	**1-cord** dB	**2-cord** dB	**3-cord** dB	**Equipment cord** dB
0,5	3,0	DR		0,32	0,38	0,44	0,14
2,0	4,0	FR		0,33	0,39	0,44	0,16
5,0	4,8			0,36	0,42	0,46	0,22
10,0	6,3	LR		0,46	0,50	0,54	0,35
20,0	11,0		S	0,72	0,75	0,78	0,66
40,0	18,0	ER		1,33	1,35	1,36	1,30
				Uncertainty values at 95 % at 1 550 nm[a]			
Distance km	**Attenuation** dB	**IEEE 802.3 designation**	**ITU span type designation**	**1-cord** dB	**2-cord** dB	**3-cord** dB	**Equipment cord** dB
0,5	3,0	DR		0,32	0,38	0,44	0,14
2,0	2,5	FR		0,32	0,38	0,44	0,14
5,0	3,3			0,33	0,38	0,44	0,14
10,0	4,5	LR		0,33	0,39	0,44	0,15
20,0	7,0		I	0,34	0,40	0,45	0,18
40,0	11,0	ER	S	0,39	0,44	0,48	0,25
80,0	22,0	ZR	L	0,53	0,57	0,60	0,44
120,0	33,0	OIF 400ZR	U	0,70	0,73	0,76	0,64
				Uncertainty values at 95 % at 1 625 nm[b]			
Distance km	**Attenuation** dB	**IEEE 802.3 designation**	**ITU span type designation**	**1-cord** dB	**2-cord** dB	**3-cord** dB	**Equipment cord** dB
80,0	24,4	ZR	L	1,75	1,77	1,78	1,73
120,0	36,6	OIF 400ZR	U	2,61	2,61	2,62	2,59

1 Third edition under preparation. Stage at the time of publication: ISO/IEC FDIS 14763-3:2024.

				Uncertainty values at 95 % at 1 625 nm[b] ± 15 nm			
Distance km	Attenuation dB	IEEE 802.3 designation	ITU span type designation	1-cord dB	2-cord dB	3-cord dB	Equipment cord dB
80,0	24,4	ZR	L	0,92	0,94	0,97	0,87
120,0	36,6	OIF 400ZR	U	1,33	1,35	1,36	1,30

When the uncertainty is larger than the measured attenuation, the measured value can be quite meaningless. In this case, it is good practice to replace the measured value with the value of the uncertainty.

[a] Although IEEE applications do not operate at 1 550 nm at the shorter distances, it is good practice to test single-mode fibre cabling at two different wavelengths (usually 1 310 nm and 1 550 nm) to identify potential issues with fibre bends; thus, knowledge of the measurement uncertainty at 1 550 nm is useful.

[b] Likewise, for longer links it is good practice to measure the attenuation at a second wavelength (e.g. at 1 625 nm), even though most transmission systems do not operate at this wavelength.

5.10 Typical uncertainty values for single-mode attenuation testing for method E

Typical uncertainties to produce Table 5 values were calculated using IEC 61280-4-3, assuming the following conditions:

- bi-directional measurement, dynamic margin: > 5 dB (see notes in Table 5);
- OTDR, linear regression: 100 data points (see notes in Table 5);
- source centroidal wavelength, reference IEC 61280-1-3: 1 310 nm and 1 550 nm ± 30 nm;
- optical fibre: IEC 60793-2-50, B-652 and B-657;
- R2 reference-grade APC connectors: ≤ 0,2 dB attenuation, reference IEC 61755-2-5.
- repeatability of connection: 0,05 dB.

NOTE At the time of writing, it was expected that the designation "R2" for single-mode reference grade connectors with 0,2 dB attenuation will be replaced by a new designation "R_{s1-2}" in the future Edition 2 of IEC 61755-2-5 and also referred to as "Rs1-Grade 2" in Edition 3 of ISO/IEC 14763-3.

Table 5 – Uncertainty for a given fibre length at 1 310 nm and 1 550 nm using an OTDR

Uncertainty values at 95 %				
Length km	1 310 nm attenuation dB	1 310 nm uncertainty dB	1 550 nm attenuation dB	1 550 nm uncertainty dB
0,5	3,0	0,44	3,0	0,43
2,0	4,0	0,45	2,5	0,43
5,0	4,8	0,47	3,3	0,43
10,0	6,3	0,55	4,5	0,43
40,0	11,0	1,39	7,0	0,50
80,0	18,0	2,63	11,0	0,61

The launch and tail cord lengths were set to 500 m for the 0,5 km to 10 km lengths, leading to a length of linear regression of 250 m (100 points); the associated attenuation allows sufficient dynamic margin for these two cases at 10 dB.

For 40 km, the linear regression length was 500 m and 100 points, using 1 000 m long launch and tail cords. However, the dynamic margin was reduced to 5 dB.

The attenuation uncertainties for 40 km and 80 km lengths at 1 310 nm wavelength are impacted by the uncertainty of the source wavelength (assumed to be 30 nm). Reducing this uncertainty from 30 nm to 20 nm would reduce the 1 310 nm attenuation uncertainties to 1,00 dB and 1,80 dB respectively.

6 Apparatus

6.1 General

Apparatus requirements that are specific to particular methods are found in Annex A through Annex E. Some of the requirements common to the ~~apparatus of~~ LSPM methods are ~~included in this clause~~ described in 6.2 to 6.10.

6.2 Light source

6.2.1 Stability

The performance of the light source is ~~defined~~ evaluated at the output of the launch cord. This is achieved by transmitting the output of a suitable radiation source, usually a laser, into the launch cord. The source shall be stable in position, wavelength, and power over the duration of the entire measurement procedure.

It is recommended that the stability of the source be verified by repeating the reference measurement at the end of the measurement procedure. It should remain within a certain tolerance ~~(typically no more than 0,5 dB)~~ of the initial reference value. Power stability should be ±0,10 dB or lower.

~~The stability of the light source will directly affect the measurement uncertainty. For measuring low loss systems, a lower value may be required to achieve the required measurement certainty.~~

6.2.2 Spectral characteristics

The wavelengths used for the attenuation measurement should be representative of the wavelengths at which transmission systems will operate over the fibre. For premises cabling and many other applications, this measurement is carried out at nominal wavelengths of 1 310 nm and 1 550 nm.

If other wavelengths are to be used for transmission, additional test wavelengths ~~may~~ can also be required. For example, if DWDM applications using the L-band (1 565 nm to 1 625 nm) are to be used, then testing at 1 625 nm is recommended as well; if a passive optical network for FTTH is being tested, then 1 490 nm testing ~~may~~ can be required.

If the cabling under test ~~may be~~ is used for CWDM systems that cover an extended wavelength range, then either the cabling ~~could~~ should be tested at each wavelength individually, or alternatively, a spectral attenuation measurement may be taken to cover the entire wavelength range of interest, using a suitable broadband light source and an optical spectrum analyser in place of the light source and power meter. See Annex K for further information.

It is recommended that OTDR testing be carried out on single-mode cabling using at least two wavelengths. This allows attenuation due to fibre bending to be identified by comparing the traces at the two wavelengths. See I.4.2 for further information on bending ~~loss~~ attenuation measurement. Often the wavelengths used are nominally 1 310 nm and 1 550 nm for shorter routes (< 40 km) or 1 550 nm and 1 625 nm for longer routes. Measurements at a wavelength of 1 650 nm, which is sometimes used for maintenance channels, are also very effective for detecting the presence of bends.

If the cabling under test includes wavelength selective elements, such as WDM, DWDM or CWDM devices, and optical filters, ~~etc.,~~ for example, then the spectral width of the light source shall be compatible with ~~the filtering to be used~~ that of the transmission bands of these elements; this ~~may~~ can require light sources with a very narrow spectral width. Alternatively, the spectral response of the system may be evaluated using a broadband light source and optical spectrum analyser, using the procedure described in Annex K.

For LSPM measurements, the spectral width of the single-mode light source shall meet the requirements of Table 6 when measured in accordance with IEC 61280-1-3.

Table 6 – Spectral requirements

Centroidal wavelength nm	Spectral width range nm
1 310 ± 30 (on B-652 and B-657 fibres)	≤ 5 (RMS) for laser diode ≤ 40 (RMS) for edge emitting LED
1 550 ± 30 (on B-652 and B-657 fibres)	≤ 5 (RMS) for laser diode ≤ 40 (RMS) for edge emitting LED

6.3 Launch cord

Except for the OTDR method, the launch cord shall be 2 m to 10 m in length. See Annex E for the length of the OTDR launch cord.

The connector or adapter terminating the launch cord shall be compatible (e.g. end face type) with the cabling, and the termination should be of reference-grade to minimize the uncertainty of measurement results.

The optical fibre within the launch cord ~~at the connection to the cabling under test shall be of the same type~~ shall have the same nominal core size as the optical fibre within the cabling under test. ~~Except for the OTDR method, the launch cord shall be no shorter than 2 m, not so long that the attenuation of the fibre has a significant effect on the measurement. See Annex D for the length of the OTDR launch cord.~~

The single-mode optical fibres supported by this document and used in the single-mode launch cord are defined in IEC 60793-2-50 as B-652 and B-657.

6.4 Receive or tail cords

The optical fibre within the receive or tail cords shall have the same ~~type~~ nominal core size as the optical fibre within the cabling under test.

The receive cord shall be ~~no shorter than~~ at least 2 m long, but it should not be so long that the attenuation of the fibre has a significant effect on the measurement (e.g. less than 10 m).

The connector or adapter terminating the receive or tail cords shall be compatible with the cabling, and the termination should be of reference-grade to minimize the uncertainty of measurement results.

The termination of a receive cord at the connection to the power meter shall be compatible with that of the power meter.

When unidirectional testing is carried out, the remote end of the tail cord used for OTDR testing does not require reference-grade termination. When bi-directional OTDR testing is carried out, the tail cord becomes the launch cord (see Annex I) and shall comply with 6.3.

6.5 Substitution cord

The optical fibre within the substitution cord shall have the same ~~type~~ nominal core size as the optical fibre within the cabling under test.

The substitution cord shall be ~~no shorter than~~ at least 2 m long but not so long that the attenuation of the fibre has a significant effect on the measurement (e.g. less than 10 m).

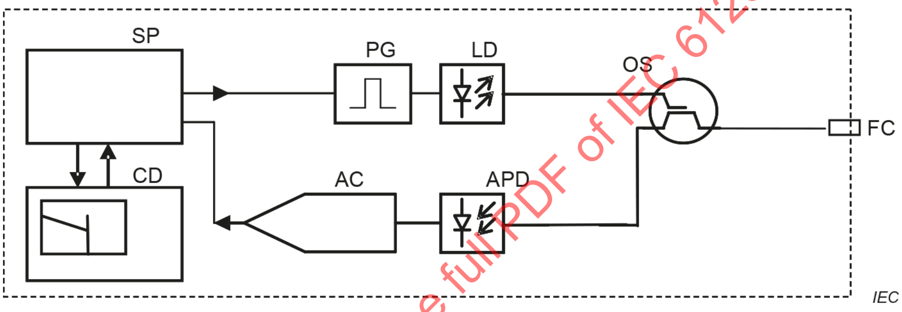
The connectors or adapters terminating the substitution cord shall be compatible with the cabling, and the terminations should be of reference-grade to minimize the uncertainty of measurement results.

6.6 Power meter – LSPM methods only

The power meter shall be capable of measuring the required range of power levels at wavelengths normally associated with the cabling, including considerations on the power launched into the cabling. The power meter shall meet the calibration requirements of IEC 61315. The meter shall have a detecting surface of sufficient size to capture all the power coming from the fibre that is put into it. If a pigtail is used, the pigtail fibre shall be sufficiently large to capture all the power coming from the test cord.

6.7 OTDR apparatus

Figure 7 displays a schematic diagram of the typical OTDR apparatus shown with a simple attachment point. The OTDR shall meet the calibration requirements of IEC 61746-1. Annex E provides more detailed requirements for the length of the launch cord and other aspects related to the OTDR measurement.



Key

PG	pulse generator
LD	laser diode
OS	optical splitter
FC	front panel connector
APD	avalanche photo diode
AC	amplifier and converter
SP	signal processor
CD	control and display

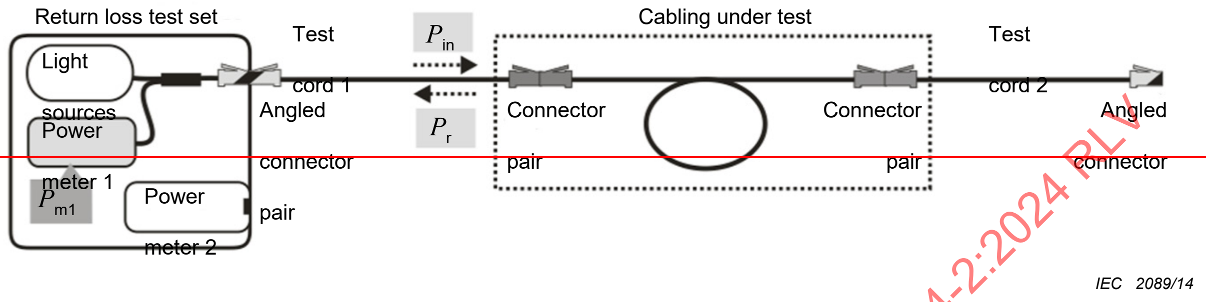
Figure 7 – Typical OTDR schematic diagram

6.8 Return loss test set

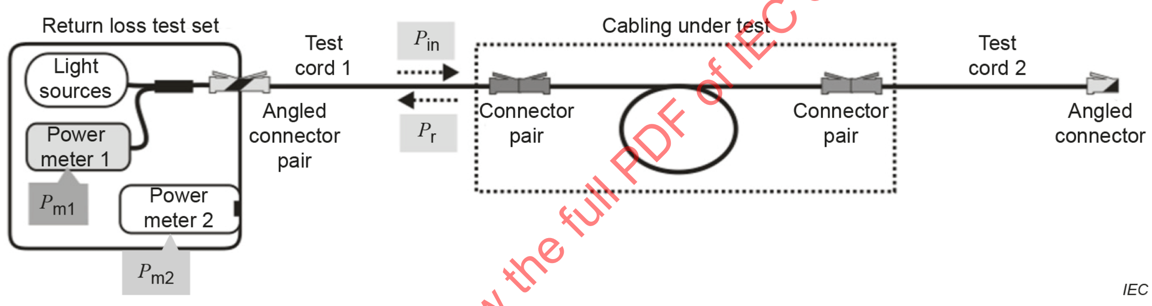
A return loss test set typically comprises one or more stabilized laser sources. As illustrated in Figure 8, the output from the source passes through a directional coupler to the output port of the RLTS that should be fitted with a low reflectance connection. ~~This should have~~ Its reflectance ~~that is~~ should be 10 dB ~~better~~ lower than the ORL of the cabling under test; an angled connector interface can usually achieve this. The other leg of the directional coupler directs reflected light back to the internal power meter (P_{m1} in Figure 8). A second power meter (P_{m2} in Figure 8 a)) with an external connector interface is often also fitted to measure the power level that is input to the cabling under test.

Alternative configurations are possible~~, including the use of~~ without the second power meter (see Figure 8 b)), provided that the input power to the cabling under test is calculated from measuring a known reflectance or a second return loss test set is used to measure the power input to the cabling under test, provided that the attenuation through the connector interface and the directional coupler can be calibrated out.

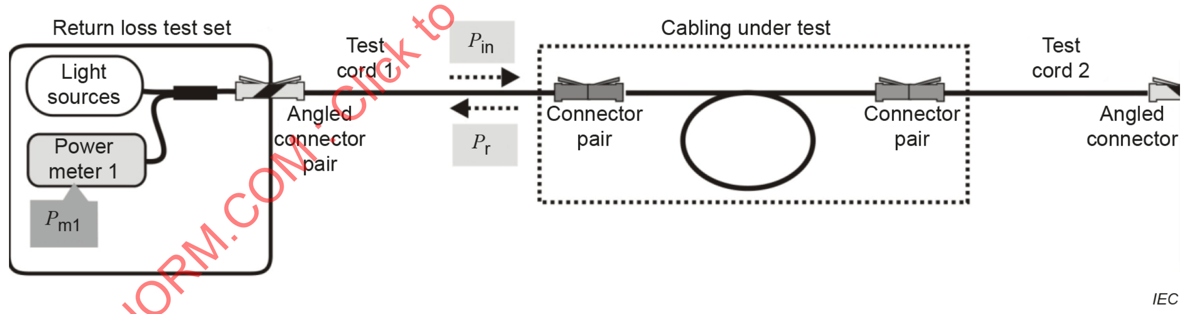
In a typical measurement configuration as shown, test cords are required to interface to the cabling under test and to suppress unwanted reflections through the use of angle-polished connectors.



~~Figure 7 – Return loss test set illustration~~



a) With internal second power meter



b) Without internal second power meter

Figure 8 – Illustration of return loss test set

6.9 Connector end-face cleaning and inspection equipment

Cleaning equipment (including apparatus, materials, and substances) and the methods to be used for cleaning shall be in accordance with IEC TR 62627-01. Connector suppliers' instructions shall be consulted where doubt exists as to the suitability of particular equipment and cleaning methods.

A microscope compatible with IEC 61300-3-35, low resolution method, is required to verify that the fibre and connector end faces of the test cords are clean and free of damage. Microscopes with adapters that are compatible with the connectors used are required.

The use of a video microscope is recommended to avoid any risk associated with direct viewing of energized fibre end faces.

6.10 Adapters

Where appropriate, adapters shall be compatible with the connector style being used and shall allow the required performance of reference-grade terminations to be achieved. Zirconia (ceramic) sleeves contained within the adapter should be used for cylindrical ferruled connectors.

7 Procedures

7.1 General

Procedure requirements specific to particular methods are found in Annex A through Annex G.

LSPM methods require a reference measurement to be taken prior to measuring the cabling. Equipment should be assessed before commencing testing to ascertain how frequently reference measurements should be taken. Generally, a new measurement reference should be taken before the equipment has drifted more than 0,1 dB (see stability in 6.2.1). The test environment (particularly the temperature) ~~may~~ can affect the frequency of re-referencing.

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

7.2 Common procedures

7.2.1 Care of the test cords

Connectors on test cords shall be inspected using the procedures of IEC 61300-3-35. The connector end faces shall be free of contamination (e.g. dust and dirt) and shall meet the requirements of the relevant table in IEC 61300-3-35. If contamination is seen, the connector end faces shall be cleaned using the equipment and methods described in 6.9.

NOTE The requirement of connector end face quality depends upon either the connector specification or the optical fibre communication system performance requirements, or both.

When the test cords are not in use, ~~the ends should be capped and~~ they should be ~~stored~~ protected from accidental damage by capping the connector ends and storing the cords in kink-free coils of a diameter greater than the minimum bending diameter.

Verify the optical performance of all test cords to be used following the procedures in Annex J before any testing commences.

7.2.2 Make reference measurements (LSPM and OCWR methods only)

The output power from the launch cord for each test wavelength shall be measured and shall be recorded in an appropriate format.

For OCWR measurements, other reference power levels shall be taken and recorded as required by the test method used (see Annex F and Annex G for more details).

7.2.3 Inspect and clean the ends of the fibres in the cabling

Connectors on installed cabling shall be inspected using the procedures of IEC 61300-3-35. They shall be free from contamination (e.g. dust and dirt). If contamination is seen, the connector end faces shall be cleaned using the equipment and methods described in 6.9 and then re-inspected.

NOTE The requirement of connector end face quality depends upon either the connector specification or the optical fibre communication system performance requirements, or both.

7.2.4 Make the measurements

As defined in Annex A through Annex G, attenuation and ORL measurements are an iterative process for each fibre in the cabling including:

- attachment of individual fibres to the launch and receive or tail cords;
- completing the measurement at each wavelength;
- storing or recording the results.

For the LSPM methods, either the power meter and receive ~~test~~ cord ~~may have to be~~ are moved to the far end of the cabling or a second power meter and receive ~~test~~ cord may be used at the far end.

7.2.5 Make the calculations

Make the calculations to determine the difference between the reference measurement and the test measurements and record the ~~final~~ result together with other information in accordance with Clause 9.

7.3 Calibration

Power meters and OTDR equipment shall be calibrated in accordance with IEC 61315 and IEC 61746-1, respectively.

The equipment used shall have a valid calibration certificate in accordance with the applicable quality system for the period over which the testing is done.

7.4 Safety

All tests that are performed on optical fibre communication systems, or that use a laser in a test set, shall be carried out following the safety precautions provided in IEC 60825-2.

8 Calculations

The calculations for each method are given in the respective annexes.

9 Documentation

9.1 Information for each test

The following information shall be provided with each test.

a) test procedure and method;
b) measurement results including
   – either attenuation or ORL, or both (in dB)
      - ~~reference power level (dBm) (LSPM and OCWR methods only),~~
      - OTDR trace(s) (OTDR method only, from both directions when bi-directional measurements were performed);
   – wavelength (in nm);
   – fibre type;
   – termination location;
   – fibre identifier;

– cable identifier;
– date of test.

9.2 Information to be made available

The following information shall be made available with each test.

- details of the spectral characteristics of the light source;
- reference power level (in dBm) (LSPM methods only);
- calibration records with reference to the test equipment;
- details of the test cords used for the measurements;
  - the performance grade of test cord connectors (e.g. reference grade or standard grade),
  - the performance grade of the fibre in the test cords (e.g. OSx),
  - whether the fibre in the test cords is of the enhanced macrobend performance level type,
  - the length of the test cords.

Annex A
(normative)

One-cord reference method

A.1 Applicability of test method

The one-cord reference method measurement includes the attenuation of both connections to the cabling under test. It is the RTM for measurement of the installed cabling plant of configuration A (see 4.2).

This method is written for the case when a single fibre is measured at a time. ~~If multiple fibres are measured simultaneously with multi-fibre connectors, the requirements of each interface shall be met as though it were a single connector as referenced in the following text.~~ If bi-directional measurements are required, the procedures are repeated by launching into the other end.

A.2 Apparatus

The light source, power meter, and test cords used shall meet the requirements specified in Clause 6.

The method described in Annex A is called the "one-cord reference method" because only one (the launch) test cord is used for the reference measurement. However, a second test (receive) cord is ~~needed~~ required for the attenuation measurement. The performance of the test cords should be verified before testing commences. This is done by connecting the receive cord to the launch cord and measuring the attenuation of the connection. See Annex J for more information.

This method calls for the launch cord to be attached directly to the power meter for the reference measurement. This assumes that the connectors used in the cabling are compatible with the connector used in the power meter.

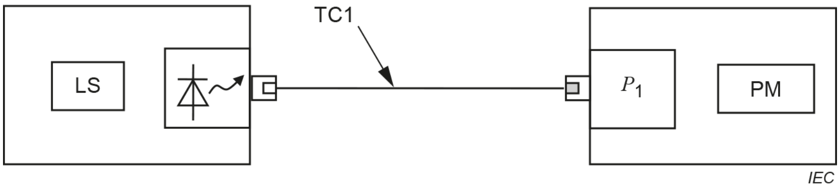
This method also assumes the following:

– The connector on the power meter is compatible with that of the cabling under test to which the launch cord is connected. Where appropriate, an adapter that introduces no additional measurement uncertainty may be attached to the power meter. The alternative method (Annex B) may be used, provided that the increased measurement inaccuracy of that method is recognized, and appropriately modified test limits are applied.
– The launch cord is not disconnected from the light source between a reference measurement and a test measurement. If either the design of the test equipment or the design of the cabling under test makes such a disconnection unavoidable, then the alternative method (Annex B) may be used, provided that the increased measurement inaccuracy of that method is recognized, and appropriately modified test limits are applied.

A.3 Procedure

a) Connect the light source and power meter using the launch cord (TC1) as shown in Figure A.1.
b) Record the measured optical power, P_1, which is the reference power measurement.
c) Disconnect the power meter from TC1. Do not disconnect TC1 from the light source without repeating a reference measurement.
d) Connect the power meter to the receive cord (TC2).
e) Connect TC1 and TC2 to the cabling under test as shown in Figure A.2.

f) Record the measured optical power, P_2, which is the test power measurement.



Key

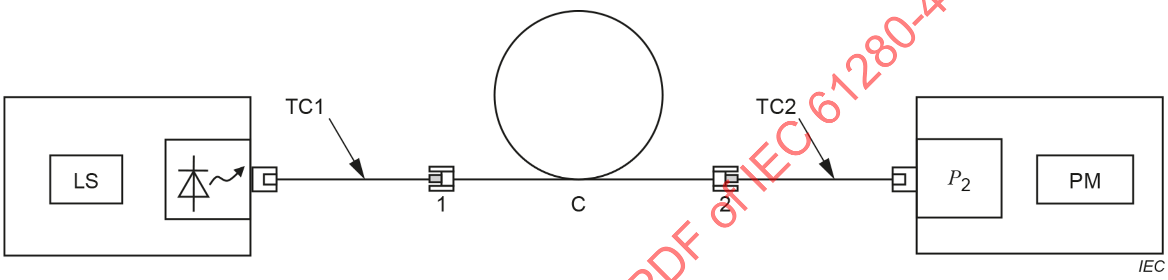
LS light source

TC1 launch cord

PM power meter

P_1 reference power measurement

Figure A.1 – One-cord reference measurement



Key

LS light source

TC1 launch cord

C cabling under test

TC2 receive cord

PM power meter

1, 2 connector sets

P_2 test power measurement

NOTE Reference-grade terminations are shaded.

Figure A.2 – One-cord test measurement

A.4 Calculation

The attenuation ~~L~~ A, expressed in dB, is given by

~~$L = 10 \log_{10}(P_1 / P_2)(\text{dB})$~~

$$A = 10 \log_{10}\left(P_1 / P_2\right) \tag{A.1}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

A.5 Components of reported attenuation

The attenuating elements are identified in Figure A.1 and Figure A.2. These are the attenuation of the cabling, ~~C~~ A_c, and ~~various~~ two connection attenuation values, A_1 and A_2, all in dB. The reported attenuation, ~~L~~ A, in dB is given by

~~$L = A + B + C$~~

$$A = A_1 + A_2 + A_c \tag{A.2}$$

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

Annex B
(normative)

Three-cord reference method

B.1 Applicability of test method

The three-cord reference method attempts to exclude the attenuation of both connections to the cabling under test. It is the RTM for measurement of the installed cabling plant of configuration B (see 4.2) and in certain circumstances, or as directed by external standards, may be used in place of the test methods specified in Annex A and Annex C.

This method is written for the case when a single fibre is being measured at a time. ~~If multiple fibres are measured simultaneously with multi-fibre connectors, the requirements of each interface shall be met as though it were a single connector as referenced in the following text.~~ If bi-directional measurements are required, the procedures are repeated by launching into the other end.

B.2 Apparatus

The light source, power meter and test cords used shall meet the requirements specified in Clause 6. Three test cords are used. The attenuation values of the connections between these cords are critical to the uncertainty of the measurement. The performance of the test cords should be verified before testing commences. This is done by connecting the substitution cord and the receive cord to the launch cord and measuring the attenuation of the connections. See Annex J for more information.

B.3 Procedure

a) Connect the launch cord (TC1) and receive cord (TC2) to the light source and power meter as shown in Figure B.1.

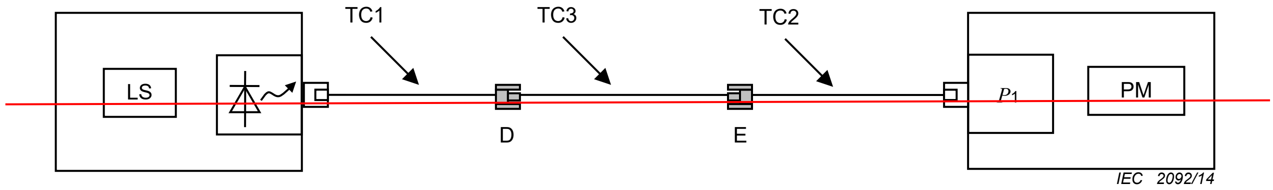
b) Connect the substitution cord (TC3) between TC1 and TC2.

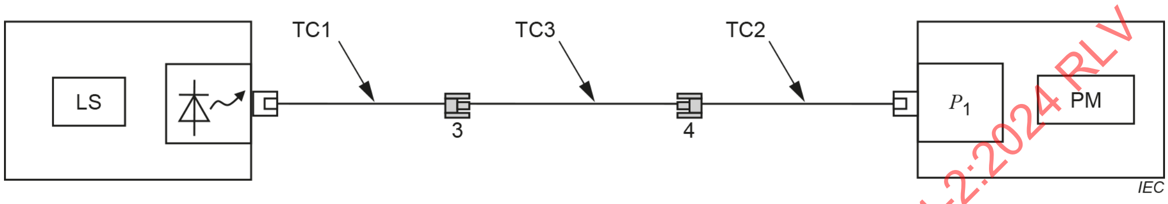
c) Record the measured optical power, P_1, which is the reference power measurement.

d) Do not disconnect TC1 from the light source without repeating a reference measurement.

e) Replace the substitution cord with the cabling under test (leaving the adapters attached to TC1 and TC2) as shown in Figure B.2.

f) Record the measured optical power, P_2, which is the test power measurement.

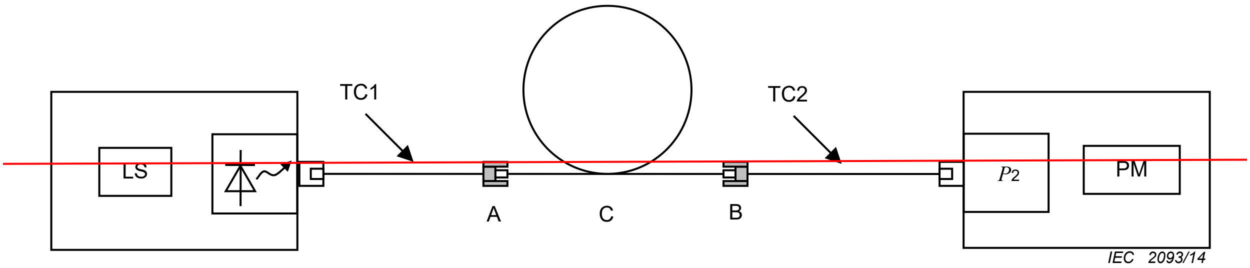


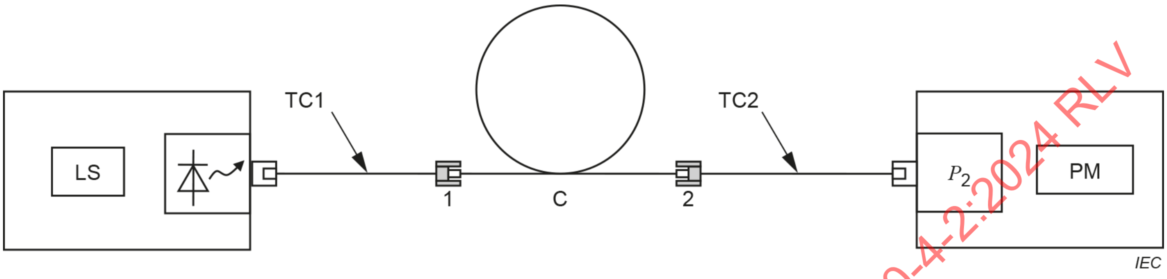


Key

LS	light source
TC1	launch cord
TC2	receive cord
TC3	substitution cord
PM	power meter
3, 4	connector sets
P_1	reference power measurement

Figure B.1 – Three-cord reference measurement





Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	test power measurement

NOTE Reference-grade terminations are shaded.

Figure B.2 – Three-cord test measurement

B.4 Calculations

The attenuation ~~L~~ A, expressed in dB, is given by

~~$$L = 10\log_{10}(P_1 / P_2)(\text{dB})$$~~

$$A = 10\ \log_{10}\left(P_1 / P_2\right) \tag{B.1}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

B.5 Components of reported attenuation

The attenuating elements are identified in Figure B.1 and Figure B.2. These are attenuation values of the cabling, ~~C~~ A_c, and ~~various~~ four connection attenuation values, A_1, A_2, A_3 and A_4, all in dB. The reported attenuation, ~~L~~ A, in dB is given by

~~$$L = A + B + C - D - E$$~~

$$A = A_1 + A_2 + A_c - A_3 - A_4 \quad (B.2)$$

~~D and E~~ A_3 and A_4 are the attenuation values of the connections in the reference test set-up and together include the fibre attenuation ~~over the length~~ of TC3, which ~~is~~ should be negligible.

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

Annex C
(normative)

Two-cord reference method

C.1 Applicability of test method

Two variants are given for the two-cord reference method. Figure C.2 shows the set-up for the case where one end is terminated with a plug-adapter assembly and the other is terminated with a plug. It includes the attenuation of one of the connections to the cabling under test. It is the RTM for measurement of the installed cabling plant of configuration C (see 4.2).

Figure C.3 shows the set-up for the case where both ends are socketed or pinned, and the launch cord connector is incompatible with the power meter. It includes the attenuation of both connections to the cabling under test. It is an alternative method for measurement of the installed cabling plant of configuration A (see 4.2).

This method is written for the case when a single fibre is being measured at a time. ~~If multiple fibres are measured simultaneously with multi-fibre connectors, the requirements of each interface shall be met as though it were a single connector as referenced in the following text.~~ If bi-directional measurements are required, the procedures are repeated by launching into the other end.

C.2 Apparatus

The light source, power meter and test cords used shall meet the requirements specified in Clause 6. The attenuation values of the connections between these test cords are critical to the uncertainty of the measurement. The performance of the test cords should be verified before testing commences. This is done by connecting the receive cord to the launch cord and measuring the attenuation of the connection. See Annex J for more information.

C.3 Procedure

a) Connect the launch cord (TC1) and receive cord (TC2) to the light source and power meter and to each other as shown in Figure C.1.

b) Record the measured optical power, P_1, which is the reference power measurement.

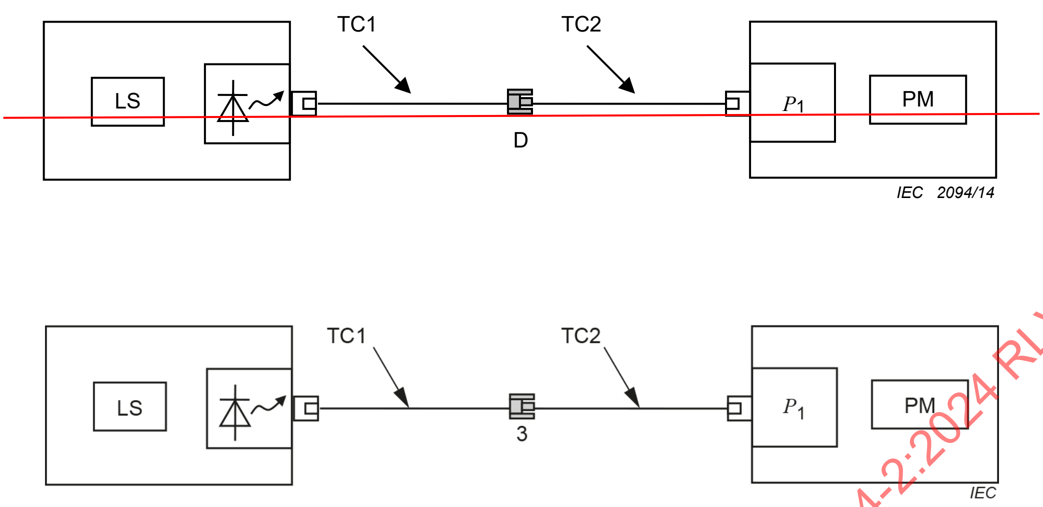
c) Disconnect TC1 and TC2 from each other. Do not disconnect TC1 from the light source without repeating a reference measurement.

d) Insert either

– the cabling under test as shown in Figure C.2,

– the adapter cord AC and the cabling under test as shown in Figure C.3.

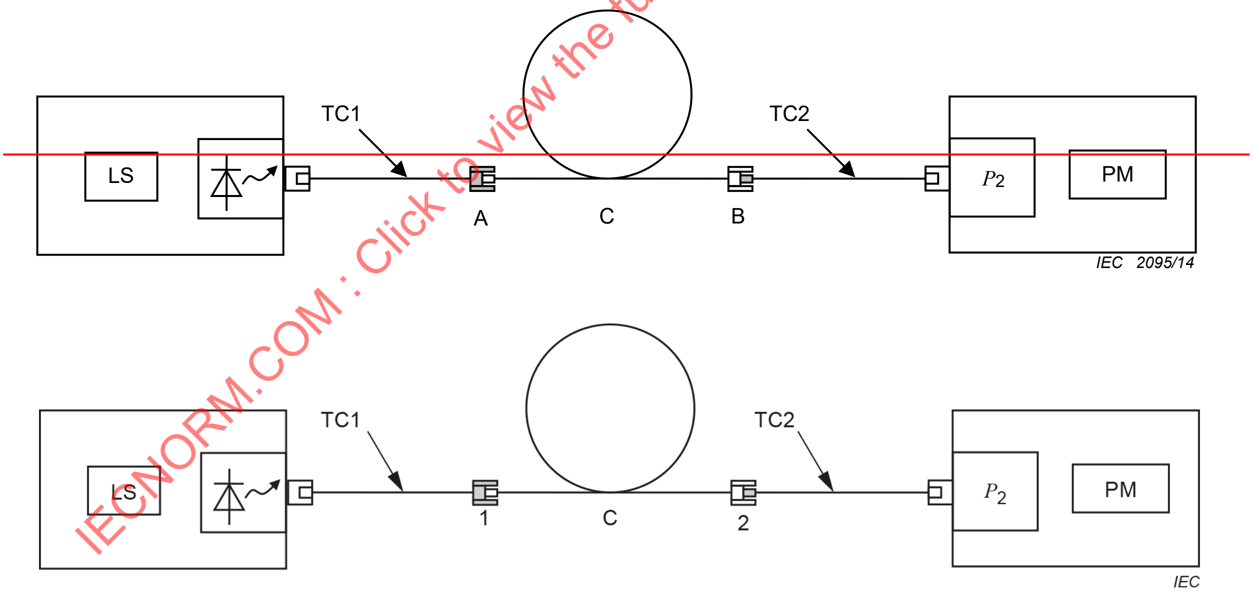
e) Record the measured optical power, P_2, which is the test power measurement.



Key

LS	light source
TC1	launch cord
TC2	receive cord
PM	power meter
3	connector set
P_1	reference power measurement

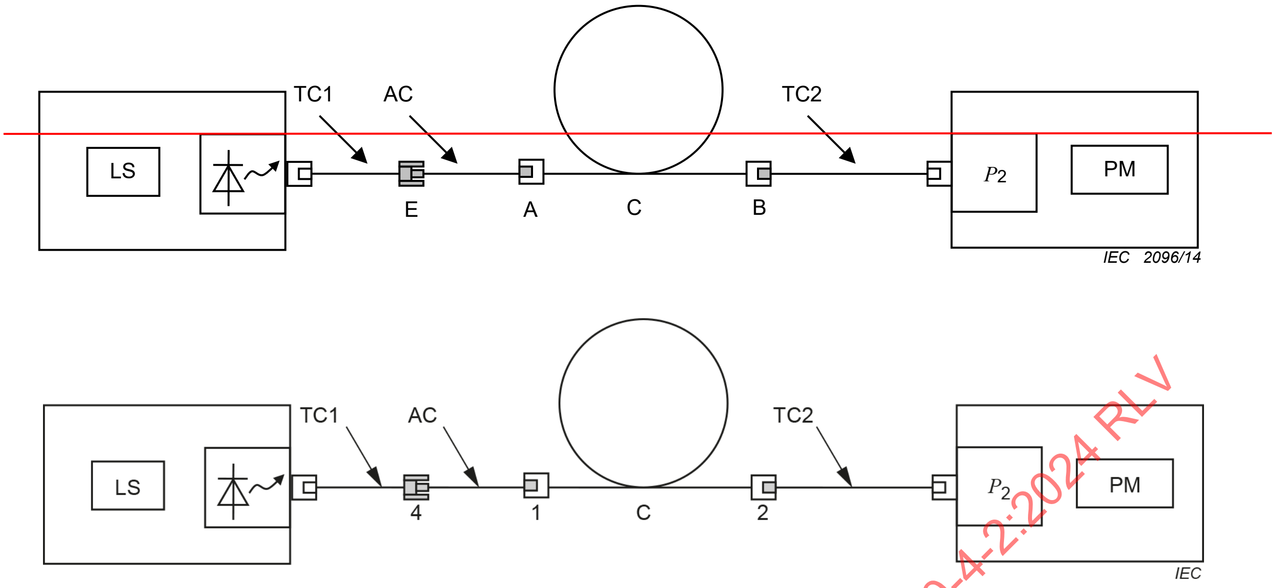
Figure C.1 – Two-cord reference measurement



Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	test power measurement

Figure C.2 – Two-cord test measurement



Key

LS	light source
TC1	launch cord
C	cabling under test
AC	adapter cord
TC2	receive cord
PM	power meter
1, 2, 4	connector sets
P_2	test power measurement

NOTE Reference-grade terminations are shaded.

Figure C.3 – Two-cord test measurement for plug-to-socket style connectors

C.4 Calculations

The attenuation ~~L~~ A, expressed in dB, is given by

~~$$L = 10\log_{10}(P_1 / P_2)(\text{dB})$$~~

$$A = 10 \log_{10} (P_1/P_2) \tag{C.1}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

C.5 Components of reported attenuation

The attenuating elements are identified in Figure C.1, Figure C.2, and Figure C.3. These are the attenuation of the cabling, ~~C~~ A_c, and ~~various connection losses~~ up to four connection attenuations, A_1, A_2, A_3 and A_4, all in dB.

For the case of Figure C.2, the reported attenuation, ~~L~~ A, is given by:

$$L = A + B + C - D$$

$$A = A_1 + A_2 + A_c - A_3 \quad (C.2)$$

For the case of Figure C.3, the reported attenuation, L A, is:

$$L = A + B + C + E - D$$

$$A = A_1 + A_2 + A_c + A_4 - A_3 \quad (C.3)$$

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

Annex D
(normative)

Equipment cord method

D.1 Applicability of the test method

The equipment cord method directly measures the attenuation of the cabling under test, the attenuation of equipment cord connections to the cabling under test, and the attenuation of the optical fibre in one of the equipment cords (EC2 in Figure D.2). The attenuation of the equipment cord connections to the equipment is not included. It is the RTM for the measurement of installed cabling plant of configuration D (see 4.2). The equipment cord test method is only suitable if both equipment cords are present during testing and are not replaced before operation. The attenuation of the optical fibre in the equipment cords is negligible if the equipment cords are short.

D.2 Apparatus

The light source, power meter and all test cords shall be in accordance with Clause 6. This is called the equipment cord method because the customer's equipment cord is used in taking the reference measurement. The second customer (receive) cord is also used for the attenuation measurement. The performance of the test cords and customer cords should be verified before testing commences. This is done by connecting the test, receive, or customer cord to the launch cord and measuring the attenuation of the connection. See Annex J for more information.

This method requires that the launch cord and the customer equipment cord be connected in series between the light source and the power meter for the reference measurement.

This method also assumes the following.

- The connector on the power meter is compatible with that of the cabling under test into which the equipment cord EC1 in Figure D.1 is connected. Where appropriate, an adapter that introduces no additional measurement uncertainty may be attached to the power meter.
- The launch cord is not disconnected from the light source between a reference measurement and a test measurement.

D.3 Procedure

a) Connect the light source and power meter using the launch cord (TC1) and equipment cord (EC1) as shown in Figure D.1.

b) Record the measured optical power, P_1. This is the reference power measurement.

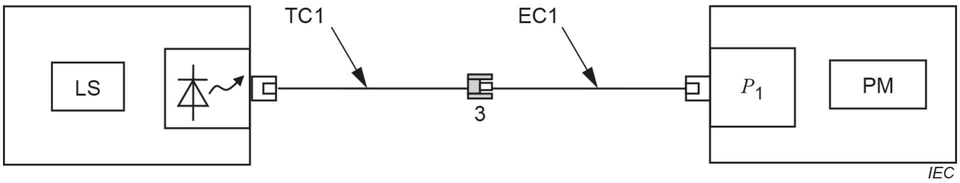
c) Disconnect the power meter from EC1.

   – Do not disconnect TC1 from the light source without first repeating a reference measurement.

d) Connect the power meter to the equipment receive cord (EC2).

e) Connect TC1/EC1 and EC2 to the cabling under test as shown in Figure D.2.

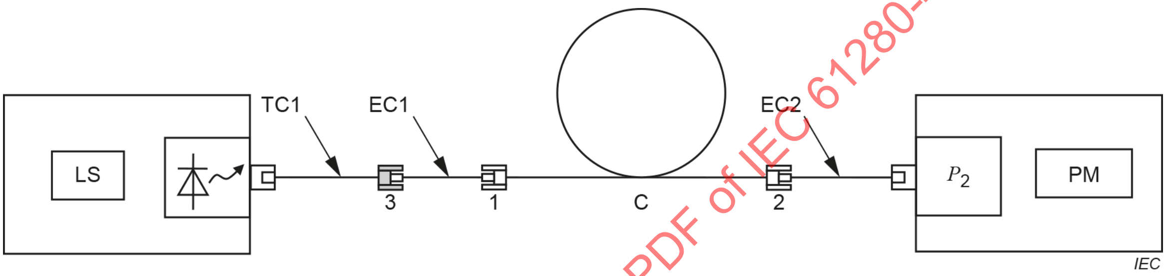
f) Record the measured optical power, P_2. This is the test power measurement.



Key

LS	light source
TC1	launch cord
EC1	equipment launch cord
PM	power meter
3	connector set
P_1	reference power measurement

Figure D.1 – Reference measurement



Key

LS	light source	EC1	equipment launch cord
TC1	launch cord	PM	power meter
C	cabling under test	EC2	equipment receive cord
P_2	test power measurement	1, 2, 3	connector sets

NOTE Reference-grade terminations are shaded.

Figure D.2 – Test measurement

D.4 Calculation

The attenuation A, expressed in dB, is given by:

$$A = 10 \log_{10}\left(P_1 / P_2\right) \qquad \text{(D.1)}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

D.5 Components of reported attenuation

The attenuating elements are identified in Figure D.1 and Figure D.2. These are the attenuation of the cabling, A_c, and two connection attenuation values, A_1 and A_2, all in dB. The reported attenuation, A, is given by:

$$A = A_1 + A_2 + A_c \tag{D.2}$$

NOTE Only the fibre of equipment cord 2 and of the cabling is included in the attenuation measurement, whereas the fibre of equipment cord 1 is already included in the reference measurement.

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

~~Annex D~~Annex E
(normative)

Optical time domain reflectometer

E.1 Applicability of test method

~~This method is written for the case when a single fibre is being measured by means of an optical time domain reflectometer (OTDR) from one end of a fibre link or channel. It is usual for these measurements to be carried out bi-directionally, in which case the procedures within this annex are repeated, but from the opposite end of the cabling under test.~~

The OTDR method measurement includes the attenuation of both connections to the cabling under test. It is the ATM for measurement of the installed cabling plant of configurations A, B, C, and D (see 4.2) and in certain circumstances, or as directed by external standards, it may be used in place of the test methods specified in Annex A, Annex B, Annex C and Annex D.

When bi-directional measurements (see Clause I.6) are specified, the procedures described in Annex E are repeated, but from the opposite end of the cabling under test, without disconnecting the launch and tail cords from the cabling under test.

E.2 Apparatus

E.2.1 General

The OTDR, test cords and adapters are required for making attenuation, optical return loss and length measurements on the installed cabling. See Figure 7 for a schematic diagram of the OTDR equipment.

The test set-up requires a launch cord and tail cord. Reflectance associated with the connectors of the test cords (launch and tail) as well as the cabling, should be minimized.

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

The use of the tail cord allows the attenuation of the remote end connection to be measured, so that the attenuation of the entire cabling section can be measured. If no tail cord is used, then there is no information regarding the remote end connector. In fact, not even continuity of the fibre is ensured since there ~~may~~ can be a break close to the far end, or the fibres ~~may~~ can be incorrectly connected somewhere along their length.

E.2.2 OTDR

The OTDR shall be capable of ~~using a~~ generating optical pulses of short ~~pulse width~~ duration (≤ 20 ns), ~~to~~ so that it can qualify short links, the beginning of a link, or to separately resolve features that are close together ~~and longer pulse widths to have sufficient dynamic range to achieve a measurement over the required length of cabling~~. It shall also be capable of generating optical pulses of longer duration, so that it has sufficient dynamic range to produce valid measurement data over the required length of cabling.

The OTDR should have an attenuation dead zone (with ΔF = ±0,5 dB; see I.2.5) of less than 10 m following standard connectors (IEC 61753-1 Grade 2) with a reflectance of –45 dB.

E.2.3 Test cords

The fibre type and geometrical characteristics of the launch and tail cords shall be the same as the fibre in the cabling under test. The fibre in the launch and tail cords shall be coated so that the cladding light is removed. The length of the launch and tail cords both shall be longer than the dead zone ~~created by~~ corresponding to the pulse width selected for a particular length of fibre to be measured. Suppliers of OTDR equipment should recommend lengths for the launch and tail cords. In addition, these ~~lengths~~ cords shall be long enough to allow a reliable straight line fit of the backscatter trace that follows the dead zone.

In the absence of other information, the minimum length of launch and tail cords ~~may~~ can be determined such that their return delay is equal to the OTDR pulse width multiplied by a suitable factor. Table E.1 gives some typical examples for minimum length of launch and tail cords to be used for measurements of premises cabling and of outside plant cabling.

Table E.1 – Typical launch and tail cord lengths

Application	Typical maximum length of cabling under test km	Example pulse width ns	Typical length of launch and tail cords m
Premises cabling	2	20	100
Outside plant – Access network	10	100	500
Outside plant – Core network	80	500	1 000
Outside plant – Ultra long-haul network	120	1 000	2 000

The following requirements apply to the test cords:

– attenuation due to induced winding loss ~~should~~ shall be minimized~~. To do this, use a minimum radius of~~ by using bend radii larger than 45 mm;

– the cords ~~are~~ shall be terminated at one end with a connector suitable for attachment to the OTDR;

– they ~~are~~ shall be terminated at the other end according to 5.4;

– ~~use~~ ruggedized fibre test cords ~~with~~ should be used in which, for example, both ends are protected by a 3 mm outer jacket with strain relief;

– the fibre used in the cord should be protected from environmental changes. This ~~may~~ can be accomplished by enclosing most of the length of the cord in a container or by using test cords that are entirely ruggedized. Up to 2 m of fibre length of the cord ~~can~~ may extend outside the container to connect the OTDR and the cabling under test.

E.3 Procedure (test method)

– Connect the test cords and the OTDR source as shown in Figure E.1.

– Configure the OTDR using the following rules:

  - the shortest pulse width possible should be selected that ~~is consistent with acquiring a trace in a reasonable timescale that is sufficiently smooth (i.e. with sufficient signal-to-noise ratio)~~ allows acquisition of a trace in a reasonable time period and with sufficient signal-to-noise ratio to allow effective analysis;

  - the averaging time per trace should ~~not need to be any greater than 3 min per trace~~ be between 10 s and 3 min. Averaging times shorter than 10 s generally provide poor results on longer systems when using narrow pulses;

  - refer to Annex I for a better understanding of the OTDR settings.

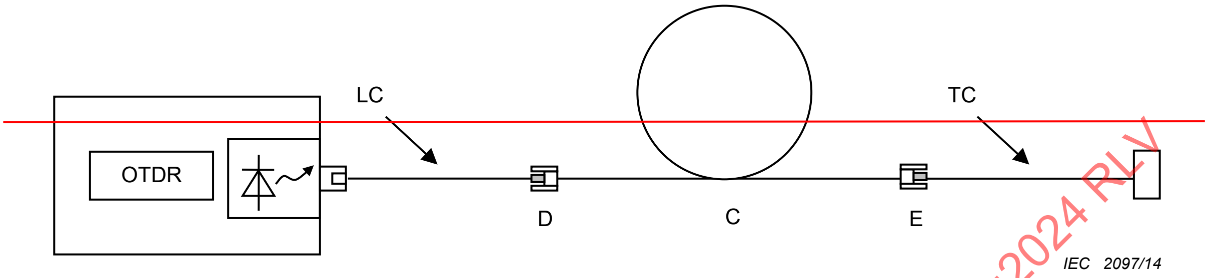
– Select the appropriate wavelengths.

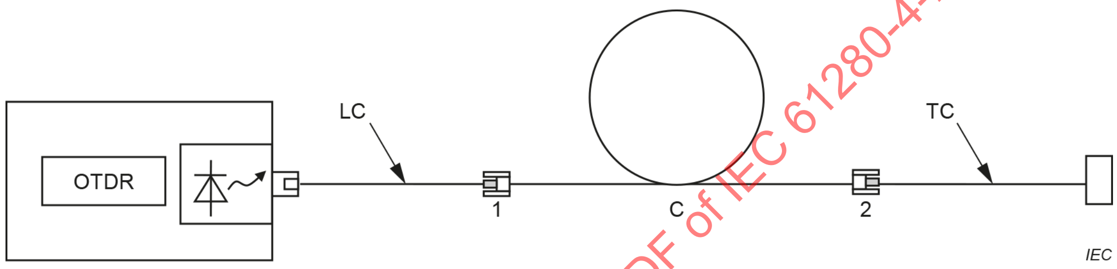
– Record the backscattered traces.

– Repeat from the other direction if required.

Bi-directional OTDR testing is recommended on single-mode cabling so that variations in ~~loss~~ attenuation measurements that are due to changes in the backscattering characteristics of different fibres can be cancelled out. Refer to Clauses I.6 and I.7 for further information on bi-directional testing and analysis.

NOTE Figure E.1 shows the set-up for cabling terminated with plug-adapter assemblies. Other arrangements are equivalent, provided the corresponding reference-grade terminations are used at the same points.





Key

OTDR optical time domain reflectometer

LC launch cord

C cabling under test

TC tail cord

1, 2 connector sets

NOTE Reference-grade terminations are shaded.

Figure E.1 – Test measurement for OTDR method ~~D~~

E.4 Calculation of attenuation

E.4.1 General

The attenuation A, expressed in dB, is given by

$$A = F_1 - F_2 \tag{E.1}$$

~~where F_1 and F_2 are the displayed power level of the input and output port of the cabling under test (see Figure D.3).~~

where

F_1 is the displayed power level at the input port of the cabling under test in dB;

F_2 is the displayed power level at the output port of the cabling under test in dB (see Figure E.3).

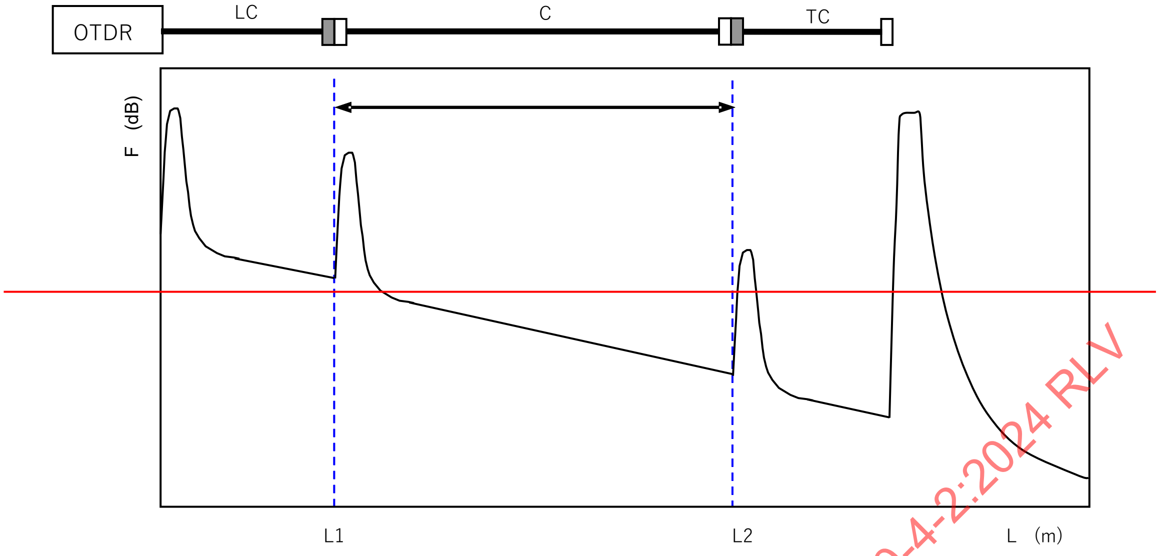
NOTE The vertical scale of the OTDR trace displays five times the logarithm of the received power (in linear units), plus a constant offset, whereas the horizontal scale of the OTDR trace displays the distance along the fibre. The horizontal scale is calculated by dividing the measured time delay of the pulse round trip by two and by the speed of light in the fibre, which is defined by the effective group refractive index of the fibre core.

It is important to properly locate the position of the two connections and to properly define the displayed power levels, as described in E.4.2 and E.4.3.

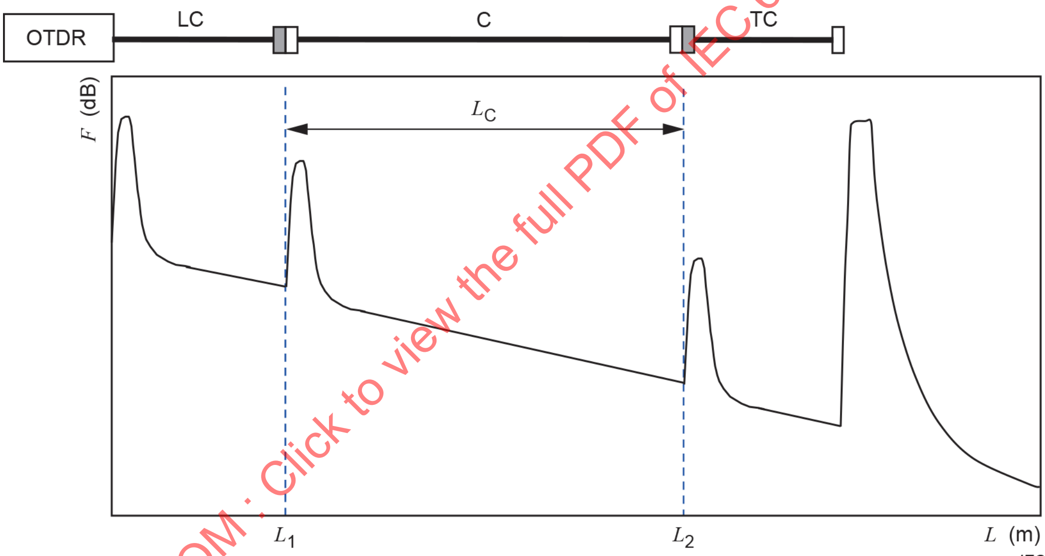
E.4.2 Connection location

The two connections of the cabling under test are located at the inflection points (change of curvature) in the trace just before the two peaks that represent the two connectors.

Figure E.2 illustrates the location of the connectors on a typical trace.



IEC 2098/14



IEC

Key

OTDR	optical time domain reflectometer
LC	launch ~~test~~ cord
C	cabling under test
TC	tail cord
L_1, L_2	cabling port locations
L_C	length of cabling under test
F	reflected power level
L	distance from output port of OTDR launch cord

Figure E.2 – Location of the cabling under test ports

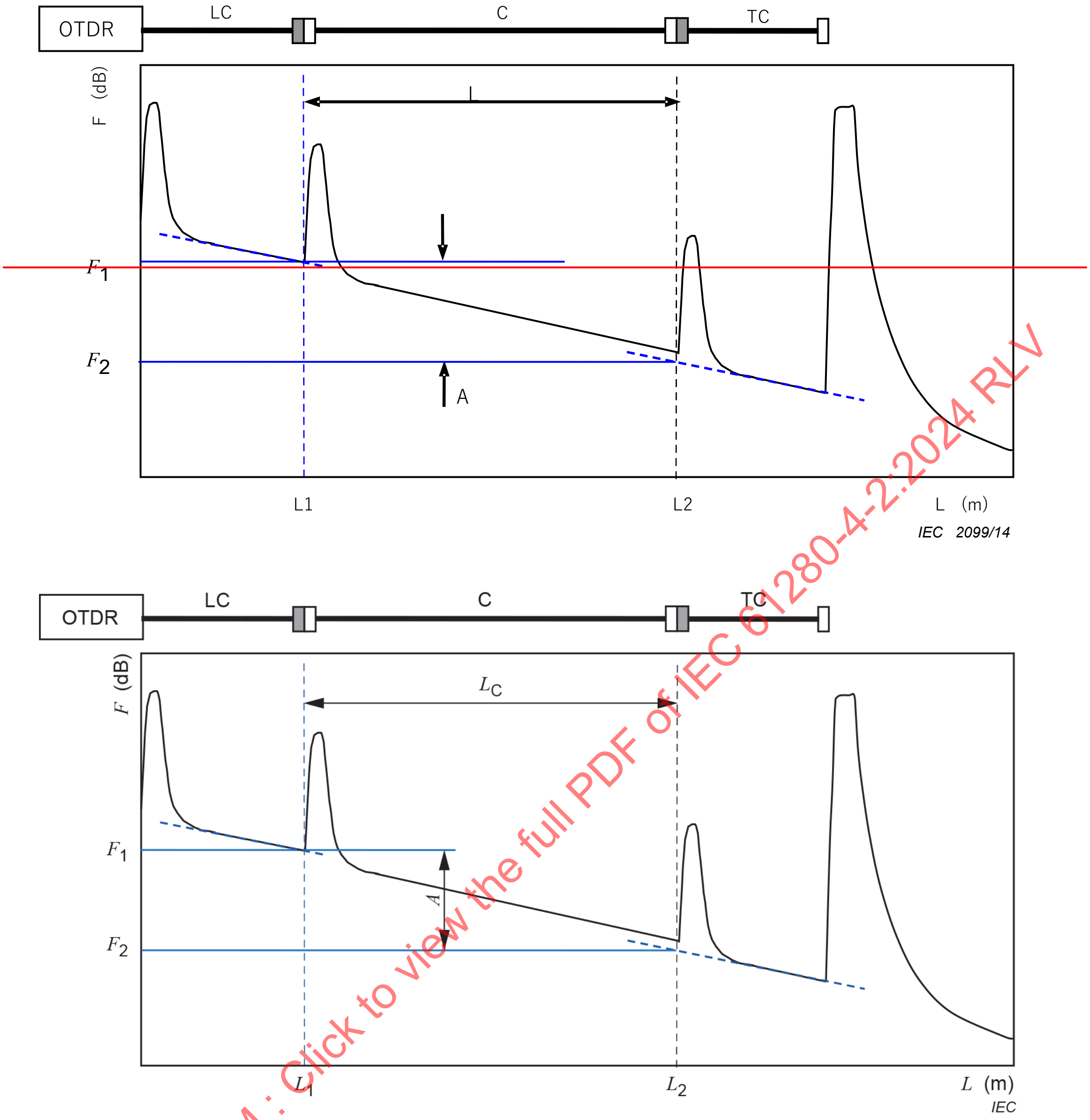
E.4.3 Definition of the power levels F_1 and F_2

The displayed power level F_1 at location L_1 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the launch ~~test~~ cord and the vertical axis at location L_1.

The displayed power level F_2 at location L_2 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the tail cord and the vertical axis at location L_2.

Figure E.3 illustrates the position of levels F_1 and F_2 on a typical trace.

This measurement process is also called five points analysis with LSA. See Annex I for more details.



Key

OTDR optical time domain reflectometer

LC launch cord

TC tail cord

C cabling under test

L_1, L_2 cabling port locations

L_C length of cabling under test

L distance from output port of OTDR launch cord

F_1, F_2 displayed power level at L_1 and L_2

F reflected power level

A attenuation of cabling under test

Figure E.3 – Graphic construction of F_1 and F_2

E.4.4 Alternative calculation

~~Alternatively, the OTDR may provide two other displayed levels F_{11} and F_{12} in order to provide a detailed analysis of the trace. See Figure D.4.~~

A more detailed analysis of the attenuation in the cabling and the connectors can be obtained by deriving two additional power levels, F_{11} and F_{12}, from the OTDR trace, as illustrated in Figure E.4.

The displayed power level F_{11} at location L_1 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the cabling under test and the vertical axis at location L_1.

The displayed power level F_{21} at location L_2 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the cabling under test and the vertical axis at location L_2.

The attenuation of the near-end connector, A_1 (in dB), is then given by

$$A_1 = F_1 - F_{11} \tag{E.2}$$

The attenuation of the far-end connector, A_2 (in dB), is given by

$$A_2 = F_{21} - F_2 \tag{E.3}$$

And the attenuation of the cabling without connectors, A_c (in dB), is given by

$$A_c = F_{11} - F_{21} \tag{E.4}$$

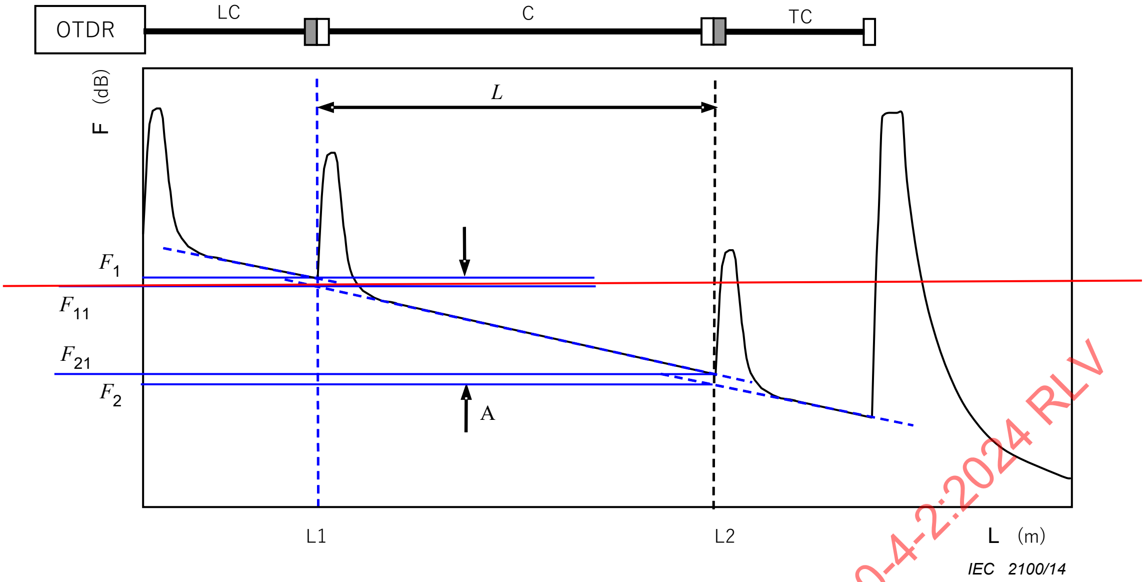
wherein the four power levels, F_1, F_2, F_{11} and F_{11}, are all expressed in dB.

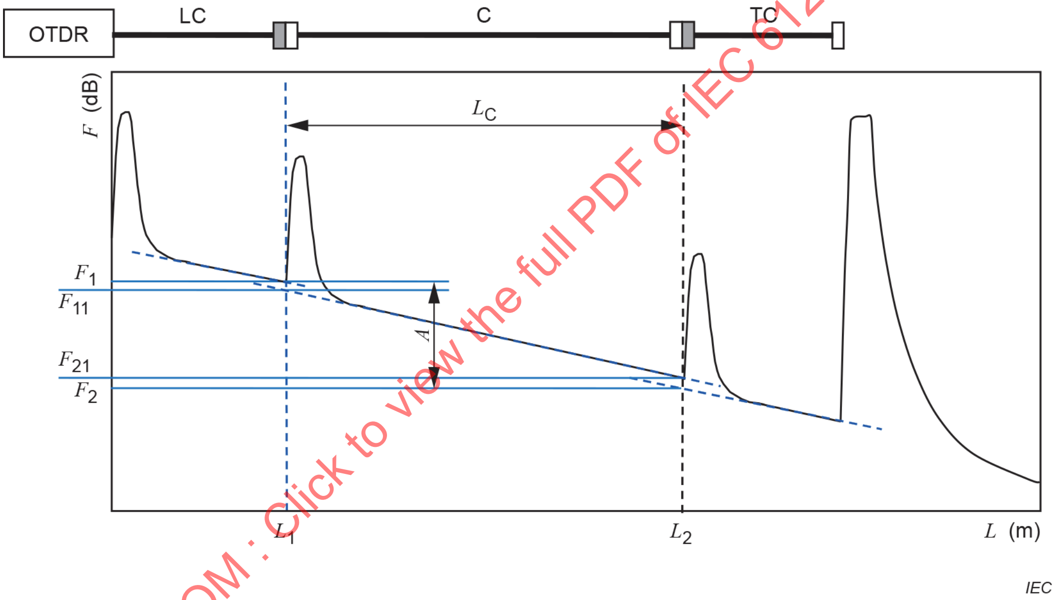
Combining Formula (E.2), Formula (E.3) and Formula (E.4) leads to Formula (E.5)

$$A = A_1 + A_c + A_2 \tag{E.5}$$

Assuming negligible calculation errors, the attenuation value A obtained from Formula (E.5) has the same validity as that obtained from Formula (E.1).

For some OTDRs, the attenuation values A_1, A_c and A_2 ~~may be~~ are available in an event table.





Key

OTDR optical time domain reflectometer

LC launch cord

C cabling under test

TC tail cord

L_1, L_2 cabling port locations

L_C length of cabling under test

L distance from output port of OTDR launch cord

F_1, F_2 displayed power level at L_1 and L_2

F_{11}, F_{21} displayed power level at L_1 and L_2 internal side

A attenuation of cabling under test

F reflected power level

Figure E.4 – Graphic construction of F_1, F_{11}, F_{21} and F_2

E.5 Calculation of optical return loss

The optical return loss ~~ORL~~, R_{ORL}, is the ratio of the ~~power~~ input ~~to the cabling under test~~ power to the ~~sum of~~ cabling under test to the total power reflected and scattered back by the cabling under test. The recommended test configuration for ~~both~~ attenuation and ORL measurements uses a long launch cord and a long tail cord; this allows the OTDR time to ~~eliminate~~ recover from saturation effects due to unwanted reflections, so that they can be removed from the ORL calculation, and allows ORL measurements to be made on very short sections of ~~cable~~ cabling under test.

The input power to the cabling under test, P_i, is a function of the OTDR laser power and the attenuation of the launch cord.

The ~~returning~~ total power returned from the cabling under test, P_r, is the integral of the ~~returning~~ reflected and backscattered power ~~(P_r)~~, $P(z)$, as a function of distance z along the cabling under test. This distance ranges from the ~~start~~ input port of the cabling under test, at the end of the OTDR launch cord, up until the output port of the cabling under test, at the beginning of the OTDR tail cord, and therefore includes the reflectance of the connections at both ends of the cabling under test.

This is illustrated graphically by the shaded area on the OTDR trace shown in Figure E.5.

Expressed mathematically the ORL is calculated as follows

~~$$\mathrm{ORL} = 10\log_{10}\left(\frac{Pi}{\int P(z)\mathrm{d}z}\right)$$~~

$$R_{\mathrm{ORL}} = 10 \times \log_{10}\left(\frac{P_{\mathrm{i}}}{\int P(z)\, dz}\right) \quad \text{(E.6)}$$

In general, the vertical scale of an OTDR is not calibrated for absolute optical power measurements. When an OTDR is used for ORL measurements, the backscatter parameter of the fibre in the cabling, K, can effectively serve as a reference level for the vertical scale. See IEC 61746-1:2009, Annex G for more details.

Therefore, ORL can be calculated as follows

~~$$\mathrm{ORL} = 10\log_{10}\left(\frac{1}{K}\frac{P_{\mathrm{t=ORL1}}}{\int_{\mathrm{t=ORL1}}^{\mathrm{t=ORL2}} P_{(t)}dt}\right)$$~~

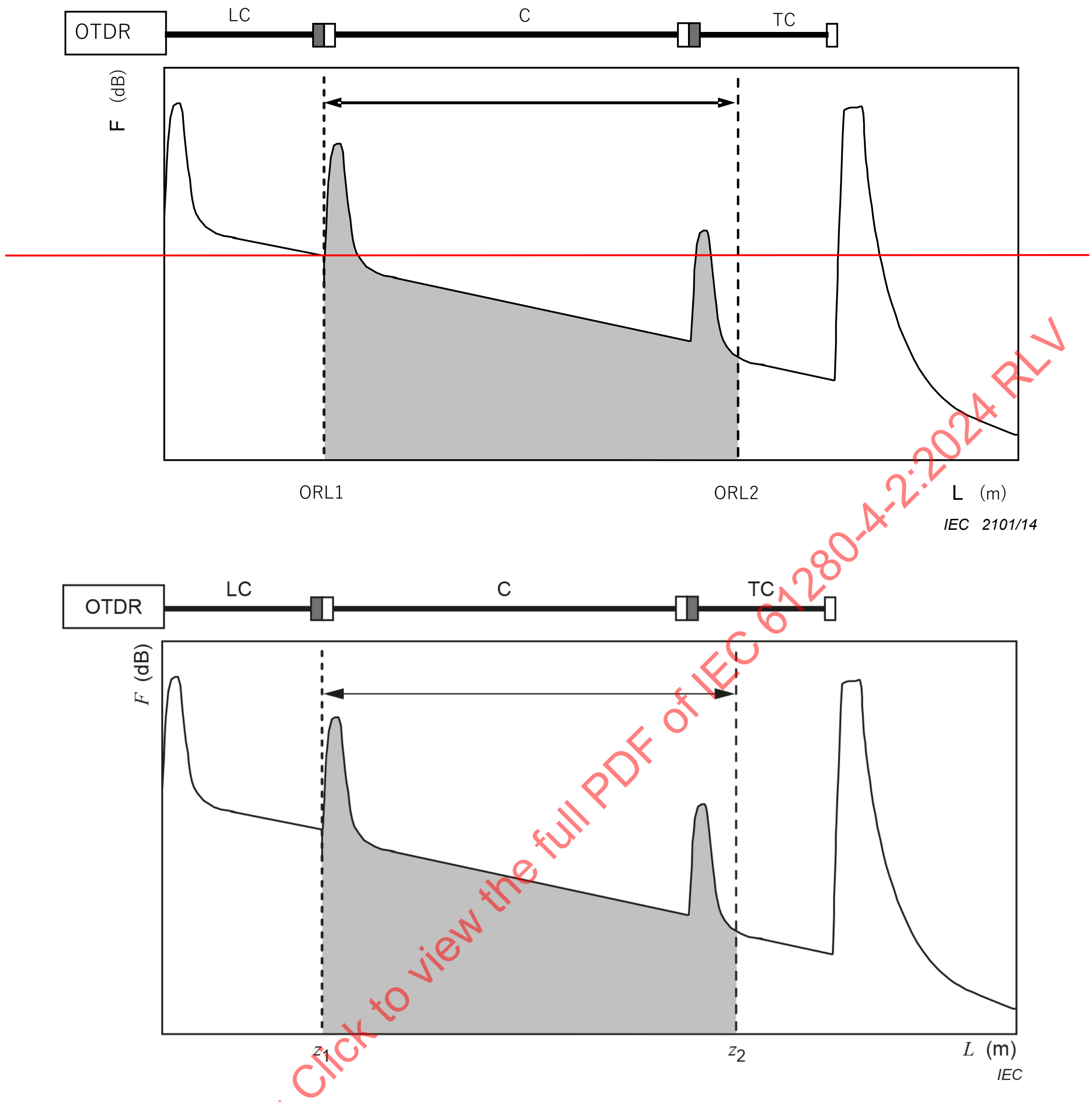
$$R_{ORL} = 10 \times \log_{10}\left(\frac{P(z_1)}{K\int_{z_1}^{z_2} P(z)dz}\right) \quad \text{(E.7)}$$

where

K is the backscatter parameter (see IEC 61746-1:2009, 9.3);

z_1 is the location of the beginning of the integration (see Figure E.5);

z_2 is the location of the end of the integration (see Figure E.5).



Key

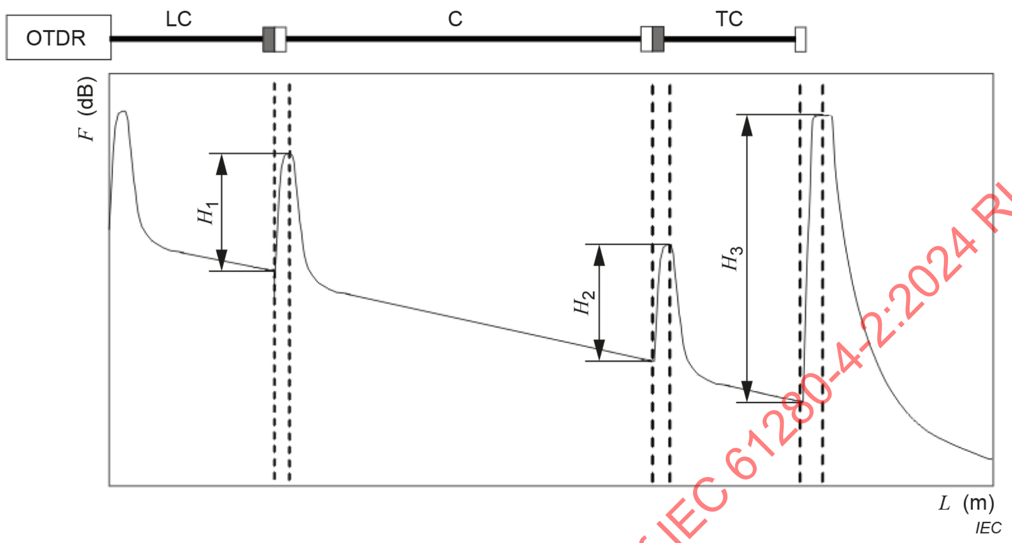
OTDR	optical time domain reflectometer
LC	launch cord
C	cabling under test
TC	tail cord
z_1	location indicating start of ORL integration
z_2	location indicating end of ORL integration
F	reflected power level
L	distance from output port of OTDR launch cord
~~ORL1~~	~~cursor defining start of ORL integration~~
~~ORL2~~	~~cursor defining end of ORL integration~~

Figure E.5 – Graphic representation of OTDR ORL measurement

E.6 Calculation of reflectance for discrete components

The reflectance of a component is the ratio of the power reflected back by that component to the power ~~input~~ incident to that component. On the OTDR trace, the reflectance is related to the height of the peak (H_n in Figure E.6) that represents the amount of light reflected back from that component, but it is also a function of the backscatter coefficient of the fibre under test and the pulse width used for the measurement.

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



Key

OTDR	optical time domain reflectometer
LC	launch cord
C	cabling under test
TC	tail cord
H_1	height of peak from first connection
H_2	height of peak from end connection
H_3	height of peak from far end of tail cord
F	reflected power level
L	distance from output port of OTDR launch cord

Figure E.6 – Graphic representation of reflectance measurement

The reflectance ~~(R)~~, R_{comp}, of a cabling component under test is calculated from the height of the reflected peak (H_1 or H_2) in Figure E.6 as follows:

~~$$R = 10 \times \log_{10}\left(10^{H/5} - 1\right) + 10 \times \log_{10}(t) + B$$~~

$$R_{\text{comp}} = 10 \times \log_{10}\left(10^{H/5} - 1\right) + 10 \times \log_{10}(t) + B \qquad \text{(E.8)}$$

where

H is the height of the peak (H_1 or H_2) in dB;

B is the Rayleigh backscattering coefficient in dB (for a time base in ns);

t is the pulse width in units of ns.

Typical values for the backscattering coefficient of single-mode fibres (e.g. type ~~B1.3~~ B-652.D of IEC 60793-2-50) are as follows:

$B \approx -80$ dB at 1 310 nm; $B \approx -82{,}5$ dB at 1 550 nm for a time base in ns

The detector in some OTDRs saturates ~~at large values of H (as shown in H3 in Figure D.6) where the peak has a flat top~~ when the value of H is very large (see peak with height H_3 in Figure E.6), so that the peak exhibits a flat top. It is necessary to use an OTDR with sufficient dynamic range for accurate reflectance measurements. This type of signal saturation ~~may~~ can be avoided by adding a variable attenuator between the OTDR and the cabling component under test.

E.7 OTDR uncertainties

The following sources of uncertainties should be considered when reporting the measurement:

– Noise level contribution: Errors due to a large amount of Gaussian noise or due to system noise; noise is always higher when the backscatter level approaches the noise floor on a logarithmic trace. A large amount of noise on the trace disturbs the linear regressions, leading to a wrong evaluation of the different displayed power levels. The noise ~~may~~ can be reduced by increasing the averaging time or by increasing the pulse width, and in all cases, it requires ensuring a dynamic margin of more than 3 dB (recommended ≥ 5 dB). When the slope of the linear regression is available (e.g. in dB/km) excessively low or high slopes are generally associated with an excessive level of noise.

– Backscatter coefficient: Intrinsic property differences between test cords and cabling under test ~~may~~ can cause variations in the apparent ~~loss~~ attenuation of individual connections. For example, when a fibre with a low backscatter coefficient is connected to one with a higher backscatter coefficient, the OTDR detector will receive more energy from the fibre with the higher backscatter coefficient. This can be interpreted as a reduction in the apparent ~~loss~~ attenuation and ~~may~~ can even appear as a gain (negative ~~loss~~ attenuation). The effect is known as a gainer.

NOTE The effect of variations in the backscatter coefficient on ~~loss~~ attenuation measurements ~~may~~ can be cancelled out by taking measurements from both ends of the cabling and averaging the values. See Clauses I.6 and I.7 for further information on bi-directional testing and analysis. As mentioned in Clause I.6, for total attenuation measurement, the uncertainty with unidirectional measurement is determined only by backscatter coefficient mismatch between launch and tail cords and is removed by using matched launch and tail cords, regardless of cabling under test.

– Strong reflections: Non-linear effects of strong reflections cause attenuation errors, attenuation coefficient errors and dead zone widening.

– Centre wavelength of OTDR laser: ~~– Causes Fibre attenuation variations between OTDR laser wavelength and cabling system transmitter wavelength~~ Fibre attenuation is wavelength dependent and, hence, can be different at the OTDR laser wavelength and the transmitter wavelengths normally used in the cabling under test.

– Spectral width of OTDR pulses: ~~– Related to centre wavelength, wider spectral widths cause fibre attenuation variations between the OTDR laser wavelength and the cabling system transmitter wavelength~~ Related to wavelength dependence of fibre attenuation; excessively wide spectral widths can yield fibre attenuation values that are different from the attenuation seen by the transmitter wavelengths normally used in the cabling under test.

– Cursor location error: Error in either software analyser placement of cursors or manual operation of cursors, which ~~may~~ can lead to significant errors when the slopes of the various fibres are very different.

Refer to IEC 61280-4-3 for a comprehensive overview of attenuation measurement uncertainties.

~~Annex E~~Annex F
(normative)

Continuous wave optical return loss measurement – Method A

F.1 Applicability of test method

This test method is closest to the definition of optical return loss given in 3.1.7. It directly measures the input power to the cabling under test as well as the reflected power, although a correction factor ~~is needed~~ shall be used to take into account the internal attenuation of the branching device and other sources of reflections.

OCWR methods have some limiting factors. Since it cannot spatially resolve different sources of reflections, unwanted reflections have to be suppressed. Moreover, the dynamic range is limited by the characteristics of the directional coupler used and the reflectance of the connector used to interface the return loss test set to the first test cord. This can limit the accuracy of the measurement when short cabling systems terminated with angle-polished connectors are being measured.

F.2 Apparatus

F.2.1 General

A typical test set for return loss measurements is shown in Figure F.1. The details have been adapted from IEC 61300-3-6 for testing installed cabling, and that standard ~~may~~ can be referred to for further information.

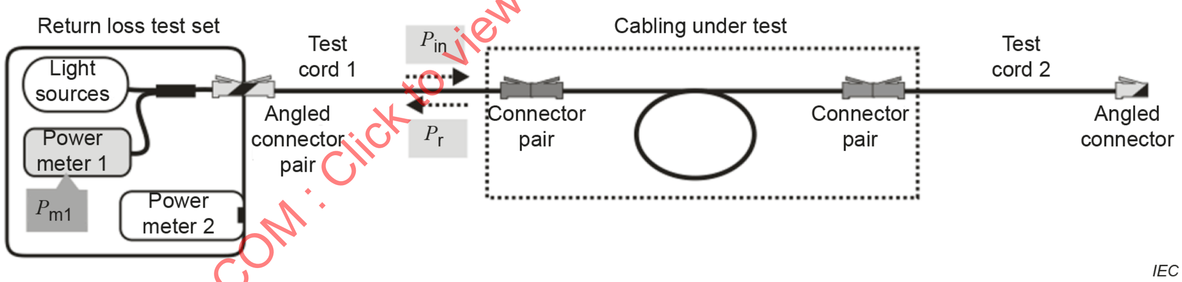


Figure F.1 – Return loss test set illustration

F.2.2 Light source

The source consists of an optical emitter (usually a laser) and its associated drive electronics, ~~with~~ where the output ~~being~~ light is available from a fibre pigtail or a fibre connector. A second source may be used for calibration, as illustrated in Figure F.3. When a second source is used, its central wavelength and spectral width shall be the same as those of the first source.

The source(s) ~~should~~ shall be stable as described in 6.2.1.

F.2.3 Branching device or coupler

The splitting ratio of the coupler shall be stable and be insensitive to polarization (< 0,1 dB polarization dependence). The directivity should be at least 10 dB higher than the maximum optical return loss to be measured.

F.2.4 Power meters

The power meters used consist of an optical detector, the associated electronics, and a means of connecting to an optical fibre. The connection to the internal power meter will be permanent; the interface to the external power meter should be equipped with interchangeable adapter caps that allow the use of connectors compatible with the cabling under test.

The linearity of the detectors in the power meters shall be specified and sufficient for the dynamic range of the measurements to be undertaken. Since all of the measurements are differential, however, it is not necessary that the calibration be absolute.

F.2.5 Connector interface

The connector interface on the return loss test set (RLTS) shall have very low reflection. The attenuation of this connection shall be stable, and the magnitude of the reflectance should be at least 10 dB greater than the magnitude of the maximum optical return loss to be measured.

NOTE The reflectance of this connector interface ~~may~~ can limit the accuracy of this measurement method when the cabling under test is terminated with angle-polished connectors and there are no other significant sources of optical return loss in the cabling under test.

F.2.6 Low reflection termination

In order to suppress unwanted reflections (typically from flat connectors open to air) the remote end of the cabling under test ~~may~~ can require termination with a test cord such that the connector interface to the cabling under test is representative of a connection made with an equipment connection cord and the reflection from the remote end of the test cord is suppressed. Reflections ~~may~~ can be suppressed using an angle-polished connector, an angled cleave, a non-reflective terminator, index matching material or by wrapping the cord tightly around a mandrel [provided that the fibre in the test cord is not bending loss insensitive (IEC 60793-2-50 type B6 or ITU-T Recommendation G.657 types)].

A similarly low reflection termination is required when calibrating the internal reflections of the test system (see Figure F.3). This termination should have a reflectance of at least 20 dB magnitude greater than the magnitude of the maximum optical return loss to be measured.

F.3 Procedure

F.3.1 Test set characterization

In order to perform an ORL measurement, it is necessary to characterize the measurement system by measuring its internal ~~losses~~ attenuations and reflections including the connection between the test equipment and test cord 1 to be used for the measurement (Figure F.2). This should be repeated whenever these ~~may~~ have been changed, for example after changing test cord 1.

The ~~system~~ internal attenuation of the RLTS shall be measured on the return path between the cabling under test and the internal power meter 1. This includes the attenuation of the connector interface and the attenuation of the coupler. Using an external source, with similar characteristics as the internal source, connect the remote end of test cord 1 to the source and the near end of test cord 1 (angled) to the external power meter, as shown in Figure F.2. Record the power level on power meter 2 as P_{ref2}.

NOTE All power measurements described in Clause F.3 are taken in linear units (W).

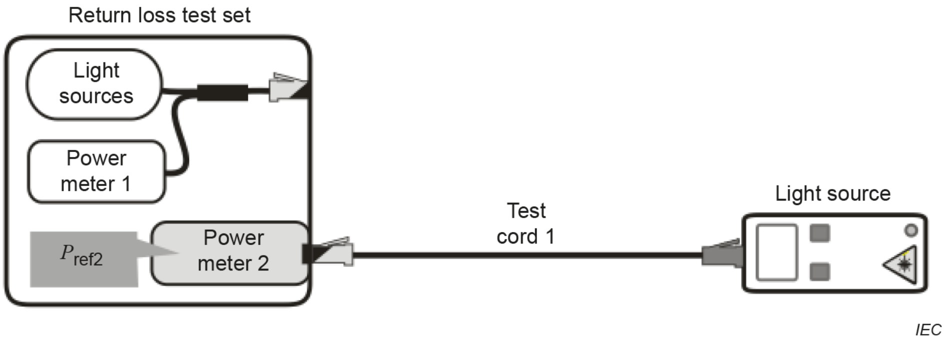


Figure F.2 – Measurement of the system internal attenuation P_{ref2}

Next, connect the near end of test cord 1 into the output port of the RLTS, as shown in Figure F.3, and record the power level on power meter 1 as P_{ref1}.

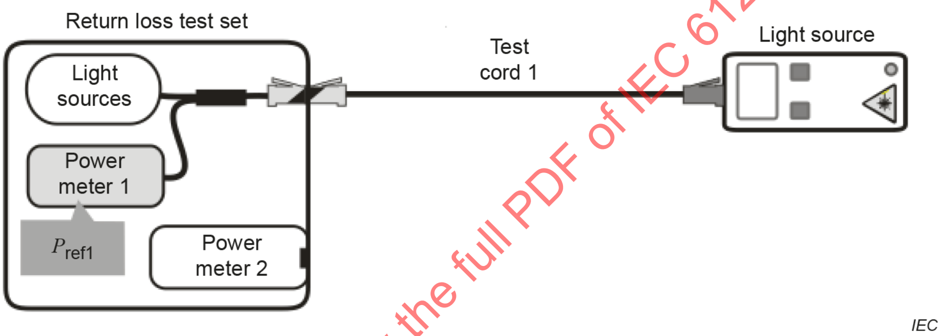


Figure F.3 – Measurement of the system internal attenuation P_{ref1}

The ~~difference between~~ ratio of these two power levels is the internal attenuation of the system.

Next, the system reflected power ~~needs~~ has to be measured. Leaving test cord 1 connected to the output port of the RLTS, suppress the reflection coming from the connector at the far end of test cord 1, as shown in Figure F.4. This is done with a low reflection termination (see F.2.6). The amount of light reflected internally within the measurement system including the interface connector ~~may~~ can now be measured on power meter 1 as P_{rs}.

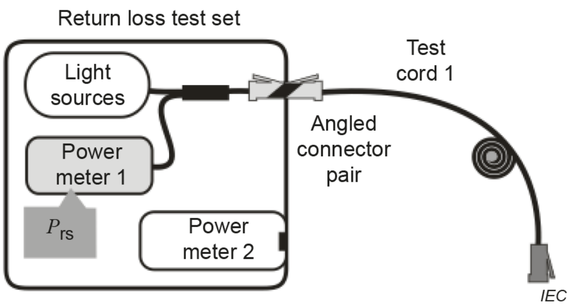


Figure F.4 – Measurement of the system reflected power P_{rs}

F.3.2 Measurement procedure

The optical return loss is the ~~difference between~~ ratio of the input power to the cabling under test, P_{in}, to the power reflected back from the cabling under test, P_r. Therefore, two power levels are required. First, the power into the cabling under test, P_{in}, is measured directly by connecting the far end of test cord 1 into power meter 2, as shown in Figure F.5.

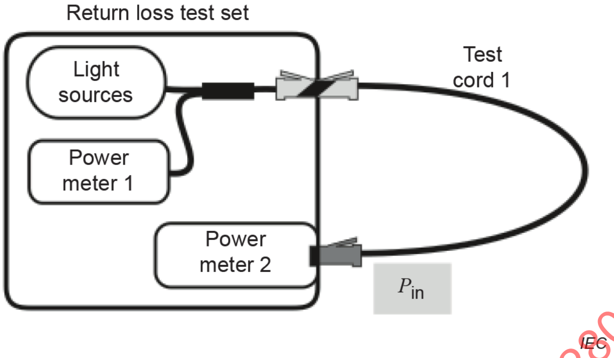


Figure F.5 – Measurement of the input power P_{in}

Then, test cord 1 is connected into the cabling under test, and any unwanted reflections from the far end should be suppressed by using a low reflection termination (see F.2.5), as shown in Figure F.6. The power level on power meter 1 should now be recorded as P_{m1} and then used to determine the reflected power by making allowances for the internal ~~losses~~ attenuations and reflections of the measurement system.

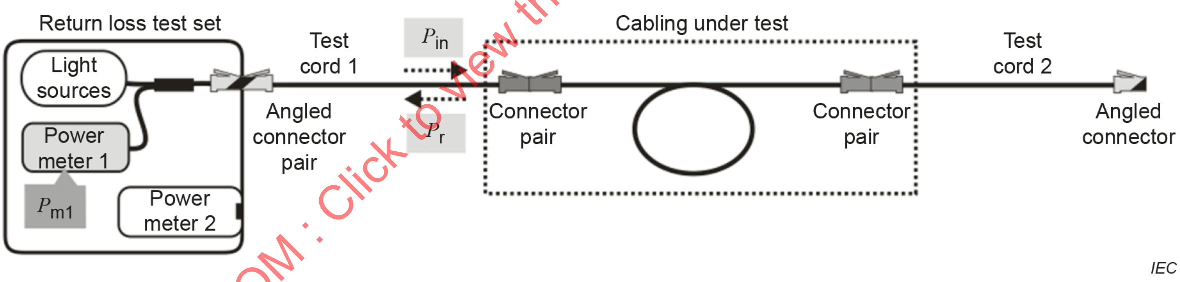


Figure F.6 – Measurement of the reflected power P_r

F.3.3 Calculations

Using the definition of optical return loss in 3.1.7

~~$ORL = 10\log_{10}(P_{in} / P_r)$~~

$$R_{ORL} = 10 \times \log_{10}(P_{in} / P_r) \tag{F.1}$$

where P_{in} is measured directly as shown in Figure F.5. P_r is calculated by taking the measured reflected power, P_{m1}, subtracting from it the contribution from the internal reflections of the measurement system, P_{rs} ~~that will still be present~~, and then compensating for the attenuation that ~~will be suffered~~ is experienced by the reflected light as it passes from test cord 1 back through the connector interface on the RLTS, through the coupler and on to the internal power meter. Formula (F.2) shows the mathematical calculation of P_r.

$$P_r = (P_{m1} - P_{rs}) \times (P_{ref2} / P_{ref1}) \qquad (F.2)$$

Substituting for P_r in Formula (F.1) then gives R_{ORL} in dB as:

~~$ORL = 10\log_{10}(P_{in} / ((P_{m1} - P_{rs}) \times (P_{ref2}/P_{ref1}))$ in dB~~

$$R_{ORL} = 10 \times \log_{10}\left[\frac{P_{in} \times P_{ref1}}{\left(P_{m1} - P_{rs}\right) \times P_{ref2}}\right] \qquad (F.3)$$

~~**E.3.4 Measurement uncertainty**~~

~~A full assessment of the measurement uncertainty is for further study.~~

~~Some contributions on uncertainty include~~

~~– absolute power measurement uncertainty for two (independent) power meters (see G.2.6 for details),~~

~~– uncertainties induced from spectral properties difference between internal and external sources.~~

~~Annex F~~Annex G
(normative)

Continuous wave optical return loss measurement – Method B

G.1 Applicability of test method

Compared with the method A described in Annex F, this method utilizes a known reflectance to characterize the measurement set-up. Rewriting Formula (F.3) as

~~$\mathrm{ORL} = 10\log_{10}(P_{in}/((P_{m1} - P_{rs}) \times (P_{ref2}/P_{ref1}))$~~

~~$= 10\log_{10}(P_{in}/L_{ret}) - 10\log_{10}(P_{m1} - P_{rs})$~~

~~$= C_f - 10\log_{10}(P_{m1} - P_{rs})$~~

$$R_{ORL} = 10 \times \log_{10}\left[\frac{P_{in} \times P_{ref1}}{(P_{m1} - P_{rs}) \times P_{ref2}}\right] = 10 \times \log_{10}\left(\frac{P_{in}}{L_{ret}}\right) - 10 \times \log_{10}(P_{m1} - P_{rs}) = C_f - 10 \times \log_{10}(P_{m1} - P_{rs}) \quad (G.1)$$

where

L_{ret} is the attenuation of the coupler between P_r and P_{m1};

$C_f = 10 \times \log_{10}(P_{in} / L_{ret})$ is the characterization factor.

G.2 Apparatus

G.2.1 General requirements

A typical test set for return loss measurements is shown in Figure G.1. In addition to the apparatus described in Annex F the reflectance termination described in G.2.2 is required.

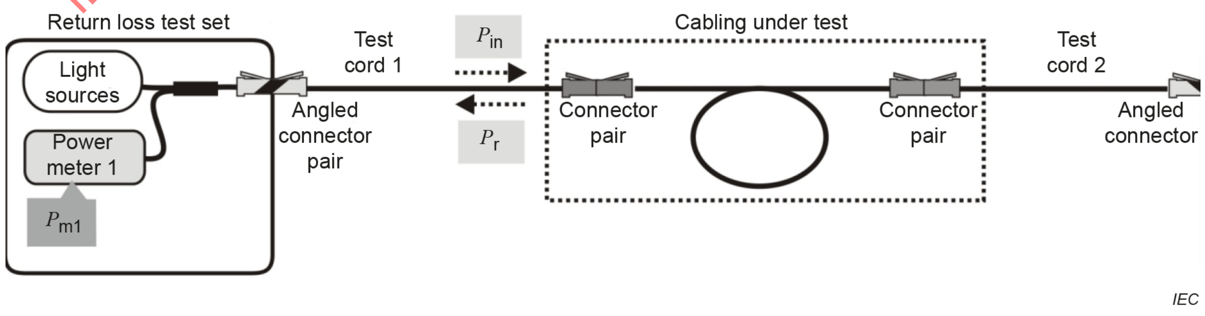


Figure G.1 – Return loss test set illustration

G.2.2 Known reflectance termination

A termination with known reflectance is required to determine the internal ~~losses~~ attenuations and reflections of the measurement system. Commonly a flat ended (PC but not angled) connector~~,~~ open to air is used, which has an assumed reflectance of –14,6 dB.

G.3 Procedure

G.3.1 Set-up characterization

In order to perform the measurement, it is necessary to characterize the measurement system by determining C_f.

C_f can be characterized by taking two measurements, the first with reflections suppressed, as shown in Figure G.2, and the second using a reference reflector with known reflection R_{ref}, as shown in Figure G.3.

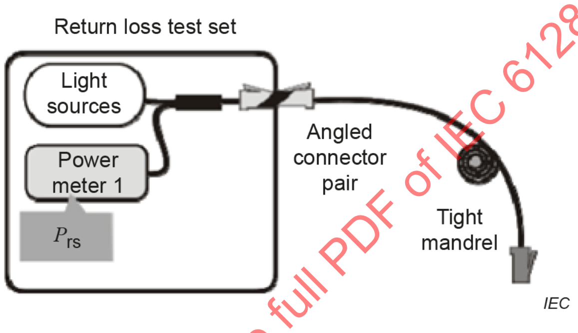


Figure G.2 – Measurement of P_{rs} with reflections suppressed

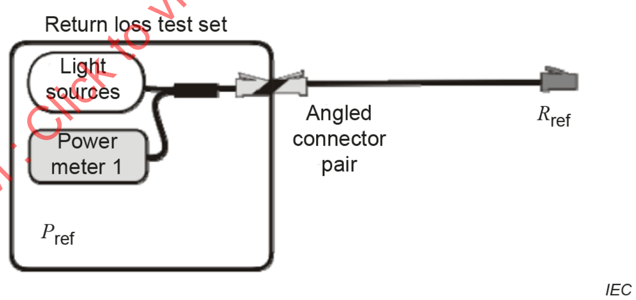


Figure G.3 – Measurement of P_{ref} with reference reflector

The first measurement yields the internally reflected power P_{rs} of the RLTS, as described in F.3.1, whereas the second measurement yields a reference power P_{ref}, so that the characterization factor can now be determined as $C_f = 10 \times \log[(P_{ref} - P_{rs}) / R_{ref}]$.

When R_{ref} is much higher than the reflectance from the connector and coupler, (i.e. $P_{ref} >> P_{rs}$, then $C_f \approx 10 \times \log(P_{ref} / R_{ref})$), so that the determination of C_f can be simplified to taking only the measurement shown in Figure G.3.

NOTE All power measurements described are taken in linear units (W).

G.3.2 Measurement procedure

The system reflected power, P_{rs}, ~~needs to be~~ is measured by suppressing the reflection coming from the connector at the far end of test cord 1, as shown in Figure G.4. This ~~is done~~ can be accomplished with a low reflection termination (see F.2.6). The amount of light reflected internally within the measurement system, including the interface connector ~~may~~, can now be measured on power meter 1 and recorded as P_{rs}.

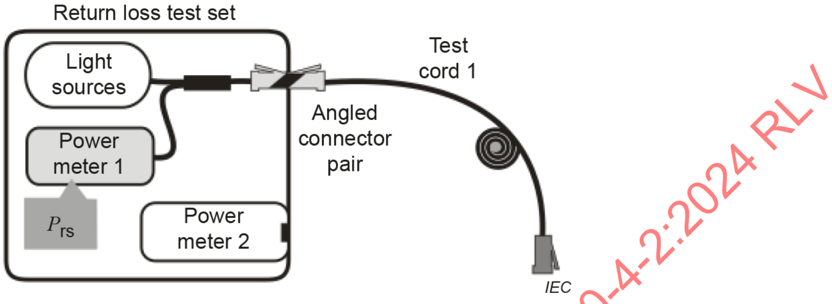


Figure G.4 – Measurement of the system reflected power P_{rs}

Then test cord 1 ~~can be~~ is connected into the cabling under test and any unwanted reflections from the far end ~~can be~~ are suppressed by using a low reflection termination (see F.2.6) at the end of test cord 2, as shown in Figure G.5. The power level on power meter 1 ~~can~~ is now ~~be~~ recorded as P_{m1} and subsequently used to determine the reflected power by making allowances for the internal ~~losses~~ attenuations and reflections of the measurement system.

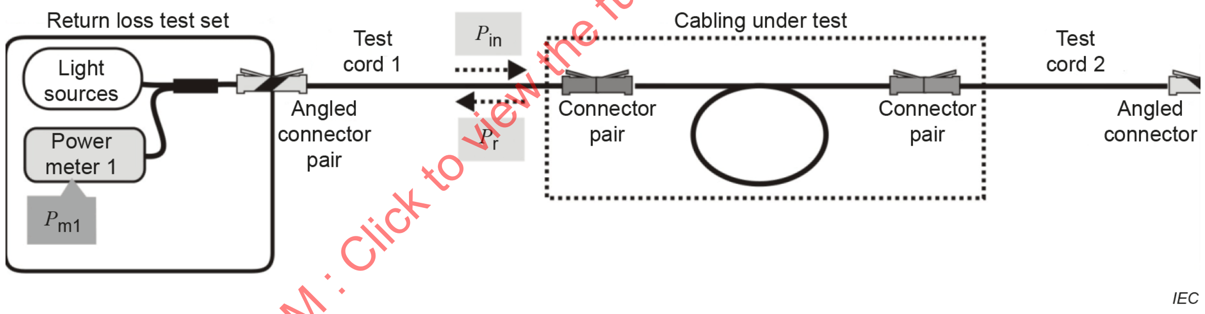


Figure G.5 – Measurement of the reflected power P_r

G.3.3 Calculation

~~From our definition of optical return loss in 3.1.7~~

$$\sout{ORL = 10\log_{10}(P_{in} / P_r)}$$

~~and the relation shown in Equation (F.1), ORL is calculated by taking the measured reflected power (P_{m1}) and subtracting from this the contribution from the internal reflections of the measurement system (P_{rs}) that will still be present, and applying of the characterization factor C_f, as~~

$$\sout{ORL = C_f - 10\log_{10}(P_{m1} - P_{rs})} \quad \text{~~(F.2)~~}$$

Using the definition of optical return loss in 3.1.7 (see also Formula (F.1)) and the relation shown in Formula (G.1), R_{ORL} is calculated by subtracting from the measured reflected power,

P_{m1}, the contribution from the internal reflections of the measurement system, P_{rs}, which was present in the measurement of P_{m1}, and finally applying the characterization factor C_f, as shown in Formula (G.2):

$$R_{ORL} = C_f - 10 \times \log_{10}(P_{m1} - P_{rs}) \tag{G.2}$$

~~F.3.4 Measurement uncertainty~~

~~A full assessment of the measurement uncertainty is for further study.~~

~~Some contributions on uncertainty include~~

- ~~connection repeatability between the unit and reference reflector jumper. See Clause G.1 for details;~~
- ~~uncertainty on R_{ref}.~~

Annex G
(informative)

Measurement uncertainty examples

G.1 Reduction of uncertainty by using reference grade terminations and related issues

G.1.1 Motivations for using reference grade terminations on test cords

Reference grade terminations are used, where possible, to reduce measurement uncertainty. If a connector with an off-centre optical fibre were to be used, the results would vary depending on the particular orientation of the fibre in the launch cord connector to the orientation of the offset of the fibre in the connector in the cabling.

The interpretation of the measured loss of the cabling is likely to be based upon comparison with a specified acceptance figure to provide a pass/fail result. This acceptance figure may be based on a total loss figure for the cabling or it may be based on addition of the attenuation contributions of the individual components.

The use of reference grade terminations on the test cords means that the measured loss of the cabling will typically be less than if standard grade terminations are used. This may mean that if the acceptance figure is based upon the assumption of standard grade terminations for the finally configured system, for example, then some adjustment of the acceptance figure is necessary.

These uncertainties are particularly significant when short lengths of cabling are being tested, as the losses associated with the connections are much higher than the losses of the fibre itself. For long haul systems, the loss of the fibre dominates the total loss and this uncertainty is less critical.

The following table shows examples of losses between the different possible combinations of reference and standard grade terminations.

Table G.1 – Expected loss for examples (see NOTE 1)

Termination 1	Termination 2	Attenuation requirement
SM reference grade	SM reference grade	≤0,2 dB
SM reference grade	SM standard grade	≤0,5 dB
SM standard grade	SM standard grade	≤0,75 dB

NOTE 1 Table G.1 shows the required performance of standard and reference grade SC connectors in accordance with IEC 60874-14-2. These values are found in other, but not all, performance standards for connecting hardware.

NOTE 2 Current studies by JWG8 of IEC SC86A and SC86B on reference grade terminations may produce values for other connector styles.

G.1.2 Adjusting acceptance limits to allow for different expected losses when using reference grade and standard grade connectors

G.1.2.1 General

The following examples are given to illustrate the impact on the test results obtained when reference grade connectors are used on the test cords. If the acceptance limits (pass/fail criteria) are based on the assumption of standard grade connector performance then these limits need to be adjusted when reference grade test cords are used to obtain the test results. These examples are based on using SC connectors in accordance with IEC 60874-14-2, where the expected losses in Table G.1 have been defined by IEC SC86B.

Other connector styles may have different values for expected losses in the different configurations illustrated in Table G.1.

G.1.2.2 Example 1 (for one-cord reference)

A single-mode cabling system 100 m long is terminated in a patch panel at each end. The expected loss, assuming standard grade connectors, would be a total of up to 1,60 dB, assuming 1,0 dB/km cabled optical fibre loss and 0,75 dB per connection.

If this system is measured using the one test cord reference method as described, and using reference grade terminations on the test cords, then the loss will be up to 1,10 dB (0,1 dB for the 100 m of optical fibre plus 0,5 dB for each connection between reference grade and standard grade terminations).

For each reference grade to standard grade connection, i.e. in the measurement configuration, an adjustment of 0,25 dB should be subtracted from the acceptance figure that is based on the assumption of using standard grade connectors.

G.1.2.3 Example 2 (for three cord reference)

Consider the above cabling system but with equipment connection cords with standard grade terminations connected into the patch panels. The expected loss excluding the terminal connectors will be the same as in example 1, i.e. up to1,60 dB.

If this is tested as a cabling system terminated with connector plugs using the three-test-cord reference method, the measured loss will up to 2,10 dB. This assumes up to 1,60 dB for the cabling as before, plus 2 dB × 0,3 dB, since two reference-grade-to-reference-grade connections were included in the reference measurement (each with a loss of up to 0,2 dB), which are replaced by two reference-grade-to-standard grade connections (each with a loss of up to 0,5 dB) in the measured power level through the cabling.

For each reference-grade-to-reference-grade connection in the reference measurement that is replaced by a reference-grade-to-standard grade connection in the measurement configuration, an adjustment of 0,3 dB should be added to the acceptance figure that is based on the assumption of using standard grade connectors.

G.1.2.4 Example 3 (two cord reference, Figure C.3)

The above cabling system is considered, but with connection cords with standard grade plug/socket style connectors, such as MTRJs, connected into patch panels. To test these systems, it is necessary to use the two-cord reference method with the addition of a reference grade adapter cord to complete the test configuration. This adapter cord allows connectivity but also adds the loss of the mated pair of connectors factored out in the referencing procedure, because all the connectors involved are reference grade. However, the reference grade termination interface with the standard grade patch panel connectors will typically have a lower loss than those of the equipment patch cords. The acceptance criteria, therefore, needs to be reduced by 2 dB × 0,25 dB = 0,5 dB.

G.1.2.5 Example 4 – Long haul system (one cord reference)

A link 80 km long is terminated at optical distribution frames by splicing on pigtails. The route is made up of 16 drums of cable each 5 km long with fusion splices between them. The expected loss of the link at 1 550 nm, assuming standard grade connectors, is 20,8 dB assuming

0,22 dB/km for the fibre loss, average 0,1 dB for the 17 splices and 0,75 dB for each of the terminations at the ODFs.

When tested using the one cord reference method, the expected loss at the terminations, assuming that reference grade termination are used on the test cords, will be up to 20,3 dB.

It can be seen that the variance in this case is much less significant than for the above cases where there are short lengths of fibre.

G.2 Estimation of the measurement uncertainties

G.2.1 Measurement uncertainty

When conducted based on ISO/IEC Guide 98-3, the determination of the measurement uncertainty is a complicated process that should take into account all the parameters involved with the measurement, including: the source, the reference cable, the power meter and the operator.

The following analysis and calculation is intended to be used to identify the parameters that really contribute to the measurement uncertainty. The example is based on the three-cord reference method (Annex B).

The measurement uncertainty of the attenuation L can be calculated from the contribution of each of the contributing elements using the standard formula for accumulation of the uncertainties

$$u_A \approx \sqrt{u_{instr.}^2 + u_{source}^2 + u_{DUT}^2} \quad (G.1)$$

where

$u_{instr.}$ is uncertainty due to the instrument;

u_{source} is uncertainty due to the source;

u_{DUT} is uncertainty due to the device under test.

G.2.2 Uncertainty due to the instrument

The following uncertainties may come from the instrument and the total uncertainty calculated as follows:

$$u_{inst}^2 = 2u_{TypeA.}^2 + 2u_{PDR}^2 + 2u_{Displ}^2 + u_{lin}^2 + u_{unif}^2 \quad (G.2)$$

where

u_{TypeA} is the type A uncertainty;

u_{PDR} is the uncertainty due to polarization dependent reflectance;

u_{Displ} is the uncertainty due to the display resolution;

u_{lin} is the uncertainty due to the linearity of the detector;

u_{unif} is the uncertainty due to the uniformity of the detector.

G.2.3 Uncertainty due to the source

The uncertainty associated with the source is mainly due to the source stability and is calculated as follows:

$$u_{\text{source}}^2 = 2\,u_{\text{stab.}}^2 \tag{G.3}$$

where

u_{source} is the uncertainty associated with the source;

$u_{\text{stab.}}$ is the uncertainty due to the source stability.

G.2.4 Uncertainty due to the device under test

The uncertainties associated with the device under test are due to the uncertainty due to polarization dependent loss, the mating loss of the connectors and the referencing process and is calculated as follows:

$$u_{\text{DUT}}^2 = 2\,u_{\text{PDL}}^2 + u_{\text{mating}}^2 + u_{\text{REF}}^2 \tag{G.4}$$

where

u_{DUT} is the uncertainty associated with the device under test;

u_{PDL} is the uncertainty from polarization dependent loss;

u_{mating} is the uncertainty from the variations in the mating of the connectors;

u_{REF} is the uncertainty associated with the reference.

The fibre manipulations generate some random variations of the connector's loss.

The amplitude of such variations can be estimated using more than 10 repetitive measurements of the reference power $P_{1,k}$, associated with repetitive connection and disconnection of the substitution cord. Then the estimation of the uncertainty u_{manip} is provided by the following calculation process.

First calculate the arithmetic mean of the power $\overline{P}$

$$\overline{P} = \frac{1}{n}\sum_{k=1}^{n} P_k \tag{G.5}$$

Then calculate the experimental standard deviation:

$$s_{\text{typeA}} = \left[\frac{1}{m-1}\sum_{i=1}^{m}\left(y_i - y_{\text{mean}}\right)^2\right]^{1/2} \tag{G.6}$$

where

$\overline{P}$ is the arithmetic mean of the reference power;

P_k are the measurements of the reference power;

n is the number of measurements.

The uncertainty u_{manip} is the experimental standard deviation of the mean:

$$\sigma_{typeA} = \frac{s_r}{\sqrt{n}} \quad (G.7)$$

Repeat the preceding procedure at the test measurement step (see Figure B.2) to determine the uncertainty of the manipulation in the measurement configuration.

G.2.5 Example of uncertainty accumulation using a single power meter

The following example provides a typical presentation of the results obtained when the same power meter is used for both power level measurements.

Table G.2 – Example of uncertainty accumulation using a single power meter

Other light source instability	0,005 dB	Maximum
Power meter linearity	0,04 dB	K=2
Power meter polarization error	0,005 dB	Maximum
Power meter resolution	0,001 dB	Maximum
Uncertainty of DUT P1	0,04 dB	K=1
Uncertainty of DUT P2	0,08 dB	K=1

Source	Units	Dist.	Value U or a	Divisor	u_i	$(u_i\ c_i)^2$
Light source stability	dB	Normal	6,932E-03	2,0000	3,466E-03	1,20E-05
Light source connector stability	dB	Rectangular	2,305E-03	1,7321	1,331E-03	1,77E-06
Other light source instability	dB	Rectangular	1,152E-03	1,7321	6,651E-04	4,42E-07
	Sum					1,42E-05

Source	Units	Dist.	Value U or a	Divisor	u_i	$(u_i\ c_i)^2$
Power meter linearity	dB	Normal	9,253E-03	2,0000	4,626E-03	2,14E-05
Power meter polarization error	dB	Rectangular	1,152E-03	1,7321	6,651E-04	4,42E-07
Power meter resolution	dB	Rectangular	2,303E-04	1,7321	1,330E-04	1,77E-08
	Sum					2,19E-05

Source	Units	Dist.	Value U or a	Divisor	u_i	$(u_i\ c_i)^2$
Uncertainty of DUT P1	dB	Normal	9,253E-03	1,0000	9,253E-03	8,56E-05
Uncertainty of DUT P2	dB	Normal	1,859E-02	1,0000	1,859E-02	3,46E-04
	Sum					4,31E-04

Combined standard uncertainty, $u(L)$	2,16E-02
Expanded uncertainty, $U = ku(L)$, with $k = 2$	**4,32E-02**
Expanded uncertainty expressed in dB	**0,18**

~~G.2.6 Example of uncertainty accumulation using two power meters~~

~~The following example provides a typical presentation of the results obtained when two different power meters are used for measuring the two power levels.~~

~~Table G.3 – Example of uncertainty accumulation using two power meters~~

UNCERTAINTY COMPONENTS		
Light source stability	0,03 dB	K=2
Light source connector stability	0,01 dB	Maximum
Other light source instability	0,005 dB	Maximum
Power meter A linearity	0,04 dB	K=2
Power meter A uncertainty	0,2 dB	K=2
Power meter B linearity	0,04 dB	K=2
Power meter B uncertainty	0,2 dB	K=2
Power meter polarization error	0,005 dB	Maximum
Power meter resolution	0,001 dB	Maximum
Uncertainty of DUT P1	0,04 dB	K=1
Uncertainty of DUT P2	0,08 dB	K=1

Source	Units	Dist.	Value	Divisor	u_i	$(u_i\ c_i)^2$
Light source stability	dB	Normal	6,932E-03	2,0000	3,466E-03	1,20E-05
Light source connector stability	dB	Rectangular	2,305E-03	1,7321	1,331E-03	1,77E-06
Other light source instability	dB	Rectangular	1,152E-03	1,7321	6,651E-04	4,42E-07
	Sum					1,42E-05

Source	Units	Dist.	Value U or a	Divisor	u_i	$(u_i\ c_i)^2$
Power meter A linearity	dB	Normal	9,253E-03	2,0000	4,626E-03	2,14E-05
Power meter A uncertainty	dB	Normal	4,713E-02	2,0000	2,356E-02	5,55E-04
Power meter B linearity	dB	Normal	9,253E-03	2,0000	4,626E-03	2,14E-05
Power meter B uncertainty	dB	Normal	4,713E-02	2,0000	2,356E-02	5,55E-04
Power meter polarization error	dB	Rectangular	1,152E-03	1,7321	6,651E-04	4,42E-07
Power meter resolution	dB	Rectangular	2,303E-04	1,7321	1,330E-04	1,77E-08
	Sum					1,15E-03

Source	Units	Dist.	Value U or a	Divisor	u_i	$(u_i\ c_i)^2$
Uncertainty of DUT P1	dB	Normal	9,253E-03	1,0000	9,253E-03	8,56E-05
Uncertainty of DUT P2	dB	Normal	1,859E-02	1,0000	1,859E-02	3,46E-04
	Sum					4,31E-04

Combined standard uncertainty, $u(L)$	4,00E-02
Expanded uncertainty, $U = ku(L)$, with $k = 2$	**8,00E-02**
Expanded uncertainty expressed in dB	**0,33**

Annex H
(normative)

On the use of reference-grade test cords

H.1 General

Test cords with reference-grade terminations are used, where possible, to reduce measurement uncertainties. If a connector with an off-centre optical fibre were to be used, the results would vary depending on the orientation of the fibre in the launch cord connector to the orientation of the offset of the fibre in the connector in the cabling. However, the use of reference-grade terminations on the test cords means that the measured attenuation of the cabling will typically be different than if standard-grade terminations were used, thus leading to an adjustment in the test limit for the measurement.

The interpretation of the measured attenuation of the cabling is likely to be based upon comparison with a specified acceptance figure (the test limit) to provide a pass or fail result. This annex provides guidance on how these test limits should be modified to take into account the use of reference-grade rather than standard-grade connectors on the test cords.

H.2 Practical configurations and assumptions

H.2.1 Component specifications

Cabling under test comprises cable(s), splice(s), and connections.

For cables and splices, the value to be used in the establishment of the attenuation contribution is the maximum value specified in the relevant cabling or cable standard. The cable attenuation is calculated by multiplying the maximum attenuation coefficient specified by the length of the cable. For example, a cabled optical fibre of Category OS2 (in accordance with ISO/IEC 11801-1) has a maximum attenuation coefficient of 0,4 dB/km at 1 310 nm, and so a 1 000 m length of cabling under test is allowed to include up to 0,4 dB of cable attenuation, in addition to the other component attenuations.

For connections, the values to be used are:

a) a maximum value specified in the relevant cabling standard, or
b) a 100 % (max.) performance value specified in a connecting hardware standard.

For the purposes of Annex H, three types of connection are considered:

1) Standard-grade where the connector performance is specified by industry accepted values (e.g. IEC 61755-2-1). In Annex H, 100 % ≤ 0,75 dB is applied as a maximum value.
2) Reference-grade where the connector performance is specified by industry accepted values (e.g. IEC 61755-2-4). In Annex H, 100 % ≤ 0,20 dB is applied as a maximum value.
3) "Mixed" where standard-grade components are connected to reference-grade components. There are no standard-based values for this performance.

NOTE 1 It is assumed that the mixed connection performance will be between standard-grade and reference-grade. For purposes of the worked examples given in Clause H.4, it is assumed to be 0,50 dB.

If reference-grade terminations are used on the test cords, the measured attenuation of the cabling will typically be different than when standard-grade terminations are used. This means that if the acceptance figure is based upon the assumption of standard-grade terminations for the finally configured system, for example, then some adjustment of the acceptance figure can be necessary.

These uncertainties are particularly significant when short lengths of cabling are being tested because the attenuations associated with the connections are much higher than the attenuations of the fibre itself. For long haul systems, the attenuation of the fibre dominates the total attenuation, and this uncertainty is less critical.

Table H.1 shows examples of attenuations between the different possible combinations of reference and standard-grade terminations, assuming the use of reference grade R2 and untuned PC (non-angled) grade C connectors with cylindrical ferrules.

NOTE 2 At the time of writing, it was expected that the designation "R2" for single-mode reference grade connectors with 0,2 dB attenuation will be replaced by a new designation "R_{s1-2}" in the future Edition 2 of IEC 61755-2-4 and also referred to as "Rs1-Grade 2" in Edition 3 of ISO/IEC 14763-3.

Table H.1 – Expected attenuation for examples

Termination 1	Termination 2	Attenuation requirement
SM reference-grade R2	SM reference-grade R2	≤ 0,2 dB
SM reference-grade R2	SM standard-grade C (untuned)	≤ 0,5 dB
SM standard-grade C (untuned)	SM standard-grade C (untuned)	≤ 0,75 dB
NOTE Table H.1 shows the required performance of standard-to-standard connectors in accordance with IEC 61755-2-1 and reference-to-reference connectors in accordance with IEC 61755-2-4.		

H.2.2 Conventions

In Annex H, the various connections in the reference and test configurations of H.2.3 are denoted by a letter. For example, the connection between the launch cord and the cabling under test is usually designated A_1.

A convention has been adopted in Annex H to denote the grade of connectors that are used in that connection as follows:

- when the connection is "standard-grade", the letter is used by itself (e.g. A);
- when the connection is "mixed", the letter is used with a single prime suffix, (e.g. A');
- when the connection is "reference-grade", the letter is used with a double prime suffix, (e.g. A'').

The maximum values used are designated as follows for single-mode connections (using "standard-grade" as an example):

- A_{max} = 0,75 dB;
- A'_{max} = 0,50 dB;
- A''_{max} = 0,20 dB.

H.2.3 Reference planes

Reference planes define the start and finish points of the required attenuation measurements. The reference planes for the four cabling configurations described in 4.2 are shown in Figure 3 to Figure 6. The term "required result" is defined as the attenuation in the cabling configuration between the reference plane start and the reference plane finish.

Figure 3 to Figure 6 show the reference planes for cabling under test using LSPM test equipment. The relevant results and discussions of uncertainty are described in Clause H.3 with examples provided in Clause H.4.

The same reference planes apply when using OTDR test equipment (the OTDR would replace the LS in Figure 3 to Figure 6 and the PM would not be present). This is discussed in Clause H.5.

H.3 Impact of using reference-grade test cords for recommended LSPM methods

In the test methods described in Annex A to Annex D, the measured attenuation result, A, is defined as the difference between the reference power level and the measured power level. For each method, the corresponding annex defines the contributions to A in terms of cabling and connection attenuations, as for example in the formula "$A = A_1 + A_2 + A_c$" in Annex A.

In Annex A to Annex C:

- A_1 is the attenuation of the connection between the launch cord and the cabling under test;
- A_2 is the attenuation of the connection between the cabling under test and the receive cord;
- A_c is the attenuation of the cabling excluding its terminating connectors;
- A_3 and A_4, where used, are the attenuations of extra connections that are necessary to implement the required reference configuration of test cords.

In Annex D, A_1 and A_2 are the attenuations of the connections between the equipment cords and each end of the fixed cabling.

Table H.2 lists the results and the test limit adjustment for the different cabling configurations and their recommended test methods when using reference-grade test cords. The table shows that no additional uncertainty (above that discussed in Clause 5) is produced when using reference-grade test cords.

Table H.2 – Test limit adjustment when using reference-grade test cords

Configuration	Method	Measured result	Required result	Test limit adjustment
A	Annex A (1 cord)	$A = A_1' + A_2' + A_c$	$A_1 + A_2 + A_c$	$(A_1'_{max} - A_{1max}) + (A_2'_{max} - A_{2max})$ ≈ −0,5 dB
B	Annex B (3 cords)	$A = A_1' + A_2' + A_c - A_3'' - A_4''$	A_c	$A_1'_{max} + A_2'_{max} - A_3''_{max} - A_4''_{max}$ ≈ +0,6 dB
C	Annex C (2 cords)	$A = A_1' + A_2' + A_c - A_3''$	$A_1 + A_c$	$(A_1'_{max} - A_{1max}) + A_2'_{max} - A_3''$ ≈ negligible
D	Annex D (equipment cord)	$A = A_1 + A_2 + A_c$	$A_1 + A_2 + A_c$	None

H.4 Examples for LSPM measurements

H.4.1 Example 1 (configuration A, one-cord method, Annex A)

A single-mode cabling system 100 m long is terminated in a patch panel at each end. The total maximum attenuation, assuming standard-grade connectors, would be 1,60 dB, assuming 1,0 dB/km cabled optical fibre attenuation (0,1 dB for the 100 m of optical fibre) and 0,75 dB per connection, as shown in Formula (H.1).

$$A_{1\max} + A_{2\max} + A_{c\ \max} = 0{,}75\ \text{dB} + 0{,}75\ \text{dB} + 0{,}10\ \text{dB} = 1{,}60\ \text{dB} \tag{H.1}$$

If this system was measured using the one-cord reference method and reference-grade terminations on the test cords, then the total maximum attenuation would be 1,10 dB (0,1 dB for the 100 m of optical fibre plus 0,5 dB for each connection between reference-grade and standard-grade terminations), as shown in Formula (H.2).

$$A_1{'}_{\max} + A_2{'}_{\max} + A_{c\ \max} = 0{,}5\ \text{dB} + 0{,}5\ \text{dB} + 0{,}10\ \text{dB} = 1{,}10\ \text{dB} \tag{H.2}$$

Thus, when the attenuation is measured using reference-grade test cords, the acceptance figure shall be adjusted by $(A_1{'}_{\max} – A_{1\max}) + (A_2{'}_{\max} − A_{2\max}) = −0{,}5$ dB, as shown in Table H.2. When measured with standard-grade test cords, there is no change to the acceptance figure, but there is a large additional uncertainty as seen in Table 5 (due to the reproducibility of standard-grade test cords). The use of reference-grade test cords is therefore recommended, provided that the acceptance figure is adjusted.

H.4.2 Example 2 (configuration B, three-cord method, Annex B)

Consider the above cabling system having equipment connection cords with standard-grade terminations connected into the patch panels. The expected maximum attenuation excluding the terminal connectors will be the fibre attenuation, $A_{c\ \max} = 0{,}1$ dB.

If this system was measured using the three-cord reference method and reference-grade terminations on the test cords, then the total maximum attenuation would be 0,70 dB (0,1 dB for the 100 m of optical fibre plus 0,5 dB for each connection between reference-grade and standard-grade terminations minus 0,2 dB for each connection between reference-grade and reference-grade connections), as shown in Formula (H.3).

$$\begin{aligned} &A_1{'}_{\max} + A_2{'}_{\max} + A_{c\ \max} − A_3{''}_{\max} − A_4{''}_{\max} \\ &= 0{,}5\ \text{dB} + 0{,}5\ \text{dB} + 0{,}10\ \text{dB} – 0{,}2\ \text{dB} – 0{,}2\ \text{dB} = 0{,}70\ \text{dB} \end{aligned} \tag{H.3}$$

For each reference-grade to reference-grade connection in the reference measurement that is replaced by a reference-grade to standard-grade connection in the attenuation measurement configuration, an adjustment of 0,3 dB should be added to the acceptance figure, which is based on the assumption of using standard-grade connectors.

H.4.3 Example 3 (configuration C, two-cord method, Annex C)

The above cabling system is considered, but with connection cords having standard-grade plug-to-socket style connectors, such as MTRJs, connected into patch panels. To test these systems, it is necessary to use the two-cord reference method with the addition of a reference-grade adapter cord to complete the test configuration. This adapter cord allows connectivity but also adds the attenuation of the mated pair of connectors factored out in the referencing procedure, because all the connectors involved are reference-grade. However, the reference-grade termination interface with the standard-grade patch panel connectors will typically have a lower attenuation than those of the equipment patch cords. The acceptance criteria, therefore, should be reduced by 2 × 0,25 dB = 0,5 dB.

H.4.4 Example 4 – Long haul system (one-cord reference method)

A link 80 km long is terminated at optical distribution frames (ODFs) by splicing on pigtails. The route is made up of 16 drums of cable each 5 km long with fusion splices between them. The expected attenuation of the link at 1 550 nm, assuming standard-grade connectors, is 20,8 dB, which assumes 0,22 dB/km for the fibre attenuation, an average 0,1 dB for the 17 splices, and 0,75 dB for each of the terminations at the ODFs.

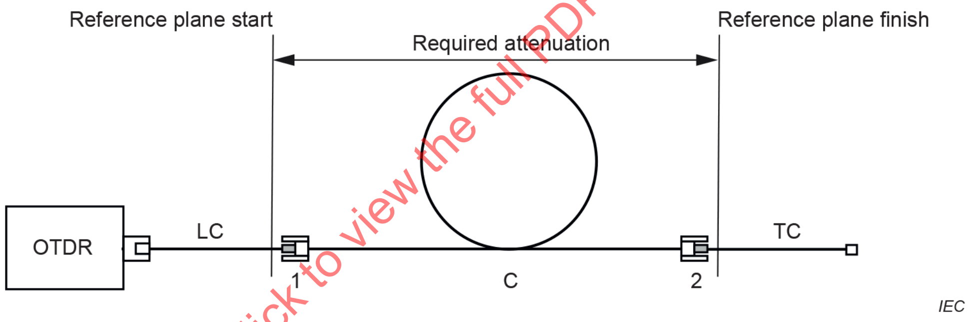
When tested using the one-cord reference method, the expected maximal attenuation between the terminations will be 20,3 dB, assuming that reference-grade terminations are used on the test cords.

It can be seen that the variance in this case is much less significant than for the above cases where there are short lengths of fibre.

H.5 Impact of using reference-grade test cords for different configurations using the OTDR test method

H.5.1 Cabling configurations A, B and C

When using the OTDR test method with a suitably high resolution OTDR and sufficiently long launch and tail cords, as shown in Figure H.1, it is possible to separately identify and measure the attenuation of each of the contributory factors (A_1 + A_2 + A_c, etc.).



Key

OTDR optical time domain reflectometer

LC launch cord

C cabling under test

TC tail cord

1, 2 connector sets

Figure H.1 – Cabling configurations A, B and C tested with the OTDR method

The OTDR will usually produce an event table or schematic diagram containing details of the distance to each event and its attenuation as well as the length and attenuation of the sections of cabling between the events.

There is no substitution of connections from a reference measurement, therefore the setting of test limits is simplified as shown in Table H.3.

Table H.3 – Test limit adjustment when using reference-grade test cords – OTDR test method

Configuration	Method	Measured result	Required result	Test limit adjustment
A	Annex D (OTDR)	$A = A_1' + A_2' + A_c$	$A_1 + A_2 + A_c$	$(A_1'_{max} - A_{1max}) + (A_2'_{max} - A_{2max})$ $\approx -0,5$ dB
B	Annex D (OTDR)	$A = A_1' + A_2' + A_c - A_3'' - A_4''$	A_c	For further study
C	Annex D (OTDR)	$A = A_1' + A_2' + A_c - A_3''$	$A_1 + A_c$	For further study
D	Annex D (OTDR)	$A = A_1 + A_2 + A_c + A_3' - A_3'$	$A_1 + A_2 + A_c$	None
D (see Note)	Annex D (OTDR)	$A = A_1 + A_3' + A_2 + A_4' + A_c$	$A_1 + A_2 + A_c$	For further study

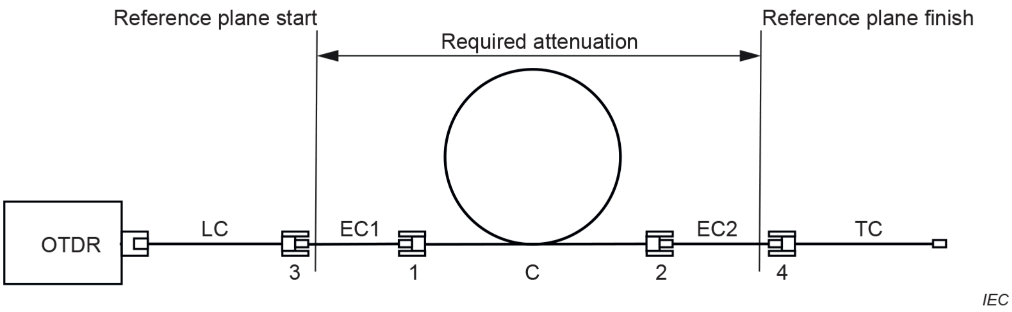
NOTE When the equipment cords are short, it can be impossible to separately identify and measure A_1 and A_3' and A_2 and A_4'. The acceptance figure could be adjusted to include the combined attenuations, but it would be unacceptable to get a false pass by doing so; this subject is still under discussion.

H.5.2 Cabling configuration D

When using the OTDR test method with a suitably high resolution OTDR and sufficiently long launch, tail and equipment cords, it is possible to separately identify and measure the attenuation of each of the contributory factors ($A_1 + A_2 + A_c$, etc.) as shown in Figure H.2.

The OTDR will usually produce an event table containing details of the distance to each event and its attenuation as well as the length and attenuation of the sections of cabling between the events.

However, the ability of the OTDR method to separately identify and measure connections A_1 and A_3, and A_2 and A_4 depends upon the capability of the OTDR and the lengths of the equipment cords. When it is not possible to separately resolve and measure the attenuations of the connections at both ends of the equipment cords accurately, then the acceptance figure can be adjusted to include the attenuation of the connection between the launch cord and the cabling under test as well as the attenuation of the connection between the tail cord and the cabling under test, shown in Figure H.2 as A_3 and A_4, but it would be risky to get a false pass by doing so; this subject is still under consideration.



Key

OTDR	optical time domain reflectometer	EC1	equipment launch cord
LC	launch cord	EC2	equipment receive cord
C	cabling under test	1, 2, 3, 4	connector sets
TC	tail cord		

Figure H.2 – Cabling configuration D tested with the OTDR method

~~Annex H~~Annex I
(informative)

OTDR configuration information

I.1 Introductory remarks

Annex I provides information regarding OTDRs and their configuration. It also provides additional diagrams to help in the application of Annex E. Refer to IEC 61746-1 ~~on the calibration of single-mode OTDRs~~ and IEC 61300-3-4 for further details and definitions on OTDR performance parameters.

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

This returning signal comes from two sources:

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

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

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

- total attenuation of the link or channel under test;
- total optical return loss of the link or channel under test;
- length (and propagation delay) of the link or channel under test;
- attenuation coefficient of the optical fibre in the cabling under test;
- attenuation of connections (splices and connector pairs);
- return loss (reflectance) of reflective ~~features~~ elements, such as connector pairs and mechanical splices;
- distance information between certain features in the trace.

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

- the optical performance of the OTDR being used;
- the correct set-up of the OTDR's measurement parameters;
- the correct measurement configuration including appropriate length launch cords and tail cords;
- measurement good practices – cleanliness of connectors, etc.;
- the use of bi-directional measurements (see Clause I.6 and Clause I.7).

I.2 Fundamental parameters that define the operational capability of an OTDR

I.2.1 Dynamic range

Dynamic range is the capability of an OTDR to measure a large amount of attenuation. The dynamic range is the difference between the maximum backscatter level near 0 m and at 98 % of the noise floor. Another method of measurement uses SNR = 1 (RMS noise). The dynamic range increases when the laser pulse width increases, and when the noise level decreases by averaging.

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

I.2.2 Dynamic margin

Dynamic margin is the difference between the minimum backscattered level at the end of the fibre and the noise floor. The dynamic margin varies the same way as the dynamic range. The estimation of the dynamic margin can be used to determine the noise amplitude on the backscatter signal which defines a large part of the measurement uncertainty. Whenever the dynamic margin is low, the noise on the backscattered signal becomes asymmetrical, leading to an under-estimation of the backscattered signal. For recommendations on dynamic margin, see IEC 61280-4-3. Dynamic margin is a contributing factor in OTDR measurement uncertainty. A dynamic margin of ≥ 3 dB is recommended; ≥ 5 dB is preferred.

I.2.3 Pulse width

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

I.2.4 Averaging time

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

I.2.5 Dead zone

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

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

For ~~most~~ single-mode applications, the most significant dead zone is the attenuation dead zone. This is the distance after a reflective event at which the backscatter level has returned to be within a certain tolerance (ΔF) of a linear fit to the backscatter trace and ~~loss~~ attenuation measurements can be made. Refer to IEC 61746-1 for a full definition of the attenuation dead zone.

NOTE An OTDR typically supports a range of pulse widths and averaging time to balance dead zone, dynamic range and test time for the optical fibre under test. Shorter (narrower) pulse widths typically provide shorter dead zones (better) but reduce dynamic range (worse). Increased averaging time typically increases dynamic range. OTDR dead zones are typically specified for short pulse widths (< 10 ns) and standard connector return loss ≥ 35 dB. Attenuation dead zone using a narrow pulse width is typically less than 8 m. Dynamic range using a wider pulse width is typically more than 20 dB.

I.3 Other parameters

I.3.1 Index of refraction

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

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

When the index of refraction is known it shall be used; otherwise use the values of Table I.1.

Table I.1 – Example of effective group index of refraction values

Centre wavelength	1 310 nm	1 550 nm	1 625 nm	1 650 nm
SMF (~~IEC B.1 nominal single-mode fibre~~ IEC B-652 or B-654 dispersion-unshifted single-mode fibre)	1,467	1,468	1,469	1,469

If fibre types other than ~~B.1~~ B-652 or B-654 are being used and if accurate length measurements are required, the fibre manufacturer should be consulted for appropriate refractive index ~~figures~~ values.

I.3.2 Measurement range

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

I.3.3 Distance sampling

The distance sampling (or sampling resolution) is the distance between two sampling points on the horizontal scale. This distance may be coupled to the measurement range (e.g. when the number of data points is constant).

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

I.4 Other measurement configurations

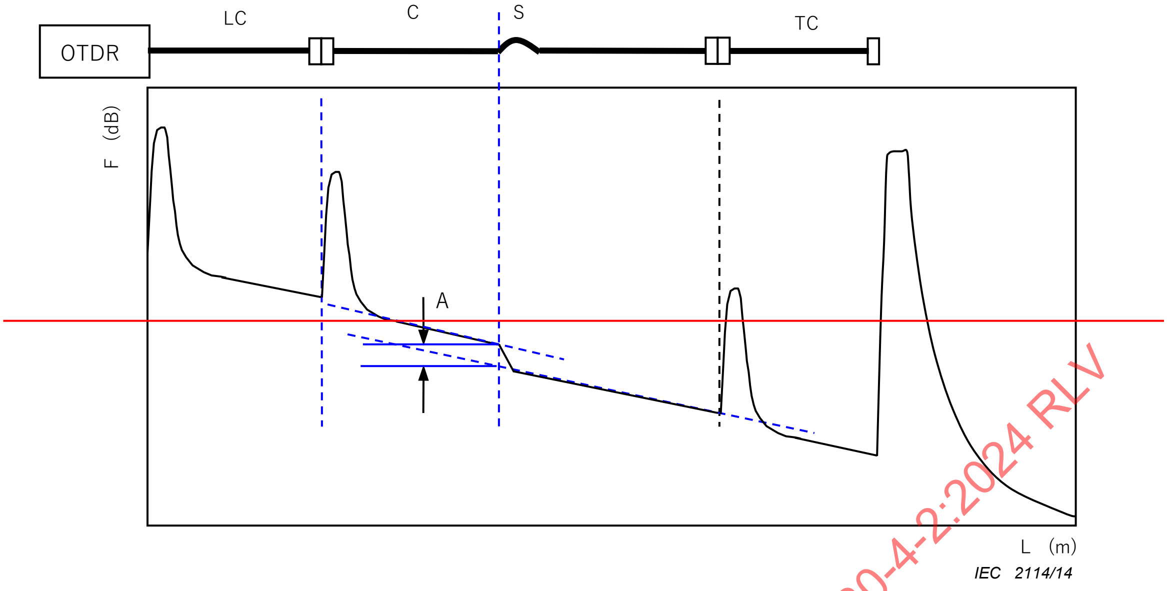
I.4.1 General

Clause I.4 reports some ~~particular~~ measurement configurations that are not part of Annex E.

I.4.2 Macrobend attenuation measurement

Figure I.1 illustrates the ~~proper~~ measurement trace ~~of~~ when a macrobend (or a fusion splice) is present within a cabling. The attenuation of a macrobend is measured using linear regressions on both sides of the macrobend. The attenuation is given by the difference of displayed power level at the intercept of the two linear regressions with the vertical axis of the bending location. Note that the bending location is before the change of curvature of the trace.

Note that on single-mode fibres the amount of ~~loss~~ attenuation introduced by a macrobend increases at longer wavelengths. Therefore, comparison of traces at two or more different wavelengths ~~may~~ can help to identify the presence of bends.



~~Key~~

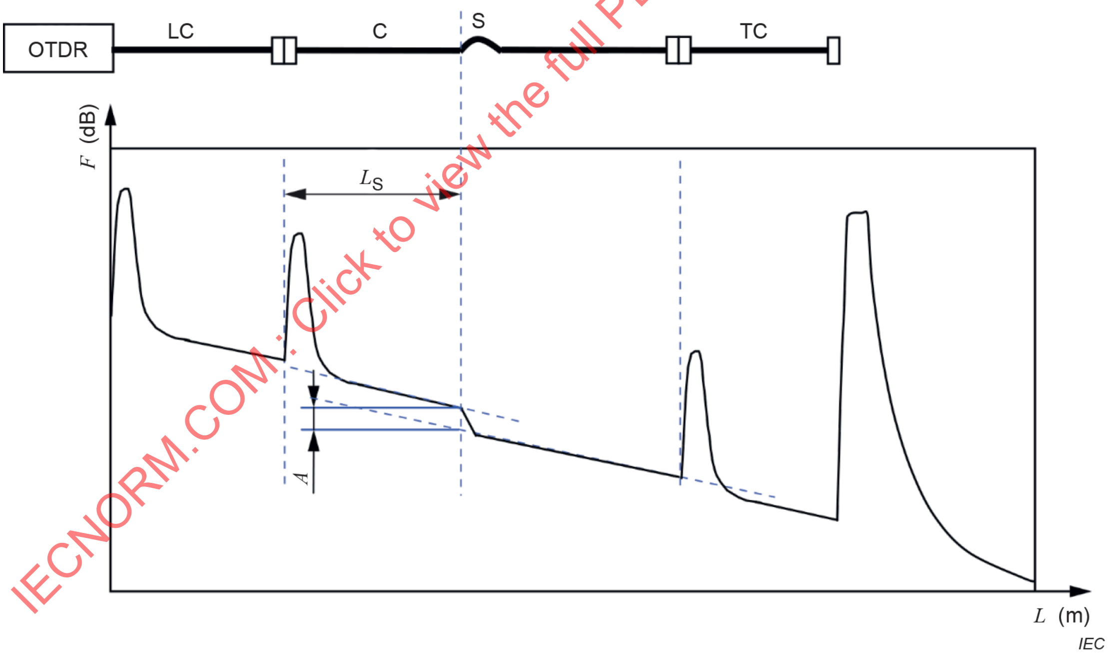
~~LC launch test cord~~

~~TC tail cord~~

~~C cabling under test~~

~~A splice attenuation~~

~~S macrobend or fusion splice~~



Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L	distance from OTDR launch cord output port
C	cabling under test	A	macrobend or splice attenuation
TC	tail cord	L_S	length of cabling before macrobend or splice
S	macrobend or splice		

Figure I.1 – Splice and macrobend attenuation measurement

I.4.3 Splice attenuation measurement

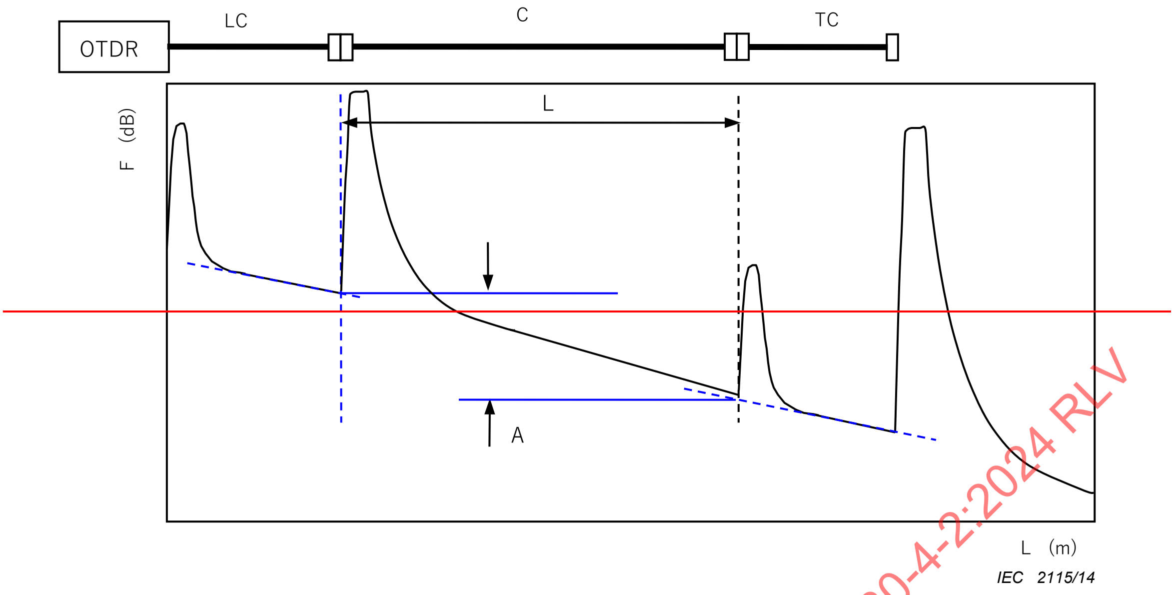
Use the same process as previously defined for a macrobend within a cabling.

I.4.4 Measurement with high reflection connectors or short length cabling

Figure I.2 illustrates a measurement of installed cabling with highly reflective connectors. The strong reflection at the launch cable causes pulse clipping and tailing. Tailing makes attenuation coefficients and closely spaced events difficult to measure.

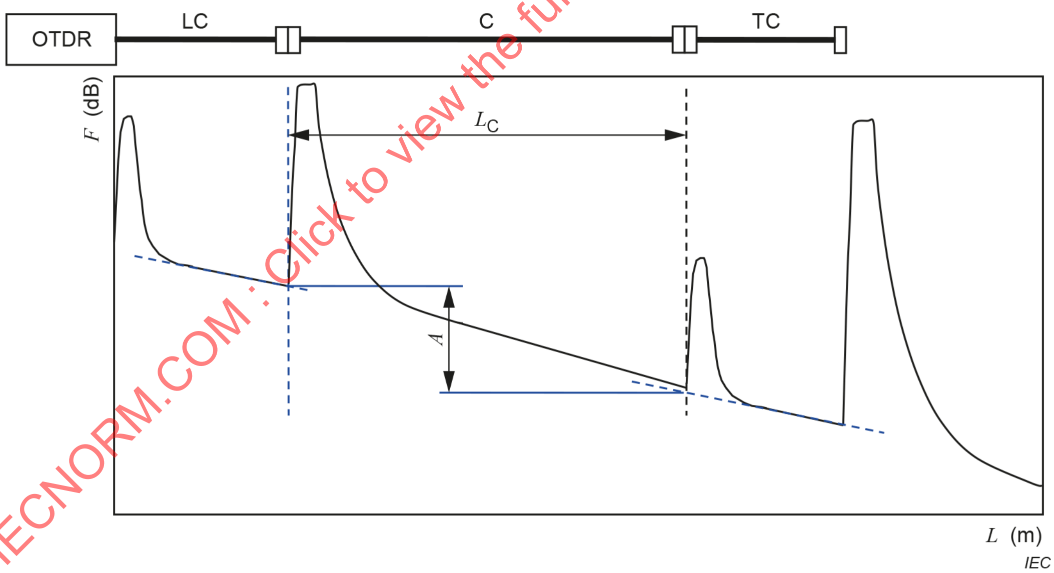
This demonstrates that it is important to follow a measurement procedure that does not use any part of the tailing signal.

Tailing is a good indication that a connector is dirty and should be cleaned before making further tests.



Key

LC	launch test cord
A	attenuation
C	cabling under test
TC	tail cord



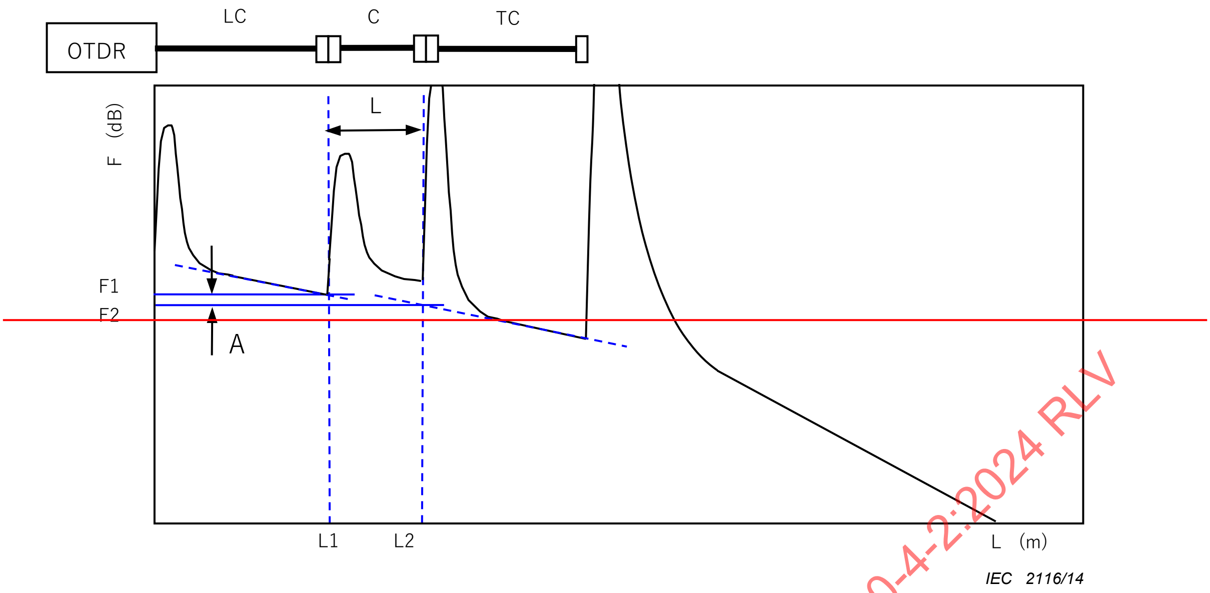
Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L_C	length of cabling under test
C	cabling under test	A	attenuation
TC	tail cord	L	distance from OTDR launch cord output port

Figure I.2 – Attenuation measurement with high reflection connectors

Figure I.3 illustrates a measurement of a short length cabling. The length of the link is shorter than the attenuation dead zone. Separate measurements of the cabling and connections are not available, while the overall measurement is still available.

This demonstrates again how it is important to follow the measurement procedure that does not use any part of the tailing signal.



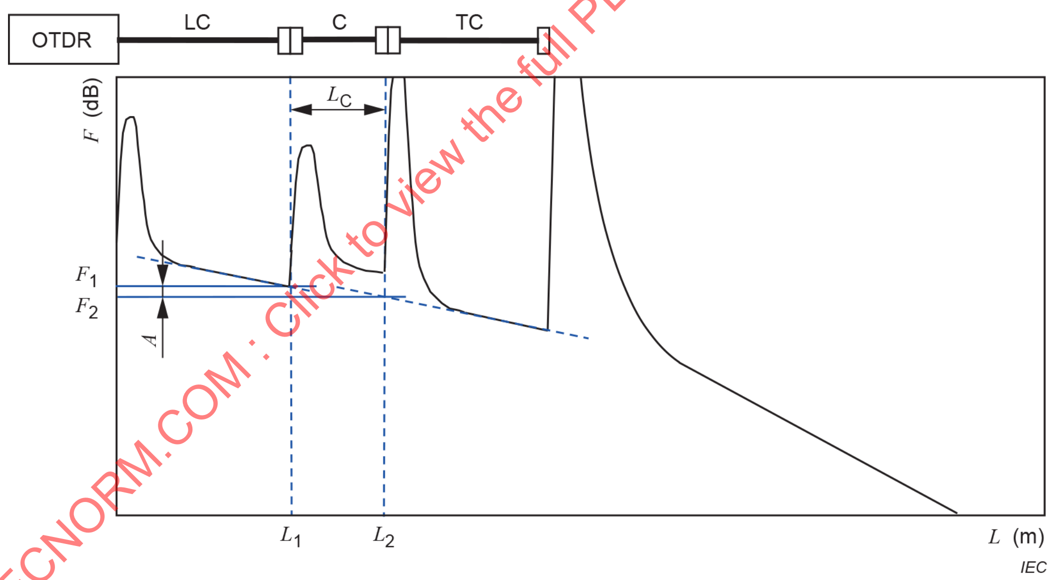
~~**Key**~~

~~LC launch test cord~~

~~C cabling under test~~

~~TC tail cord~~

~~A attenuation~~



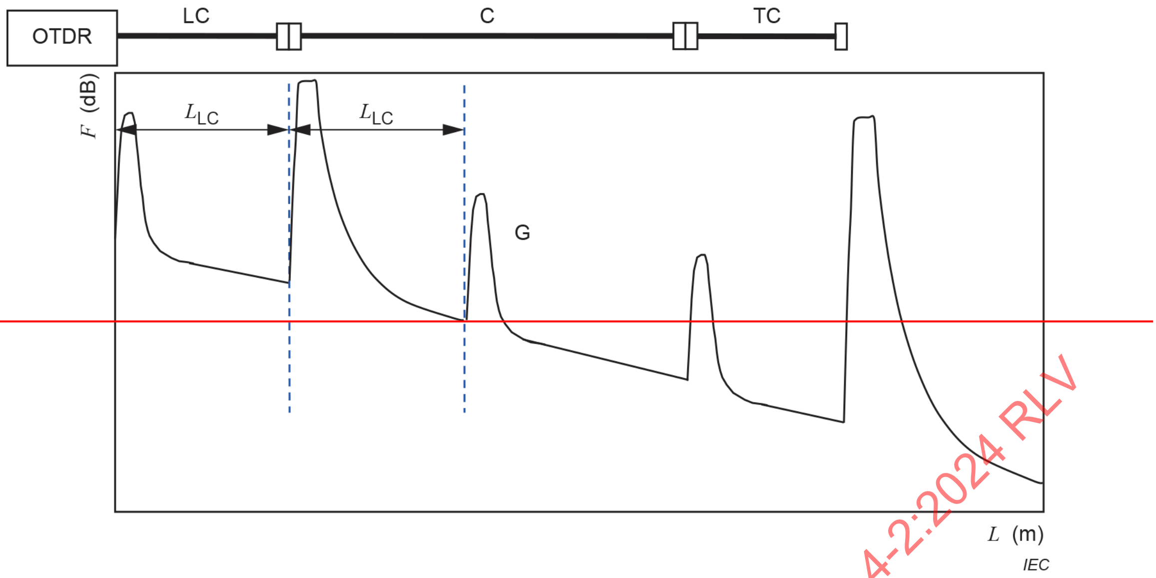
Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L_C	length of cabling under test
C	cabling under test	A	attenuation
TC	tail cord	L_1, L_2	cabling port locations
L	distance from OTDR launch cord output port	F_1, F_2	reflected power levels corresponding to attenuation

Figure I.3 – Attenuation measurement of a short length cabling

I.4.5 Ghost

Figure I.4 illustrates a measurement of installed cabling with a highly reflective connector and resulting ghost. Sometimes, the OTDR software ~~may identify~~ is capable of identifying ghosts properly; if not, a ghost can be identified when the distance between two events on the optical fibre is duplicated.



~~Key~~

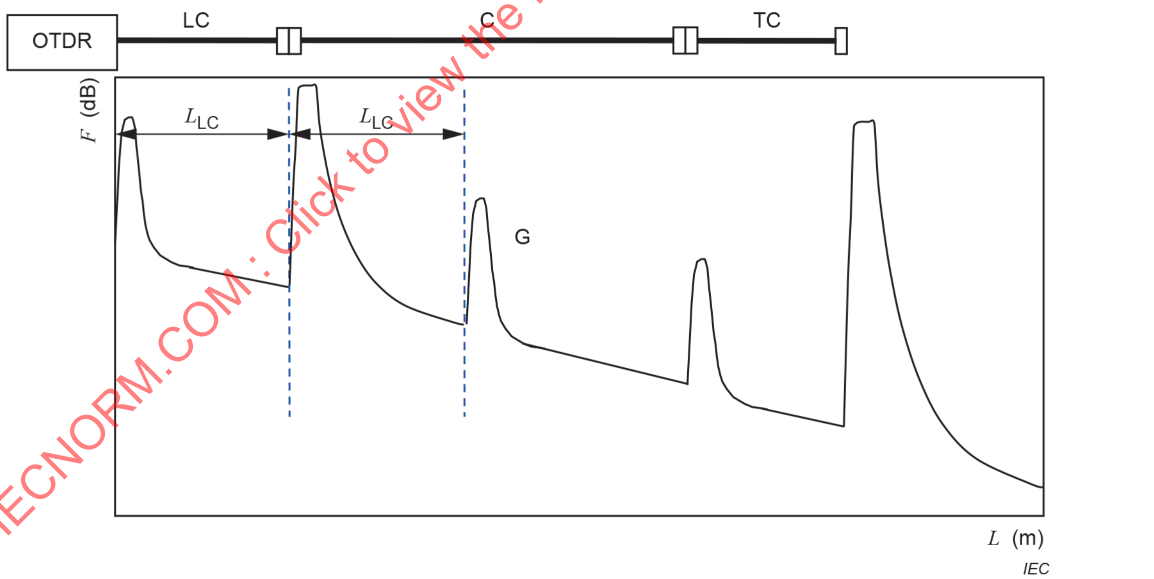
~~LC launch test cord~~

~~L length of the launch test cord (duplicated)~~

~~C cabling under test~~

~~G ghost reflection~~

~~TC tail cord~~



Key

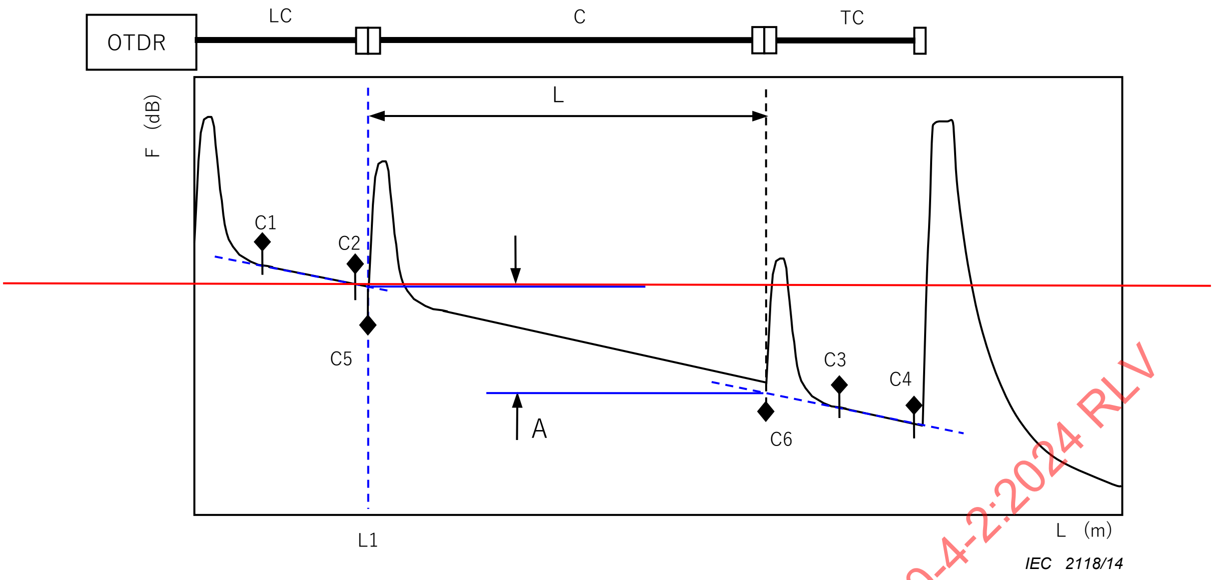
OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L_{LC}	length of the launch cord (duplicated)
C	cabling under test	G	ghost reflection
TC	tail cord	L	distance from OTDR launch cord output port

Figure I.4 – OTDR trace with ghost

I.5 More on the measurement method

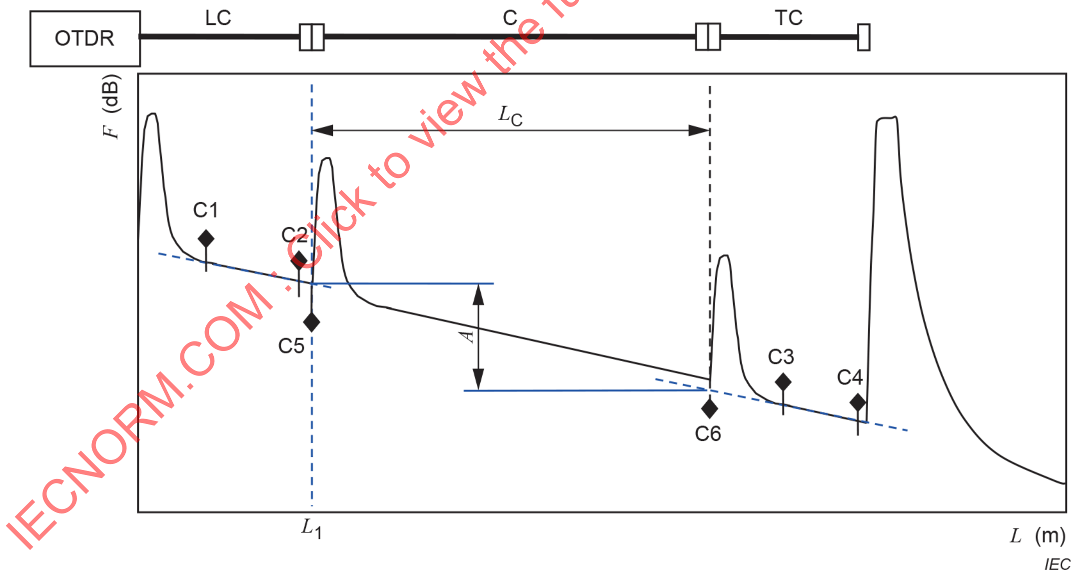
The measurement method defined in Annex E is also called the five cursors method. This is due to the fact that readings at five cursor positions are used to complete the measurement.

Figure I.5 shows the positioning of the five cursors on the backscattering trace. Cursors C1 and C2 define the area of linear regression in the launch ~~test cable~~ cord, whereas cursors C3 and C4 define the area of linear regression in the tail ~~test cable~~ cord. Cursor C5 is positioned to define the start of the measured attenuation (e.g. L_1), and cursor C6 is placed to define the end of the measured attenuation. Often the instrument will calculate and display this attenuation as part of an event table.



~~**Key**~~

~~LC~~	~~launch test cord~~
~~C~~	~~cabling under test~~
~~C1, C2, C3, C4~~	~~cursors for linear regression definition~~
~~C5~~	~~cursor at attenuation start location~~
~~C6~~	~~cursor at attenuation end location~~
~~TC~~	~~tail cord~~
~~A~~	~~attenuation~~



Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L	distance from OTDR launch cord output port
C	cabling under test	L_C	length of cabling under test
TC	tail cord	A	attenuation
C1, C2, C3, C4	cursors for linear regression definition	L_1	distance to cabling under test
C5, C6	cursors for attenuation measurement		

Figure I.5 – Cursor positioning

Make sure that the OTDR is configured for the application of a linear regression between the cursors. This configuration ~~may~~ is sometimes also ~~be~~ called least square approximation (LSA).

NOTE The alternative of the linear regression setting (LSA) is generally called two points. This configuration generally leads to significant errors since the calculation of the slope is made using only two points of the backscattering trace while the LSA reduces the consequence of the noise and nonlinear response due to dead zone effects.

I.6 Bi-directional measurement

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

If the launch cord and tail cord have similar scattering characteristics, verified according to IEC 61280-4-3:2022, B.5.2, and only the total attenuation of the link is required to be measured, it is sufficient to carry out OTDR testing in one direction only. However, if the launch cord and tail cord have different characteristics from each other, bi-directional OTDR testing is required.

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

An individual attenuation, in dB, is defined as the half sum of the attenuations, in dB, recorded from each end, as shown in Formula (I.1).

$$A = \frac{A_{oe} + A_{eo}}{2} \qquad (I.1)$$

where

A_{oe} is the attenuation measured in the direction from the origin to the extremity;

A_{eo} is the attenuation measured in the direction from the extremity to the origin (see also IEC TR 62316 for more details).

NOTE Some OTDRs include specific firmware to manage bi-directional measurements.

Averaging bi-directional testing for determining reflectance will produce incorrect results, since fundamentally, connector reflectance is direction dependent.

I.7 OTDR bi-directional trace analysis

Figure I.6 shows a typical bi-directional OTDR display. The trace from one end is shown reversed and superimposed on the trace from the opposite end of the same fibre so that the positions of all events correlate. The corresponding event table, displayed in Figure I.7, shows the results after bi-directional averaging. Note, for example, the high ~~loss~~ attenuation splice on the reversed trace at event 3, where there is a "gainer" (apparent negative splice ~~loss~~ attenuation) when measured from the opposite end. Note also that the ~~loss~~ attenuation of the connector (event 12) is much less when measured in the forward direction, significantly reducing the bi-directionally averaged connector ~~loss~~ attenuation.

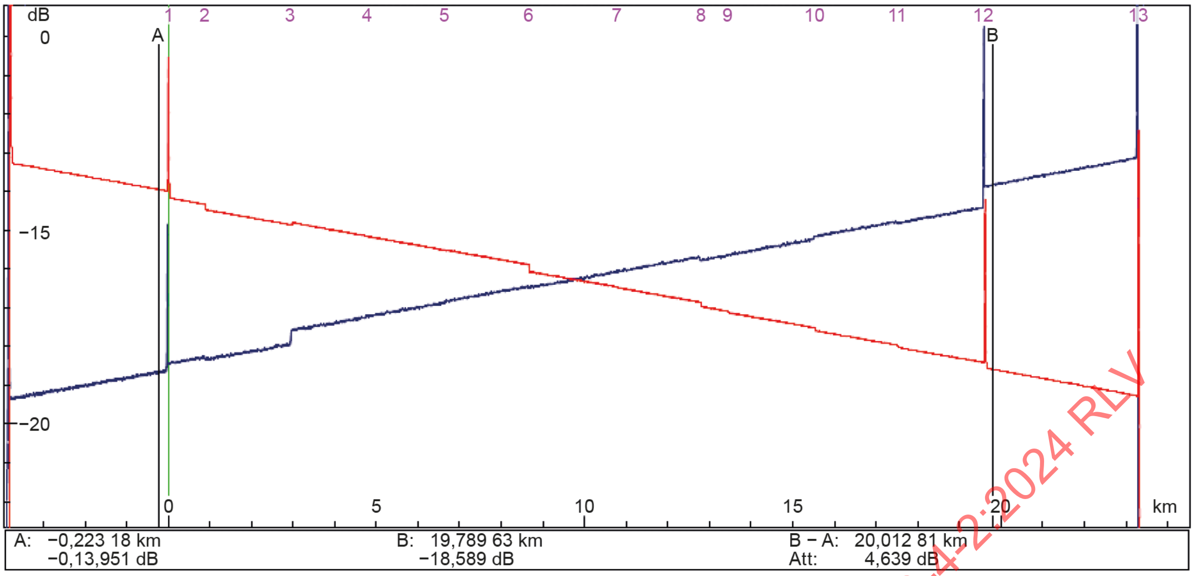


Figure I.6 – Bi-directional OTDR trace display

Way O→E (13)	Way O←E (13)	Distance (km)	Attenuation (dB)	Attenuation (dB)	Average (dB)	Slope (dB/km)	Slope (dB/km)	Average (dB/km)
	13							
1*	12*	0,000 00	0,169			0,193	0,193	0,193
2*	11	0,914 47	0,136	−0,062	0,037	0,195	0,187	0,191
3*	10	2,973 62	−0,062	0,362	0,150	0,190	0,190	0,190
4*	9	4,814 07	0,009	0,025	0,017	0,192	0,184	0,188
5*	8	6,677 54	−0,006	0,029	0,011	0,190	0,190	0,190
6*	7	8,676 59	0,177	−0,034	0,071	0,190	0,192	0,191
7*	6	10,795 21	0,014	0,004	0,009	0,188	0,194	0,191
8*	5	12,816 00	0,110	−0,094	0,008	0,191	0,191	0,191
9*	4	13,476 59	0,034	0,007	0,021	0,186	0,203	0,195
10*	3	15,531 91	0,077	0,076	0,077	0,187	0,196	0,191
11*	2	17,527 76	0,067	−0,038	0,014	0,187	0,190	0,189
12*	1	19,625 28	0,136	0,534	0,335	0,182	0,198	0,190
13*						0,197	0,200	0,199

IEC

Figure I.7 – Bi-directional OTDR trace ~~loss~~ attenuation analysis

I.8 Non-recommended practices

I.8.1 Measurement without tail cord

If the tail cord is missing, the attenuation of the connector at the end of the cabling is not taken into account. Also, the measurement is not possible when the length of the cabling is short regarding the attenuation dead zone (see I.4.4).

This type of measurement is only acceptable for the qualification of a repair of the cabling that had been tested before the damage (assuming configurations of the OTDR and the cabling allow for visualization of the repair).

I.8.2 Two cursors measurement

OTDRs generally provide easy access to two cursors showing location and power level position as well as the attenuation between the two cursors.

~~The use of such a function is not recommended for qualification because the LSA function is not used and because the measurement location may not be correct.~~

~~However, such functionality can be useful in an optimization process.~~

The use of a cursor measurement is not recommended for attenuation measurements, because of all the factors mentioned in Clause I.4 and the fundamental importance of properly evaluating the backscatter slope and level before and after the intended event or section. Therefore, an advanced LSA analysis is preferred.

~~Annex I~~Annex J
(informative)

Test cord attenuation verification

J.1 Introductory remarks

The validity of installed cabling attenuation measurements critically depends on the attenuation performance of the test cords used in all LSPM methods. Test cord attenuation verification should be performed before formal testing of installed cabling begins. Cords should be re-verified at the beginning of each testing session, for example daily, or after the number of plug insertions is approached as stated in the mating durability specification, typically defined in hundreds of mate and de-mate cycles.

Test cord attenuation performance verification involves measuring the attenuation of the test cords, and possibly performing steps to obtain acceptably low attenuation performance prior to measuring the installed cabling. The maximum acceptable attenuation ~~may~~ can be established in a number of ways, for example, by customer testing requirements, the specifications claimed by the manufacturer of the test cords, or by cabling standards. It is not advisable to set acceptance criteria for test cords to levels as high as the minimum performance level (i.e. maximum allowable connection attenuation) permitted by cabling standards, as the magnitude of this allowance, typically up to 0,75 dB, contributes directly to uncertainty of the measured cabling attenuation.

J.2 Apparatus

The light source, power meter and test cords defined in Clause 6 are required.

It is necessary to use a power meter that will mate to the plugs of the test cords, that is, offer a socket or adapter of the same type as that of the installed cabling to be tested. This ~~may~~ can be accomplished in two ways:

a) by using a compatible socket on the power meter, or
b) by attaching to the power meter, a short (< 2 m) "bucket cord", free of bends of radius less than 30 mm, having a cable-plant-compatible adapter on one end and a plug compatible with the power meter socket on the other. The optical fibre within the bucket cord is of a larger core diameter and higher numerical aperture than that of the cords under test so that substantially all light ~~may~~ can be collected from the cords under test.

J.3 Procedure

J.3.1 General

The verification procedure depends on the number and type of cords used in the test method. A power meter with a compatible socket is illustrated. The bucket cord adaptation is not shown.

The procedures are presented in the following organization and order:

a) One-cord and two-cord methods:
   - use J.3.2 for test cord interfaces that are non-pinned or unpinned and non-plug or socket connector styles, such as LC, SC, or other plug-adapter-plug types;
   - use J.3.3 for test cord interfaces that are of the pinned-to-unpinned style, like the MT-RJ, or are of the plug-to-socket style, like the SG.

b) Three-cord method:

- use J.3.4 for test cord interfaces that are non-pinned or unpinned and non-plug or socket connector styles, such as LC, SC, or other plug-adapter-plug types;
- use J.3.5 for test cord interfaces that are of the pinned-to-unpinned style, like the MT-RJ, or are of the plug-to-socket style, like the SG.

Most of the procedures contain optional sequences that are designed to test the cords bi-directionally. Regardless of whether these optional steps are performed, labelling of the cords is advised so that their orientation and order in the test cord sequence can be identified.

The attenuation formulae assume that power readings are made in absolute linear units such as microwatts (μW) or milliwatts (mW) that have to be converted to decibels using logarithms. If the power readings are made in relative logarithmic units such as decibels relative to a milliwatt (i.e. in dBm), then the attenuation is determined by subtraction of the reading from the reference. For example, if the reference is –12 dBm and the reading is –12,5 dBm, the attenuation is (–12 dBm) – (–12,5 dBm) = 0,5 dB.

In any of the procedures, if the connection between the launch cord TC1 and the light source is disturbed, for example by disconnection or mechanical stress, a new reference power level ~~has to~~ should be obtained, because the amount of power coupled from the light source is typically sensitive to these disturbances.

J.3.2 Test cord verification for the one-cord and two-cord reference test methods when using non-pinned or unpinned and non-plug or socket style connectors

The procedure is as follows:

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.1.

b) Insert adapter A1 and receive cord TC2 between TC1 and power meter as shown in Figure J.2 and record P_1.

c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).

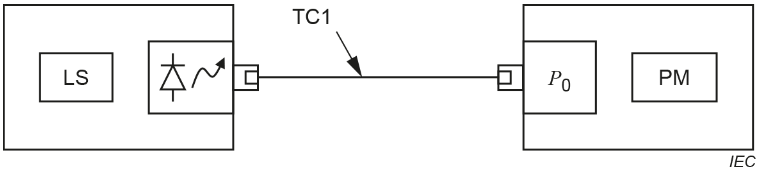
Steps d), e) and f) are recommended but optional. If steps d), e) and f) are not performed, then the cords ~~must~~ shall be used only in their tested orientation. More precisely, performing steps d) and e) allows TC2 to be used in either orientation; performing step f) allows TC1 to be used in either orientation.

d) Disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a second power level, P_2.

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).

f) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through e), obtaining a new reference reading P_3 and power readings P_4 and P_5 as above.

NOTE All power measurements described are taken in linear units (W).



Key

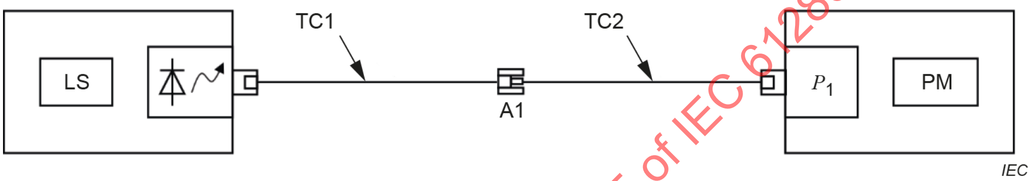
LS light source

TC1 launch cord

PM power meter

P_0 reference power measurement

Figure J.1 – Obtaining reference power level P_0



Key

LS light source

TC1 launch cord

A1 connector set

TC2 test cord

PM power meter

P_1 test power measurement

Figure J.2 – Obtaining power level P_1

J.3.3 Test cord verification for the one-cord and two-cord reference test methods using pinned-to-unpinned or plug-to-socket style connectors

J.3.3.1 General

This procedure is subdivided into two parts, one for compatible interfaces and one for incompatible interfaces. The procedure of J.3.3.2 applies to cases where TC1 and TC2 provide mutually compatible interfaces between them, where, for example, one plug is pinned and the other unpinned, or where one is a plug and the other a socket. The procedure of J.3.3.3 applies to cases where TC1 and TC2 do not provide mutually compatible interfaces between them, where, for example, both plugs are pinned or unpinned, or both are plugs or sockets.

NOTE All power measurements described are taken in linear units (W).

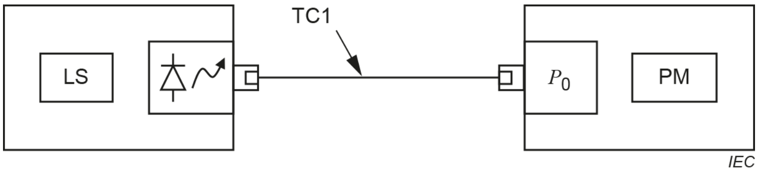
J.3.3.2 Compatible interfaces

This procedure differs from that of J.3.3.3 because the cords are assumed to be directional due to their pinning or plug-to-socket arrangements. In cases where this assumption does not apply, the procedures of J.3.3.3 are recommended so that bi-directional test cord verification can be established. In cases where bi-directional verification ~~may be~~ is possible, power meters that can accept both pinned and unpinned plugs shall be included.

a) Obtain the reference power measurement P_0 with launch cord TC1 as shown in Figure J.3.

b) Insert adapter A1 and receive cord TC2 between TC1 and the power meter as shown in Figure J.4 and record P_1. A socket for plug-to-socket style connections replaces adapter A1.

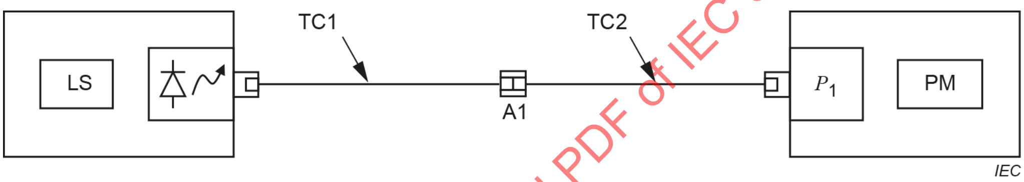
c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify that the attenuation is within acceptable limits. If not, clean the plugs and adapter A1 (or socket), or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).



Key

LS	light source
TC1	launch cord
PM	power meter
P_0	reference power measurement

Figure J.3 – Obtaining reference power level P_0



Key

LS	light source	TC2	test cord
TC1	launch cord	PM	power meter
A1	connector set	P_1	test power measurement

Figure J.4 – Obtaining power level P_1

J.3.3.3 Incompatible interfaces

Particular configurations of pinned-to-unpinned and plug-to-socket style connections necessitate the introduction of a third cord that provides a compatible interface between the cords under test. The attenuation of this three-cord combination ~~shall~~ should be sufficiently low so that the combined attenuation still passes the acceptance criteria for the attenuation of a single interface. Configurations that necessitate a third cord include those where TC1 and TC2 are both pinned or unpinned or are both plugs or sockets in a plug-to-socket style arrangement.

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.5.

b) Insert adapters A1, A2, substitution cord TC3, and receive cord TC2 between TC1 and power meter as shown in Figure J.6 and record P_1. For plug-to-socket styles, the adapters are replaced by sockets on the ends of TC3.

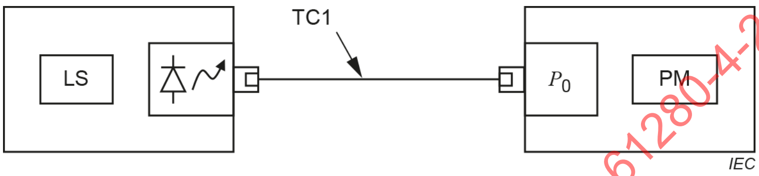
c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC1, TC2, TC3 and adapters A1 and A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

Steps d), e) and f) are recommended but optional. If steps d), e) and f) are not performed, then the cords shall be used only in their tested orientation. More precisely, performing steps d) and e) allows TC2 to be used in either orientation; performing step f) allows TC1 to be used in either orientation.

d) In configurations that permit, disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a second power level, P_2.

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC2, TC3 and adapter A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

f) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through c).



Key

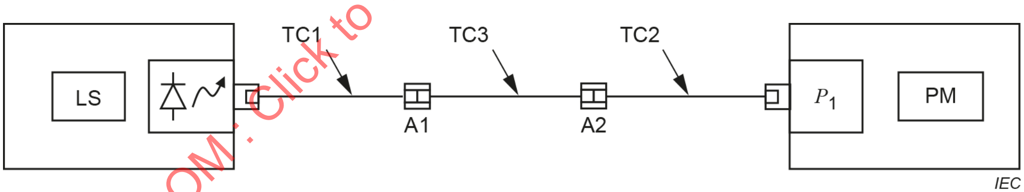
LS light source

TC1 launch cord

PM power meter

P_0 reference power measurement

Figure J.5 – Obtaining reference power level P_0



Key

LS light source

TC1 launch cord

A1 connector set

A2 connector set

TC3 test cord

TC2 test cord

PM power meter

P_1 test power measurement

Figure J.6 – Obtaining power level P_1

J.3.4 Test cord verification for the three-cord reference test method using non-pinned or unpinned and non-plug or socket style connectors

The procedure is as follows:

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.7.

b) Insert adapter A1 and receive cord TC2 between TC1 and power meter as shown in Figure J.8 and record P_1.

c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).

Steps d, e) and f) are recommended but optional. If steps d), e) and f) are not performed, then the cords shall be used only in their tested orientation. More precisely, performing steps d) and e) allows TC2 to be used in either orientation; performing step f) allows TC1 to be used in either orientation. If steps d), e) and f) are skipped, P_1 becomes the reference power level P_{ref} in step h).

d) Disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a second power level, P_2.

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify that the attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a). If step f) is not performed, P_2 becomes the new reference power level P_{ref} in step h).

f) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through e), obtaining a new reference reading P_3 and power readings P_4 and P_5 as above, then proceed to step g). P_5 becomes the new reference power level P_{ref} in step h).

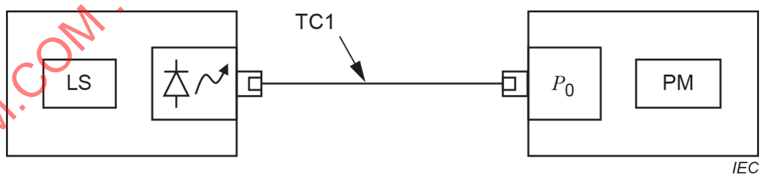
g) Insert substitution cord TC3 and adapter A2 between A1 and TC2 as shown in Figure J.9 and record power level P_6.

h) Determine the ~~loss~~ attenuation in dB as 10 × log(P_{ref}/P_6). Verify ~~loss~~ attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC3 and A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

i) Disconnect TC3 from the adapters, interchange the ends, reinsert, and record power level P_7.

j) Determine the attenuation in dB as 10 × log(P_{ref}/P_7). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC3 and adapters as necessary before continuing. After cleaning or replacement, repeat from step a).

NOTE All power measurements described are taken in linear units (W).



Key

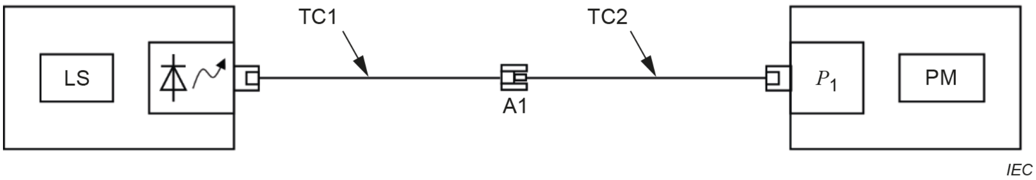
LS light source

TC1 launch cord

PM power meter

P_0 reference power measurement

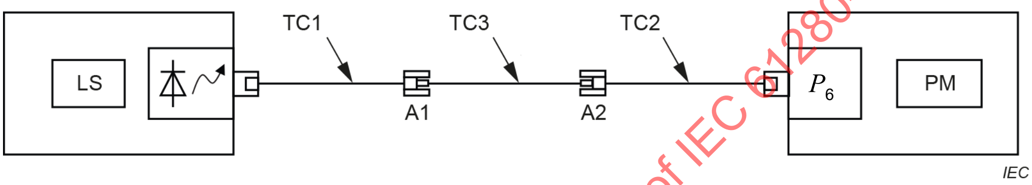
Figure J.7 – Obtaining reference power level P_0



Key

LS	light source	TC2	test cord
TC1	launch cord	PM	power meter
A1	connector set	P_1	test power measurement

Figure J.8 – Obtaining power level P_1



Key

LS	light source	TC3	test cord
TC1	launch cord	TC2	test cord
A1	connector set	PM	power meter
A2	connector set	P_6	test power measurement

Figure J.9 – Obtaining power level P_6

J.3.5 Test cord verification for the three-cord reference test method using pinned-to-unpinned or plug-to-socket style connectors

The procedure is as follows:

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.10.

b) Insert adapters A1, A2, substitution cord TC3, and receive cord TC2 between TC1 and power meter as shown in Figure J.11 and record P_1. For plug-to-socket styles, the adapters are replaced by sockets.

c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC1, TC2, TC3 and adapters as necessary before continuing. After cleaning or replacement, repeat from step a).

d) If the plugs of TC3 are of the same type on both ends, disconnect TC3, interchange the ends, reinsert, and record power level P_2. If the plugs are not the same type, skip step e).

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC1, TC2, TC3 and adapters as necessary before continuing. After cleaning or replacement, repeat from step a).

NOTE 1 The limits in steps c) and e) for this case are normally set to two times the acceptable limit of a single interface.

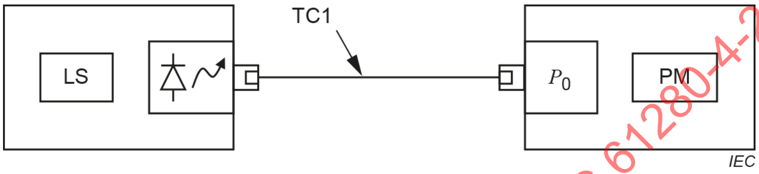
Steps f), g) and h) are recommended but optional. If steps f), g) and h) are not performed, then TC1 and TC2 shall be used only in their tested orientation. More precisely, performing steps f) and g) allows TC2 to be used in either orientation; performing step h) allows TC1 to be used in either orientation.

f) In configurations that permit, disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a power level, P_3.

g) Determine the attenuation in dB as 10 × log(P_0/P_3). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC2, TC3 and adapter A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

h) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through e).

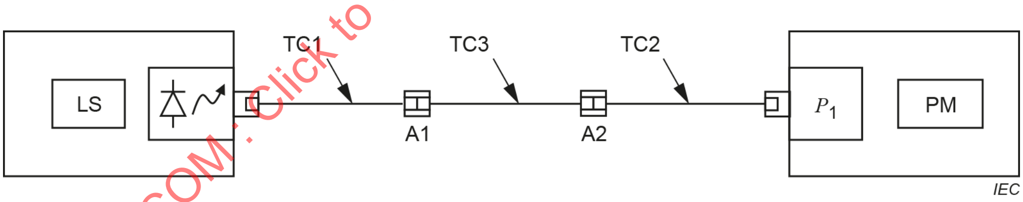
NOTE 2 All power measurements described are taken in linear units (W).



Key

LS	light source
TC1	launch cord
PM	power meter
P_0	reference power measurement

Figure J.10 – Obtaining reference power level P_0



Key

LS	light source	TC3	test cord
TC1	launch cord	TC2	test cord
A1	connector set	PM	power meter
A2	connector set	P_1	test power measurement

Figure J.11 – Obtaining power level P_1

~~Annex J~~Annex K
(informative)

Spectral attenuation measurement

K.1 Applicability of test method

The spectral attenuation of installed cabling is a measure of the attenuation of the cabling as a function of wavelength over a broad wavelength range. Whereas the measurements described in Annex A through Annex D are typically performed at a few discrete wavelengths (e.g. 1 310 nm and 1 550 nm plus 1 625 nm for long distance systems), a spectral attenuation measurement ~~may~~ can cover a wide wavelength range (e.g. the S, C and L bands (1 450 nm to 1 625 nm) or the full wavelength range covering the O, E, S, C and L bands from 1 260 nm to 1 625 nm).

These measurements are useful when extended wavelength operation ~~may be~~ is required (as in CWDM or DWDM systems for example), or if it is required to identify the category of fibre in the installed cabling (i.e. whether this is a category with or without a water peak). In particular, there are wavelength ranges where the ~~loss~~ attenuation of installed cabling ~~may~~ can vary significantly such as around the water peak centred in the E-band at 1 383 nm. It is useful to know the height and width of this peak.

It is possible to carry out attenuation measurements at a large number of discrete wavelengths, for example using a tuneable laser source, but usually the range of wavelengths covered is quite small, and the principles of Annex A through Annex D ~~may~~ can be applied.

This annex focuses on the use of a broad band light source and an optical spectrum analyser for carrying out this measurement.

K.2 Apparatus

K.2.1 Broadband light source

The broadband light source shall have sufficient spectral power density to cover the wavelength range of interest. This ~~may~~ can be achieved by using one or more high powered LEDs. Alternatively, or in addition, the amplified spontaneous emissions (ASE) of a fibre amplifier ~~may~~ can be used, for example to cover the C-band.

There is no requirement for uniform spectral power density as a reference measurement will be taken of the power in the input spectrum.

The emissions of the light source shall be stable for the duration of the measurement.

K.2.2 Optical spectrum analyser

The optical spectrum analyser shall be capable of measuring power as a function of wavelength across the wavelength range of interest and shall be capable of storing and processing these wavelength scans.

K.3 Procedure

K.3.1 Reference scan

- Connect the broadband source directly to the optical spectrum analyser with the appropriate number of test cords depending upon the cabling configuration (see 4.2).
- Turn on the broadband source and allow sufficient time for the output to stabilize.
- Take a reference scan of the power in the input spectrum across the wavelength range of interest and record this power, in units of dB or dBm, as a function of wavelength: $P_{ref}(\lambda)$.

K.3.2 Measurement scan

- Connect the broadband source and associated test cord to one end of the cabling under test, connect the optical spectrum analyser with an appropriate test cord to the other end of the cabling under test.
- Turn on the broadband source and allow sufficient time for the output to stabilize.
- Take a measurement scan of the power in the output spectrum across the wavelength range of interest and record this power, in units of dB or dBm, as a function of wavelength: $P_{meas}(\lambda)$.

K.4 Calculations

The spectral attenuation of the cabling under test, $L(\lambda)$, expressed in dB, is obtained by subtracting the measured scan from the reference scan, as shown in Formula (K.1):

~~$L(\lambda)$(dB])$P_{Ref}(\lambda)$(dBm) – $P_{Meas}(\lambda)$(dBm)~~

$$L(\lambda) = P_{ref}(\lambda) - P_{meas}(\lambda) \qquad \text{(K.1)}$$

The result of such a measurement ~~may~~ can be presented in a table for particular wavelengths of interest (e.g. the ~~CWDM~~ WDM wavelengths defined by ITU-T) or graphically as shown in Figure K.1, which clearly shows very high ~~loss~~ attenuation at the water peak and a low ~~loss~~ attenuation region in the C and L bands (1 530 nm to 1 625 nm).

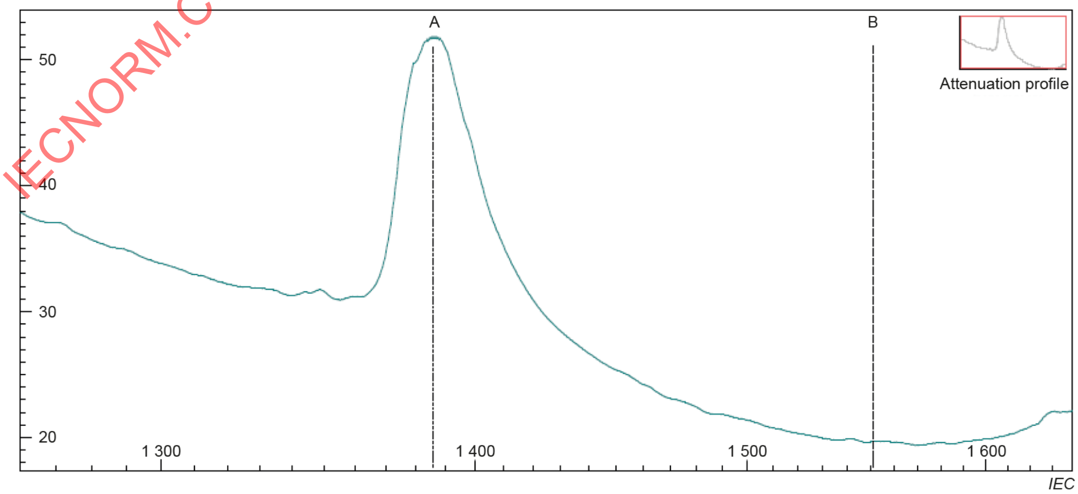


Figure K.1 – Result of spectral attenuation measurement

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ITU-T Recommendation G.657, *Characteristics of a bending-loss insensitive single-mode optical fibre and cable ~~for the access network~~*

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~~[2] To be published.~~

IEC 61280-4-2

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INTERNATIONAL STANDARD

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**Fibre- optic communication subsystem test procedures –
Part 4-2: Installed cabling plant – Single-mode attenuation and optical return loss measurements**

**Procédures d'essai des sous-systèmes de télécommunication fibroniques –
Partie 4-2: Installations câblées – Mesures de l'affaiblissement de réflexion optique et de l'affaiblissement des fibres unimodales**

IEC 61280-4-2:2024-05(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FIBRE-OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-2: Installed cabling plant – Single-mode attenuation and optical return loss measurements

FOREWORD

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IEC 61280-4-2 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is an International Standard.

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

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

a) addition of the equipment cord method;
b) addition of test limit adjustment related to test cord grades;
c) refinements on measurement uncertainties.

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

Draft	Report on voting
86C/1912/FDIS	86C/1916/RVD

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

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

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61280 series, published under the general title *Fibre optic communication subsystem test procedures*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

This document is part of a series of IEC standards for measurements of installed fibre optic cabling plants. This document is applicable for the measurement of installed single-mode fibres.

Cabling design standards such as ISO/IEC 11801-1 provide general requirements for this type of cabling. These standards support cabling lengths of up to 2 km for commercial premises and data centres and up to 10 km for industrial premises. ISO/IEC 14763-3, which supports ISO/IEC 11801-1, normatively references IEC 61280-4-2.

Various recommendations from ITU-T have requirements for longer distance applications, including short haul (40 km), long haul (80 km), and ultra-long haul (160 km). The testing of cabling plant for these applications is covered in ITU-T Recommendation G.650.3, which refers to the test methods of this document.

FIBRE-OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-2: Installed cabling plant – Single-mode attenuation and optical return loss measurements

1 Scope

This part of IEC 61280 is applicable to the measurements of attenuation and optical return loss of an installed optical fibre cabling plant using single-mode fibre. This cabling plant can include single-mode optical fibres, connectors, adapters, splices, and other passive devices. The cabling can be installed in a variety of environments including residential, commercial, industrial and data centre premises, as well as outside plant environments.

This document is applicable to all single-mode fibre types including those designated by IEC 60793-2-50 as Class B fibres.

The principles of this document can be applied to cabling plants containing branching devices (splitters) and at specific wavelength ranges in situations where passive wavelength selective components are deployed, such as WDM, CWDM and DWDM devices.

This document is not intended to apply to cabling plants that include active devices such as fibre amplifiers or dynamic channel equalizers.

2 Normative references

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

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

IEC 61300-3-35, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-35: Examinations and measurements – Visual inspection of fibre optic connectors and fibre-stub transceivers*

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

IEC 61746-1:2009, *Calibration of optical time-domain reflectometers (OTDR) – Part 1: OTDR for single-mode fibres*

IEC TR 62627-01, *Fibre optic interconnecting devices and passive components – Part 01: Fibre optic connector cleaning methods*

3 Terms, definitions, graphical symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1.1
adapter
device that enables interconnection between terminated optical fibre cables

3.1.2
attenuation
reduction of optical power induced through a medium like cabling given as A:

$$A = 10 \times \log_{10} (P_{in}/P_{out})$$

where

P_{in} and P_{out} are the power, typically measured in mW, into and out of the cabling

Note 1 to entry: Attenuation is expressed in dB.

Note 2 to entry: Alternatively, attenuation can be expressed as $A = -10 \times \log_{10} (P_{out}/P_{in})$. Both formulae are mathematically equivalent, resulting in positive decibel values.

3.1.3
bi-directional measurement
two measurements of the same optical fibre made by launching light into opposite ends of that fibre

3.1.4
configuration
form or arrangement of parts or elements such as terminations, connections, and splices

3.1.5
connector
component normally attached to an optical cable or piece of apparatus, for the purpose of providing frequent optical interconnection/disconnection of optical fibres or cables

[SOURCE: IEC TR 61931:1998, 2.6.1, modified – The words in brackets, "(optical) (fibre)", have been omitted from the term.]

3.1.6
light source and power meter
LSPM
test system consisting of a light source (LS), power meter (PM) and associated test cords used to measure the attenuation of an installed cabling plant

3.1.7
optical return loss
ORL
R_{ORL}
ratio of the input power, P_{in}, of the cabling under test to the backward power, P_r, reflected by the cabling under test:

$$R_{ORL} = 10 \times \log_{10}(P_{in}/P_r)$$

Note 1 to entry: Optical return loss is a positive number.

Note 2 to entry: Optical return loss is expressed in dB.

3.1.8
optical time domain reflectometer
OTDR
test system consisting of an optical time-domain reflectometer and associated test cords, used to characterize and measure the attenuation and optical return loss of an installed cabling plant and specific elements within that cabling plant

3.1.9
plug
free connector
male part of a connector

[SOURCE: IEC TR 61931:1998, 2.6.2]

3.1.10
reference-grade termination
connector plug with tightened tolerances terminated onto a single-mode optical fibre with tightened tolerances such that the expected attenuation of a connection formed by mating two such assemblies is lower and more repeatable than a standard-grade termination

Note 1 to entry: An adapter, required to ensure this performance, can be considered to be part of the reference-grade termination where required by the test configuration.

Note 2 to entry: IEC 61755-2-4 for non-angled (PC) and IEC 61755-2-5 for angled (APC) cylindrical ferrule connectors define reference-grade terminations. These standards can be referenced for further information.

3.1.11
reference test method
RTM
test method for measuring a given characteristic strictly according to the definition of this characteristic, and giving results which are accurate, reproducible, and relatable to practical use

[SOURCE: IEC TR 61931:1998, 2.8.1, modified – The words in brackets, "(for optical fibres)", have been omitted from the term.]

3.1.12
reflectance
R_{comp}
for a discrete component in the cabling, ratio of the backward power, P_r, reflected by the component, to the input power, P_{in}, into the component:

$$R_{comp} = 10 \times \log_{10}(P_r / P_{in})$$

Note 1 to entry: Reflectance is a negative number.

Note 2 to entry: Alternatively, this is referred to (e.g. by IEC 61300-3-6) as the return loss of individual components and is expressed as $R_L = -10 \times \log_{10}(P_r / P_{in})$, which is a positive number.

Note 3 to entry: Reflectance is expressed in dB.

3.1.13
return loss test set
RLTS
test system consisting of a light source (LS) and internal power meter (PM), directional coupler and additional external power meter and associated test cords used to measure the optical return loss of an installed cabling plant

3.1.14
socket style connector
connector for which the adapter, including any alignment device, is integrated with and permanently attached to the connector plug on one side of the connection

Note 1 to entry: Examples include the SG connector (see IEC 61754-19) and many harsh environment connectors.

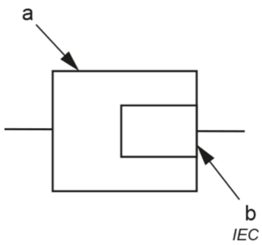
3.1.15
test cord
terminated optical fibre cord used to connect the optical source or detector to the cabling or to provide suitable interfaces to the cabling under test

Note 1 to entry: There are five types of test cords:

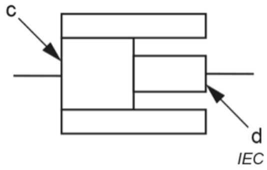
– launch cord: used to connect the light source to the cabling;
– receive cord: used to connect the cabling to the power meter (LSPM only);
– tail cord: attached to the far end of the cabling when an OTDR is used at the near end. This provides a means of evaluating attenuation and optical return loss of the whole of the cabling including the far end connection;
– adapter cord: used to transition between sockets or other incompatible connectors in a required test configuration;
– substitution cord: a test cord used within a reference measurement which is replaced during the measurement of the attenuation of the cabling under test.

3.2 Graphical symbols

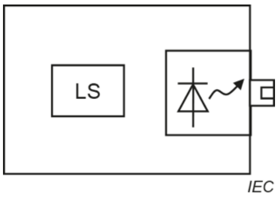
The graphical symbols shown in Figure 1 for different connection options are as given in IEC TR 61930:1998, except for the angled connector pair shown in Figure 1 g).



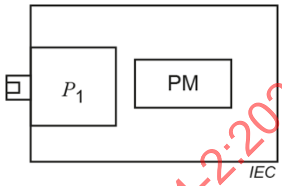
a) Socket and plug assembly



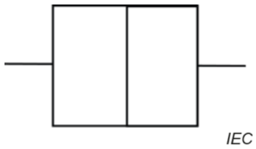
b) Connector set (plug, adapter, plug)



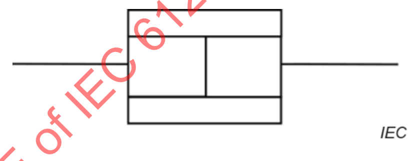
c) Light source



d) Power meter



e) Generic connection



f) Pinned-to-unpinned connection

g) Angled connector pair

Key

a socket

b plug

c plug-adapter assembly

d plug inserted into plug-adapter assembly

LS light source

PM power meter

P_1 measured power level

Figure 1 – Connector symbols

NOTE 1 In Figure 1 b) and elsewhere in this document, the plugs are shown with different sizes to indicate directionality where the cabling has adapters pre-attached, and the test cord does not, or vice versa. In Figure 1 b), the plug on the left has the adapter pre-attached.

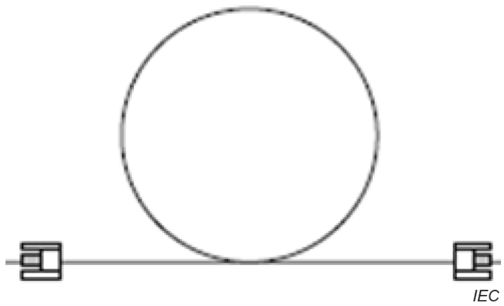
NOTE 2 Where used in all figures in this document, including those in the annexes, reference-grade terminations and adapters are shaded with grey.

NOTE 3 A simplified two-block connection used in Annex E and Annex I is shown in Figure 1 e).

NOTE 4 A simplified connection for pinned-to-unpinned and socketed connections used in Annex J is shown in Figure 1 f).

NOTE 5 An angled connector pair used in Figure 8, Annex F, and Annex G is shown in Figure 1 g).

In the figures that illustrate the measurement configurations in Annex A through Annex E, the cabling under test is illustrated by a loop, as shown in Figure 2. Although illustrated as a loop of fibre, it can contain additional splices and connectors in addition to the terminal connectors. Note that for purposes of measuring the attenuation of this cabling, the attenuations associated with the terminal connectors are considered separately from the cabling itself.



NOTE The cabling is shown with adapters pre-attached, and the plugs going into them are associated with reference-grade test cord plugs.

Figure 2 – Symbol for cabling under test

3.3 Abbreviated terms

APC	angled physical contact (description of connector style)
ASE	amplified spontaneous emissions
ATM	alternative test method
CW	continuous wave
CWDM	coarse wavelength division multiplexing
DWDM	dense wavelength division multiplexing
FTTH	fibre to the home
LED	light emitting diode
LS	light source
LSA	least squares approximation
OCWR	optical continuous wave reflectometer
PC	physical contact (description of connector style that is not angled)
PM	power meter
WDM	wavelength division multiplexing

4 Measurement methods

4.1 General

4.1.1 Document structure

General requirements for apparatus, procedures, and calculations common to all methods are given in the main text of this document. Requirements that are specific to each method are documented in Annex A through Annex G. Procedures for connector end face cleaning and inspection are described in 6.9 and 7.2.

4.1.2 Attenuation

Five attenuation measurement methods are described in this document. The five measurement methods use test cords to interface with the cabling plant and are designated as follows:

1) one-cord reference method (see Annex A);
2) three-cord reference method (see Annex B);
3) two-cord reference method (see Annex C);
4) equipment cord method (see Annex D);
5) optical time domain reflectometer (OTDR) method (see Annex E).

The first four methods use an optical light source and power meter (LSPM) to measure input and output power levels of the cabling under test to determine the attenuation. The main functional difference between these methods is the way the input power level, known as the reference power level, is measured and, hence, the inclusion or exclusion of the attenuations associated with the connections to the cabling under test, and the associated uncertainties of these connections. The process of measuring the input power level is commonly referred to as "taking the reference power level."

The use of the term "reference" in the description of the test methods refers to the process of measuring the input power, not the status of the test.

The one-cord reference method produces results that include the attenuation associated with connections at both ends of the cabling under test. The three-cord reference method produces results that attempt to exclude the attenuation of the connections of both ends of the cabling under test. The two-cord reference method normally produces results that include the attenuation associated with one of the connections of the cabling under test. The equipment cord method includes the attenuation associated with the connections between the equipment cords and the fixed cabling, but excludes the attenuation associated with the connectors that will be connected into the equipment (i.e. transmission system).

NOTE The maximum cabling attenuation specified for a transmission system (e.g. through an optical power budget or channel insertion loss) normally excludes the connections made to the transmission equipment. It is therefore appropriate to use the three-cord reference method where the cabling under test is intended to be connected directly to the transmission equipment.

In the OTDR method, short light pulses are injected into the cabling, and the backscattered power is measured as a function of propagation time delay or length along the fibre. This method also allows the determination of the attenuation values of individual cabling components. It does not require a separate reference measurement to be completed. Requirements for the launch and tail cords are defined in Annex E. In addition to commissioning new cabling plant, the OTDR method is useful for optical fibre cabling testing during troubleshooting and maintenance, since the cabling plant can be characterized by a detailed mapping (the OTDR trace) that can be analysed to highlight any changes.

Guidance on each attenuation measurement method is provided in Annex A through Annex E. An overview of the uncertainties for each measurement method is given in Clause 5.

4.1.3 Optical return loss

This document also defines two types of test methods that can be used for measuring the optical return loss of installed cabling:

a) OTDR based method;
b) continuous wave method using a return loss test set.

The OTDR method allows the optical return loss of the entire cabling to be measured as well as the reflectance of individual discrete components or the optical return loss of specific sections of the cabling. The measurement can be carried out in one step from each end of the cabling under test. This method is described in detail in Clause E.5.

The continuous wave method described in Annex F directly measures the forward power into the cabling under test as an initial measurement step and then compares this with the reflected power measured back through a directional coupler. Additional reference or calibration measurements are required to quantify the attenuation through the directional coupler and to cancel out any internal reflections in the measurement apparatus.

The continuous wave test method described in Annex G calculates the forward power level and the reflected power in a similar way to the method described in Annex F. An additional reference measurement of a known reflectance termination is required to implement this method.

4.2 Cabling configurations and applicable test methods

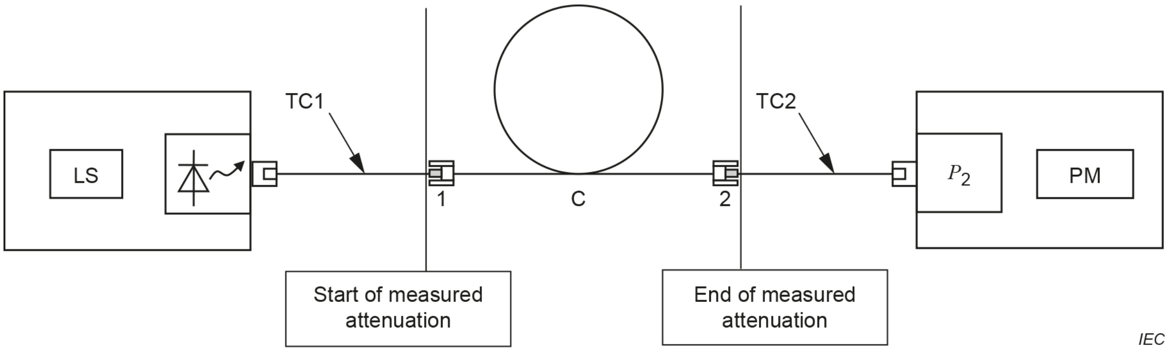
4.2.1 Cabling configurations and applicable test methods for attenuation measurements

This document assumes that the installed cabling takes one of the four forms shown in Table 1. If the cabling is terminated with an adapter, the test cord shall be terminated with a plug and vice versa.

Table 1 – Cabling configurations

Configuration	Description	End connections attenuation included
A	Adapters attached to plugs or sockets attached to both ends of the cabling	Two
B	Plugs on both ends	None
C	Mixed, where one end of the cabling is terminated with an adapter and the other end is terminated with a plug	One (terminated with an adapter)
D	Plugs on both ends utilizing equipment cords	None

The variations in test method used to measure the cabling are dependent on the cabling configuration. For example, a common cabling configuration is that of having adapters or sockets on both ends of the cabling (e.g. within patch panels) awaiting connection to fibre optic transmitter or receiver equipment with an equipment cord. This corresponds to configuration A. In this case, the one-cord reference method is used to include the attenuations associated with both end connectors of the cabling as illustrated in Figure 3.



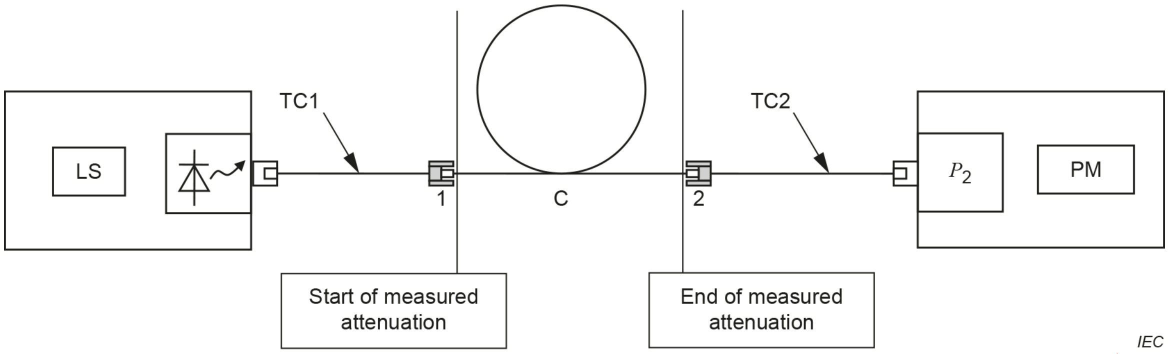
Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	measured power level

NOTE Figure 3 is an example of cabling in configuration A with test cords TC1 and TC2 attached, illustrating the start and end points of the measured attenuations when the reference test method is used (the one-cord reference method as detailed in Annex A).

Figure 3 – Configuration A – Start and end of measured attenuations in RTM

Another example is a cabling configuration where ruggedized pigtails have been spliced onto the ends of the main cable, and the connectors on the pigtails are to be directly connected into the fibre optic transmitter or receiver equipment. This corresponds to configuration B, which is illustrated in Figure 4. In this case, a three-cord reference method is used to exclude the attenuations of the end plug connections. Figure 4 illustrates the start and end points of the measured attenuations when the reference test method is used (the three-cord reference method as detailed in Annex B).



Key

LS light source

TC1 launch cord

C cabling under test

TC2 receive cord

PM power meter

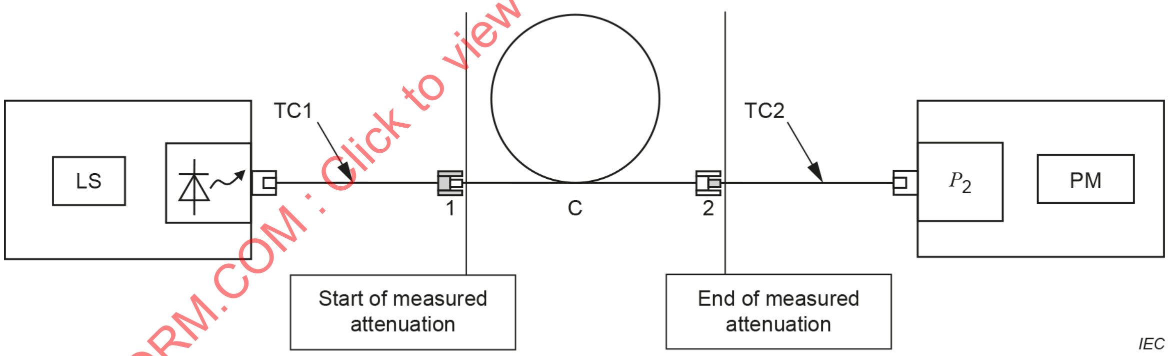
1, 2 connector sets

P_2 measured power level

NOTE The plugs are shown with different sizes to indicate directionality where the cabling has adapters pre-attached, and the test cord does not, or vice versa.

Figure 4 – Configuration B – Start and end of measured attenuations in RTM

Figure 5 shows an example of cabling in configuration C with test cords attached, illustrating the start and end points of the measured attenuations when the reference test method is used (the two-cord reference method as detailed in Annex C).



Key

LS light source

TC1 launch cord

C cabling under test

TC2 receive cord

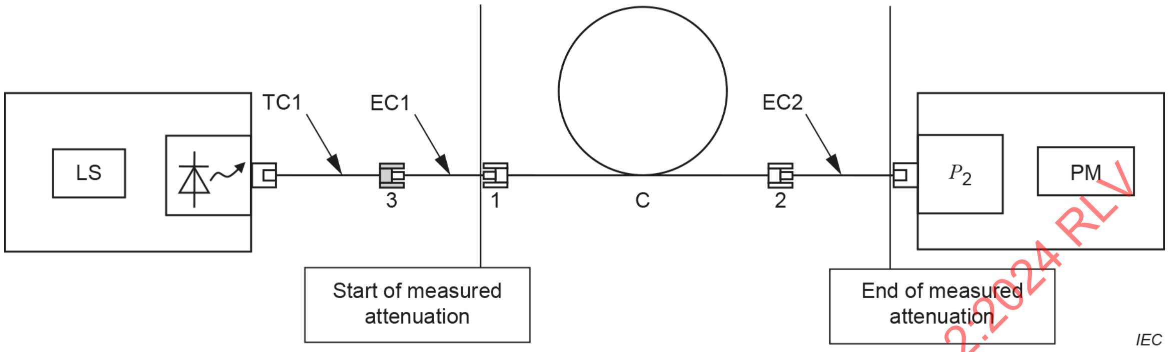
PM power meter

1, 2 connector sets

P_2 measured power level

Figure 5 – Configuration C – Start and end of measured attenuations in RTM

A further example is a cabling configuration in which equipment cords are installed on both ends of the cabling and are awaiting connection to fibre optic transmitter or receiver equipment. This corresponds to configuration D, which is illustrated in Figure 6. In this case, the equipment cord method (or, when this is not practical, the three-cord method) is used to exclude the attenuation of the end plug connections.



Key

LS	light source
TC1	launch cord
EC1	equipment launch cord
C	cabling under test
EC2	equipment receive cord
PM	power meter
1, 2, 3	connector sets
P_2	measured power level

Figure 6 – Configuration D – Start and end of measured attenuations in RTM

The specific configuration used in the attenuation measurement (i.e. A, B, C, or D) defines the test method (or test methods) that should be applied, as described in Table 2. The reference test method (RTM) offers the best measurement accuracy. Alternative test methods (ATM) may be called up in specific circumstances, or by other standards, but are subject to reduced measurement accuracy compared with the reference test method. Unless otherwise agreed, resolutions of dispute shall employ the appropriate RTM in conjunction with the applicable reference-grade terminations and adapters, as described in 6.3, 6.4, 6.5, and 6.10.

Table 2 – Test methods and configurations

Configuration	RTM	ATM
A	Annex A (1-cord)	Annex B (3-cord)[a], Annex C (2-cord), Annex E (OTDR)
B	Annex B (3-cord)	Annex E (OTDR)
C	Annex C (2-cord)	Annex B (3-cord), Annex E (OTDR)
D	Annex D (equipment cord)	Annex B (3-cord), Annex E (OTDR)

NOTE The configurations, RTMs, and annexes are ordered according to the frequency in which different configurations are typically encountered.

[a] For situations where pinned-to-unpinned or plug-to-socket style connectors are used, such as MTRJ, SG or another harsh environment connector, where the power meter does not accept the unpinned or plug connector of the launch cord, the method illustrated in Figure C.3 can be used.

Where information is required about the discrete components installed within the cabling under test, Annex E is the only one of these test methods that provides this information.

4.2.2 Cabling configurations and applicable test methods for optical return loss measurements

Any of the cabling configurations described in 4.2.1 can be measured using any of the three defined ORL test methods described in Annex E, Annex F, and Annex G.

The OTDR ORL test method described in Clause E.5 requires no separate reference measurements to be taken and is least likely to be affected by measurement errors. When the cabling is tested using suitable launch and tail cords, it is easy to define the start and end points of the ORL measurement as shown in Figure E.5.

The continuous wave ORL test methods described in Annex F and Annex G offer a way to measure ORL. The method described in Annex G is more applicable for field measurements because it uses the same light source and power meter. Particular care shall be taken if a short (< 10 km) length of cable is tested with a PC (non-angled) connector at the far end. If this connector is left open, the unwanted reflection from this glass-to-air interface will dominate the total ORL. Hence the use of a tail cord with PC connection at one end and APC connection at the other end, as shown in Figure F.1, helps to suppress the glass-to-air reflection whilst providing a contribution from a representative reflectance from a connector pair at the far end of the system.

The test method of continuous wave (CW) ORL measurement, as described in Annex G, does not include a direct measurement of the forward power going into the system under test, and requires reference measurements on known reflectance terminations.

5 Overview of uncertainties for attenuation measurements

5.1 General

The measurement uncertainties should be determined using the calculations provided in IEC TR 61282-14.

Even if a calculation spreadsheet is provided, the full calculation of measurement uncertainties is relatively complex due to the large number of considered parameters. Subclauses 5.2 to 5.8 provide an alternative to this calculation.

5.2 Sources of significant uncertainties

For typical conditions, calculations using IEC TR 61282-14 show that significant sources of uncertainties are limited to those generated by source instability, measurement method, and connector mating reproducibility.

Other sources of uncertainties, such as source wavelength, measurement resolution, power meter linearity, are less significant and do not impact measurements, because the accumulation of uncertainties is a quadratic summation.

5.3 Consideration of the power meter

The power meter (PM) should have a detector large enough to capture the entire incident light. In this way, the attenuation and uncertainty associated with coupling the receive cord to the power meter is minimal.

5.4 Consideration of test cord and connector grade

5.4.1 General

The attenuation and reflectance associated with the test cord connections can be different from the attenuation and reflectance present when the cabling is connected to other cords or transmission equipment. The use of reference-grade terminations on the test cords reduces this uncertainty and improves reproducibility of the measurement, but the allocation of acceptable attenuation is different, as listed in Table H.1.

Test cords can be reference-grade or standard-grade, so that two different measurement conditions shall be considered. Using reference-grade connectors on test cords reduces measurement uncertainty but changes the test limits that should be applied when a pass or fail assessment is required, whereas using standard-grade connectors implies a much higher measurement uncertainty, which sometimes exceeds the actual attenuation measurement (see Table 3 and Annex H) although no adjustment of test limits is necessary.

Table 3 – Test limit adjustment and uncertainty related to test cord connector grade

Test cord termination grade	Cabling and equipment cord termination grade	Test limit adjustment	Total uncertainty
SM reference-grade	SM standard-grade	A lower test limit is required for most measurements, including the one-test cord reference method and OTDR testing. However, the 3-test cord reference method requires a higher test limit. See Annex H for more details and examples.	Can be estimated using IEC TR 61282-14 default values
SM standard-grade	SM standard-grade	None	Uncertainty values are higher than the values estimated using the IEC TR 61282-14 default values (see Table 4)

5.4.2 Mode field diameter variation

If the test interfaces employ fibres with significant differences in mode field diameter, additional attenuation can be introduced that will affect the measurement accuracy. Optical interface standards developed for single-mode fibres provide details of the attenuation introduced by mode field diameter mismatches, see for example IEC 61755-2-1 for non-angled interfaces and IEC 61755-2-2 for 8-degree angled interfaces.

5.5 Reflections from other interfaces

When conducting optical return loss measurements, reflections from other interfaces can be a significant cause of measurement uncertainty, particularly for the continuous wave method. It is important to configure the cabling under test such that unwanted reflections are suppressed. For example, when testing a short length of cable, a test cord should be coupled to the far end of the cabling under test with an angled connector at the remote end of the test cord. Usually, the connector interface to the return loss test set has an angled connector.

For the OTDR based return loss method, the use of suitably long launch and tail cords helps to eliminate the effect of unwanted reflections.

5.6 Optical source

The following sources of uncertainties are relevant to the attenuation measurements:

– wavelength of the light source, because the fibre attenuation can be different at the source wavelength and at the transmitter wavelength of the cabling system;

– spectral width of the light source, because spectrally wider light sources can measure different fibre attenuation values than spectrally narrower light sources, whereas optical sources with overly narrow spectral width can introduce undesired coherent interference effects.

5.7 Output power reference

For methods using a light source and power meter (LSPM), one of the main sources of uncertainty is the variable coupling efficiency of the light source to the launch cord due to mechanical tolerances. To minimize this uncertainty, a reference power reading should be made whenever the connection is disturbed by stress on the connector or by disconnection.

For LSPM methods, a reference measurement shall be made to determine the output power of the launch cord which will be coupled to the cable or cabling plant under test. This measurement should be made each time the launch cord is attached to the source, as the coupling can be slightly different each time it is carried out.

5.8 Bi-directional measurements

For the LSPM methods of measuring attenuation, the test results from each end of the cabling should be very similar. A good practice for assessing the validity of the measurement results is to compare the measurement results from each end and to make sure that they are within a certain tolerance (for example 0,5 dB) of each other, thus making sure that no additional uncertainty is present due to measurement errors.

5.9 Typical uncertainties for attenuation methods A, B, C, and D

Typical uncertainties for attenuation measurements are shown in Table 4. These values were calculated using IEC TR 61282-14 and assuming the following conditions:

- PM: use of the same photodetector in the power meter for the reference power measurement and attenuation power measurement; the polarity of the reference measurement is the same as the cabling under test;
- source centroidal wavelength, reference IEC 61280-1-3: 1 310 nm and 1 550 nm ± 30 nm;
- source level: ≥ −7 dBm (0,2 mW);
- source stability: ±0,10 dB (k = 2);
- optical fibre: IEC 60793-2-50, B-652 and B-657;
- R2 reference-grade PC connectors: ≤ 0,2 dB attenuation, reference IEC 61755-2-4;
- repeatability of connection: 0,05 dB.

NOTE At the time of writing, it was expected that the designation "R2" for single-mode reference grade connectors with 0,2 dB attenuation will be replaced by a new designation "R_{s1-2}" in the future Edition 2 of IEC 61755-2-4 and also referred to as "Rs1-Grade 2" in Edition 3 of ISO/IEC 14763-3[1].

[1] Third edition under preparation. Stage at the time of publication: ISO/IEC FDIS 14763-3:2024.

Table 4 – Uncertainty for given fibre length and attenuation at 1 310 nm, 1 550 nm and 1 625 nm

				Uncertainty values at 95 % at 1 310 nm			
Distance km	Attenuation dB	IEEE 802.3 designation	ITU span type designation	1-cord dB	2-cord dB	3-cord dB	Equipment cord dB
0,5	3,0	DR		0,32	0,38	0,44	0,14
2,0	4,0	FR		0,33	0,39	0,44	0,16
5,0	4,8			0,36	0,42	0,46	0,22
10,0	6,3	LR		0,46	0,50	0,54	0,35
20,0	11,0		S	0,72	0,75	0,78	0,66
40,0	18,0	ER		1,33	1,35	1,36	1,30
				Uncertainty values at 95 % at 1 550 nm[a]			
Distance km	Attenuation dB	IEEE 802.3 designation	ITU span type designation	1-cord dB	2-cord dB	3-cord dB	Equipment cord dB
0,5	3,0	DR		0,32	0,38	0,44	0,14
2,0	2,5	FR		0,32	0,38	0,44	0,14
5,0	3,3			0,33	0,38	0,44	0,14
10,0	4,5	LR		0,33	0,39	0,44	0,15
20,0	7,0		I	0,34	0,40	0,45	0,18
40,0	11,0	ER	S	0,39	0,44	0,48	0,25
80,0	22,0	ZR	L	0,53	0,57	0,60	0,44
120,0	33,0	OIF 400ZR	U	0,70	0,73	0,76	0,64
				Uncertainty values at 95 % at 1 625 nm[b]			
Distance km	Attenuation dB	IEEE 802.3 designation	ITU span type designation	1-cord dB	2-cord dB	3-cord dB	Equipment cord dB
80,0	24,4	ZR	L	1,75	1,77	1,78	1,73
120,0	36,6	OIF 400ZR	U	2,61	2,61	2,62	2,59
				Uncertainty values at 95 % at 1 625 nm[b] ± 15 nm			
Distance km	Attenuation dB	IEEE 802.3 designation	ITU span type designation	1-cord dB	2-cord dB	3-cord dB	Equipment cord dB
80,0	24,4	ZR	L	0,92	0,94	0,97	0,87
120,0	36,6	OIF 400ZR	U	1,33	1,35	1,36	1,30

When the uncertainty is larger than the measured attenuation, the measured value can be quite meaningless. In this case, it is good practice to replace the measured value with the value of the uncertainty.

[a] Although IEEE applications do not operate at 1 550 nm at the shorter distances, it is good practice to test single-mode fibre cabling at two different wavelengths (usually 1 310 nm and 1 550 nm) to identify potential issues with fibre bends; thus, knowledge of the measurement uncertainty at 1 550 nm is useful.

[b] Likewise, for longer links it is good practice to measure the attenuation at a second wavelength (e.g. at 1 625 nm), even though most transmission systems do not operate at this wavelength.

5.10 Typical uncertainty values for single-mode attenuation testing for method E

Typical uncertainties to produce Table 5 values were calculated using IEC 61280-4-3, assuming the following conditions:

- bi-directional measurement, dynamic margin: > 5 dB (see notes in Table 5);
- OTDR, linear regression: 100 data points (see notes in Table 5);
- source centroidal wavelength, reference IEC 61280-1-3: 1 310 nm and 1 550 nm ± 30 nm;
- optical fibre: IEC 60793-2-50, B-652 and B-657;
- R2 reference-grade APC connectors: ≤ 0,2 dB attenuation, reference IEC 61755-2-5.
- repeatability of connection: 0,05 dB.

NOTE At the time of writing, it was expected that the designation "R2" for single-mode reference grade connectors with 0,2 dB attenuation will be replaced by a new designation "R_{s1-2}" in the future Edition 2 of IEC 61755-2-5 and also referred to as "Rs1-Grade 2" in Edition 3 of ISO/IEC 14763-3.

Table 5 – Uncertainty for a given fibre length at 1 310 nm and 1 550 nm using an OTDR

Uncertainty values at 95 %				
Length km	1 310 nm attenuation dB	1 310 nm uncertainty dB	1 550 nm attenuation dB	1 550 nm uncertainty dB
0,5	3,0	0,44	3,0	0,43
2,0	4,0	0,45	2,5	0,43
5,0	4,8	0,47	3,3	0,43
10,0	6,3	0,55	4,5	0,43
40,0	11,0	1,39	7,0	0,50
80,0	18,0	2,63	11,0	0,61

The launch and tail cord lengths were set to 500 m for the 0,5 km to 10 km lengths, leading to a length of linear regression of 250 m (100 points); the associated attenuation allows sufficient dynamic margin for these two cases at 10 dB.

For 40 km, the linear regression length was 500 m and 100 points, using 1 000 m long launch and tail cords. However, the dynamic margin was reduced to 5 dB.

The attenuation uncertainties for 40 km and 80 km lengths at 1 310 nm wavelength are impacted by the uncertainty of the source wavelength (assumed to be 30 nm). Reducing this uncertainty from 30 nm to 20 nm would reduce the 1 310 nm attenuation uncertainties to 1,00 dB and 1,80 dB respectively.

6 Apparatus

6.1 General

Apparatus requirements that are specific to particular methods are found in Annex A through Annex E. Some of the requirements common to the LSPM methods are described in 6.2 to 6.10.

6.2 Light source

6.2.1 Stability

The performance of the light source is evaluated at the output of the launch cord. This is achieved by transmitting the output of a suitable radiation source, usually a laser, into the launch cord. The source shall be stable in position, wavelength, and power over the duration of the entire measurement procedure.

It is recommended that the stability of the source be verified by repeating the reference measurement at the end of the measurement procedure. It should remain within a certain tolerance of the initial reference value. Power stability should be ±0,10 dB or lower.

6.2.2 Spectral characteristics

The wavelengths used for the attenuation measurement should be representative of the wavelengths at which transmission systems will operate over the fibre. For premises cabling and many other applications, this measurement is carried out at nominal wavelengths of 1 310 nm and 1 550 nm.

If other wavelengths are to be used for transmission, additional test wavelengths can also be required. For example, if DWDM applications using the L-band (1 565 nm to 1 625 nm) are to be used, then testing at 1 625 nm is recommended as well; if a passive optical network for FTTH is being tested, then 1 490 nm testing can be required.

If the cabling under test is used for CWDM systems that cover an extended wavelength range, then either the cabling should be tested at each wavelength individually, or alternatively, a spectral attenuation measurement may be taken to cover the entire wavelength range of interest, using a suitable broadband light source and an optical spectrum analyser in place of the light source and power meter. See Annex K for further information.

It is recommended that OTDR testing be carried out on single-mode cabling using at least two wavelengths. This allows attenuation due to fibre bending to be identified by comparing the traces at the two wavelengths. See I.4.2 for further information on bending attenuation measurement. Often the wavelengths used are nominally 1 310 nm and 1 550 nm for shorter routes (< 40 km) or 1 550 nm and 1 625 nm for longer routes. Measurements at a wavelength of 1 650 nm, which is sometimes used for maintenance channels, are also very effective for detecting the presence of bends.

If the cabling under test includes wavelength selective elements, such as WDM, DWDM or CWDM devices, and optical filters, for example, then the spectral width of the light source shall be compatible with that of the transmission bands of these elements; this can require light sources with a very narrow spectral width. Alternatively, the spectral response of the system may be evaluated using a broadband light source and optical spectrum analyser, using the procedure described in Annex K.

For LSPM measurements, the spectral width of the single-mode light source shall meet the requirements of Table 6 when measured in accordance with IEC 61280-1-3.

Table 6 – Spectral requirements

Centroidal wavelength nm	Spectral width range nm
1 310 ± 30 (on B-652 and B-657 fibres)	≤ 5 (RMS) for laser diode ≤ 40 (RMS) for edge emitting LED
1 550 ± 30 (on B-652 and B-657 fibres)	≤ 5 (RMS) for laser diode ≤ 40 (RMS) for edge emitting LED

6.3 Launch cord

Except for the OTDR method, the launch cord shall be 2 m to 10 m in length. See Annex E for the length of the OTDR launch cord.

The connector or adapter terminating the launch cord shall be compatible (e.g. end face type) with the cabling, and the termination should be of reference-grade to minimize the uncertainty of measurement results.

The optical fibre within the launch cord shall have the same nominal core size as the optical fibre within the cabling under test.

The single-mode optical fibres supported by this document and used in the single-mode launch cord are defined in IEC 60793-2-50 as B-652 and B-657.

6.4 Receive or tail cords

The optical fibre within the receive or tail cords shall have the same nominal core size as the optical fibre within the cabling under test.

The receive cord shall be at least 2 m long, but it should not be so long that the attenuation of the fibre has a significant effect on the measurement (e.g. less than 10 m).

The connector or adapter terminating the receive or tail cords shall be compatible with the cabling, and the termination should be of reference-grade to minimize the uncertainty of measurement results.

The termination of a receive cord at the connection to the power meter shall be compatible with that of the power meter.

When unidirectional testing is carried out, the remote end of the tail cord used for OTDR testing does not require reference-grade termination. When bi-directional OTDR testing is carried out, the tail cord becomes the launch cord (see Annex I) and shall comply with 6.3.

6.5 Substitution cord

The optical fibre within the substitution cord shall have the same nominal core size as the optical fibre within the cabling under test.

The substitution cord shall be at least 2 m long but not so long that the attenuation of the fibre has a significant effect on the measurement (e.g. less than 10 m).

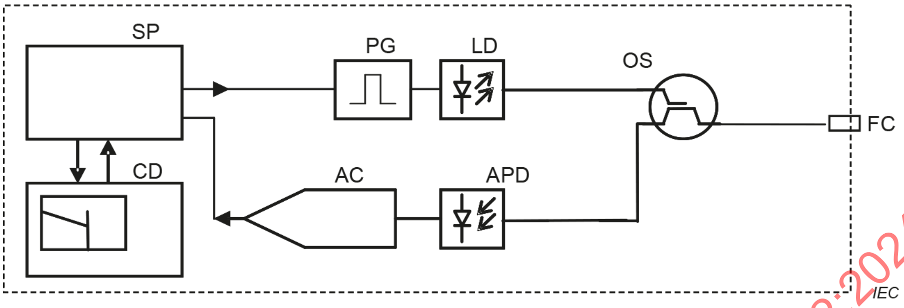
The connectors or adapters terminating the substitution cord shall be compatible with the cabling, and the terminations should be of reference-grade to minimize the uncertainty of measurement results.

6.6 Power meter – LSPM methods only

The power meter shall be capable of measuring the required range of power levels at wavelengths normally associated with the cabling, including considerations on the power launched into the cabling. The power meter shall meet the calibration requirements of IEC 61315. The meter shall have a detecting surface of sufficient size to capture all the power coming from the fibre that is put into it. If a pigtail is used, the pigtail fibre shall be sufficiently large to capture all the power coming from the test cord.

6.7 OTDR apparatus

Figure 7 displays a schematic diagram of the typical OTDR apparatus shown with a simple attachment point. The OTDR shall meet the calibration requirements of IEC 61746-1. Annex E provides more detailed requirements for the length of the launch cord and other aspects related to the OTDR measurement.



Key

PG	pulse generator
LD	laser diode
OS	optical splitter
FC	front panel connector
APD	avalanche photo diode
AC	amplifier and converter
SP	signal processor
CD	control and display

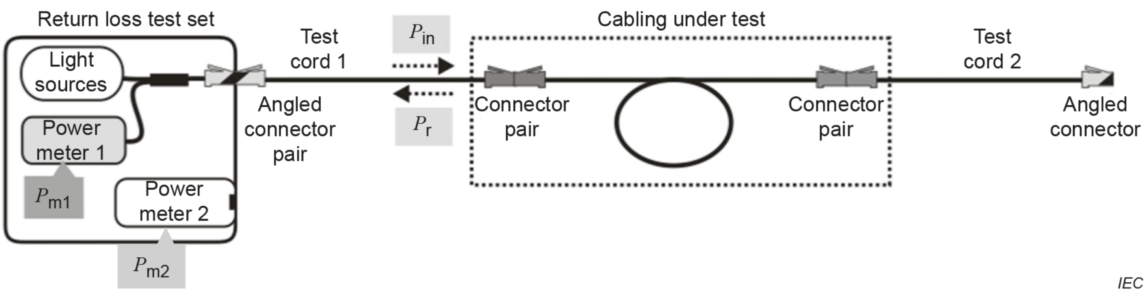
Figure 7 – Typical OTDR schematic diagram

6.8 Return loss test set

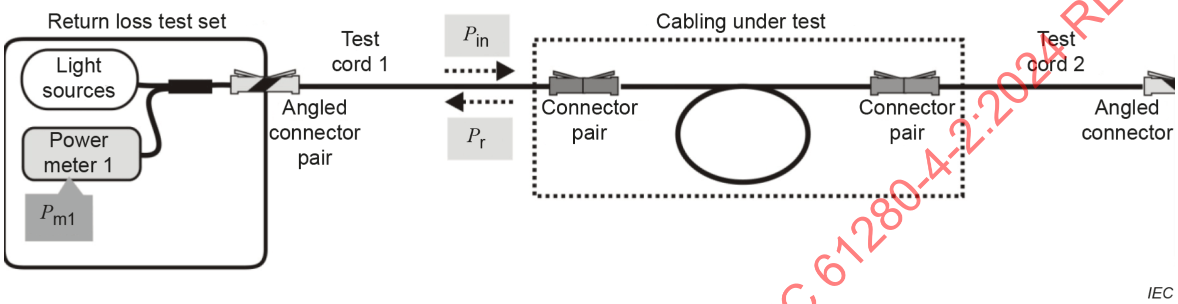
A return loss test set typically comprises one or more stabilized laser sources. As illustrated in Figure 8, the output from the source passes through a directional coupler to the output port of the RLTS that should be fitted with a low reflectance connection. Its reflectance should be 10 dB lower than the ORL of the cabling under test; an angled connector interface can usually achieve this. The other leg of the directional coupler directs reflected light back to the internal power meter (P_{m1} in Figure 8). A second power meter (P_{m2} in Figure 8 a)) with an external connector interface is often also fitted to measure the power level that is input to the cabling under test.

Alternative configurations are possible without the second power meter (see Figure 8 b)), provided that the input power to the cabling under test is calculated from measuring a known reflectance or a second return loss test set is used to measure the power input to the cabling under test, provided that the attenuation through the connector interface and the directional coupler can be calibrated out.

In a typical measurement configuration as shown, test cords are required to interface to the cabling under test and to suppress unwanted reflections through the use of angle-polished connectors.



a) **With internal second power meter**



b) **Without internal second power meter**

Figure 8 – Illustration of return loss test set

6.9 Connector end-face cleaning and inspection equipment

Cleaning equipment (including apparatus, materials, and substances) and the methods to be used for cleaning shall be in accordance with IEC TR 62627-01. Connector suppliers' instructions shall be consulted where doubt exists as to the suitability of particular equipment and cleaning methods.

A microscope compatible with IEC 61300-3-35, low resolution method, is required to verify that the fibre and connector end faces of the test cords are clean and free of damage. Microscopes with adapters that are compatible with the connectors used are required.

The use of a video microscope is recommended to avoid any risk associated with direct viewing of energized fibre end faces.

6.10 Adapters

Where appropriate, adapters shall be compatible with the connector style being used and shall allow the required performance of reference-grade terminations to be achieved. Zirconia (ceramic) sleeves contained within the adapter should be used for cylindrical ferruled connectors.

7 Procedures

7.1 General

Procedure requirements specific to particular methods are found in Annex A through Annex G.

LSPM methods require a reference measurement to be taken prior to measuring the cabling. Equipment should be assessed before commencing testing to ascertain how frequently reference measurements should be taken. Generally, a new measurement reference should be taken before the equipment has drifted more than 0,1 dB (see stability in 6.2.1). The test environment (particularly the temperature) can affect the frequency of re-referencing.

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

7.2 Common procedures

7.2.1 Care of the test cords

Connectors on test cords shall be inspected using the procedures of IEC 61300-3-35. The connector end faces shall be free of contamination (e.g. dust and dirt) and shall meet the requirements of the relevant table in IEC 61300-3-35. If contamination is seen, the connector end faces shall be cleaned using the equipment and methods described in 6.9.

NOTE The requirement of connector end face quality depends upon either the connector specification or the optical fibre communication system performance requirements, or both.

When the test cords are not in use, they should be protected from accidental damage by capping the connector ends and storing the cords in kink-free coils of a diameter greater than the minimum bending diameter.

Verify the optical performance of all test cords to be used following the procedures in Annex J before any testing commences.

7.2.2 Make reference measurements (LSPM and OCWR methods only)

The output power from the launch cord for each test wavelength shall be measured and shall be recorded in an appropriate format.

For OCWR measurements, other reference power levels shall be taken and recorded as required by the test method used (see Annex F and Annex G for more details).

7.2.3 Inspect and clean the ends of the fibres in the cabling

Connectors on installed cabling shall be inspected using the procedures of IEC 61300-3-35. They shall be free from contamination (e.g. dust and dirt). If contamination is seen, the connector end faces shall be cleaned using the equipment and methods described in 6.9 and then re-inspected.

NOTE The requirement of connector end face quality depends upon either the connector specification or the optical fibre communication system performance requirements, or both.

7.2.4 Make the measurements

As defined in Annex A through Annex G, attenuation and ORL measurements are an iterative process for each fibre in the cabling including:

- attachment of individual fibres to the launch and receive or tail cords;
- completing the measurement at each wavelength;
- storing or recording the results.

For the LSPM methods, either the power meter and receive cord are moved to the far end of the cabling or a second power meter and receive cord may be used at the far end.

7.2.5 Make the calculations

Make the calculations to determine the difference between the reference measurement and the test measurements and record the result together with other information in accordance with Clause 9.

7.3 Calibration

Power meters and OTDR equipment shall be calibrated in accordance with IEC 61315 and IEC 61746-1, respectively.

The equipment used shall have a valid calibration certificate in accordance with the applicable quality system for the period over which the testing is done.

7.4 Safety

All tests that are performed on optical fibre communication systems, or that use a laser in a test set, shall be carried out following the safety precautions provided in IEC 60825-2.

8 Calculations

The calculations for each method are given in the respective annexes.

9 Documentation

9.1 Information for each test

The following information shall be provided with each test.

a) test procedure and method;
b) measurement results including
   – either attenuation or ORL, or both (in dB)
      - OTDR trace(s) (OTDR method only, from both directions when bi-directional measurements were performed);
   – wavelength (in nm);
   – fibre type;
   – termination location;
   – fibre identifier;
   – cable identifier;
   – date of test.

9.2 Information to be made available

The following information shall be made available with each test.

- details of the spectral characteristics of the light source;
- reference power level (in dBm) (LSPM methods only);
- calibration records with reference to the test equipment;
- details of the test cords used for the measurements;
  - the performance grade of test cord connectors (e.g. reference grade or standard grade),
  - the performance grade of the fibre in the test cords (e.g. OSx),
  - whether the fibre in the test cords is of the enhanced macrobend performance level type,
  - the length of the test cords.

Annex A
(normative)

One-cord reference method

A.1 Applicability of test method

The one-cord reference method measurement includes the attenuation of both connections to the cabling under test. It is the RTM for measurement of the installed cabling plant of configuration A (see 4.2).

This method is written for the case when a single fibre is measured at a time. If bi-directional measurements are required, the procedures are repeated by launching into the other end.

A.2 Apparatus

The light source, power meter, and test cords used shall meet the requirements specified in Clause 6.

The method described in Annex A is called the "one-cord reference method" because only one (the launch) test cord is used for the reference measurement. However, a second test (receive) cord is required for the attenuation measurement. The performance of the test cords should be verified before testing commences. This is done by connecting the receive cord to the launch cord and measuring the attenuation of the connection. See Annex J for more information.

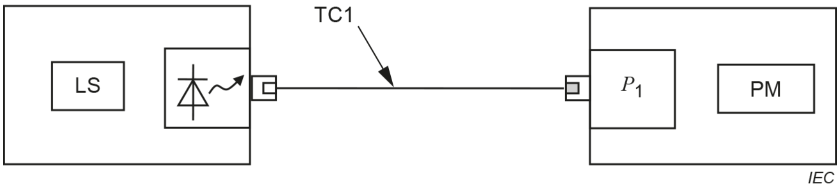
This method calls for the launch cord to be attached directly to the power meter for the reference measurement. This assumes that the connectors used in the cabling are compatible with the connector used in the power meter.

This method also assumes the following:

– The connector on the power meter is compatible with that of the cabling under test to which the launch cord is connected. Where appropriate, an adapter that introduces no additional measurement uncertainty may be attached to the power meter. The alternative method (Annex B) may be used, provided that the increased measurement inaccuracy of that method is recognized, and appropriately modified test limits are applied.
– The launch cord is not disconnected from the light source between a reference measurement and a test measurement. If either the design of the test equipment or the design of the cabling under test makes such a disconnection unavoidable, then the alternative method (Annex B) may be used, provided that the increased measurement inaccuracy of that method is recognized, and appropriately modified test limits are applied.

A.3 Procedure

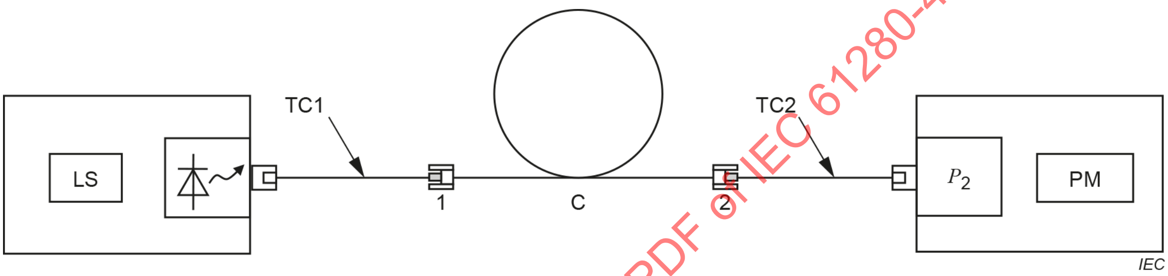
a) Connect the light source and power meter using the launch cord (TC1) as shown in Figure A.1.
b) Record the measured optical power, P_1, which is the reference power measurement.
c) Disconnect the power meter from TC1. Do not disconnect TC1 from the light source without repeating a reference measurement.
d) Connect the power meter to the receive cord (TC2).
e) Connect TC1 and TC2 to the cabling under test as shown in Figure A.2.
f) Record the measured optical power, P_2, which is the test power measurement.



Key

LS	light source
TC1	launch cord
PM	power meter
P_1	reference power measurement

Figure A.1 – One-cord reference measurement



Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	test power measurement

NOTE Reference-grade terminations are shaded.

Figure A.2 – One-cord test measurement

A.4 Calculation

The attenuation A, expressed in dB, is given by

$$A = 10 \log_{10}\left(P_1 / P_2\right) \quad \text{(A.1)}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

A.5 Components of reported attenuation

The attenuating elements are identified in Figure A.1 and Figure A.2. These are the attenuation of the cabling, A_c, and two connection attenuation values, A_1 and A_2, all in dB. The reported attenuation, A, in dB is given by

$$A = A_1 + A_2 + A_c \tag{A.2}$$

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

Annex B
(normative)

Three-cord reference method

B.1 Applicability of test method

The three-cord reference method attempts to exclude the attenuation of both connections to the cabling under test. It is the RTM for measurement of the installed cabling plant of configuration B (see 4.2) and in certain circumstances, or as directed by external standards, may be used in place of the test methods specified in Annex A and Annex C.

This method is written for the case when a single fibre is being measured at a time. If bi-directional measurements are required, the procedures are repeated by launching into the other end.

B.2 Apparatus

The light source, power meter and test cords used shall meet the requirements specified in Clause 6. Three test cords are used. The attenuation values of the connections between these cords are critical to the uncertainty of the measurement. The performance of the test cords should be verified before testing commences. This is done by connecting the substitution cord and the receive cord to the launch cord and measuring the attenuation of the connections. See Annex J for more information.

B.3 Procedure

a) Connect the launch cord (TC1) and receive cord (TC2) to the light source and power meter as shown in Figure B.1.

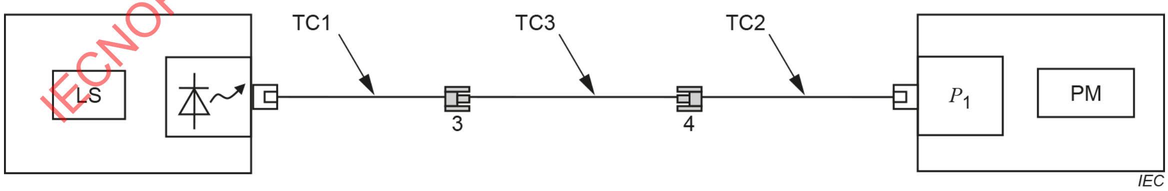
b) Connect the substitution cord (TC3) between TC1 and TC2.

c) Record the measured optical power, P_1, which is the reference power measurement.

d) Do not disconnect TC1 from the light source without repeating a reference measurement.

e) Replace the substitution cord with the cabling under test (leaving the adapters attached to TC1 and TC2) as shown in Figure B.2.

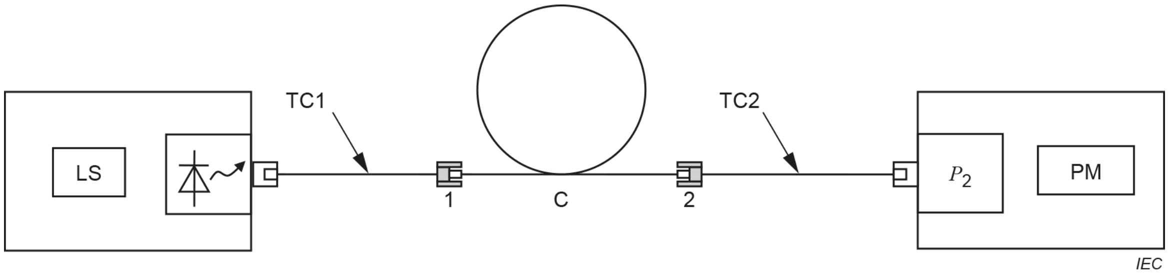
f) Record the measured optical power, P_2, which is the test power measurement.



Key

LS	light source
TC1	launch cord
TC2	receive cord
TC3	substitution cord
PM	power meter
3, 4	connector sets
P_1	reference power measurement

Figure B.1 – Three-cord reference measurement



Key

LS	light source
TC1	launch cord
C	cabling under test
TC2	receive cord
PM	power meter
1, 2	connector sets
P_2	test power measurement

NOTE Reference-grade terminations are shaded.

Figure B.2 – Three-cord test measurement

B.4 Calculations

The attenuation A, expressed in dB, is given by

$$A = 10 \log_{10} \left(P_1 / P_2 \right) \quad \text{(B.1)}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

B.5 Components of reported attenuation

The attenuating elements are identified in Figure B.1 and Figure B.2. These are attenuation values of the cabling, A_c, and four connection attenuation values, A_1, A_2, A_3 and A_4, all in dB. The reported attenuation, A, in dB is given by

$$A = A_1 + A_2 + A_c - A_3 - A_4 \quad \text{(B.2)}$$

A_3 and A_4 are the attenuation values of the connections in the reference test set-up and together include the fibre attenuation of TC3, which should be negligible.

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

Annex C
(normative)

Two-cord reference method

C.1 Applicability of test method

Two variants are given for the two-cord reference method. Figure C.2 shows the set-up for the case where one end is terminated with a plug-adapter assembly and the other is terminated with a plug. It includes the attenuation of one of the connections to the cabling under test. It is the RTM for measurement of the installed cabling plant of configuration C (see 4.2).

Figure C.3 shows the set-up for the case where both ends are socketed or pinned, and the launch cord connector is incompatible with the power meter. It includes the attenuation of both connections to the cabling under test. It is an alternative method for measurement of the installed cabling plant of configuration A (see 4.2).

This method is written for the case when a single fibre is being measured at a time. If bi-directional measurements are required, the procedures are repeated by launching into the other end.

C.2 Apparatus

The light source, power meter and test cords used shall meet the requirements specified in Clause 6. The attenuation values of the connections between these test cords are critical to the uncertainty of the measurement. The performance of the test cords should be verified before testing commences. This is done by connecting the receive cord to the launch cord and measuring the attenuation of the connection. See Annex J for more information.

C.3 Procedure

a) Connect the launch cord (TC1) and receive cord (TC2) to the light source and power meter and to each other as shown in Figure C.1.

b) Record the measured optical power, P_1, which is the reference power measurement.

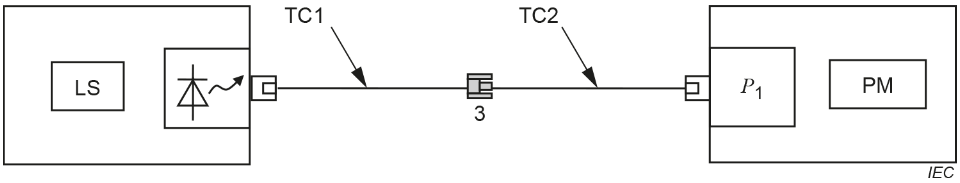
c) Disconnect TC1 and TC2 from each other. Do not disconnect TC1 from the light source without repeating a reference measurement.

d) Insert either

   – the cabling under test as shown in Figure C.2,

   – the adapter cord AC and the cabling under test as shown in Figure C.3.

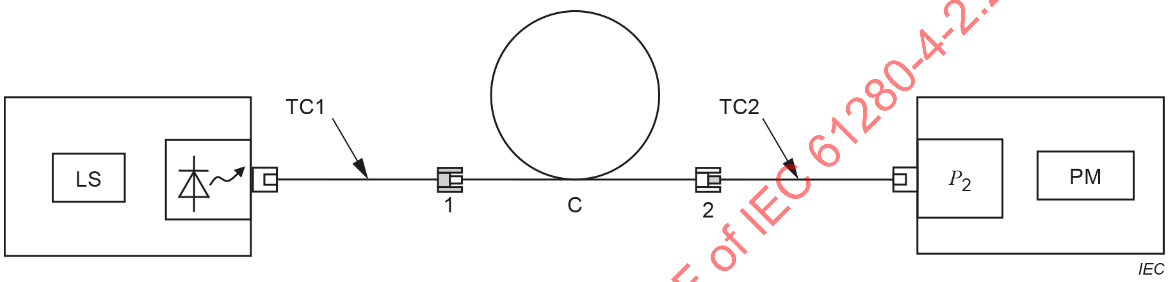
e) Record the measured optical power, P_2, which is the test power measurement.



Key

LS light source
TC1 launch cord
TC2 receive cord
PM power meter
3 connector set
P_1 reference power measurement

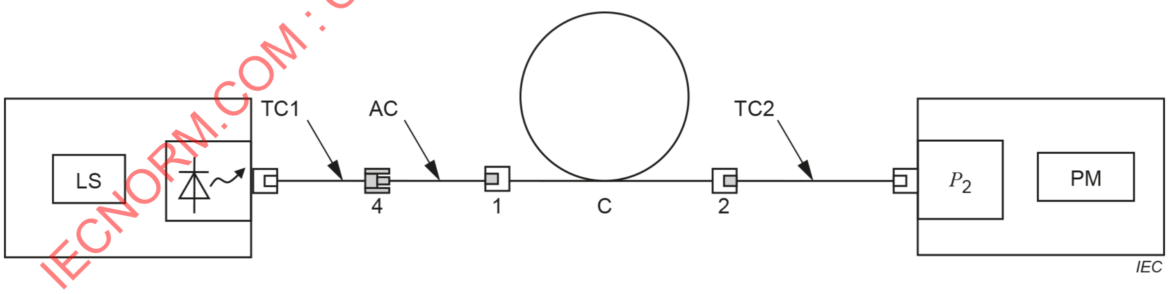
Figure C.1 – Two-cord reference measurement



Key

LS light source
TC1 launch cord
C cabling under test
TC2 receive cord
PM power meter
1, 2 connector sets
P_2 test power measurement

Figure C.2 – Two-cord test measurement



Key

LS light source
TC1 launch cord
C cabling under test
AC adapter cord
TC2 receive cord
PM power meter
1, 2, 4 connector sets
P_2 test power measurement

NOTE Reference-grade terminations are shaded.

Figure C.3 – Two-cord test measurement for plug-to-socket style connectors

C.4 Calculations

The attenuation A, expressed in dB, is given by

$$A = 10 \log_{10} (P_1/P_2) \tag{C.1}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

C.5 Components of reported attenuation

The attenuating elements are identified in Figure C.1, Figure C.2, and Figure C.3. These are the attenuation of the cabling, A_c, and up to four connection attenuations, A_1, A_2, A_3 and A_4, all in dB.

For the case of Figure C.2, the reported attenuation, A, is given by:

$$A = A_1 + A_2 + A_c - A_3 \tag{C.2}$$

For the case of Figure C.3, the reported attenuation, A, is:

$$A = A_1 + A_2 + A_c + A_4 - A_3 \tag{C.3}$$

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

Annex D
(normative)

Equipment cord method

D.1 Applicability of the test method

The equipment cord method directly measures the attenuation of the cabling under test, the attenuation of equipment cord connections to the cabling under test, and the attenuation of the optical fibre in one of the equipment cords (EC2 in Figure D.2). The attenuation of the equipment cord connections to the equipment is not included. It is the RTM for the measurement of installed cabling plant of configuration D (see 4.2). The equipment cord test method is only suitable if both equipment cords are present during testing and are not replaced before operation. The attenuation of the optical fibre in the equipment cords is negligible if the equipment cords are short.

D.2 Apparatus

The light source, power meter and all test cords shall be in accordance with Clause 6. This is called the equipment cord method because the customer's equipment cord is used in taking the reference measurement. The second customer (receive) cord is also used for the attenuation measurement. The performance of the test cords and customer cords should be verified before testing commences. This is done by connecting the test, receive, or customer cord to the launch cord and measuring the attenuation of the connection. See Annex J for more information.

This method requires that the launch cord and the customer equipment cord be connected in series between the light source and the power meter for the reference measurement.

This method also assumes the following.

- The connector on the power meter is compatible with that of the cabling under test into which the equipment cord EC1 in Figure D.1 is connected. Where appropriate, an adapter that introduces no additional measurement uncertainty may be attached to the power meter.
- The launch cord is not disconnected from the light source between a reference measurement and a test measurement.

D.3 Procedure

a) Connect the light source and power meter using the launch cord (TC1) and equipment cord (EC1) as shown in Figure D.1.

b) Record the measured optical power, P_1. This is the reference power measurement.

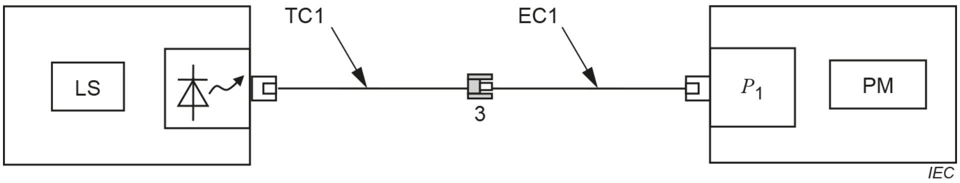
c) Disconnect the power meter from EC1.

   – Do not disconnect TC1 from the light source without first repeating a reference measurement.

d) Connect the power meter to the equipment receive cord (EC2).

e) Connect TC1/EC1 and EC2 to the cabling under test as shown in Figure D.2.

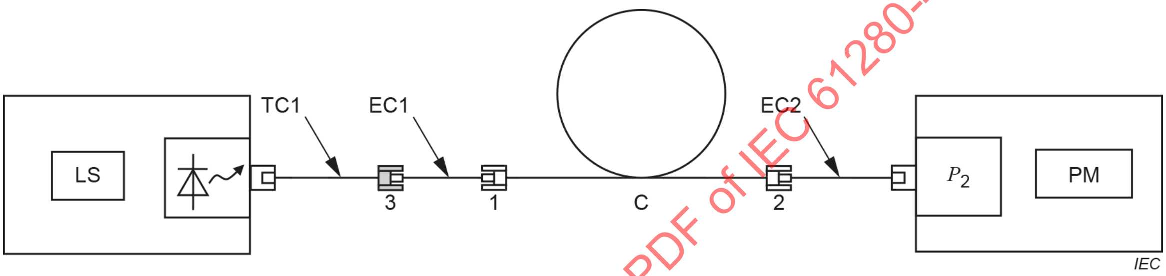
f) Record the measured optical power, P_2. This is the test power measurement.



Key

LS	light source
TC1	launch cord
EC1	equipment launch cord
PM	power meter
3	connector set
P_1	reference power measurement

Figure D.1 – Reference measurement



Key

LS	light source	EC1	equipment launch cord
TC1	launch cord	PM	power meter
C	cabling under test	EC2	equipment receive cord
P_2	test power measurement	1, 2, 3	connector sets

NOTE Reference-grade terminations are shaded.

Figure D.2 – Test measurement

D.4 Calculation

The attenuation A, expressed in dB, is given by:

$$A = 10 \log_{10}\left(P_1 / P_2\right) \tag{D.1}$$

where

P_1 is the reference power in linear units (e.g. in W),

P_2 is the test power in linear units (e.g. in W).

D.5 Components of reported attenuation

The attenuating elements are identified in Figure D.1 and Figure D.2. These are the attenuation of the cabling, A_c, and two connection attenuation values, A_1 and A_2, all in dB. The reported attenuation, A, is given by:

$$A = A_1 + A_2 + A_c \tag{D.2}$$

NOTE Only the fibre of equipment cord 2 and of the cabling is included in the attenuation measurement, whereas the fibre of equipment cord 1 is already included in the reference measurement.

Differences between the result reported by this method and the other LSPM methods are described in Annex H (see Table H.2).

Annex E
(normative)

Optical time domain reflectometer

E.1 Applicability of test method

The OTDR method measurement includes the attenuation of both connections to the cabling under test. It is the ATM for measurement of the installed cabling plant of configurations A, B, C, and D (see 4.2) and in certain circumstances, or as directed by external standards, it may be used in place of the test methods specified in Annex A, Annex B, Annex C and Annex D.

When bi-directional measurements (see Clause I.6) are specified, the procedures described in Annex E are repeated, but from the opposite end of the cabling under test, without disconnecting the launch and tail cords from the cabling under test.

E.2 Apparatus

E.2.1 General

The OTDR, test cords and adapters are required for making attenuation, optical return loss and length measurements on the installed cabling. See Figure 7 for a schematic diagram of the OTDR equipment.

The test set-up requires a launch cord and tail cord. Reflectance associated with the connectors of the test cords (launch and tail) as well as the cabling, should be minimized.

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

The use of the tail cord allows the attenuation of the remote end connection to be measured, so that the attenuation of the entire cabling section can be measured. If no tail cord is used, then there is no information regarding the remote end connector. In fact, not even continuity of the fibre is ensured since there can be a break close to the far end, or the fibres can be incorrectly connected somewhere along their length.

E.2.2 OTDR

The OTDR shall be capable of generating optical pulses of short duration (≤ 20 ns), so that it can qualify short links, the beginning of a link, or to separately resolve features that are close together. It shall also be capable of generating optical pulses of longer duration, so that it has sufficient dynamic range to produce valid measurement data over the required length of cabling.

The OTDR should have an attenuation dead zone (with ΔF = ±0,5 dB; see I.2.5) of less than 10 m following standard connectors (IEC 61753-1 Grade 2) with a reflectance of –45 dB.

E.2.3 Test cords

The fibre type and geometrical characteristics of the launch and tail cords shall be the same as the fibre in the cabling under test. The fibre in the launch and tail cords shall be coated so that the cladding light is removed. The length of the launch and tail cords both shall be longer than the dead zone corresponding to the pulse width selected for a particular length of fibre to be measured. Suppliers of OTDR equipment should recommend lengths for the launch and tail cords. In addition, these cords shall be long enough to allow a reliable straight line fit of the backscatter trace that follows the dead zone.

In the absence of other information, the minimum length of launch and tail cords can be determined such that their return delay is equal to the OTDR pulse width multiplied by a suitable factor. Table E.1 gives some typical examples for minimum length of launch and tail cords to be used for measurements of premises cabling and of outside plant cabling.

Table E.1 – Typical launch and tail cord lengths

Application	Typical maximum length of cabling under test km	Example pulse width ns	Typical length of launch and tail cords m
Premises cabling	2	20	100
Outside plant – Access network	10	100	500
Outside plant – Core network	80	500	1 000
Outside plant – Ultra long-haul network	120	1 000	2 000

The following requirements apply to the test cords:

– attenuation due to induced winding loss shall be minimized by using bend radii larger than 45 mm;

– the cords shall be terminated at one end with a connector suitable for attachment to the OTDR;

– they shall be terminated at the other end according to 5.4;

– ruggedized fibre test cords should be used in which, for example, both ends are protected by a 3 mm outer jacket with strain relief;

– the fibre used in the cord should be protected from environmental changes. This can be accomplished by enclosing most of the length of the cord in a container or by using test cords that are entirely ruggedized. Up to 2 m of fibre length of the cord may extend outside the container to connect the OTDR and the cabling under test.

E.3 Procedure (test method)

– Connect the test cords and the OTDR source as shown in Figure E.1.

– Configure the OTDR using the following rules:

  • the shortest pulse width possible should be selected that allows acquisition of a trace in a reasonable time period and with sufficient signal-to-noise ratio to allow effective analysis;

  • the averaging time per trace should be between 10 s and 3 min. Averaging times shorter than 10 s generally provide poor results on longer systems when using narrow pulses;

  • refer to Annex I for a better understanding of the OTDR settings.

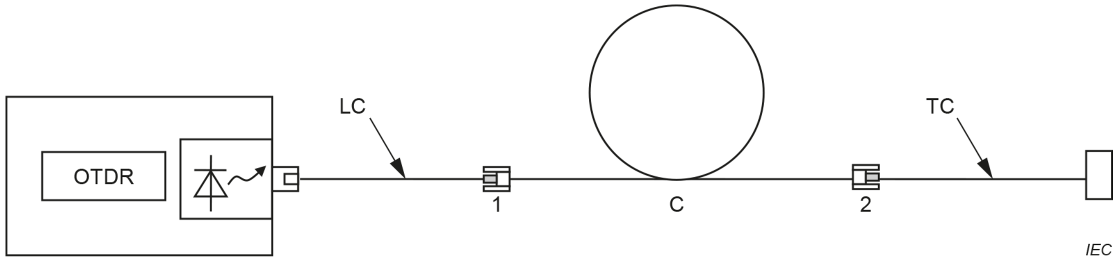
– Select the appropriate wavelengths.

– Record the backscattered traces.

– Repeat from the other direction if required.

Bi-directional OTDR testing is recommended on single-mode cabling so that variations in attenuation measurements that are due to changes in the backscattering characteristics of different fibres can be cancelled out. Refer to Clauses I.6 and I.7 for further information on bi-directional testing and analysis.

NOTE Figure E.1 shows the set-up for cabling terminated with plug-adapter assemblies. Other arrangements are equivalent, provided the corresponding reference-grade terminations are used at the same points.



Key

OTDR optical time domain reflectometer

LC launch cord

C cabling under test

TC tail cord

1, 2 connector sets

NOTE Reference-grade terminations are shaded.

Figure E.1 – Test measurement for OTDR method

E.4 Calculation of attenuation

E.4.1 General

The attenuation A, expressed in dB, is given by

$$A = F_1 - F_2 \tag{E.1}$$

where

F_1 is the displayed power level at the input port of the cabling under test in dB;

F_2 is the displayed power level at the output port of the cabling under test in dB (see Figure E.3).

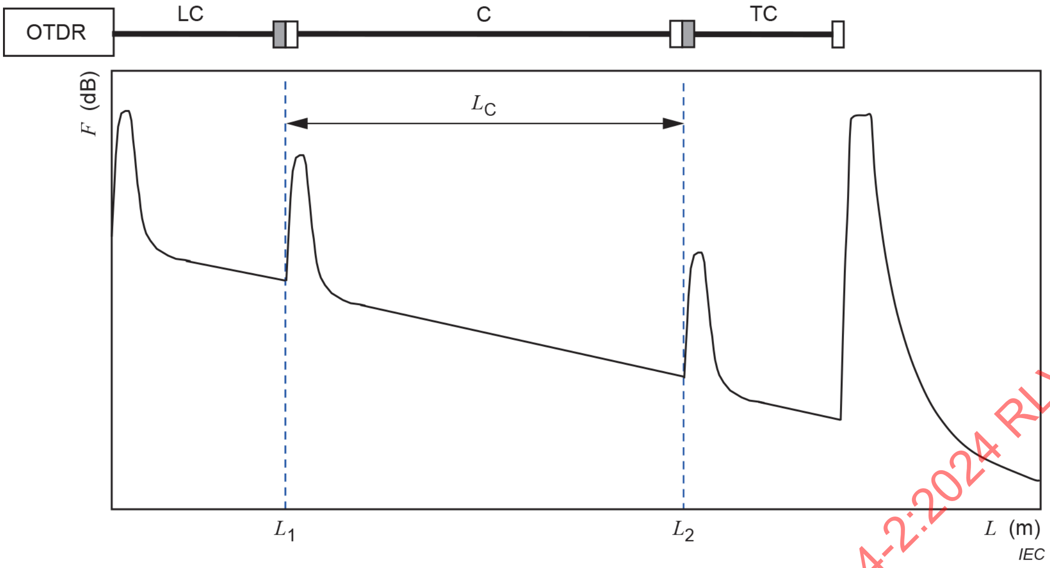
NOTE The vertical scale of the OTDR trace displays five times the logarithm of the received power (in linear units), plus a constant offset, whereas the horizontal scale of the OTDR trace displays the distance along the fibre. The horizontal scale is calculated by dividing the measured time delay of the pulse round trip by two and by the speed of light in the fibre, which is defined by the effective group refractive index of the fibre core.

It is important to properly locate the position of the two connections and to properly define the displayed power levels, as described in E.4.2 and E.4.3.

E.4.2 Connection location

The two connections of the cabling under test are located at the inflection points (change of curvature) in the trace just before the two peaks that represent the two connectors.

Figure E.2 illustrates the location of the connectors on a typical trace.



Key

OTDR	optical time domain reflectometer
LC	launch cord
C	cabling under test
TC	tail cord
L_1, L_2	cabling port locations
L_C	length of cabling under test
F	reflected power level
L	distance from output port of OTDR launch cord

Figure E.2 – Location of the cabling under test ports

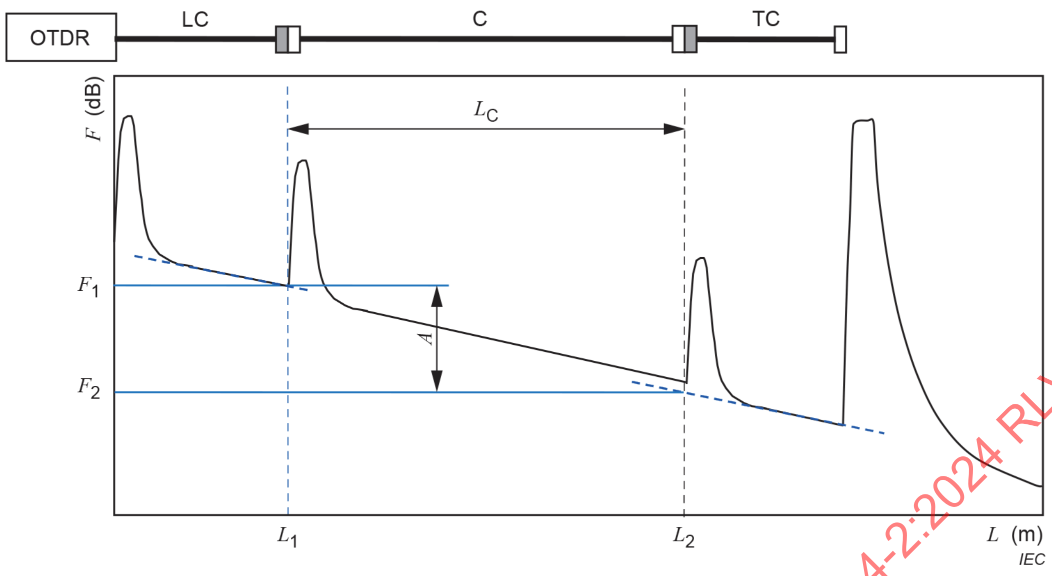
E.4.3 Definition of the power levels F_1 and F_2

The displayed power level F_1 at location L_1 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the launch cord and the vertical axis at location L_1.

The displayed power level F_2 at location L_2 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the tail cord and the vertical axis at location L_2.

Figure E.3 illustrates the position of levels F_1 and F_2 on a typical trace.

This measurement process is also called five points analysis with LSA. See Annex I for more details.



Key

OTDR	optical time domain reflectometer
LC	launch cord
TC	tail cord
C	cabling under test
L_1, L_2	cabling port locations
L_C	length of cabling under test
L	distance from output port of OTDR launch cord
F_1, F_2	displayed power level at L_1 and L_2
F	reflected power level
A	attenuation of cabling under test

Figure E.3 – Graphic construction of F_1 and F_2

E.4.4 Alternative calculation

A more detailed analysis of the attenuation in the cabling and the connectors can be obtained by deriving two additional power levels, F_{11} and F_{12}, from the OTDR trace, as illustrated in Figure E.4.

The displayed power level F_{11} at location L_1 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the cabling under test and the vertical axis at location L_1.

The displayed power level F_{21} at location L_2 is defined by the intercept of the linear regression (LSA) obtained from the linear part of the backscattering power provided by the cabling under test and the vertical axis at location L_2.

The attenuation of the near-end connector, A_1 (in dB), is then given by

$$A_1 = F_1 - F_{11} \tag{E.2}$$

The attenuation of the far-end connector, A_2 (in dB), is given by

$$A_2 = F_{21} - F_2 \quad \text{(E.3)}$$

And the attenuation of the cabling without connectors, A_c (in dB), is given by

$$A_c = F_{11} - F_{21} \quad \text{(E.4)}$$

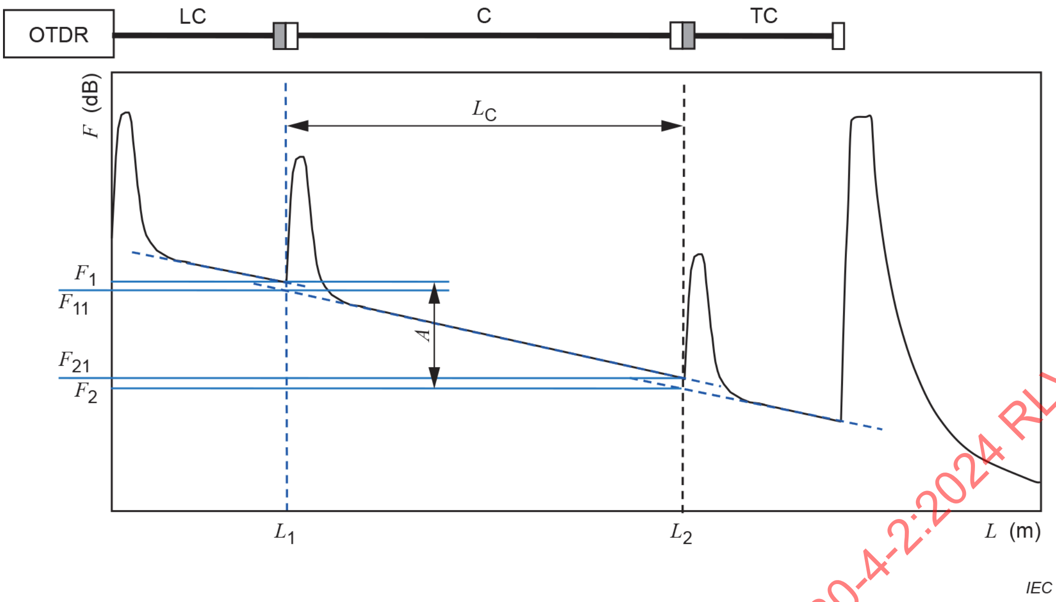
wherein the four power levels, F_1, F_2, F_{11} and F_{11}, are all expressed in dB.

Combining Formula (E.2), Formula (E.3) and Formula (E.4) leads to Formula (E.5)

$$A = A_1 + A_c + A_2 \quad \text{(E.5)}$$

Assuming negligible calculation errors, the attenuation value A obtained from Formula (E.5) has the same validity as that obtained from Formula (E.1).

For some OTDRs, the attenuation values A_1, A_c and A_2 are available in an event table.



Key

OTDR	optical time domain reflectometer
LC	launch cord
C	cabling under test
TC	tail cord
L_1, L_2	cabling port locations
L_C	length of cabling under test
L	distance from output port of OTDR launch cord
F_1, F_2	displayed power level at L_1 and L_2
F_{11}, F_{21}	displayed power level at L_1 and L_2 internal side
A	attenuation of cabling under test
F	reflected power level

Figure E.4 – Graphic construction of F_1, F_{11}, F_{21} and F_2

E.5 Calculation of optical return loss

The optical return loss, R_{ORL}, is the ratio of the input power to the cabling under test to the total power reflected and scattered back by the cabling under test. The recommended test configuration for attenuation and ORL measurements uses a long launch cord and a long tail cord; this allows the OTDR time to recover from saturation effects due to unwanted reflections, so that they can be removed from the ORL calculation, and allows ORL measurements to be made on very short sections of cabling under test.

The input power to the cabling under test, P_i, is a function of the OTDR laser power and the attenuation of the launch cord.

The total power returned from the cabling under test, P_r, is the integral of the reflected and backscattered power, $P(z)$, as a function of distance z along the cabling under test. This distance ranges from the input port of the cabling under test, at the end of the OTDR launch cord, up until the output port of the cabling under test, at the beginning of the OTDR tail cord, and therefore includes the reflectance of the connections at both ends of the cabling under test.

This is illustrated graphically by the shaded area on the OTDR trace shown in Figure E.5.

Expressed mathematically the ORL is calculated as follows

$$R_{\text{ORL}} = 10 \times \log_{10} \left(\frac{P_{\text{i}}}{\int P(z)\, dz} \right) \quad \text{(E.6)}$$

In general, the vertical scale of an OTDR is not calibrated for absolute optical power measurements. When an OTDR is used for ORL measurements, the backscatter parameter of the fibre in the cabling, K, can effectively serve as a reference level for the vertical scale. See IEC 61746-1:2009, Annex G for more details.

Therefore, ORL can be calculated as follows

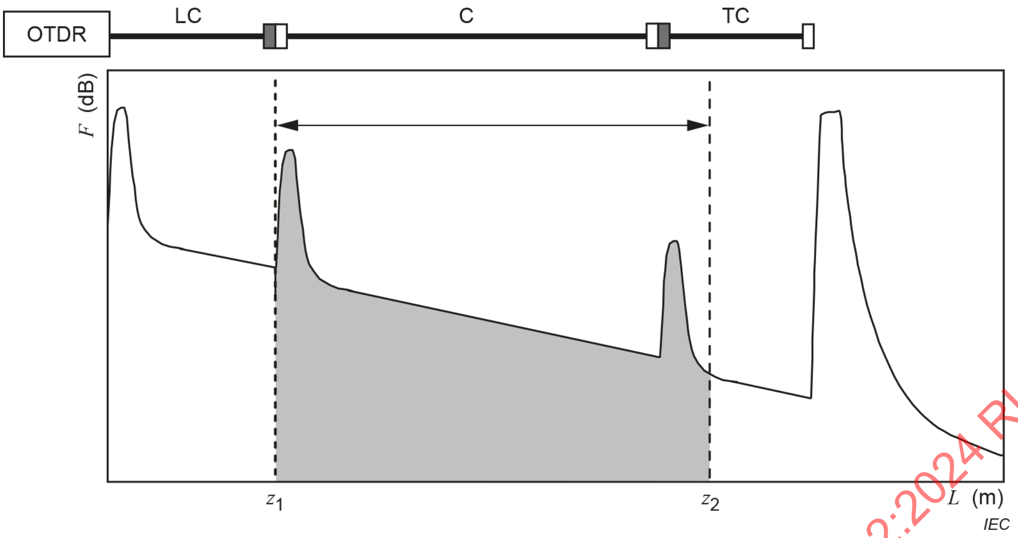
$$R_{\text{ORL}} = 10 \times \log_{10} \left(\frac{P(z_1)}{K \int_{z_1}^{z_2} P(z)\, dz} \right) \quad \text{(E.7)}$$

where

K is the backscatter parameter (see IEC 61746-1:2009, 9.3);

z_1 is the location of the beginning of the integration (see Figure E.5);

z_2 is the location of the end of the integration (see Figure E.5).



Key

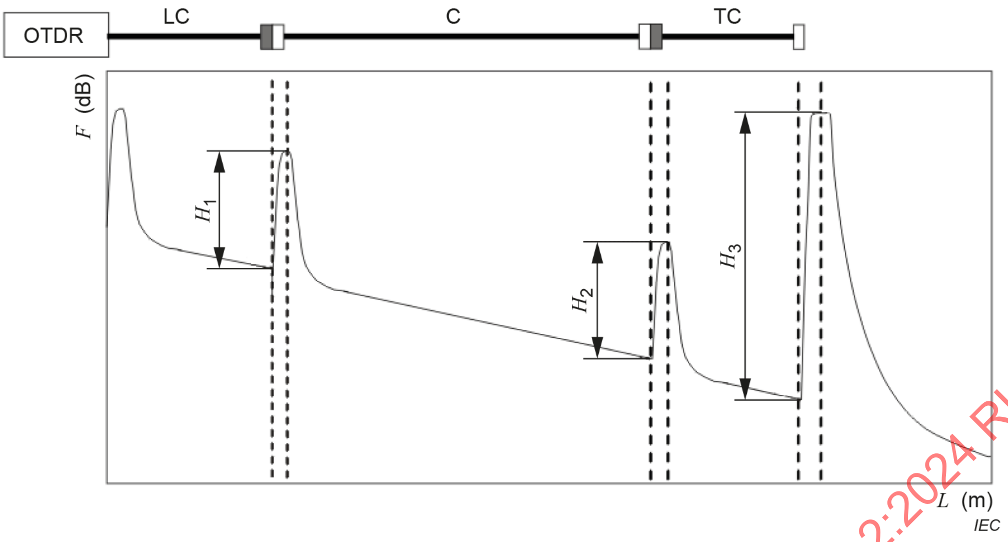
OTDR	optical time domain reflectometer
LC	launch cord
C	cabling under test
TC	tail cord
z_1	location indicating start of ORL integration
z_2	location indicating end of ORL integration
F	reflected power level
L	distance from output port of OTDR launch cord

Figure E.5 – Graphic representation of OTDR ORL measurement

E.6 Calculation of reflectance for discrete components

The reflectance of a component is the ratio of the power reflected back by that component to the power incident to that component. On the OTDR trace, the reflectance is related to the height of the peak (H_n in Figure E.6) that represents the amount of light reflected back from that component, but it is also a function of the backscatter coefficient of the fibre under test and the pulse width used for the measurement.

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



Key

OTDR	optical time domain reflectometer
LC	launch cord
C	cabling under test
TC	tail cord
H_1	height of peak from first connection
H_2	height of peak from end connection
H_3	height of peak from far end of tail cord
F	reflected power level
L	distance from output port of OTDR launch cord

Figure E.6 – Graphic representation of reflectance measurement

The reflectance, R_{comp}, of a cabling component under test is calculated from the height of the reflected peak (H_1 or H_2) in Figure E.6 as follows:

$$R_{comp} = 10 \times \log_{10}\left(10^{H/5} - 1\right) + 10 \times \log_{10}(t) + B \quad \text{(E.8)}$$

where

H is the height of the peak (H_1 or H_2) in dB;

B is the Rayleigh backscattering coefficient in dB (for a time base in ns);

t is the pulse width in units of ns.

Typical values for the backscattering coefficient of single-mode fibres (e.g. type B-652.D of IEC 60793-2-50) are as follows:

$B \approx -80$ dB at 1 310 nm; $B \approx -82{,}5$ dB at 1 550 nm for a time base in ns

The detector in some OTDRs saturates when the value of H is very large (see peak with height H_3 in Figure E.6), so that the peak exhibits a flat top. It is necessary to use an OTDR with sufficient dynamic range for accurate reflectance measurements. This type of signal saturation can be avoided by adding a variable attenuator between the OTDR and the cabling component under test.

E.7 OTDR uncertainties

The following sources of uncertainties should be considered when reporting the measurement:

– Noise level contribution: Errors due to a large amount of Gaussian noise or due to system noise; noise is always higher when the backscatter level approaches the noise floor on a logarithmic trace. A large amount of noise on the trace disturbs the linear regressions, leading to a wrong evaluation of the different displayed power levels. The noise can be reduced by increasing the averaging time or by increasing the pulse width, and in all cases, it requires ensuring a dynamic margin of more than 3 dB (recommended ≥ 5 dB). When the slope of the linear regression is available (e.g. in dB/km) excessively low or high slopes are generally associated with an excessive level of noise.

– Backscatter coefficient: Intrinsic property differences between test cords and cabling under test can cause variations in the apparent attenuation of individual connections. For example, when a fibre with a low backscatter coefficient is connected to one with a higher backscatter coefficient, the OTDR detector will receive more energy from the fibre with the higher backscatter coefficient. This can be interpreted as a reduction in the apparent attenuation and can even appear as a gain (negative attenuation). The effect is known as a gainer.

NOTE The effect of variations in the backscatter coefficient on attenuation measurements can be cancelled out by taking measurements from both ends of the cabling and averaging the values. See Clauses I.6 and I.7 for further information on bi-directional testing and analysis. As mentioned in Clause I.6, for total attenuation measurement, the uncertainty with unidirectional measurement is determined only by backscatter coefficient mismatch between launch and tail cords and is removed by using matched launch and tail cords, regardless of cabling under test.

– Strong reflections: Non-linear effects of strong reflections cause attenuation errors, attenuation coefficient errors and dead zone widening.

– Centre wavelength of OTDR laser: Fibre attenuation is wavelength dependent and, hence, can be different at the OTDR laser wavelength and the transmitter wavelengths normally used in the cabling under test.

– Spectral width of OTDR pulses: Related to wavelength dependence of fibre attenuation; excessively wide spectral widths can yield fibre attenuation values that are different from the attenuation seen by the transmitter wavelengths normally used in the cabling under test.

– Cursor location error: Error in either software analyser placement of cursors or manual operation of cursors, which can lead to significant errors when the slopes of the various fibres are very different.

Refer to IEC 61280-4-3 for a comprehensive overview of attenuation measurement uncertainties.

Annex F
(normative)

Continuous wave optical return loss measurement – Method A

F.1 Applicability of test method

This test method is closest to the definition of optical return loss given in 3.1.7. It directly measures the input power to the cabling under test as well as the reflected power, although a correction factor shall be used to take into account the internal attenuation of the branching device and other sources of reflections.

OCWR methods have some limiting factors. Since it cannot spatially resolve different sources of reflections, unwanted reflections have to be suppressed. Moreover, the dynamic range is limited by the characteristics of the directional coupler used and the reflectance of the connector used to interface the return loss test set to the first test cord. This can limit the accuracy of the measurement when short cabling systems terminated with angle-polished connectors are being measured.

F.2 Apparatus

F.2.1 General

A typical test set for return loss measurements is shown in Figure F.1. The details have been adapted from IEC 61300-3-6 for testing installed cabling, and that standard can be referred to for further information.

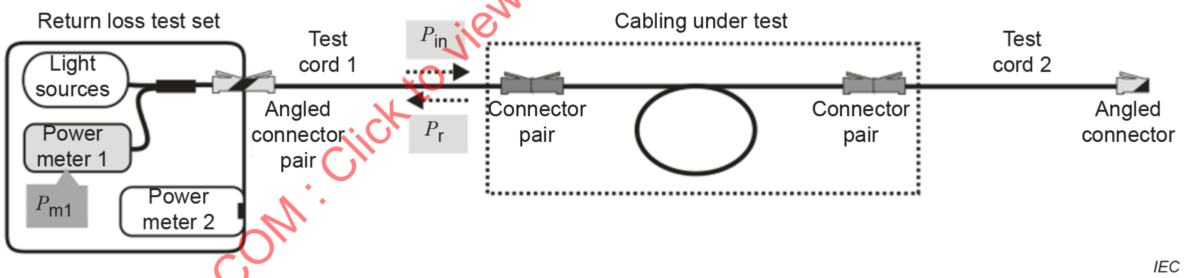


Figure F.1 – Return loss test set illustration

F.2.2 Light source

The source consists of an optical emitter (usually a laser) and its associated drive electronics, where the output light is available from a fibre pigtail or a fibre connector. A second source may be used for calibration, as illustrated in Figure F.3. When a second source is used, its central wavelength and spectral width shall be the same as those of the first source.

The source(s) shall be stable as described in 6.2.1.

F.2.3 Branching device or coupler

The splitting ratio of the coupler shall be stable and be insensitive to polarization (< 0,1 dB polarization dependence). The directivity should be at least 10 dB higher than the maximum optical return loss to be measured.

F.2.4 Power meters

The power meters used consist of an optical detector, the associated electronics, and a means of connecting to an optical fibre. The connection to the internal power meter will be permanent; the interface to the external power meter should be equipped with interchangeable adapter caps that allow the use of connectors compatible with the cabling under test.

The linearity of the detectors in the power meters shall be specified and sufficient for the dynamic range of the measurements to be undertaken. Since all of the measurements are differential, however, it is not necessary that the calibration be absolute.

F.2.5 Connector interface

The connector interface on the return loss test set (RLTS) shall have very low reflection. The attenuation of this connection shall be stable, and the magnitude of the reflectance should be at least 10 dB greater than the magnitude of the maximum optical return loss to be measured.

NOTE The reflectance of this connector interface can limit the accuracy of this measurement method when the cabling under test is terminated with angle-polished connectors and there are no other significant sources of optical return loss in the cabling under test.

F.2.6 Low reflection termination

In order to suppress unwanted reflections (typically from flat connectors open to air) the remote end of the cabling under test can require termination with a test cord such that the connector interface to the cabling under test is representative of a connection made with an equipment connection cord and the reflection from the remote end of the test cord is suppressed. Reflections can be suppressed using an angle-polished connector, an angled cleave, a non-reflective terminator, index matching material or by wrapping the cord tightly around a mandrel [provided that the fibre in the test cord is not bending loss insensitive (IEC 60793-2-50 type B6 or ITU-T Recommendation G.657 types)].

A similarly low reflection termination is required when calibrating the internal reflections of the test system (see Figure F.3). This termination should have a reflectance of at least 20 dB magnitude greater than the magnitude of the maximum optical return loss to be measured.

F.3 Procedure

F.3.1 Test set characterization

In order to perform an ORL measurement, it is necessary to characterize the measurement system by measuring its internal attenuations and reflections including the connection between the test equipment and test cord 1 to be used for the measurement (Figure F.2). This should be repeated whenever these have been changed, for example after changing test cord 1.

The internal attenuation of the RLTS shall be measured on the return path between the cabling under test and the internal power meter 1. This includes the attenuation of the connector interface and the attenuation of the coupler. Using an external source, with similar characteristics as the internal source, connect the remote end of test cord 1 to the source and the near end of test cord 1 (angled) to the external power meter, as shown in Figure F.2. Record the power level on power meter 2 as P_{ref2}.

NOTE All power measurements described in Clause F.3 are taken in linear units (W).

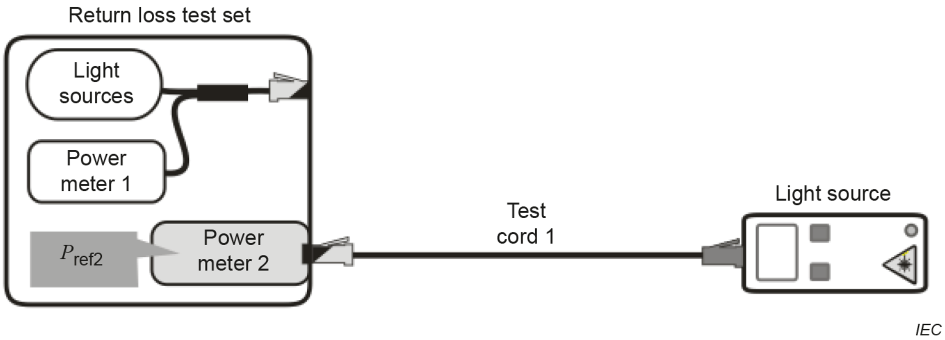


Figure F.2 – Measurement of the system internal attenuation P_{ref2}

Next, connect the near end of test cord 1 into the output port of the RLTS, as shown in Figure F.3, and record the power level on power meter 1 as P_{ref1}.

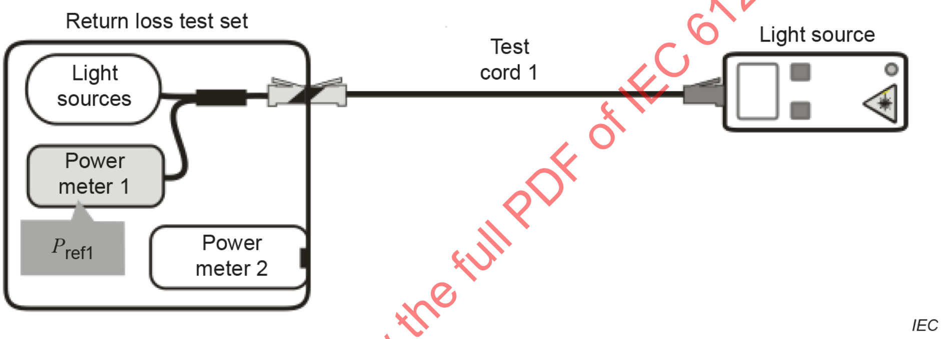


Figure F.3 – Measurement of the system internal attenuation P_{ref1}

The ratio of these two power levels is the internal attenuation of the system.

Next, the system reflected power has to be measured. Leaving test cord 1 connected to the output port of the RLTS, suppress the reflection coming from the connector at the far end of test cord 1, as shown in Figure F.4. This is done with a low reflection termination (see F.2.6). The amount of light reflected internally within the measurement system including the interface connector can now be measured on power meter 1 as P_{rs}.

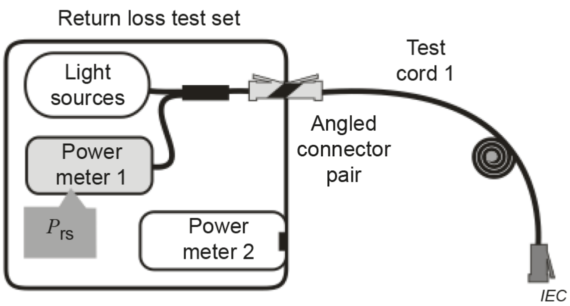


Figure F.4 – Measurement of the system reflected power P_{rs}

F.3.2 Measurement procedure

The optical return loss is the ratio of the input power to the cabling under test, P_{in}, to the power reflected back from the cabling under test, P_r. Therefore, two power levels are required. First, the power into the cabling under test, P_{in}, is measured directly by connecting the far end of test cord 1 into power meter 2, as shown in Figure F.5.

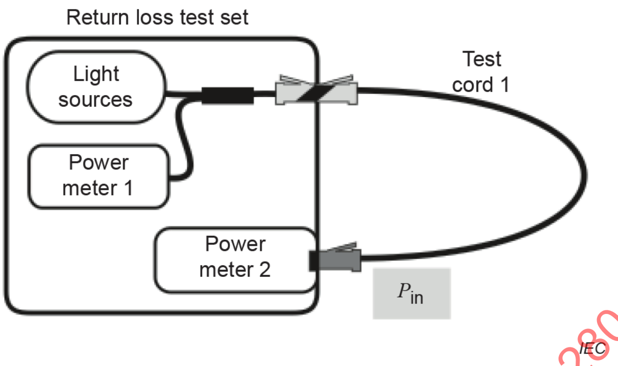


Figure F.5 – Measurement of the input power P_{in}

Then, test cord 1 is connected into the cabling under test, and any unwanted reflections from the far end should be suppressed by using a low reflection termination (see F.2.5), as shown in Figure F.6. The power level on power meter 1 should now be recorded as P_{m1} and then used to determine the reflected power by making allowances for the internal attenuations and reflections of the measurement system.

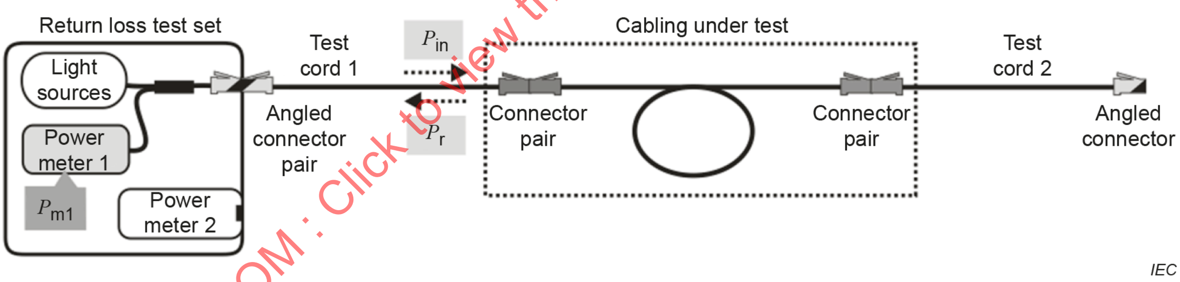


Figure F.6 – Measurement of the reflected power P_r

F.3.3 Calculations

Using the definition of optical return loss in 3.1.7

$$R_{ORL} = 10 \times \log_{10}(P_{in} / P_r) \tag{F.1}$$

where P_{in} is measured directly as shown in Figure F.5. P_r is calculated by taking the measured reflected power, P_{m1}, subtracting from it the contribution from the internal reflections of the measurement system, P_{rs}, and then compensating for the attenuation that is experienced by the reflected light as it passes from test cord 1 back through the connector interface on the RLTS, through the coupler and on to the internal power meter. Formula (F.2) shows the mathematical calculation of P_r.

$$P_r = (P_{m1} - P_{rs}) \times (P_{ref2} / P_{ref1}) \tag{F.2}$$

Substituting for P_r in Formula (F.1) then gives R_{ORL} in dB as:

$$R_{ORL} = 10 \times \log_{10}\left[\frac{P_{in} \times P_{ref1}}{\left(P_{m1} - P_{rs}\right) \times P_{ref2}}\right] \tag{F.3}$$

Annex G
(normative)

Continuous wave optical return loss measurement – Method B

G.1 Applicability of test method

Compared with the method A described in Annex F, this method utilizes a known reflectance to characterize the measurement set-up. Rewriting Formula (F.3) as

$$\begin{aligned} R_{ORL} &= 10 \times \log_{10}\left[\frac{P_{in} \times P_{ref1}}{\left(P_{m1} - P_{rs}\right) \times P_{ref2}}\right] \\ &= 10 \times \log_{10}\left(\frac{P_{in}}{L_{ret}}\right) - 10 \times \log_{10}\left(P_{m1} - P_{rs}\right) \\ &= C_f - 10 \times \log_{10}\left(P_{m1} - P_{rs}\right) \end{aligned} \quad (G.1)$$

where

L_{ret} is the attenuation of the coupler between P_r and P_{m1};

$C_f = 10 \times \log_{10}(P_{in} / L_{ret})$ is the characterization factor.

G.2 Apparatus

G.2.1 General requirements

A typical test set for return loss measurements is shown in Figure G.1. In addition to the apparatus described in Annex F the reflectance termination described in G.2.2 is required.

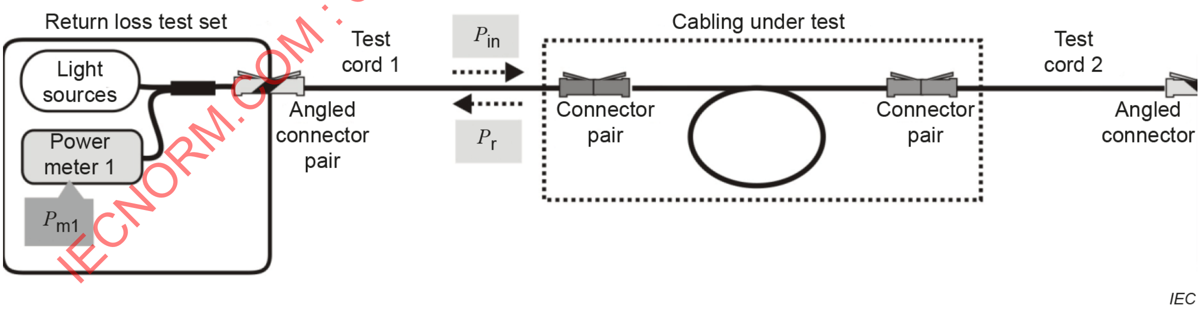


Figure G.1 – Return loss test set illustration

G.2.2 Known reflectance termination

A termination with known reflectance is required to determine the internal attenuations and reflections of the measurement system. Commonly a flat ended (PC but not angled) connector open to air is used, which has an assumed reflectance of –14,6 dB.

G.3 Procedure

G.3.1 Set-up characterization

In order to perform the measurement, it is necessary to characterize the measurement system by determining C_f.

C_f can be characterized by taking two measurements, the first with reflections suppressed, as shown in Figure G.2, and the second using a reference reflector with known reflection R_{ref}, as shown in Figure G.3.

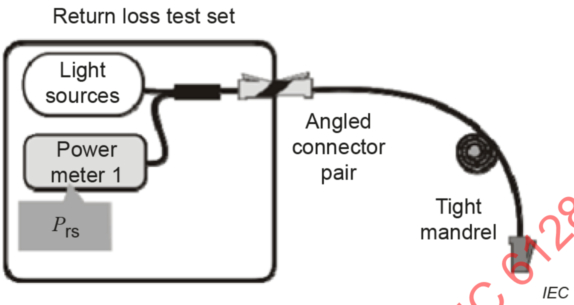


Figure G.2 – Measurement of P_{rs} with reflections suppressed

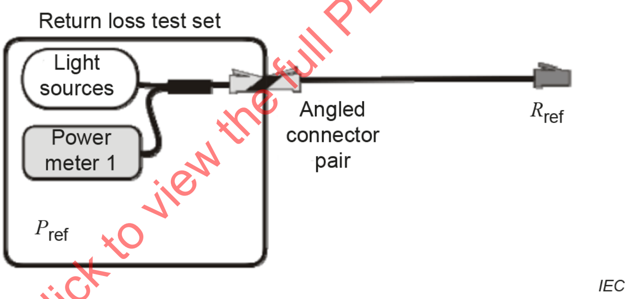


Figure G.3 – Measurement of P_{ref} with reference reflector

The first measurement yields the internally reflected power P_{rs} of the RLTS, as described in F.3.1, whereas the second measurement yields a reference power P_{ref}, so that the characterization factor can now be determined as $C_f = 10 \times \log[(P_{ref} - P_{rs}) / R_{ref}]$.

When R_{ref} is much higher than the reflectance from the connector and coupler, (i.e. $P_{ref} >> P_{rs}$, then $C_f \approx 10 \times \log(P_{ref} / R_{ref})$), so that the determination of C_f can be simplified to taking only the measurement shown in Figure G.3.

NOTE All power measurements described are taken in linear units (W).

G.3.2 Measurement procedure

The system reflected power, P_{rs}, is measured by suppressing the reflection coming from the connector at the far end of test cord 1, as shown in Figure G.4. This can be accomplished with a low reflection termination (see F.2.6). The amount of light reflected internally within the measurement system, including the interface connector, can now be measured on power meter 1 and recorded as P_{rs}.

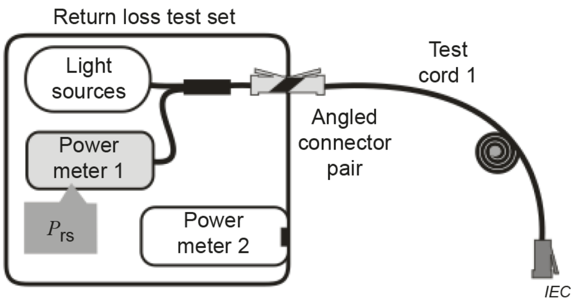


Figure G.4 – Measurement of the system reflected power P_{rs}

Then test cord 1 is connected into the cabling under test and any unwanted reflections from the far end are suppressed by using a low reflection termination (see F.2.6) at the end of test cord 2, as shown in Figure G.5. The power level on power meter 1 is now recorded as P_{m1} and subsequently used to determine the reflected power by making allowances for the internal attenuations and reflections of the measurement system.

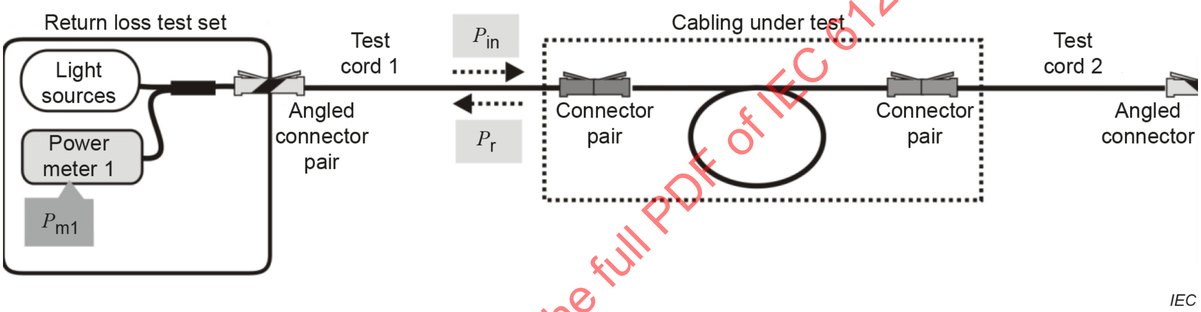


Figure G.5 – Measurement of the reflected power P_r

G.3.3 Calculation

Using the definition of optical return loss in 3.1.7 (see also Formula (F.1)) and the relation shown in Formula (G.1), R_{ORL} is calculated by subtracting from the measured reflected power, P_{m1}, the contribution from the internal reflections of the measurement system, P_{rs}, which was present in the measurement of P_{m1}, and finally applying the characterization factor C_f, as shown in Formula (G.2):

$$R_{ORL} = C_f - 10 \times \log_{10}(P_{m1} - P_{rs}) \quad (G.2)$$

Annex H
(normative)

On the use of reference-grade test cords

H.1 General

Test cords with reference-grade terminations are used, where possible, to reduce measurement uncertainties. If a connector with an off-centre optical fibre were to be used, the results would vary depending on the orientation of the fibre in the launch cord connector to the orientation of the offset of the fibre in the connector in the cabling. However, the use of reference-grade terminations on the test cords means that the measured attenuation of the cabling will typically be different than if standard-grade terminations were used, thus leading to an adjustment in the test limit for the measurement.

The interpretation of the measured attenuation of the cabling is likely to be based upon comparison with a specified acceptance figure (the test limit) to provide a pass or fail result. This annex provides guidance on how these test limits should be modified to take into account the use of reference-grade rather than standard-grade connectors on the test cords.

H.2 Practical configurations and assumptions

H.2.1 Component specifications

Cabling under test comprises cable(s), splice(s), and connections.

For cables and splices, the value to be used in the establishment of the attenuation contribution is the maximum value specified in the relevant cabling or cable standard. The cable attenuation is calculated by multiplying the maximum attenuation coefficient specified by the length of the cable. For example, a cabled optical fibre of Category OS2 (in accordance with ISO/IEC 11801-1) has a maximum attenuation coefficient of 0,4 dB/km at 1 310 nm, and so a 1 000 m length of cabling under test is allowed to include up to 0,4 dB of cable attenuation, in addition to the other component attenuations.

For connections, the values to be used are:

a) a maximum value specified in the relevant cabling standard, or

b) a 100 % (max.) performance value specified in a connecting hardware standard.

For the purposes of Annex H, three types of connection are considered:

1) Standard-grade where the connector performance is specified by industry accepted values (e.g. IEC 61755-2-1). In Annex H, 100 % ≤ 0,75 dB is applied as a maximum value.

2) Reference-grade where the connector performance is specified by industry accepted values (e.g. IEC 61755-2-4). In Annex H, 100 % ≤ 0,20 dB is applied as a maximum value.

3) "Mixed" where standard-grade components are connected to reference-grade components. There are no standard-based values for this performance.

NOTE 1 It is assumed that the mixed connection performance will be between standard-grade and reference-grade. For purposes of the worked examples given in Clause H.4, it is assumed to be 0,50 dB.

If reference-grade terminations are used on the test cords, the measured attenuation of the cabling will typically be different than when standard-grade terminations are used. This means that if the acceptance figure is based upon the assumption of standard-grade terminations for the finally configured system, for example, then some adjustment of the acceptance figure can be necessary.

These uncertainties are particularly significant when short lengths of cabling are being tested because the attenuations associated with the connections are much higher than the attenuations of the fibre itself. For long haul systems, the attenuation of the fibre dominates the total attenuation, and this uncertainty is less critical.

Table H.1 shows examples of attenuations between the different possible combinations of reference and standard-grade terminations, assuming the use of reference grade R2 and untuned PC (non-angled) grade C connectors with cylindrical ferrules.

NOTE 2 At the time of writing, it was expected that the designation "R2" for single-mode reference grade connectors with 0,2 dB attenuation will be replaced by a new designation "R_{s1-2}" in the future Edition 2 of IEC 61755-2-4 and also referred to as "Rs1-Grade 2" in Edition 3 of ISO/IEC 14763-3.

Table H.1 – Expected attenuation for examples

Termination 1	Termination 2	Attenuation requirement
SM reference-grade R2	SM reference-grade R2	≤ 0,2 dB
SM reference-grade R2	SM standard-grade C (untuned)	≤ 0,5 dB
SM standard-grade C (untuned)	SM standard-grade C (untuned)	≤ 0,75 dB
NOTE Table H.1 shows the required performance of standard-to-standard connectors in accordance with IEC 61755-2-1 and reference-to-reference connectors in accordance with IEC 61755-2-4.		

H.2.2 Conventions

In Annex H, the various connections in the reference and test configurations of H.2.3 are denoted by a letter. For example, the connection between the launch cord and the cabling under test is usually designated A_1.

A convention has been adopted in Annex H to denote the grade of connectors that are used in that connection as follows:

- when the connection is "standard-grade", the letter is used by itself (e.g. A);
- when the connection is "mixed", the letter is used with a single prime suffix, (e.g. A');
- when the connection is "reference-grade", the letter is used with a double prime suffix, (e.g. A'').

The maximum values used are designated as follows for single-mode connections (using "standard-grade" as an example):

- A_{max} = 0,75 dB;
- A'_{max} = 0,50 dB;
- A''_{max} = 0,20 dB.

H.2.3 Reference planes

Reference planes define the start and finish points of the required attenuation measurements. The reference planes for the four cabling configurations described in 4.2 are shown in Figure 3 to Figure 6. The term "required result" is defined as the attenuation in the cabling configuration between the reference plane start and the reference plane finish.

Figure 3 to Figure 6 show the reference planes for cabling under test using LSPM test equipment. The relevant results and discussions of uncertainty are described in Clause H.3 with examples provided in Clause H.4.

The same reference planes apply when using OTDR test equipment (the OTDR would replace the LS in Figure 3 to Figure 6 and the PM would not be present). This is discussed in Clause H.5.

H.3 Impact of using reference-grade test cords for recommended LSPM methods

In the test methods described in Annex A to Annex D, the measured attenuation result, A, is defined as the difference between the reference power level and the measured power level. For each method, the corresponding annex defines the contributions to A in terms of cabling and connection attenuations, as for example in the formula "$A = A_1 + A_2 + A_c$" in Annex A.

In Annex A to Annex C:

- A_1 is the attenuation of the connection between the launch cord and the cabling under test;
- A_2 is the attenuation of the connection between the cabling under test and the receive cord;
- A_c is the attenuation of the cabling excluding its terminating connectors;
- A_3 and A_4, where used, are the attenuations of extra connections that are necessary to implement the required reference configuration of test cords.

In Annex D, A_1 and A_2 are the attenuations of the connections between the equipment cords and each end of the fixed cabling.

Table H.2 lists the results and the test limit adjustment for the different cabling configurations and their recommended test methods when using reference-grade test cords. The table shows that no additional uncertainty (above that discussed in Clause 5) is produced when using reference-grade test cords.

Table H.2 – Test limit adjustment when using reference-grade test cords

Configuration	Method	Measured result	Required result	Test limit adjustment
A	Annex A (1 cord)	$A = A_1' + A_2' + A_c$	$A_1 + A_2 + A_c$	$(A_1'_{max} - A_{1max}) + (A_2'_{max} - A_{2max})$ ≈ −0,5 dB
B	Annex B (3 cords)	$A = A_1' + A_2' + A_c - A_3'' - A_4''$	A_c	$A_1'_{max} + A_2'_{max} - A_3''_{max} - A_4''_{max}$ ≈ +0,6 dB
C	Annex C (2 cords)	$A = A_1' + A_2' + A_c - A_3''$	$A_1 + A_c$	$(A_1'_{max} - A_{1max}) + A_2'_{max} - A_3''$ ≈ negligible
D	Annex D (equipment cord)	$A = A_1 + A_2 + A_c$	$A_1 + A_2 + A_c$	None

H.4 Examples for LSPM measurements

H.4.1 Example 1 (configuration A, one-cord method, Annex A)

A single-mode cabling system 100 m long is terminated in a patch panel at each end. The total maximum attenuation, assuming standard-grade connectors, would be 1,60 dB, assuming 1,0 dB/km cabled optical fibre attenuation (0,1 dB for the 100 m of optical fibre) and 0,75 dB per connection, as shown in Formula (H.1).

$$A_{1max} + A_{2max} + A_{c\ max} = 0{,}75\ dB + 0{,}75\ dB + 0{,}10\ dB = 1{,}60\ dB \quad (H.1)$$

If this system was measured using the one-cord reference method and reference-grade terminations on the test cords, then the total maximum attenuation would be 1,10 dB (0,1 dB for the 100 m of optical fibre plus 0,5 dB for each connection between reference-grade and standard-grade terminations), as shown in Formula (H.2).

$$A_1{'}_{max} + A_2{'}_{max} + A_{c\ max} = 0{,}5\ dB + 0{,}5\ dB + 0{,}10\ dB = 1{,}10\ dB \quad (H.2)$$

Thus, when the attenuation is measured using reference-grade test cords, the acceptance figure shall be adjusted by $(A_1{'}_{max} – A_{1max}) + (A_2{'}_{max} − A_{2max}) = −0{,}5$ dB as shown in Table H.2. When measured with standard-grade test cords, there is no change to the acceptance figure, but there is a large additional uncertainty as seen in Table 5 (due to the reproducibility of standard-grade test cords). The use of reference-grade test cords is therefore recommended, provided that the acceptance figure is adjusted.

H.4.2 Example 2 (configuration B, three-cord method, Annex B)

Consider the above cabling system having equipment connection cords with standard-grade terminations connected into the patch panels. The expected maximum attenuation excluding the terminal connectors will be the fibre attenuation, $A_{c\ max}$ = 0,1 dB.

If this system was measured using the three-cord reference method and reference-grade terminations on the test cords, then the total maximum attenuation would be 0,70 dB (0,1 dB for the 100 m of optical fibre plus 0,5 dB for each connection between reference-grade and standard-grade terminations minus 0,2 dB for each connection between reference-grade and reference-grade connections), as shown in Formula (H.3).

$$\begin{aligned} &A_1{'}_{max} + A_2{'}_{max} + A_{c\ max} - A_3{''}_{max} - A_4{''}_{max} \\ &= 0{,}5\ dB + 0{,}5\ dB + 0{,}10\ dB – 0{,}2\ dB – 0{,}2\ dB = 0{,}70\ dB \end{aligned} \quad (H.3)$$

For each reference-grade to reference-grade connection in the reference measurement that is replaced by a reference-grade to standard-grade connection in the attenuation measurement configuration, an adjustment of 0,3 dB should be added to the acceptance figure, which is based on the assumption of using standard-grade connectors.

H.4.3 Example 3 (configuration C, two-cord method, Annex C)

The above cabling system is considered, but with connection cords having standard-grade plug-to-socket style connectors, such as MTRJs, connected into patch panels. To test these systems, it is necessary to use the two-cord reference method with the addition of a reference-grade adapter cord to complete the test configuration. This adapter cord allows connectivity but also adds the attenuation of the mated pair of connectors factored out in the referencing procedure, because all the connectors involved are reference-grade. However, the reference-grade termination interface with the standard-grade patch panel connectors will typically have a lower attenuation than those of the equipment patch cords. The acceptance criteria, therefore, should be reduced by 2 × 0,25 dB = 0,5 dB.

H.4.4 Example 4 – Long haul system (one-cord reference method)

A link 80 km long is terminated at optical distribution frames (ODFs) by splicing on pigtails. The route is made up of 16 drums of cable each 5 km long with fusion splices between them. The expected attenuation of the link at 1 550 nm, assuming standard-grade connectors, is 20,8 dB, which assumes 0,22 dB/km for the fibre attenuation, an average 0,1 dB for the 17 splices, and 0,75 dB for each of the terminations at the ODFs.

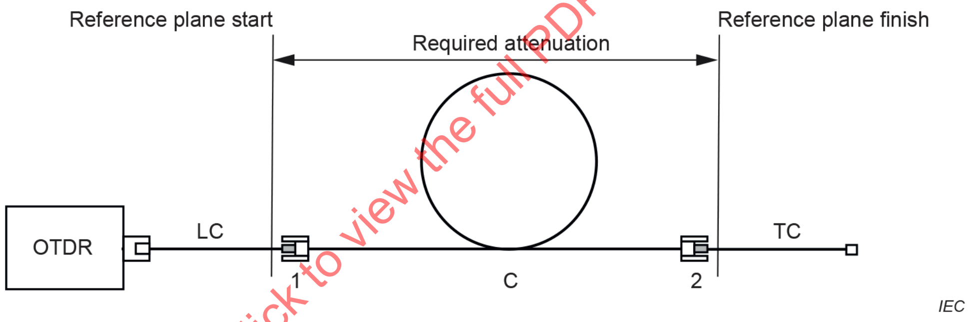
When tested using the one-cord reference method, the expected maximal attenuation between the terminations will be 20,3 dB, assuming that reference-grade terminations are used on the test cords.

It can be seen that the variance in this case is much less significant than for the above cases where there are short lengths of fibre.

H.5 Impact of using reference-grade test cords for different configurations using the OTDR test method

H.5.1 Cabling configurations A, B and C

When using the OTDR test method with a suitably high resolution OTDR and sufficiently long launch and tail cords, as shown in Figure H.1, it is possible to separately identify and measure the attenuation of each of the contributory factors (A_1 + A_2 + A_c, etc.).



Key

OTDR optical time domain reflectometer

LC launch cord

C cabling under test

TC tail cord

1, 2 connector sets

Figure H.1 – Cabling configurations A, B and C tested with the OTDR method

The OTDR will usually produce an event table or schematic diagram containing details of the distance to each event and its attenuation as well as the length and attenuation of the sections of cabling between the events.

There is no substitution of connections from a reference measurement, therefore the setting of test limits is simplified as shown in Table H.3.

Table H.3 – Test limit adjustment when using reference-grade test cords – OTDR test method

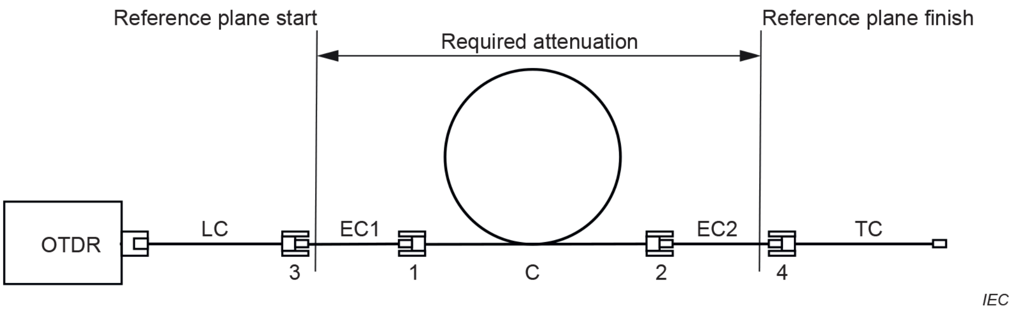
Configuration	Method	Measured result	Required result	Test limit adjustment
A	Annex D (OTDR)	$A = A_1' + A_2' + A_c$	$A_1 + A_2 + A_c$	$(A_1'_{max} - A_{1max}) + (A_2'_{max} - A_{2max})$ ≈ −0,5 dB
B	Annex D (OTDR)	$A = A_1' + A_2' + A_c - A_3'' - A_4''$	A_c	For further study
C	Annex D (OTDR)	$A = A_1' + A_2' + A_c - A_3''$	$A_1 + A_c$	For further study
D	Annex D (OTDR)	$A = A_1 + A_2 + A_c + A_3' - A_3'$	$A_1 + A_2 + A_c$	None
D (see Note)	Annex D (OTDR)	$A = A_1 + A_3' + A_2 + A_4' + A_c$	$A_1 + A_2 + A_c$	For further study
NOTE When the equipment cords are short, it can be impossible to separately identify and measure A_1 and A_3' and A_2 and A_4'. The acceptance figure could be adjusted to include the combined attenuations, but it would be unacceptable to get a false pass by doing so; this subject is still under discussion.				

H.5.2 Cabling configuration D

When using the OTDR test method with a suitably high resolution OTDR and sufficiently long launch, tail and equipment cords, it is possible to separately identify and measure the attenuation of each of the contributory factors ($A_1 + A_2 + A_c$, etc.) as shown in Figure H.2.

The OTDR will usually produce an event table containing details of the distance to each event and its attenuation as well as the length and attenuation of the sections of cabling between the events.

However, the ability of the OTDR method to separately identify and measure connections A_1 and A_3, and A_2 and A_4 depends upon the capability of the OTDR and the lengths of the equipment cords. When it is not possible to separately resolve and measure the attenuations of the connections at both ends of the equipment cords accurately, then the acceptance figure can be adjusted to include the attenuation of the connection between the launch cord and the cabling under test as well as the attenuation of the connection between the tail cord and the cabling under test, shown in Figure H.2 as A_3 and A_4, but it would be risky to get a false pass by doing so; this subject is still under consideration.



Key

OTDR	optical time domain reflectometer	EC1	equipment launch cord
LC	launch cord	EC2	equipment receive cord
C	cabling under test	1, 2, 3, 4	connector sets
TC	tail cord		

Figure H.2 – Cabling configuration D tested with the OTDR method

Annex I
(informative)

OTDR configuration information

I.1 Introductory remarks

Annex I provides information regarding OTDRs and their configuration. It also provides additional diagrams to help in the application of Annex E. Refer to IEC 61746-1 and IEC 61300-3-4 for further details and definitions on OTDR performance parameters.

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

This returning signal comes from two sources:

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

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

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

- total attenuation of the link or channel under test;
- total optical return loss of the link or channel under test;
- length (and propagation delay) of the link or channel under test;
- attenuation coefficient of the optical fibre in the cabling under test;
- attenuation of connections (splices and connector pairs);
- return loss (reflectance) of reflective elements, such as connector pairs and mechanical splices;
- distance information between certain features in the trace.

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

- the optical performance of the OTDR being used;
- the correct set-up of the OTDR's measurement parameters;
- the correct measurement configuration including appropriate length launch cords and tail cords;
- measurement good practices – cleanliness of connectors, etc.;
- the use of bi-directional measurements (see Clause I.6 and Clause I.7).

I.2 Fundamental parameters that define the operational capability of an OTDR

I.2.1 Dynamic range

Dynamic range is the capability of an OTDR to measure a large amount of attenuation. The dynamic range is the difference between the maximum backscatter level near 0 m and at 98 % of the noise floor. Another method of measurement uses SNR = 1 (RMS noise). The dynamic range increases when the laser pulse width increases, and when the noise level decreases by averaging.

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

I.2.2 Dynamic margin

Dynamic margin is the difference between the minimum backscattered level at the end of the fibre and the noise floor. The dynamic margin varies the same way as the dynamic range. The estimation of the dynamic margin can be used to determine the noise amplitude on the backscatter signal which defines a large part of the measurement uncertainty. Whenever the dynamic margin is low, the noise on the backscattered signal becomes asymmetrical, leading to an under-estimation of the backscattered signal. For recommendations on dynamic margin, see IEC 61280-4-3. Dynamic margin is a contributing factor in OTDR measurement uncertainty. A dynamic margin of ≥ 3 dB is recommended; ≥ 5 dB is preferred.

I.2.3 Pulse width

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

I.2.4 Averaging time

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

I.2.5 Dead zone

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

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

For single-mode applications, the most significant dead zone is the attenuation dead zone. This is the distance after a reflective event at which the backscatter level has returned to be within a certain tolerance (ΔF) of a linear fit to the backscatter trace and attenuation measurements can be made. Refer to IEC 61746-1 for a full definition of the attenuation dead zone.

NOTE An OTDR typically supports a range of pulse widths and averaging time to balance dead zone, dynamic range and test time for the optical fibre under test. Shorter (narrower) pulse widths typically provide shorter dead zones (better) but reduce dynamic range (worse). Increased averaging time typically increases dynamic range. OTDR dead zones are typically specified for short pulse widths (< 10 ns) and standard connector return loss ≥ 35 dB. Attenuation dead zone using a narrow pulse width is typically less than 8 m. Dynamic range using a wider pulse width is typically more than 20 dB.

I.3 Other parameters

I.3.1 Index of refraction

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

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

When the index of refraction is known it shall be used; otherwise use the values of Table I.1.

Table I.1 – Example of effective group index of refraction values

Centre wavelength	1 310 nm	1 550 nm	1 625 nm	1 650 nm
SMF (IEC B-652 or B-654 dispersion-unshifted single-mode fibre)	1,467	1,468	1,469	1,469

If fibre types other than B-652 or B-654 are being used and if accurate length measurements are required, the fibre manufacturer should be consulted for appropriate refractive index values.

I.3.2 Measurement range

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

I.3.3 Distance sampling

The distance sampling (or sampling resolution) is the distance between two sampling points on the horizontal scale. This distance may be coupled to the measurement range (e.g. when the number of data points is constant).

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

I.4 Other measurement configurations

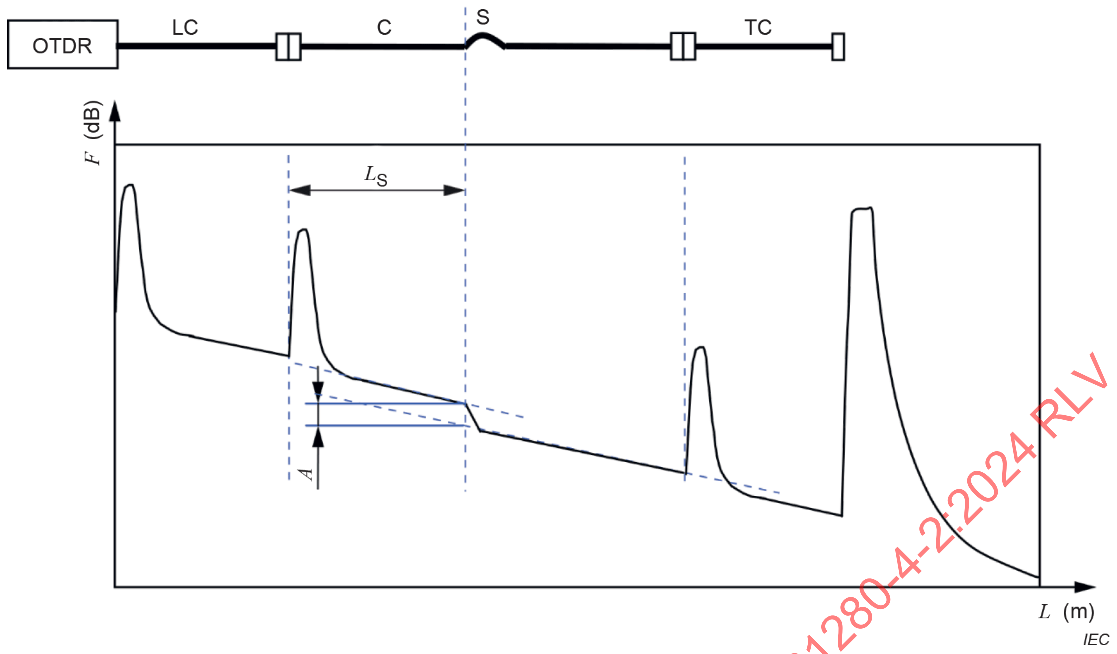
I.4.1 General

Clause I.4 reports some measurement configurations that are not part of Annex E.

I.4.2 Macrobend attenuation measurement

Figure I.1 illustrates the measurement trace when a macrobend (or a fusion splice) is present within a cabling. The attenuation of a macrobend is measured using linear regressions on both sides of the macrobend. The attenuation is given by the difference of displayed power level at the intercept of the two linear regressions with the vertical axis of the bending location. Note that the bending location is before the change of curvature of the trace.

Note that on single-mode fibres the amount of attenuation introduced by a macrobend increases at longer wavelengths. Therefore, comparison of traces at two or more different wavelengths can help to identify the presence of bends.



Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L	distance from OTDR launch cord output port
C	cabling under test	A	macrobend or splice attenuation
TC	tail cord	L_S	length of cabling before macrobend or splice
S	macrobend or splice		

Figure I.1 – Splice and macrobend attenuation measurement

I.4.3 Splice attenuation measurement

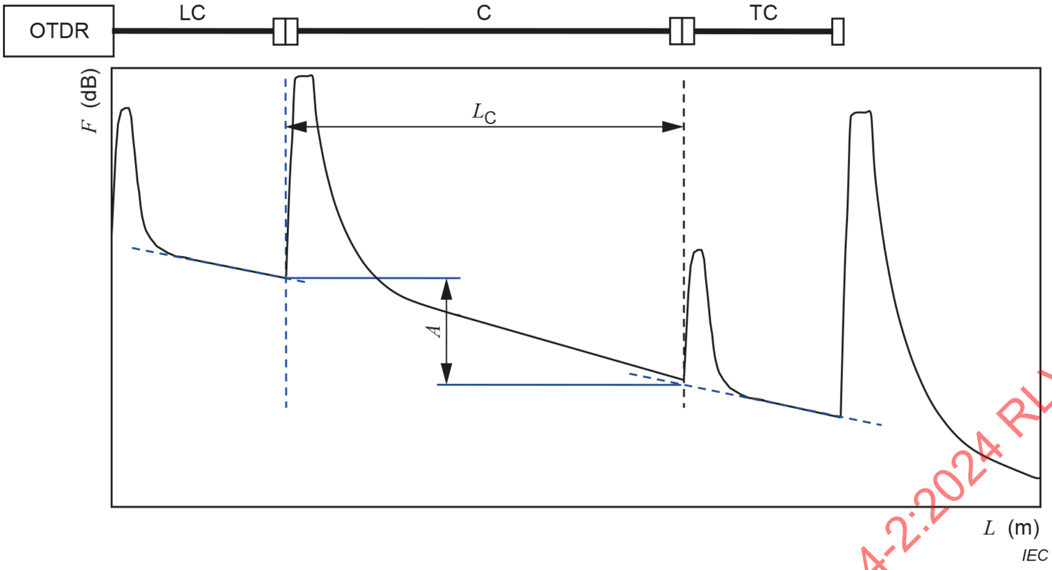
Use the same process as previously defined for a macrobend within a cabling.

I.4.4 Measurement with high reflection connectors or short length cabling

Figure I.2 illustrates a measurement of installed cabling with highly reflective connectors. The strong reflection at the launch cable causes pulse clipping and tailing. Tailing makes attenuation coefficients and closely spaced events difficult to measure.

This demonstrates that it is important to follow a measurement procedure that does not use any part of the tailing signal.

Tailing is a good indication that a connector is dirty and should be cleaned before making further tests.



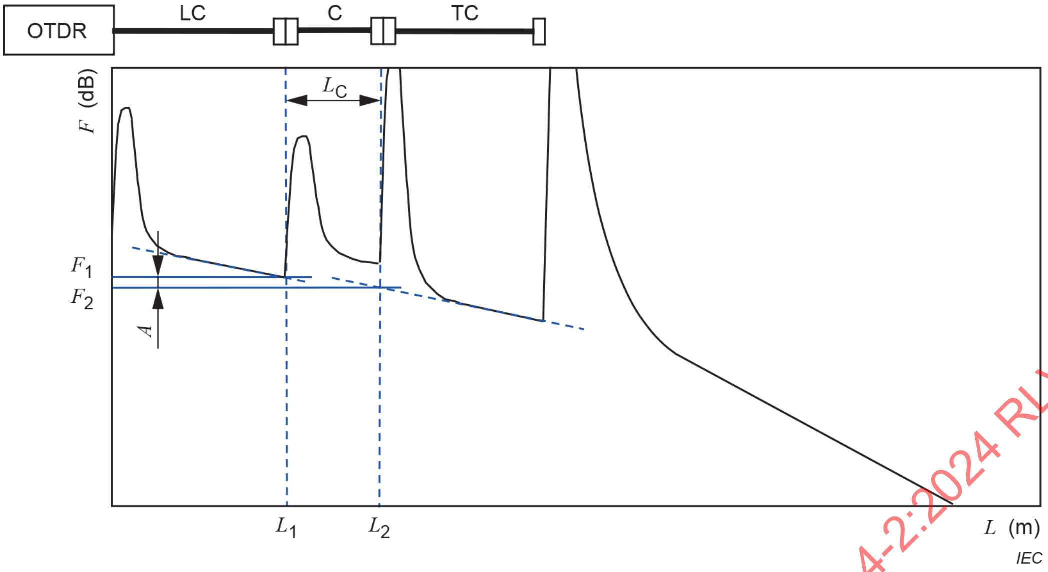
Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L_C	length of cabling under test
C	cabling under test	A	attenuation
TC	tail cord	L	distance from OTDR launch cord output port

Figure I.2 – Attenuation measurement with high reflection connectors

Figure I.3 illustrates a measurement of a short length cabling. The length of the link is shorter than the attenuation dead zone. Separate measurements of the cabling and connections are not available, while the overall measurement is still available.

This demonstrates again how it is important to follow the measurement procedure that does not use any part of the tailing signal.



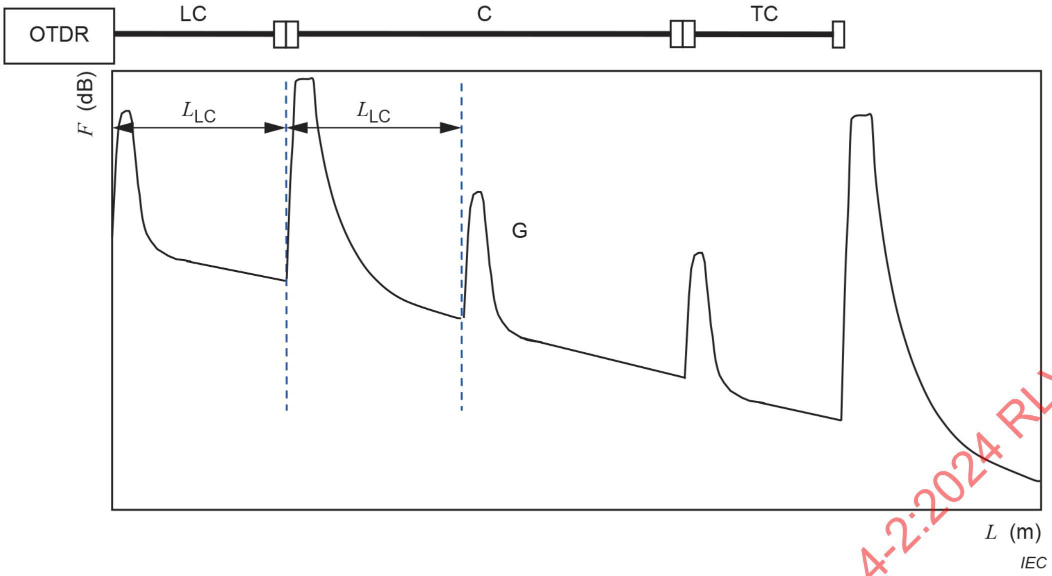
Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L_C	length of cabling under test
C	cabling under test	A	attenuation
TC	tail cord	L_1, L_2	cabling port locations
L	distance from OTDR launch cord output port	F_1, F_2	reflected power levels corresponding to attenuation

Figure I.3 – Attenuation measurement of a short length cabling

I.4.5 Ghost

Figure I.4 illustrates a measurement of installed cabling with a highly reflective connector and resulting ghost. Sometimes, the OTDR software is capable of identifying ghosts properly; if not, a ghost can be identified when the distance between two events on the optical fibre is duplicated.



Key

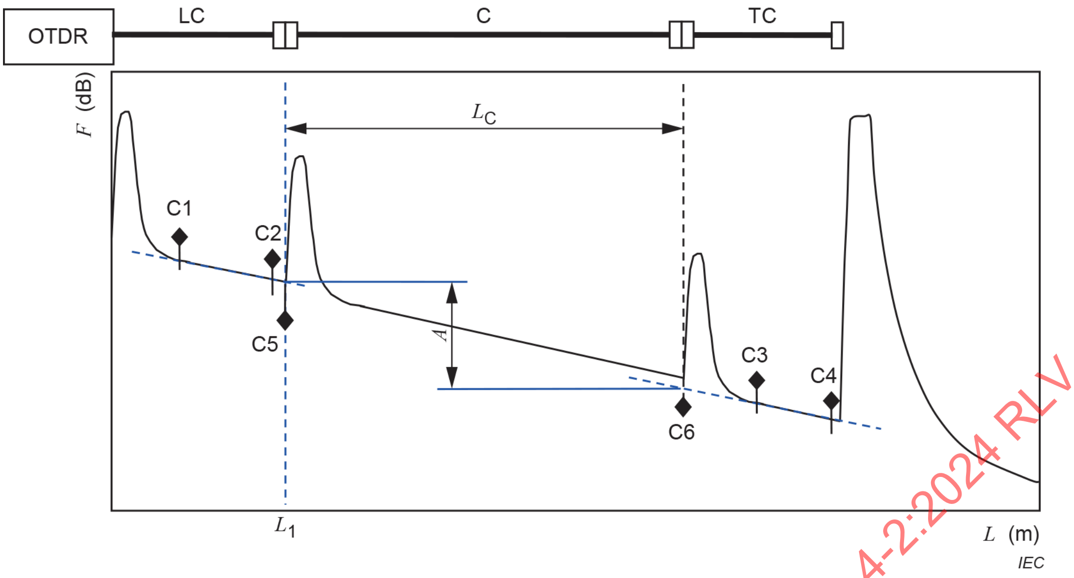
OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L_{LC}	length of the launch cord (duplicated)
C	cabling under test	G	ghost reflection
TC	tail cord	L	distance from OTDR launch cord output port

Figure I.4 – OTDR trace with ghost

I.5 More on the measurement method

The measurement method defined in Annex E is also called the five cursors method. This is due to the fact that readings at five cursor positions are used to complete the measurement.

Figure I.5 shows the positioning of the five cursors on the backscattering trace. Cursors C1 and C2 define the area of linear regression in the launch cord, whereas cursors C3 and C4 define the area of linear regression in the tail cord. Cursor C5 is positioned to define the start of the measured attenuation (e.g. L_1), and cursor C6 is placed to define the end of the measured attenuation. Often the instrument will calculate and display this attenuation as part of an event table.



Key

OTDR	optical time domain reflectometer	F	reflected power level
LC	launch cord	L	distance from OTDR launch cord output port
C	cabling under test	L_C	length of cabling under test
TC	tail cord	A	attenuation
C1, C2, C3, C4	cursors for linear regression definition	L_1	distance to cabling under test
C5, C6	cursors for attenuation measurement		

Figure I.5 – Cursor positioning

Make sure that the OTDR is configured for the application of a linear regression between the cursors. This configuration is sometimes also called least square approximation (LSA).

NOTE The alternative of the linear regression setting (LSA) is generally called two points. This configuration generally leads to significant errors since the calculation of the slope is made using only two points of the backscattering trace while the LSA reduces the consequence of the noise and nonlinear response due to dead zone effects.

I.6 Bi-directional measurement

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

If the launch cord and tail cord have similar scattering characteristics, verified according to IEC 61280-4-3:2022, B.5.2, and only the total attenuation of the link is required to be measured, it is sufficient to carry out OTDR testing in one direction only. However, if the launch cord and tail cord have different characteristics from each other, bi-directional OTDR testing is required.

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

An individual attenuation, in dB, is defined as the half sum of the attenuations, in dB, recorded from each end, as shown in Formula (I.1).

$$A = \frac{A_{oe} + A_{eo}}{2} \tag{I.1}$$

where

A_{oe} is the attenuation measured in the direction from the origin to the extremity;

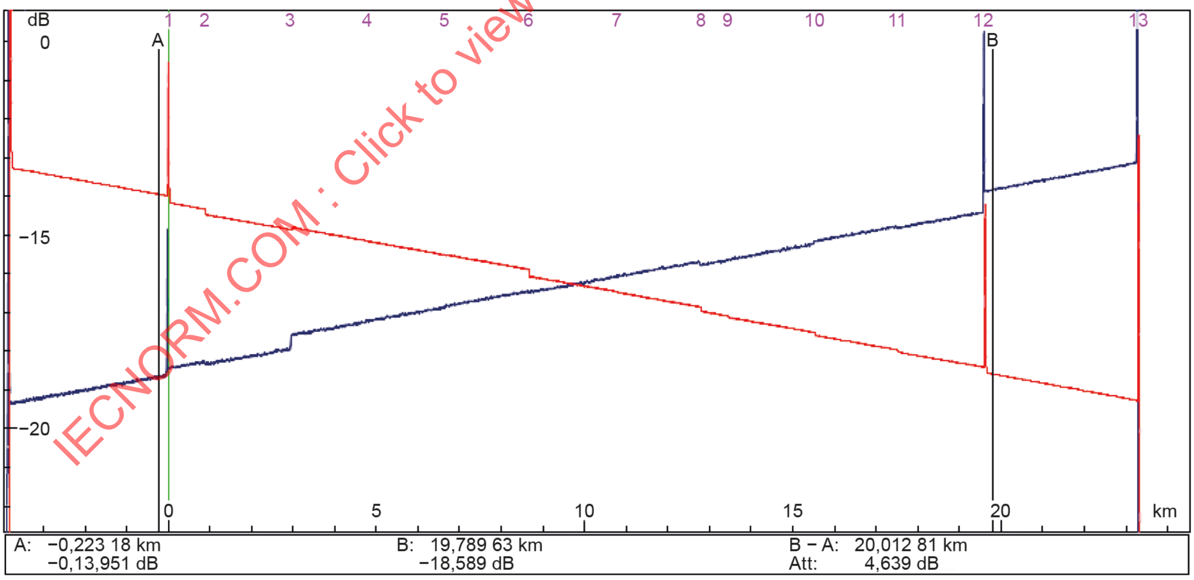
A_{eo} is the attenuation measured in the direction from the extremity to the origin (see also IEC TR 62316 for more details).

NOTE Some OTDRs include specific firmware to manage bi-directional measurements.

Averaging bi-directional testing for determining reflectance will produce incorrect results, since fundamentally, connector reflectance is direction dependent.

I.7 OTDR bi-directional trace analysis

Figure I.6 shows a typical bi-directional OTDR display. The trace from one end is shown reversed and superimposed on the trace from the opposite end of the same fibre so that the positions of all events correlate. The corresponding event table, displayed in Figure I.7, shows the results after bi-directional averaging. Note, for example, the high attenuation splice on the reversed trace at event 3, where there is a "gainer" (apparent negative splice attenuation) when measured from the opposite end. Note also that the attenuation of the connector (event 12) is much less when measured in the forward direction, significantly reducing the bi-directionally averaged connector attenuation.



IEC

Figure I.6 – Bi-directional OTDR trace display

Way O→E (13)	Way O←E (13)	Distance (km)	Attenuation (dB)	Attenuation (dB)	Average (dB)	Slope (dB/km)	Slope (dB/km)	Average (dB/km)
	13							
1*	12*	0,000 00	0,169			0,193	0,193	0,193
2*	11	0,914 47	0,136	−0,062	0,037	0,195	0,187	0,191
3*	10	2,973 62	−0,062	0,362	0,150	0,190	0,190	0,190
4*	9	4,814 07	0,009	0,025	0,017	0,192	0,184	0,188
5*	8	6,677 54	−0,006	0,029	0,011	0,190	0,190	0,190
6*	7	8,676 59	0,177	−0,034	0,071	0,190	0,192	0,191
7*	6	10,795 21	0,014	0,004	0,009	0,188	0,194	0,191
8*	5	12,816 00	0,110	−0,094	0,008	0,191	0,191	0,191
9*	4	13,476 59	0,034	0,007	0,021	0,186	0,203	0,195
10*	3	15,531 91	0,077	0,076	0,077	0,187	0,196	0,191
11*	2	17,527 76	0,067	−0,038	0,014	0,187	0,190	0,189
12*	1	19,625 28	0,136	0,534	0,335	0,182	0,198	0,190
13*						0,197	0,200	0,199

IEC

Figure I.7 – Bi-directional OTDR trace attenuation analysis

I.8 Non-recommended practices

I.8.1 Measurement without tail cord

If the tail cord is missing, the attenuation of the connector at the end of the cabling is not taken into account. Also, the measurement is not possible when the length of the cabling is short regarding the attenuation dead zone (see I.4.4).

This type of measurement is only acceptable for the qualification of a repair of the cabling that had been tested before the damage (assuming configurations of the OTDR and the cabling allow for visualization of the repair).

I.8.2 Two cursors measurement

OTDRs generally provide easy access to two cursors showing location and power level position as well as the attenuation between the two cursors.

The use of a cursor measurement is not recommended for attenuation measurements, because of all the factors mentioned in Clause I.4 and the fundamental importance of properly evaluating the backscatter slope and level before and after the intended event or section. Therefore, an advanced LSA analysis is preferred.

Annex J
(informative)

Test cord attenuation verification

J.1 Introductory remarks

The validity of installed cabling attenuation measurements critically depends on the attenuation performance of the test cords used in all LSPM methods. Test cord attenuation verification should be performed before formal testing of installed cabling begins. Cords should be re-verified at the beginning of each testing session, for example daily, or after the number of plug insertions is approached as stated in the mating durability specification, typically defined in hundreds of mate and de-mate cycles.

Test cord attenuation performance verification involves measuring the attenuation of the test cords, and possibly performing steps to obtain acceptably low attenuation performance prior to measuring the installed cabling. The maximum acceptable attenuation can be established in a number of ways, for example, by customer testing requirements, the specifications claimed by the manufacturer of the test cords, or by cabling standards. It is not advisable to set acceptance criteria for test cords to levels as high as the minimum performance level (i.e. maximum allowable connection attenuation) permitted by cabling standards, as the magnitude of this allowance, typically up to 0,75 dB, contributes directly to uncertainty of the measured cabling attenuation.

J.2 Apparatus

The light source, power meter and test cords defined in Clause 6 are required.

It is necessary to use a power meter that will mate to the plugs of the test cords, that is, offer a socket or adapter of the same type as that of the installed cabling to be tested. This can be accomplished in two ways:

a) by using a compatible socket on the power meter, or
b) by attaching to the power meter, a short (< 2 m) "bucket cord", free of bends of radius less than 30 mm, having a cable-plant-compatible adapter on one end and a plug compatible with the power meter socket on the other. The optical fibre within the bucket cord is of a larger core diameter and higher numerical aperture than that of the cords under test so that substantially all light can be collected from the cords under test.

J.3 Procedure

J.3.1 General

The verification procedure depends on the number and type of cords used in the test method. A power meter with a compatible socket is illustrated. The bucket cord adaptation is not shown.

The procedures are presented in the following organization and order:

a) One-cord and two-cord methods:
   - use J.3.2 for test cord interfaces that are non-pinned or unpinned and non-plug or socket connector styles, such as LC, SC, or other plug-adapter-plug types;
   - use J.3.3 for test cord interfaces that are of the pinned-to-unpinned style, like the MT-RJ, or are of the plug-to-socket style, like the SG.

b) Three-cord method:

- use J.3.4 for test cord interfaces that are non-pinned or unpinned and non-plug or socket connector styles, such as LC, SC, or other plug-adapter-plug types;
- use J.3.5 for test cord interfaces that are of the pinned-to-unpinned style, like the MT-RJ, or are of the plug-to-socket style, like the SG.

Most of the procedures contain optional sequences that are designed to test the cords bi-directionally. Regardless of whether these optional steps are performed, labelling of the cords is advised so that their orientation and order in the test cord sequence can be identified.

The attenuation formulae assume that power readings are made in absolute linear units such as microwatts (μW) or milliwatts (mW) that have to be converted to decibels using logarithms. If the power readings are made in relative logarithmic units such as decibels relative to a milliwatt (i.e. in dBm), then the attenuation is determined by subtraction of the reading from the reference. For example, if the reference is –12 dBm and the reading is –12,5 dBm, the attenuation is (–12 dBm) – (–12,5 dBm) = 0,5 dB.

In any of the procedures, if the connection between the launch cord TC1 and the light source is disturbed, for example by disconnection or mechanical stress, a new reference power level should be obtained, because the amount of power coupled from the light source is typically sensitive to these disturbances.

J.3.2 Test cord verification for the one-cord and two-cord reference test methods when using non-pinned or unpinned and non-plug or socket style connectors

The procedure is as follows:

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.1.

b) Insert adapter A1 and receive cord TC2 between TC1 and power meter as shown in Figure J.2 and record P_1.

c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).

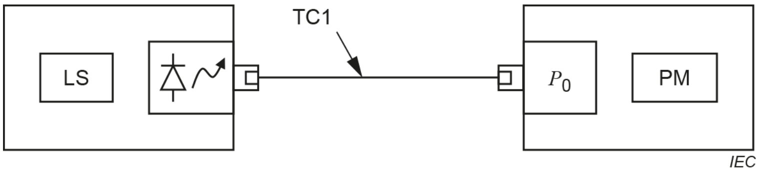
Steps d), e) and f) are recommended but optional. If steps d), e) and f) are not performed, then the cords shall be used only in their tested orientation. More precisely, performing steps d) and e) allows TC2 to be used in either orientation; performing step f) allows TC1 to be used in either orientation.

d) Disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a second power level, P_2.

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).

f) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through e), obtaining a new reference reading P_3 and power readings P_4 and P_5 as above.

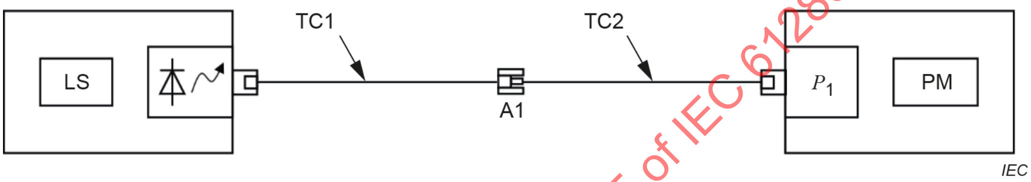
NOTE All power measurements described are taken in linear units (W).



Key

LS light source
TC1 launch cord
PM power meter
P_0 reference power measurement

Figure J.1 – Obtaining reference power level P_0



Key

LS light source
TC1 launch cord
A1 connector set
TC2 test cord
PM power meter
P_1 test power measurement

Figure J.2 – Obtaining power level P_1

J.3.3 Test cord verification for the one-cord and two-cord reference test methods using pinned-to-unpinned or plug-to-socket style connectors

J.3.3.1 General

This procedure is subdivided into two parts, one for compatible interfaces and one for incompatible interfaces. The procedure of J.3.3.2 applies to cases where TC1 and TC2 provide mutually compatible interfaces between them, where, for example, one plug is pinned and the other unpinned, or where one is a plug and the other a socket. The procedure of J.3.3.3 applies to cases where TC1 and TC2 do not provide mutually compatible interfaces between them, where, for example, both plugs are pinned or unpinned, or both are plugs or sockets.

NOTE All power measurements described are taken in linear units (W).

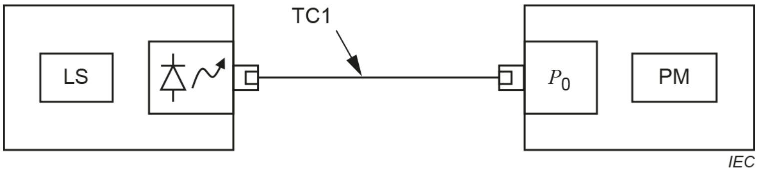
J.3.3.2 Compatible interfaces

This procedure differs from that of J.3.3.3 because the cords are assumed to be directional due to their pinning or plug-to-socket arrangements. In cases where this assumption does not apply, the procedures of J.3.3.3 are recommended so that bi-directional test cord verification can be established. In cases where bi-directional verification is possible, power meters that can accept both pinned and unpinned plugs shall be included.

a) Obtain the reference power measurement P_0 with launch cord TC1 as shown in Figure J.3.

b) Insert adapter A1 and receive cord TC2 between TC1 and the power meter as shown in Figure J.4 and record P_1. A socket for plug-to-socket style connections replaces adapter A1.

c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify that the attenuation is within acceptable limits. If not, clean the plugs and adapter A1 (or socket), or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).



Key

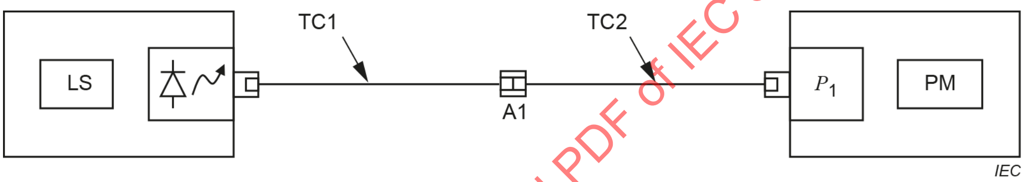
LS light source

TC1 launch cord

PM power meter

P_0 reference power measurement

Figure J.3 – Obtaining reference power level P_0



Key

LS light source

TC1 launch cord

A1 connector set

TC2 test cord

PM power meter

P_1 test power measurement

Figure J.4 – Obtaining power level P_1

J.3.3.3 Incompatible interfaces

Particular configurations of pinned-to-unpinned and plug-to-socket style connections necessitate the introduction of a third cord that provides a compatible interface between the cords under test. The attenuation of this three-cord combination should be sufficiently low so that the combined attenuation still passes the acceptance criteria for the attenuation of a single interface. Configurations that necessitate a third cord include those where TC1 and TC2 are both pinned or unpinned or are both plugs or sockets in a plug-to-socket style arrangement.

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.5.

b) Insert adapters A1, A2, substitution cord TC3, and receive cord TC2 between TC1 and power meter as shown in Figure J.6 and record P_1. For plug-to-socket styles, the adapters are replaced by sockets on the ends of TC3.

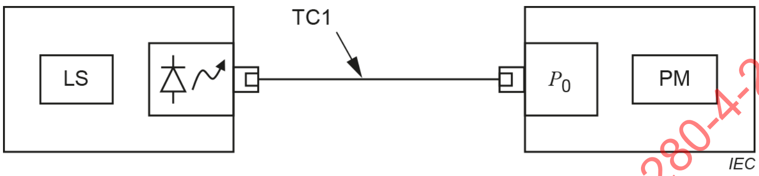
c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC1, TC2, TC3 and adapters A1 and A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

Steps d), e) and f) are recommended but optional. If steps d), e) and f) are not performed, then the cords shall be used only in their tested orientation. More precisely, performing steps d) and e) allows TC2 to be used in either orientation; performing step f) allows TC1 to be used in either orientation.

d) In configurations that permit, disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a second power level, P_2.

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC2, TC3 and adapter A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

f) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through c).



Key

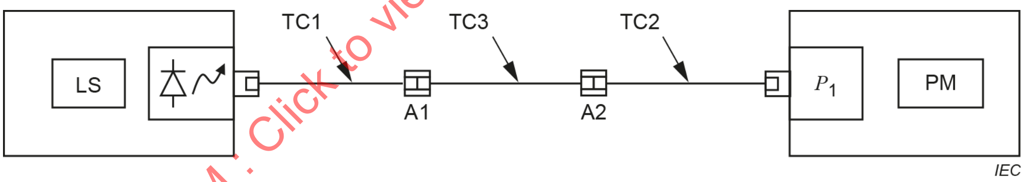
LS light source

TC1 launch cord

PM power meter

P_0 reference power measurement

Figure J.5 – Obtaining reference power level P_0



Key

LS light source

TC1 launch cord

A1 connector set

A2 connector set

TC3 test cord

TC2 test cord

PM power meter

P_1 test power measurement

Figure J.6 – Obtaining power level P_1

J.3.4 Test cord verification for the three-cord reference test method using non-pinned or unpinned and non-plug or socket style connectors

The procedure is as follows:

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.7.

b) Insert adapter A1 and receive cord TC2 between TC1 and power meter as shown in Figure J.8 and record P_1.

c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a).

Steps d, e) and f) are recommended but optional. If steps d), e) and f) are not performed, then the cords shall be used only in their tested orientation. More precisely, performing steps d) and e) allows TC2 to be used in either orientation; performing step f) allows TC1 to be used in either orientation. If steps d), e) and f) are skipped, P_1 becomes the reference power level P_{ref} in step h).

d) Disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a second power level, P_2.

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify that the attenuation is within acceptable limits. If not, clean the plugs and adapter A1, or replace TC1, TC2 and A1 as necessary before continuing. After cleaning or replacement, repeat from step a). If step f) is not performed, P_2 becomes the new reference power level P_{ref} in step h).

f) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through e), obtaining a new reference reading P_3 and power readings P_4 and P_5 as above, then proceed to step g). P_5 becomes the new reference power level P_{ref} in step h).

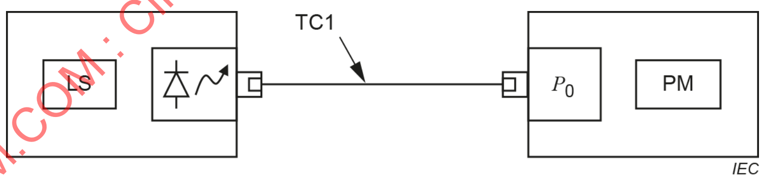
g) Insert substitution cord TC3 and adapter A2 between A1 and TC2 as shown in Figure J.9 and record power level P_6.

h) Determine the attenuation in dB as 10 × log(P_{ref}/P_6). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC3 and A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

i) Disconnect TC3 from the adapters, interchange the ends, reinsert, and record power level P_7.

j) Determine the attenuation in dB as 10 × log(P_{ref}/P_7). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC3 and adapters as necessary before continuing. After cleaning or replacement, repeat from step a).

NOTE All power measurements described are taken in linear units (W).



Key

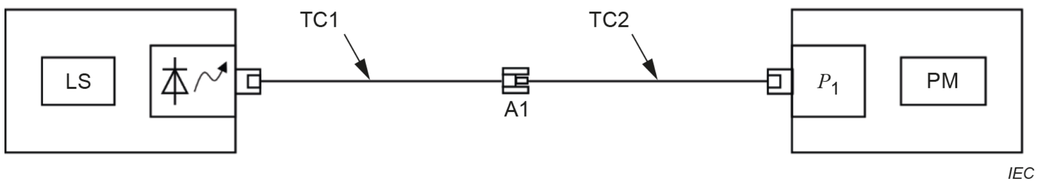
LS light source

TC1 launch cord

PM power meter

P_0 reference power measurement

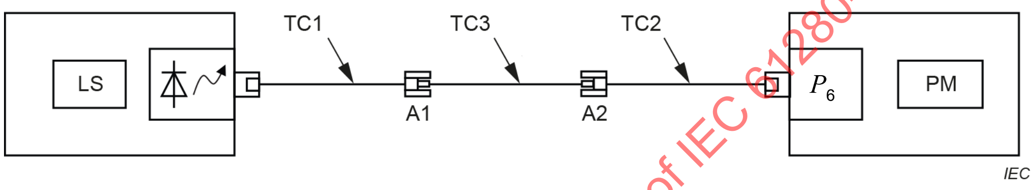
Figure J.7 – Obtaining reference power level P_0



Key

LS	light source	TC2	test cord
TC1	launch cord	PM	power meter
A1	connector set	P_1	test power measurement

Figure J.8 – Obtaining power level P_1



Key

LS	light source	TC3	test cord
TC1	launch cord	TC2	test cord
A1	connector set	PM	power meter
A2	connector set	P_6	test power measurement

Figure J.9 – Obtaining power level P_6

J.3.5 Test cord verification for the three-cord reference test method using pinned-to-unpinned or plug-to-socket style connectors

The procedure is as follows:

a) Obtain reference power measurement P_0 with launch cord TC1 as shown in Figure J.10.

b) Insert adapters A1, A2, substitution cord TC3, and receive cord TC2 between TC1 and power meter as shown in Figure J.11 and record P_1. For plug-to-socket styles, the adapters are replaced by sockets.

c) Determine the attenuation in dB as 10 × log(P_0/P_1). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC1, TC2, TC3 and adapters as necessary before continuing. After cleaning or replacement, repeat from step a).

d) If the plugs of TC3 are of the same type on both ends, disconnect TC3, interchange the ends, reinsert, and record power level P_2. If the plugs are not the same type, skip step e).

e) Determine the attenuation in dB as 10 × log(P_0/P_2). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC1, TC2, TC3 and adapters as necessary before continuing. After cleaning or replacement, repeat from step a).

NOTE 1 The limits in steps c) and e) for this case are normally set to two times the acceptable limit of a single interface.

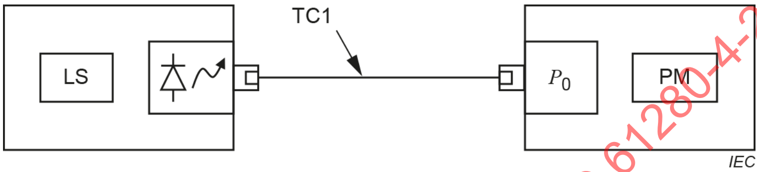
Steps f), g) and h) are recommended but optional. If steps f), g) and h) are not performed, then TC1 and TC2 shall be used only in their tested orientation. More precisely, performing steps f) and g) allows TC2 to be used in either orientation; performing step h) allows TC1 to be used in either orientation.

f) In configurations that permit, disconnect TC2 from the power meter and adapter, interchange the ends, reinsert between adapter and power meter, and record a power level, P_3.

g) Determine the attenuation in dB as 10 × log(P_0/P_3). Verify attenuation is within acceptable limits. If not, clean the plugs and adapters, or replace TC2, TC3 and adapter A2 as necessary before continuing. After cleaning or replacement, repeat from step a).

h) If the plugs of TC1 are of the same type on both ends, disconnect TC1 from the light source and adapter, interchange the ends, and repeat steps a) through e).

NOTE 2 All power measurements described are taken in linear units (W).



Key

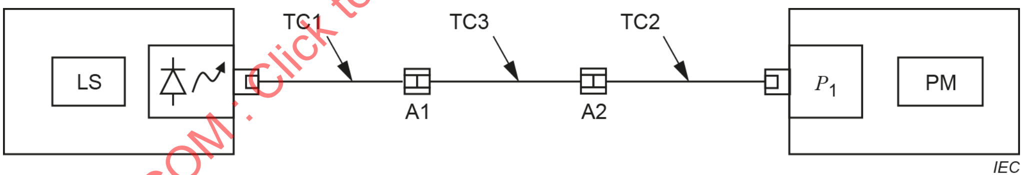
LS light source

TC1 launch cord

PM power meter

P_0 reference power measurement

Figure J.10 – Obtaining reference power level P_0



Key

LS light source

TC1 launch cord

A1 connector set

A2 connector set

TC3 test cord

TC2 test cord

PM power meter

P_1 test power measurement

Figure J.11 – Obtaining power level P_1

Annex K
(informative)

Spectral attenuation measurement

K.1 Applicability of test method

The spectral attenuation of installed cabling is a measure of the attenuation of the cabling as a function of wavelength over a broad wavelength range. Whereas the measurements described in Annex A through Annex D are typically performed at a few discrete wavelengths (e.g. 1 310 nm and 1 550 nm plus 1 625 nm for long distance systems), a spectral attenuation measurement can cover a wide wavelength range (e.g. the S, C and L bands (1 450 nm to 1 625 nm) or the full wavelength range covering the O, E, S, C and L bands from 1 260 nm to 1 625 nm).

These measurements are useful when extended wavelength operation is required (as in CWDM or DWDM systems for example), or if it is required to identify the category of fibre in the installed cabling (i.e. whether it is a category with or without a water peak). In particular, there are wavelength ranges where the attenuation of installed cabling can vary significantly such as around the water peak centred in the E-band at 1 383 nm. It is useful to know the height and width of this peak.

It is possible to carry out attenuation measurements at a large number of discrete wavelengths, for example using a tuneable laser source, but usually the range of wavelengths covered is quite small, and the principles of Annex A through Annex D can be applied.

This annex focuses on the use of a broad band light source and an optical spectrum analyser for carrying out this measurement.

K.2 Apparatus

K.2.1 Broadband light source

The broadband light source shall have sufficient spectral power density to cover the wavelength range of interest. This can be achieved by using one or more high powered LEDs. Alternatively, or in addition, the amplified spontaneous emissions (ASE) of a fibre amplifier can be used, for example to cover the C-band.

There is no requirement for uniform spectral power density as a reference measurement will be taken of the power in the input spectrum.

The emissions of the light source shall be stable for the duration of the measurement.

K.2.2 Optical spectrum analyser

The optical spectrum analyser shall be capable of measuring power as a function of wavelength across the wavelength range of interest and shall be capable of storing and processing these wavelength scans.

K.3 Procedure

K.3.1 Reference scan

- Connect the broadband source directly to the optical spectrum analyser with the appropriate number of test cords depending upon the cabling configuration (see 4.2).
- Turn on the broadband source and allow sufficient time for the output to stabilize.
- Take a reference scan of the power in the input spectrum across the wavelength range of interest and record this power, in units of dB or dBm, as a function of wavelength: $P_{\text{ref}}\ (\lambda)$.

K.3.2 Measurement scan

- Connect the broadband source and associated test cord to one end of the cabling under test, connect the optical spectrum analyser with an appropriate test cord to the other end of the cabling under test.
- Turn on the broadband source and allow sufficient time for the output to stabilize.
- Take a measurement scan of the power in the output spectrum across the wavelength range of interest and record this power, in units of dB or dBm, as a function of wavelength: $P_{\text{meas}}\ (\lambda)$.

K.4 Calculations

The spectral attenuation of the cabling under test, $L(\lambda)$, expressed in dB, is obtained by subtracting the measured scan from the reference scan, as shown in Formula (K.1):

$$L(\lambda) = P_{\text{ref}}(\lambda) - P_{\text{meas}}(\lambda) \qquad \text{(K.1)}$$

The result of such a measurement can be presented in a table for particular wavelengths of interest (e.g. the WDM wavelengths defined by ITU-T) or graphically as shown in Figure K.1, which clearly shows very high attenuation at the water peak and a low attenuation region in the C and L bands (1 530 nm to 1 625 nm).

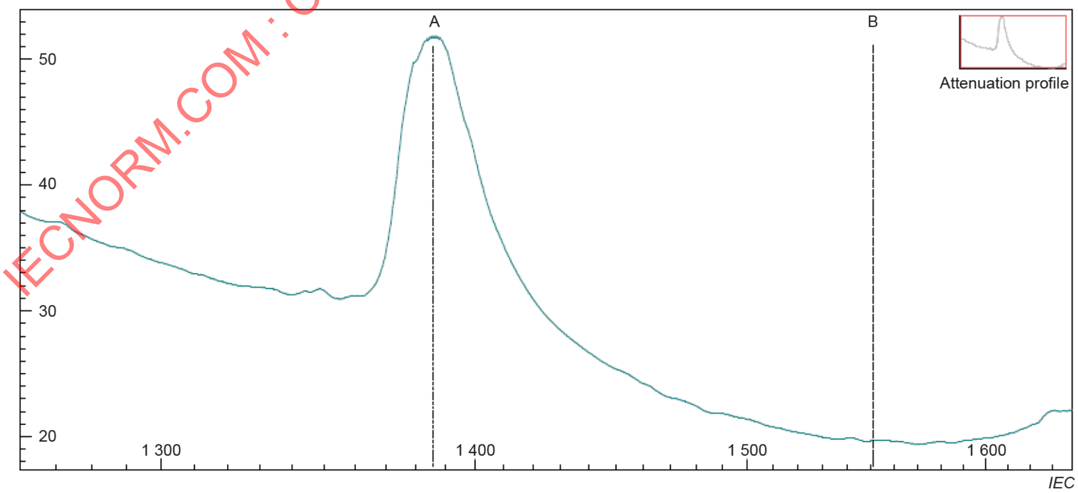


Figure K.1 – Result of spectral attenuation measurement

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IEC 61280-4-3:2022, *Fibre optic communication subsystem test procedures – Part 4-3: Installed passive optical networks – Attenuation and optical return loss measurements*

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

IEC TR 61282-14, *Fibre optic communication system design guidelines – Part 14: Determination of the uncertainties of attenuation measurements in fibre plants*

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

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

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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PROCÉDURES D'ESSAI DES SOUS-SYSTÈMES DE TÉLÉCOMMUNICATION FIBRONIQUES –

PARTIE 4-2: Installations câblées – Mesures de l'affaiblissement de réflexion optique et de l'affaiblissement des fibres unimodales

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L'IEC 61280-4-2 a été établie par le sous-comité 86C: Systèmes et dispositifs actifs à fibres optiques, du comité d'étude 86 de l'IEC: Fibres optiques. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2014. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) ajout de la méthode des cordons d'équipement;
b) ajout de l'ajustement de limite d'essai lié aux classes de cordons d'essai;
c) affinements des incertitudes de mesure.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
86C/1912/FDIS	86C/1916/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

La version française de cette norme n'a pas été soumise au vote.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 61280, publiées sous le titre général *Procédures d'essai des sous-systèmes de télécommunication fibroniques*, se trouve sur le site Web de l'IEC.

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INTRODUCTION

Le présent document fait partie d'une série de normes IEC relatives aux mesures des installations câblées fibroniques. Le présent document s'applique au mesurage de fibres unimodales installées.

Les normes de conception de câblage telles que l'ISO/IEC 11801-1 donnent les exigences générales relatives à ce type de câblage. Ces normes prennent en charge des longueurs de câble pouvant atteindre 2 km pour les bâtiments commerciaux et les centres de traitement de données et 10 km pour les bâtiments industriels. L'ISO/IEC 14763-3, qui prend en charge l'ISO/IEC 11801-1, fait référence à la norme IEC 61280-4-2.

Différentes recommandations de l'UIT-T ont des exigences pour des applications sur des distances supérieures, à savoir les courtes distances (40 km), les longues distances (80 km) et les très longues distances (160 km). Les essais d'installations câblées pour ces applications sont couverts par la recommandation G.650.3 de l'UIT-T, qui fait référence aux méthodes d'essai du présent document.

PROCÉDURES D'ESSAI DES SOUS-SYSTÈMES DE TÉLÉCOMMUNICATION FIBRONIQUES –

PARTIE 4-2: Installations câblées – Mesures de l'affaiblissement de réflexion optique et de l'affaiblissement des fibres unimodales

1 Domaine d'application

La présente partie de l'IEC 61280 s'applique aux mesures de l'affaiblissement et de l'affaiblissement de réflexion optique d'une installation câblée à fibres optiques utilisant des fibres unimodales. Cette installation câblée peut inclure des fibres optiques unimodales, des connecteurs, des adaptateurs, des épissures et d'autres dispositifs passifs. Le câblage peut être installé dans une diversité d'environnements, notamment dans des locaux résidentiels, commerciaux ou industriels et des centres de traitement de données, ainsi que dans des environnements d'installations extérieures.

Le présent document s'applique à tous les types de fibres unimodales, y compris celles désignées comme des fibres de Classe B par l'IEC 60793-2-50.

Les principes du présent document peuvent s'appliquer aux installations câblées contenant des dispositifs de commutation (répartiteurs) et sur des plages de longueurs d'onde spécifiques, dans des situations dans lesquelles sont déployés des composants passifs sélectifs en longueurs d'onde, par exemple des dispositifs WDM, CWDM et DWDM.

Le présent document n'est pas destiné à s'appliquer à des installations câblées qui incluent des dispositifs actifs tels que des amplificateurs à fibres ou des égaliseurs de canaux de transmission dynamiques.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60825-2, *Sécurité des appareils à laser – Partie 2: Sécurité des systèmes de télécommunications par fibres optiques (STFO)*

IEC 61300-3-35, *Dispositifs d'interconnexion et composants passifs fibroniques – Procédures fondamentales d'essais et de mesures – Partie 3-35: Examens et mesures – Examen visuel des connecteurs fibroniques et des émetteurs-récepteurs à embase fibrée*

IEC 61315, *Étalonnage de wattmètres pour dispositifs à fibres optiques*

IEC 61746-1:2009, *Étalonnage des réflectomètres optiques dans le domaine temporel (OTDR) – Partie 1: OTDR pour fibres unimodales*

IEC TR 62627-01, *Fibre optic interconnecting devices and passive components – Part 01: Fibre optic connector cleaning methods* (disponible en anglais seulement)

3 Termes, définitions, symboles graphiques et abréviations

3.1 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1.1
adaptateur
appareil qui permet l'interconnexion entre les câbles à fibres optiques équipés

3.1.2
affaiblissement
diminution de la puissance optique induite à travers un support tel qu'une installation de câblage, donnée sous la forme A:

$$A = 10 \times \log_{10} (P_{in}/P_{out})$$

où

P_{in} et P_{out} sont les puissances d'entrée et de sortie du câblage, mesurées généralement en mW

Note 1 à l'article: L'affaiblissement est exprimé en dB.

Note 2 à l'article: Par ailleurs, l'affaiblissement peut être exprimé sous la forme $A = -10 \times \log_{10} (P_{out}/P_{in})$. Les deux formules sont équivalentes mathématiquement, leur résultat est une valeur en décibels positifs.

3.1.3
mesure bidirectionnelle
deux mesures de la même fibre optique effectuées en injectant le rayonnement lumineux par les extrémités opposées de cette fibre

3.1.4
configuration
forme ou disposition de pièces ou d'éléments tels que des terminaisons, des connexions et des épissures

3.1.5
connecteur
composant qui est normalement fixé à un câble optique ou à un élément d'un appareillage, ayant pour but de permettre des connexions/déconnexions optiques fréquentes de fibres ou de câbles optiques

[SOURCE: IEC TR 61931:1998, 2.6.1, modifié – Le terme entre parenthèses "optique" a été supprimé du terme et la définition a été reformulée en français]

3.1.6
appareil de mesure de la puissance et source lumineuse optique
LSPM
système d'essai consistant en une source lumineuse optique (LS), un appareil de mesure de la puissance (MP) et des cordons d'essai associés utilisés pour mesurer l'affaiblissement d'une installation câblée

Note 1 à l'article: L'abréviation "LSPM" est dérivée du terme anglais développé correspondant "light source and power meter".

3.1.7
affaiblissement de réflexion optique
ORL
R_{ORL}
rapport entre la puissance d'entrée, P_{in}, du câblage en essai et la puissance retour, P_r, réfléchie par le câblage en essai:

$$R_{ORL} = 10 \times \log_{10}(P_{in}/P_r)$$

Note 1 à l'article: L'affaiblissement de réflexion optique est un nombre positif.

Note 2 à l'article: L'affaiblissement de réflexion optique est exprimé en dB.

Note 3 à l'article: L'abréviation "ORL" est dérivée du terme anglais développé correspondant "optical return loss".

3.1.8
réflectomètre optique dans le domaine temporel
OTDR
système d'essai consistant en un réflectomètre optique dans le domaine temporel et des cordons d'essai associés utilisés pour caractériser et mesurer l'affaiblissement et l'affaiblissement de réflexion optique d'une installation câblée et des éléments spécifiques de cette installation câblée

Note 1 à l'article: L'abréviation "OTDR" est dérivée du terme anglais développé correspondant "optical time domain reflectometer".

3.1.9
fiche
fiche
partie mâle d'un connecteur

[SOURCE: IEC TR 61931:1998, 2.6.2]

3.1.10
terminaison de classe de référence
fiche de connecteur avec des tolérances serrées se terminant sur une fibre optique unimodale avec des tolérances serrées, tels que l'affaiblissement attendu d'une connexion formée par accouplement de deux de ces ensembles est inférieur et plus reproductible que celui d'une terminaison de classe normale

Note 1 à l'article: Un adaptateur dont il est exigé qu'il assure ces performances, peut être considéré comme appartenant à la terminaison de classe de référence lorsque la configuration d'essai l'exige.

Note 2 à l'article: L'IEC 61755-2-4 relative aux connecteurs avec férule cylindrique pour les contacts sans angle (PC) et l'IEC 61755-2-5 relative aux connecteurs avec férule cylindrique pour les contacts avec angle (APC) définissent les terminaisons de classe de référence. Ces normes peuvent être référencées pour de plus amples informations.

3.1.11
méthode d'essai de référence
RTM
méthode d'essai selon laquelle une caractéristique donnée est mesurée en se conformant rigoureusement à la définition de cette caractéristique et qui donne des résultats exacts, reproductibles et se rapportant à la pratique

Note 1 à l'article: L'abréviation "RTM" est dérivée du terme anglais développé correspondant "reference test method".

[SOURCE: IEC TR 61931:1998, 2.8.1, modifié – Les termes entre parenthèses "en optique des fibres" ont été supprimés du terme et la définition a été reformulée en français]

3.1.12
réflectance
R_{comp}
pour un composant discret dans le câblage, rapport entre la puissance retour, P_r, réfléchie par le composant et la puissance d'entrée, P_{in}, dans le composant:

$$R_{comp} = 10 \times \log_{10}(P_r / P_{in})$$

Note 1 à l'article: La réflectance est un nombre négatif.

Note 2 à l'article: En variante, elle est appelée (par exemple dans l'IEC 61300-3-6) l'affaiblissement de réflexion des composants individuels, exprimé par la formule $R_L = -10 \times \log_{10}(P_r/P_{in})$, qui est un nombre positif.

Note 3 à l'article: La réflectance est exprimée en dB.

3.1.13
montage d'essai pour l'affaiblissement de réflexion
RLTS
système d'essai consistant en une source lumineuse optique (LS), un appareil de mesure de la puissance interne (MP), un coupleur directif, un appareil de mesure de la puissance externe supplémentaire et des cordons d'essai associés utilisés pour mesurer l'affaiblissement de réflexion optique d'un câblage installé

Note 1 à l'article: L'abréviation "RLTS" est dérivée du terme anglais développé correspondant "return loss test set".

3.1.14
connecteur de type embase
connecteur auquel est intégré l'adaptateur, y compris tout dispositif d'alignement, qui est fixé de manière permanente à la fiche d'un côté de la connexion

Note 1 à l'article: Il s'agit, par exemple, du connecteur SG (IEC 61754-19) et d'un grand nombre de connecteurs pour environnement hostile.

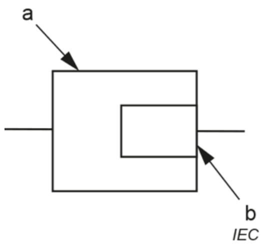
3.1.15
cordon d'essai
cordon à fibres optiques terminé, utilisé pour connecter la source ou le détecteur optique au câblage, ou pour réaliser des interfaces appropriées au câblage en essai

Note 1 à l'article: Il existe cinq types de cordons d'essai:

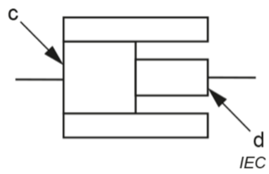
– cordon d'injection: utilisé pour connecter la source lumineuse optique au câblage;
– cordon de réception: utilisé pour connecter le câblage à l'appareil de mesure de la puissance (LSPM seulement);
– cordon de fin: fixé à l'extrémité éloignée du câblage lorsqu'un OTDR est utilisé à l'extrémité proche. Celui-ci constitue un moyen pour évaluer l'affaiblissement et l'affaiblissement de réflexion optique de la totalité du câblage, y compris la connexion à l'extrémité éloignée;
– cordon adaptateur: utilisé pour réaliser une transition entre des embases ou d'autres connecteurs incompatibles dans une configuration d'essai exigée;
– cordon de substitution: cordon d'essai utilisé dans une mesure de référence qui est remplacé durant la mesure de l'affaiblissement du câblage en essai.

3.2 Symboles graphiques

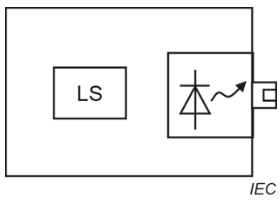
Les symboles graphiques représentés à la Figure 1 pour différentes options de connexion sont tels qu'ils sont donnés dans l'IEC TR 61930:1998, à l'exception de la paire de connecteurs avec angle représentée à la Figure 1 g).



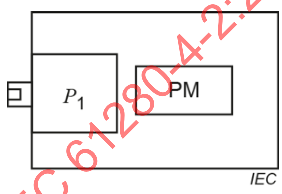
a) **Assemblage embase et fiche**



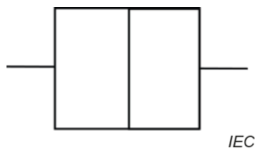
b) **Jeu de connecteurs (fiche, adaptateur, fiche)**



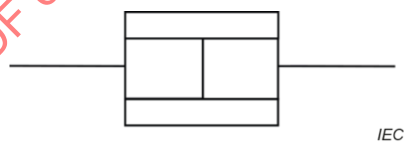
c) **Source lumineuse optique**



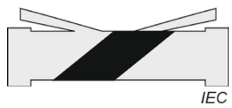
d) **Appareil de mesure de la puissance**



e) **Connexion générique**



f) **Connexion brochée/non brochée**



g) **Paire de connecteurs avec angle**

Légende

a embase

b fiche

c assemblage fiche-adaptateur

d fiche insérée dans un assemblage fiche-adaptateur

LS source lumineuse optique

MP appareil de mesure de la puissance

P_1 niveau de puissance mesuré

Figure 1 – Symboles des connecteurs

NOTE 1 À la Figure 1 b) et ailleurs dans le présent document, les fiches sont représentées avec des tailles différentes pour indiquer le caractère directionnel lorsque le câblage comporte des adaptateurs connectés à l'avance et que le cordon d'essai n'en comporte pas, ou inversement. À la Figure 1 b), un adaptateur est connecté à l'avance sur la fiche située à gauche.

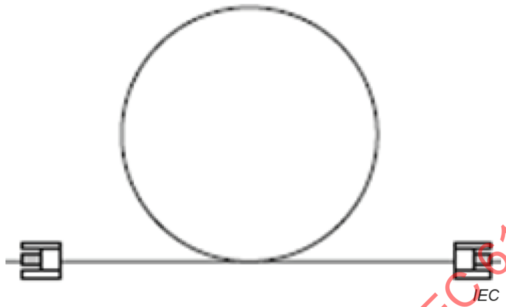
NOTE 2 Lorsqu'elles sont utilisées sur toutes les figures du présent document, y compris celles des annexes, les terminaisons de classe de référence et les adaptateurs sont grisés.

NOTE 3 Une connexion simplifiée de deux blocs utilisée à l'Annexe E et à l'Annexe I est représentée à la Figure 1 e).

NOTE 4 Une connexion simplifiée pour les connecteurs avec des broches d'alignement sur une embase utilisée à l'Annexe J est représentée à la Figure 1 f).

NOTE 5 Une paire de connecteurs avec angle utilisée à la Figure 8, à l'Annexe F et à l'Annexe G est représentée à la Figure 1 g).

Aux figures qui présentent les configurations de mesure des annexes de l'Annexe A à l'Annexe E, le câblage en essai est représenté par une boucle, comme représenté à la Figure 2. Bien qu'elle soit présentée comme une boucle de fibre, elle peut contenir des épissures et des connecteurs supplémentaires, en plus des connecteurs d'extrémité. Noter que pour mesurer l'affaiblissement de ce câblage, les affaiblissements associés aux connecteurs d'extrémité sont considérés séparément de ceux du câblage en lui-même.



NOTE Le câblage est représenté avec des adaptateurs connectés à l'avance, et les fiches qui y sont branchées sont associées aux fiches du cordon d'essai de la classe de référence.

Figure 2 – Symbole d'un câblage en essai

3.3 Abréviations

APC	Angled Physical Contact (contact physique avec angle) (description d'un modèle de connecteur)
ASE	Amplified Spontaneous Emissions (émissions spontanées amplifiées)
ATM	Alternative Test Method (méthode d'essai en variante)
CW	Continuous Wave (onde entretenue)
CWDM	Coarse Wavelength Division Multiplexing (multiplexage par répartition en longueur d'onde grossière)
DWDM	Dense Wavelength Division Multiplexing (multiplexage par répartition en longueur d'onde à forte densité)
FTTH	Fibre-To-The-Home (fibre jusqu'à l'abonné)
LED	Light Emitting Diode (diode électroluminescente)
LS	Light Source (source lumineuse optique)
LSA	Least Squares Approximation (approximation par la méthode des moindres carrés)
OCWR	Optical Continuous Wave Reflectometer (réflectomètre à onde entretenue optique)
PC	Physical Contact (contact physique) (description d'un modèle de connecteur sans angle)
MP	appareil de mesure de la puissance
WDM	Wavelength Division Multiplexing (multiplexage par répartition en longueur d'onde)

4 Méthodes de mesure

4.1 Généralités

4.1.1 Structure du document

Les exigences générales concernant l'appareillage, les procédures et les calculs, qui sont communes à toutes les méthodes, sont indiquées dans le texte principal du présent document. Les exigences spécifiques à chaque méthode sont rapportées de l'Annexe A à l'Annexe G. Les procédures de nettoyage et d'examen des faces d'extrémité des connecteurs sont décrites en 6.9 et en 7.2.

4.1.2 Affaiblissement

Le présent document décrit cinq méthodes de mesure de l'affaiblissement. Les cinq méthodes de mesure utilisent des cordons d'essai comme interface avec l'installation câblée et sont désignées par:

1) méthode de référence à un seul cordon (voir l'Annexe A);
2) méthode de référence à trois cordons (voir l'Annexe B);
3) méthode de référence à deux cordons (voir l'Annexe C);
4) méthode des cordons d'équipement (voir l'Annexe D);
5) méthode par réflectomètre optique dans le domaine temporel (OTDR) (voir l'Annexe E).

Les quatre premières méthodes utilisent une source lumineuse optique et un appareil de mesure de la puissance (LSPM) pour mesurer les niveaux de puissance d'entrée et de sortie du câblage en essai afin de déterminer l'affaiblissement. La différence fonctionnelle principale entre ces méthodes est la façon dont le niveau de puissance d'entrée, appelé niveau de puissance de référence, est mesuré et ainsi, l'inclusion ou l'exclusion des pertes associées aux connexions avec le câblage en essai, et les incertitudes associées à ces connexions. Le processus de mesure du niveau de puissance d'entrée est couramment appelé "prise du niveau de puissance de référence".

L'utilisation du terme "référence" dans la description des méthodes d'essai se réfère au procédé de mesure de la puissance d'entrée et non à l'état de l'essai.

La méthode de référence à un seul cordon produit des résultats qui comportent l'affaiblissement associé aux connexions aux deux extrémités du câblage en essai. La méthode de référence à trois cordons produit des résultats qui tentent d'exclure l'affaiblissement des connexions aux deux extrémités du câblage en essai. La méthode de référence à deux cordons produit normalement des résultats qui comportent l'affaiblissement associé à l'une des connexions du câblage en essai. La méthode des cordons d'équipement inclut l'affaiblissement associé aux connexions entre les cordons d'équipement et le câblage fixe, mais exclut l'affaiblissement associé aux connecteurs qui sont connectés à l'équipement (c'est-à-dire le système de transmission).

NOTE L'affaiblissement maximal du câblage spécifié pour un système de transmission (par perte de bilan de puissance optique ou perte d'insertion dans le canal, par exemple) exclut normalement les connexions effectuées avec l'équipement de transmission. Il est donc approprié d'utiliser la méthode de référence à trois cordons lorsqu'il est prévu de connecter directement le câblage en essai à l'équipement de transmission.

Dans la méthode par OTDR, de courtes impulsions lumineuses sont injectées dans le câblage et la puissance rétrodiffusée est mesurée en fonction du temps de propagation ou de la longueur de la fibre. Cette méthode permet également de déterminer les valeurs d'affaiblissement dans des composants de câblage individuels. Elle n'exige pas d'effectuer une mesure de référence séparée. Les exigences relatives aux cordons d'injection et de fin sont définies à l'Annexe E. Outre la mise en service des nouvelles installations câblées, la méthode par OTDR s'avère utile pour soumettre le câblage à fibres optiques à essai pendant le dépannage et la maintenance, car l'installation câblée peut être caractérisée par une carte détaillée (la trace OTDR) qui peut être analysée afin de mettre en exergue tout changement.

Des recommandations sur chaque méthode de mesure de l'affaiblissement sont fournies de l'Annexe A à l'Annexe E. Une vue d'ensemble des incertitudes pour chaque méthode de mesure est donnée à l'Article 5.

4.1.3 Affaiblissement de réflexion optique

Le présent document définit également deux types de méthodes d'essais qui peuvent être utilisées pour mesurer l'affaiblissement de réflexion optique d'une installation de câblage:

a) la méthode basée sur l'OTDR;
b) la méthode des ondes continues utilisant un montage d'essai pour l'affaiblissement de réflexion.

La méthode par OTDR permet de mesurer l'affaiblissement de réflexion optique de tout le câblage et la réflectance de composants discrets individuels ou l'affaiblissement de réflexion optique de sections spécifiques du câblage. La mesure peut être effectuée en une étape à partir de chaque extrémité du câblage en essai. Cette méthode est décrite en détail dans l'Article E.5.

La méthode des ondes continues décrite à l'Annexe F mesure directement la puissance émise dans le câblage en essai sous la forme d'une étape de mesure initiale, puis la compare à la puissance réfléchie mesurée par un coupleur directif. Des mesures de référence ou d'étalonnage supplémentaires sont exigées pour quantifier l'affaiblissement par le coupleur directif et pour annuler toutes les réflexions internes dans l'appareil de mesure.

La méthode d'essai utilisant les ondes continues décrite à l'Annexe G calcule le niveau de puissance émis et la puissance réfléchie d'une manière semblable à la méthode décrite à l'Annexe F. Une autre mesure de référence d'une terminaison de réflectance connue est exigée pour mettre en œuvre cette méthode.

4.2 Configurations de câblage et méthodes d'essai applicables

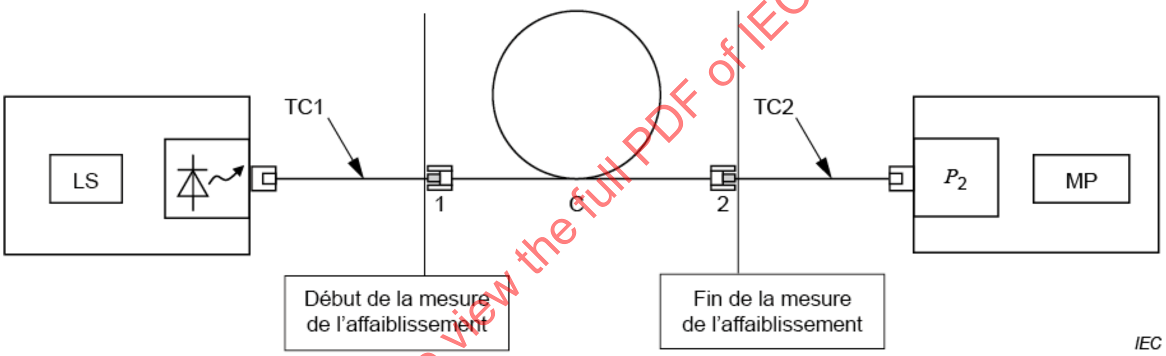
4.2.1 Configurations de câblage et méthodes d'essai applicables pour les mesures de l'affaiblissement

Le présent document prend pour hypothèse que le câblage installé prend l'une des trois formes indiquées dans le Tableau 1. Si le câblage se termine par un adaptateur, le cordon d'essai doit se terminer par une fiche et réciproquement.

Tableau 1 – Configurations du câblage

Configuration	Description	Connexions d'extrémité (affaiblissement inclus)
A	Adaptateurs fixés à des fiches ou des embases fixées aux deux extrémités du câblage	Deux
B	Fiches aux deux extrémités	Néant
C	Configuration mixte dans laquelle une extrémité du câblage est équipée d'un adaptateur et l'autre extrémité d'une fiche	Une (terminée avec un adaptateur)
D	Fiches aux deux extrémités utilisant des cordons d'équipement	Néant

Les variantes de la méthode d'essai utilisée pour mesurer le câblage dépendent de la configuration de câblage. Par exemple, une configuration de câblage courante comporte des adaptateurs ou des embases aux deux extrémités du câblage (par l'intermédiaire de panneaux de brassage, par exemple) en attendant d'être connectés à un équipement de transmission ou de réception fibronique avec un cordon d'équipement. Il s'agit de la configuration A. Dans ce cas, la méthode de référence à un cordon est utilisée pour tenir compte des affaiblissements associés aux deux connecteurs d'extrémité du câblage (voir la Figure 3).



Légende

LS source lumineuse optique

TC1 cordon d'injection

C câblage en essai

TC2 cordon de réception

MP appareil de mesure de la puissance

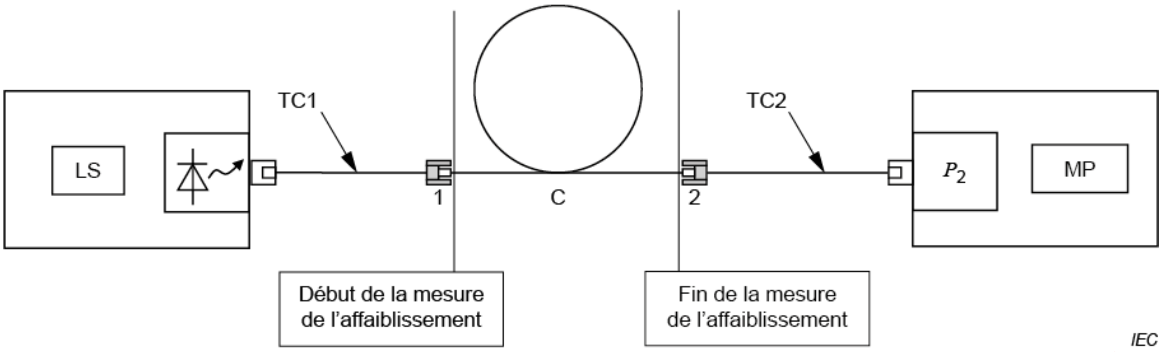
1, 2 jeux de connecteurs

P_2 niveau de puissance mesuré

NOTE La Figure 3 est un exemple de câblage dans la configuration A avec les cordons d'essai TC1 et TC2 attachés, montrant le début et la fin des affaiblissements mesurés lorsque la méthode d'essai de référence est utilisée (la méthode de référence à un seul cordon détaillée à l'Annexe A).

Figure 3 – Configuration A – Début et fin des affaiblissements mesurés dans la méthode d'essai de référence

Un autre exemple est une configuration de câblage dans laquelle des fibres amorces renforcées ont été épissurées aux extrémités du câble principal, les connecteurs des fibres amorces devant être directement connectés à l'équipement de transmission ou de réception fibronique. Il s'agit de la configuration B, présentée à la Figure 4. Dans ce cas, une méthode de référence à trois cordons est utilisée pour exclure l'affaiblissement des connexions mâles d'extrémité. La Figure 4 présente le début et la fin des affaiblissements mesurés lorsque la méthode d'essai de référence est utilisée (méthode de référence à trois cordons, comme détaillé à l'Annexe B).



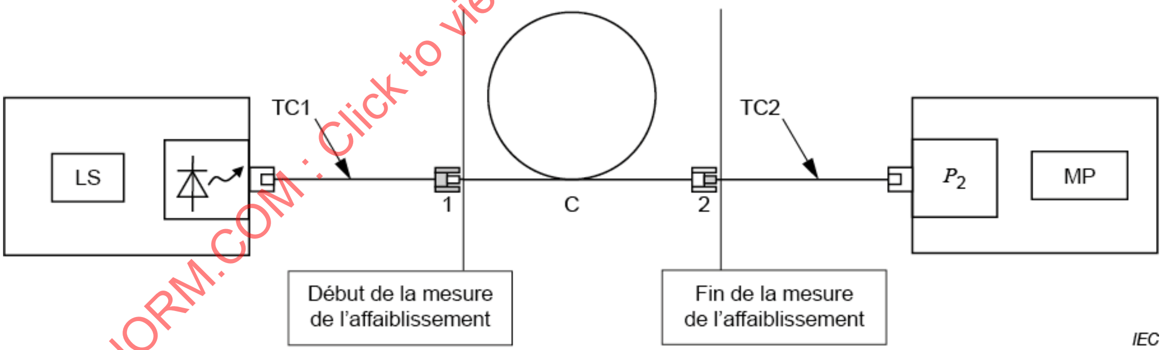
Légende

LS	source lumineuse optique
TC1	cordon d'injection
C	câblage en essai
TC2	cordon de réception
MP	appareil de mesure de la puissance
1, 2	jeux de connecteurs
P_2	niveau de puissance mesuré

NOTE Les fiches sont représentées avec des tailles différentes pour indiquer le caractère directionnel lorsque le câblage comporte des adaptateurs connectés à l'avance et que le cordon d'essai n'en comporte pas, ou inversement.

Figure 4 – Configuration B – Début et fin des affaiblissements mesurés dans la méthode d'essai de référence

La Figure 5 est un exemple de câblage dans la configuration C avec les cordons d'essai attachés, montrant le début et la fin des affaiblissements mesurés lorsque la méthode d'essai de référence est utilisée (la méthode de référence à deux cordons détaillée à l'Annexe C).

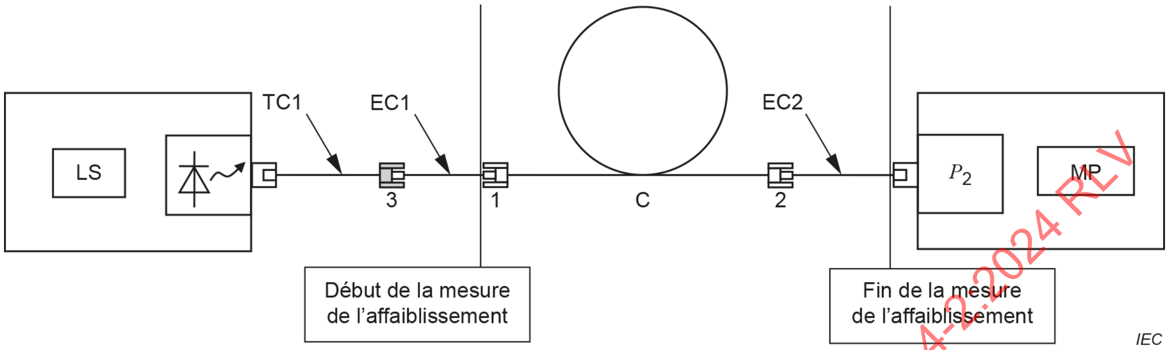


Légende

LS	source lumineuse optique
TC1	cordon d'injection
C	câblage en essai
TC2	cordon de réception
MP	appareil de mesure de la puissance
1, 2	jeux de connecteurs
P_2	niveau de puissance mesuré

Figure 5 – Configuration C – Début et fin des affaiblissements mesurés dans la méthode d'essai de référence

Un exemple supplémentaire est une configuration de câblage dans laquelle les cordons d'équipement sont installés aux deux extrémités du câblage et sont en attente de connexion à un équipement de transmission ou de réception fibronique. Il s'agit de la configuration D, présentée à la Figure 6. Dans ce cas, la méthode des cordons d'équipement (ou, si elle ne peut pas être appliquée, la méthode à trois cordons) est utilisée pour exclure l'affaiblissement des connexions mâles d'extrémité.



Légende

LS	source lumineuse optique
TC1	cordon d'injection
EC1	cordon d'injection de l'équipement
C	câblage en essai
EC2	cordon de réception de l'équipement
MP	appareil de mesure de la puissance
1, 2, 3	jeux de connecteurs
P_2	niveau de puissance mesuré

Figure 6 – Configuration D – Début et fin de l'affaiblissement mesuré dans la méthode d'essai de référence

La configuration spécifique utilisée pour mesurer l'affaiblissement (c'est-à-dire A, B, C ou D) définit la méthode d'essai (ou les méthodes d'essai) qu'il convient d'appliquer (voir le Tableau 2). La méthode de mesure de référence (RTM) offre la meilleure exactitude de mesure. D'autres méthodes d'essai (ATM) peuvent être invoquées dans certaines circonstances spécifiques ou par d'autres normes, mais leur exactitude de mesure apparaît moins bonne lorsqu'elles sont comparées à la méthode d'essai de référence. Sauf accord contraire, pour la résolution des litiges, la méthode d'essai de référence appropriée doit être utilisée conjointement avec les terminaisons de classe de référence et les adaptateurs applicables, comme décrit en 6.3, 6.4, 6.5 et 6.10.

Tableau 2 – Méthodes et configuration des essais

Configuration	RTM	ATM
A	Annexe A (1 cordon)	Annexe B (3 cordons)[a], Annexe C (2cordons), Annexe E (OTDR)
B	Annexe B (3 cordons)	Annexe E (OTDR)
C	Annexe C (2 cordons)	Annexe B (3 cordons), Annexe E (OTDR)
D	Annexe D (cordon d'équipement)	Annexe B (3 cordons), Annexe E (OTDR)

NOTE Ces configurations, les RTM et les annexes sont indiquées dans l'ordre des fréquences rencontrées généralement avec les différentes configurations.

[a] Si des connecteurs de type broché/non broché ou fiche/embase sont utilisés (MTRJ, SG ou d'autres connecteurs pour environnement hostile, par exemple) et si l'appareil de mesure de la puissance n'accepte pas le connecteur non broché ou la fiche du cordon d'injection, la méthode représentée à la Figure C.3 peut être utilisée.

Si des informations sur les composants discrets installés à l'intérieur du câblage en essai sont exigées, l'Annexe E présente la seule de ces méthodes d'essai à fournir ces informations.

4.2.2 Configurations de câblage et méthodes d'essai applicables pour les mesures de l'affaiblissement de réflexion optique

N'importe laquelle des configurations de câblage décrites en 4.2.1 peut être mesurée en utilisant l'une des trois méthodes d'essai par ORL définies à l'Annexe E, à l'Annexe F et à l'Annexe G.

La méthode d'essai par ORL d'un OTDR décrite à l'Article E.5 n'exige pas de réaliser de mesure de référence séparée et est la moins sujette aux erreurs de mesure. Quand le câblage est soumis à un essai en utilisant des cordons d'injection et de fin appropriés, il est aisé de définir le début et la fin de la mesure par ORL comme cela est représenté à la Figure E.5.

Les méthodes d'essai par ORL à ondes continues décrites à l'Annexe F et à l'Annexe G offrent un moyen de mesurer l'ORL. La méthode décrite à l'Annexe G est plus applicable aux mesures sur le terrain, car elle utilise la même source lumineuse optique et le même appareil de mesure de la puissance. Des précautions particulières doivent être prises si un câble court (< 10 km) est soumis aux essais avec un connecteur PC (sans angle) à l'extrémité éloignée. Si ce connecteur est laissé ouvert, la réflexion indésirable sur cette interface verre/air domine la totalité de l'ORL. C'est pourquoi l'utilisation d'un cordon de fin avec une connexion PC à une extrémité et une connexion APC à l'autre extrémité (voir la Figure F.1) permet de supprimer la réflexion verre/air tout en fournissant une contribution d'une réflectance représentative depuis une paire de connecteurs à l'extrémité éloignée du système.

La méthode d'essai de mesure par ORL à ondes continues (CW), telle que décrite à l'Annexe G, ne comprend pas de mesure directe de la puissance émise entrant dans le système soumis à essai, et exige des mesures de référence sur les terminaisons de réflectance connue.

5 Vue d'ensemble des incertitudes pour les mesures de l'affaiblissement

5.1 Généralités

Il convient de déterminer les incertitudes de mesure en utilisant le calcul présenté dans l'IEC TR 61282-14.

Même si une feuille de calcul est fournie, le calcul complet des incertitudes de mesure est relativement complexe compte tenu du grand nombre de paramètres à prendre en compte. Les paragraphes 5.2 à 5.8 sont une alternative à ce calcul.

5.2 Sources d'incertitudes significatives

Pour les conditions types, les calculs effectués sur la base de l'IEC TR 61282-14 indiquent que les sources d'incertitudes significatives sont limitées à celles induites par l'instabilité de la source, la méthode de mesure et la reproductibilité de l'accouplement des connecteurs.

Les autres sources d'incertitudes, telles que la longueur d'onde de la source, la résolution de mesure, la linéarité de l'appareil de mesure de la puissance, sont moins significatives et n'ont pas de répercussion sur les mesurages, car le cumul des incertitudes est une somme quadratique.

5.3 Prise en compte de l'appareil de mesure de la puissance

Il convient que le détecteur de l'appareil de mesure de la puissance (MP) soit suffisamment grand pour capter la totalité de la lumière incidente. De cette façon, l'affaiblissement et l'incertitude associée à l'accouplement du cordon de réception à l'appareil de mesure de la puissance sont minimaux.

5.4 Facteurs à prendre en compte pour la classe de cordon et de connecteur d'essai

5.4.1 Généralités

L'affaiblissement et la réflectance associés aux connexions du cordon d'essai peuvent être différents de l'affaiblissement et de la réflectance présents lorsque le câblage est connecté à d'autres cordons ou à un autre équipement de transmission. L'utilisation de terminaisons de classe de référence sur les cordons d'essai diminue cette incertitude et améliore la reproductibilité de la mesure, mais l'affectation d'un affaiblissement acceptable est différente, conformément à la liste donnée dans le Tableau H.1.

Les cordons d'essai peuvent être de classe de référence ou de classe normale, de sorte que deux conditions de mesure différentes doivent être étudiées. L'utilisation de connecteurs de classe de référence sur des cordons d'essai réduit l'incertitude de mesure, mais modifie les limites d'essai qu'il convient d'appliquer lorsqu'une évaluation de type réussite ou échec est exigée, alors que l'utilisation de connecteurs de classe normale implique une incertitude de mesure beaucoup plus élevée, qui dépasse parfois la mesure réelle de l'affaiblissement (voir le Tableau 3 et l'Annexe H) bien qu'aucun ajustement des limites d'essai ne soit nécessaire.

Tableau 3 – Ajustement de la limite d'essai et incertitude relative à la classe de connecteur du cordon d'essai

Classe de terminaison des cordons d'essai	Classe de terminaison du câblage et des cordons d'équipement	Ajustement de la limite d'essai	Incertitude totale
Classe de référence SM	Classe normale SM	Une limite d'essai inférieure est exigée pour la plupart des mesures, y compris la méthode de référence à cordon d'essai unique et l'essai par OTDR. Toutefois, la méthode de référence à 3 cordons d'essai exige une limite d'essai plus élevée. Voir l'Annexe H pour plus de détails et d'exemples.	Peut être estimée en utilisant les valeurs par défaut de l'IEC TR 61282-14
Classe normale SM	Classe normale SM	Néant	Les valeurs d'incertitude sont supérieures aux valeurs estimées en utilisant les valeurs par défaut de l'IEC TR 61282-14 (voir le Tableau 4)

5.4.2 Variation du diamètre de champ de mode

Si les interfaces d'essai utilisent des fibres dont les diamètres de champ de mode présentent une différence importante, un affaiblissement supplémentaire peut être introduit qui va affecter l'exactitude de mesure. Les normes d'interface optique développées pour les fibres unimodales donnent des détails sur l'affaiblissement introduit par des différences de diamètre de champ de mode (voir par exemple l'IEC 61755-2-1 pour les interfaces sans angle et l'IEC 61755-2-2 pour les interfaces avec angle de 8 degrés).

5.5 Réflexions sur d'autres interfaces

Pendant les mesures de l'affaiblissement de réflexion optique, des réflexions sur d'autres interfaces peuvent constituer une cause importante d'incertitude de mesure, en particulier pour la méthode des ondes entretenues. Il est important de configurer le câblage en essai pour supprimer les réflexions indésirables. Par exemple, pendant l'essai d'un câble court, il convient de coupler un cordon d'essai à l'extrémité éloignée du câblage en essai avec un connecteur avec angle à l'extrémité distante du cordon d'essai. En règle générale, l'interface de connecteur du montage d'essai pour l'affaiblissement de réflexion est un connecteur avec angle.

Pour la méthode de mesure de l'affaiblissement de réflexion par OTDR, l'utilisation de cordons d'injection et de cordons de fin de longueur appropriée permet d'éliminer l'effet des réflexions indésirables.

5.6 Source optique

Les sources d'incertitude suivantes sont pertinentes pour les mesures de l'affaiblissement:

– longueur d'onde de la source lumineuse optique, car l'affaiblissement de la fibre peut être différent à la longueur d'onde de la source et à la longueur d'onde de l'émetteur du système de câblage;
– largeur spectrale de la source lumineuse optique, car des sources lumineuses optiques à spectre plus large peuvent mesurer différentes valeurs d'affaiblissement des fibres que les sources lumineuses optiques à spectre plus étroit, alors que les sources optiques ayant une largeur spectrale trop étroite peuvent introduire des effets d'interférence cohérents indésirables.

5.7 Référence de puissance de sortie

Pour les méthodes utilisant une source lumineuse optique et un appareil de mesure de la puissance (LSPM), l'une des principales sources d'incertitude est le rendement du couplage variable entre la source lumineuse optique et le cordon d'injection, compte tenu des tolérances mécaniques. Pour réduire le plus possible cette incertitude, il convient d'effectuer un relevé de la puissance de référence à chaque fois que la connexion est perturbée par une contrainte exercée sur le connecteur ou par une déconnexion.

Pour les méthodes LSPM, une mesure de référence doit être réalisée pour déterminer la puissance de sortie du cordon d'injection couplé au câble ou à l'installation câblée en essai. Il convient d'effectuer cette mesure à chaque fois que le cordon d'injection est relié à la source, car le couplage peut être légèrement différent à chaque fois qu'il est effectué.

5.8 Mesures bidirectionnelles

Pour les méthodes LSPM de mesure de l'affaiblissement, il convient que les résultats d'essai de chaque extrémité du câblage soient très semblables. Une bonne pratique pour évaluer la validité des résultats de mesure consiste à comparer les résultats de mesure de chaque extrémité et à s'assurer qu'ils sont dans les limites d'une certaine tolérance (0,5 dB, par exemple) l'un de l'autre, en veillant à n'introduire aucune incertitude supplémentaire en raison d'erreurs de mesure.

5.9 Incertitudes types pour les méthodes d'affaiblissement A, B, C et D

Les incertitudes types relatives aux mesures d'affaiblissement sont présentées dans le Tableau 4. Ces valeurs ont été calculées en utilisant l'IEC TR 61282-14, en prenant pour hypothèse les conditions suivantes:

- MP: utilisation du même photodétecteur dans l'appareil de mesure de la puissance pour mesurer la puissance de référence et la puissance d'affaiblissement; la polarité de la mesure de référence est la même que celle du câblage soumis à essai;
- longueur d'onde centroïdale de la source (voir l'IEC 61280-1-3): 1 310 nm et 1 550 nm ± 30 nm ;
- niveau de la source: ≥ −7 dBm (0,2 mW);
- stabilité de la source: ±0,10 dB (k = 2);
- fibres optiques: catégories B-652 et B-657 de l'IEC 60793-2-50;
- connecteurs PC de classe de référence R2: affaiblissement ≤ 0,2 dB, référence IEC 61755-2-4;
- reproductibilité de la connexion: 0,05 dB.

NOTE Au moment de la rédaction du présent document, il était prévu que la désignation "R2" pour les connecteurs de classe de référence pour fibres unimodales avec un affaiblissement de 0,2 dB soit remplacée par une nouvelle désignation "R_{s1-2}" dans la future Édition 2 de l'IEC 61755-2-4, qui soit également appelée "Rs1-Grade 2" dans l'Édition 3 de l'ISO/IEC 14763-3[1].

[1] Troisième édition en préparation. Stade au moment de la publication: ISO/IEC FDIS 14763-3:2024.

Tableau 4 – Incertitude pour une longueur et un affaiblissement de fibre donnés à 1 310 nm, 1 550 nm et 1 625 nm

				Valeurs d'incertitude à 95 % à 1 310 nm			
Distance km	Affaiblis-sement dB	Désignation IEEE 802.3	Désignation de type selon l'UIT	1 cordon dB	2 cordons dB	3 cordons dB	Cordon d'équi-pement dB
0,5	3,0	DR		0,32	0,38	0,44	0,14
2,0	4,0	FR		0,33	0,39	0,44	0,16
5,0	4,8			0,36	0,42	0,46	0,22
10,0	6,3	LR		0,46	0,50	0,54	0,35
20,0	11,0		S	0,72	0,75	0,78	0,66
40,0	18,0	ER		1,33	1,35	1,36	1,30
				Valeurs d'incertitude à 95 % à 1 550 nm[a]			
Distance km	Affaiblis-sement dB	Désignation IEEE 802.3	Désignation de type selon l'UIT	1 cordon dB	2 cordons dB	3 cordons dB	Cordon d'équi-pement dB
0,5	3,0	DR		0,32	0,38	0,44	0,14
2,0	2,5	FR		0,32	0,38	0,44	0,14
5,0	3,3			0,33	0,38	0,44	0,14
10,0	4,5	LR		0,33	0,39	0,44	0,15
20,0	7,0		I	0,34	0,40	0,45	0,18
40,0	11,0	ER	S	0,39	0,44	0,48	0,25
80,0	22,0	ZR	L	0,53	0,57	0,60	0,44
120,0	33,0	OIF 400ZR	U	0,70	0,73	0,76	0,64
				Valeurs d'incertitude à 95 % à 1 625 nm[b]			
Distance km	Affaiblis-sement dB	Désignation IEEE 802.3	Désignation de type selon l'UIT	1 cordon dB	2 cordons dB	3 cordons dB	Cordon d'équi-pement dB
80,0	24,4	ZR	L	1,75	1,77	1,78	1,73
120,0	36,6	OIF 400ZR	U	2,61	2,61	2,62	2,59
				Valeurs d'incertitude à 95 % à 1 625 nm[b] ± 15 nm			
Distance km	Affaiblis sement dB	Désignation IEEE 802.3	Désignation de type selon l'UIT	1 cordon dB	2 cordons dB	3 cordons dB	Cordon d'équipeme nt dB
80,0	24,4	ZR	L	0,92	0,94	0,97	0,87
120,0	36,6	OIF 400ZR	U	1,33	1,35	1,36	1,30

Si l'incertitude est supérieure à l'affaiblissement mesuré, la valeur mesurée peut être sans signification. Dans ce cas, il est recommandé de remplacer la valeur mesurée par la valeur de l'incertitude.

[a] Bien que les applications de l'IEEE ne fonctionnent pas à 1 550 nm sur de plus courtes distances, il est recommandé de soumettre à essai le câblage à fibres unimodales à deux longueurs d'onde différentes (généralement 1 310 nm et 1 550 nm) pour identifier les éventuels problèmes avec les courbures de fibre. Il est donc utile de connaître l'incertitude de mesure à 1 550 nm.

[b] De même, pour les liaisons plus longues, il est recommandé de mesurer l'affaiblissement à une deuxième longueur d'onde (1 625 nm, par exemple) même si la plupart des systèmes de transmission ne fonctionnent pas à cette longueur d'onde.

5.10 Valeurs d'incertitude type pour les essais d'affaiblissement des fibres unimodales pour la méthode E

Les incertitudes types qui ont généré les valeurs du Tableau 5 ont été calculées en utilisant l'IEC 61280-4-3, en prenant pour hypothèse les conditions suivantes:

- mesure bidirectionnelle, marge dynamique: > 5 dB (voir notes dans le Tableau 5);
- OTDR, régression linéaire: 100 points de données (voir notes dans le Tableau 5);
- longueur d'onde centroïdale de la source (voir l'IEC 61280-1-3): 1 310 nm et (1 550 ± 30) nm;
- fibres optiques: catégories B-652 et B-657 de l'IEC 60793-2-50;
- connecteurs APC de classe de référence R2: affaiblissement ≤ 0,2 dB, référence IEC 61755-2-5.
- reproductibilité de la connexion: 0,05 dB.

NOTE Au moment de la rédaction du présent document, il était prévu que la désignation "R2" pour les connecteurs de classe de référence pour fibres unimodales avec un affaiblissement de 0,2 dB soit remplacée par une nouvelle désignation "R_{s1-2}" dans la future Édition 2 de l'IEC 61755-2-5, qui soit également appelée "Rs1-Grade 2" dans l'Édition 3 de l'ISO/IEC 14763-3.

Tableau 5 – Incertitude pour une longueur de fibre donnée à 1 310 nm et 1 550 nm par OTDR

Valeurs d'incertitude à 95 %				
Longueur km	**Affaiblissement à 1310 nm** dB	**Incertitude à 1 310 nm** dB	**Affaiblissement à 1 550 nm** dB	**Incertitude à 1 550 nm** dB
0,5	3,0	0,44	3,0	0,43
2,0	4,0	0,45	2,5	0,43
5,0	4,8	0,47	3,3	0,43
10,0	6,3	0,55	4,5	0,43
40,0	11,0	1,39	7,0	0,50
80,0	18,0	2,63	11,0	0,61
Les longueurs des cordons d'injection et de fin ont été définies à 500 m pour les longueurs allant de 0,5 km à 10 km, ce qui a conduit à une longueur de régression linéaire de 250 m (100 points). L'affaiblissement associé permet une marge dynamique suffisante à 10 dB dans ces deux cas. À 40 km, la longueur de régression linéaire était de 500 m et 100 points, en utilisant des cordons d'injection et de fin de 1 000 m de longueur. Toutefois, la marge dynamique a été réduite à 5 dB. L'incertitude de la longueur d'onde de la source (par hypothèse de 30 nm) a des répercussions sur les incertitudes d'affaiblissement pour des longueurs de 40 km et 80 km à une longueur d'onde de 1 310 nm. Le fait de ramener cette incertitude de 30 nm à 20 nm réduirait les incertitudes d'affaiblissement à 1 310 nm à respectivement 1,00 dB et 1,80 dB.				

6 Appareillage

6.1 Généralités

L'Annexe A et l'Annexe E donnent les exigences relatives aux appareillages spécifiques à des méthodes particulières. Certaines des exigences communes aux méthodes LSPM sont décrites de 6.2 à 6.10.

6.2 Source lumineuse optique

6.2.1 Stabilité

Les performances de la source lumineuse optique sont évaluées à la sortie du cordon d'injection, en transmettant dans le cordon d'injection la sortie d'une source de rayonnement adaptée, généralement un laser. La source doit être stable en ce qui concerne la position, la longueur d'onde et la puissance pendant toute la durée de la procédure de mesure.

Il est recommandé de vérifier la stabilité de la source en répétant la mesure de référence à la fin de la procédure de mesure. Il convient qu'elle reste dans certaines limites de tolérance de la valeur de référence initiale. Il convient que la stabilité de puissance soit d'au moins ±0,10 dB.

6.2.2 Caractéristiques spectrales

Il convient que les longueurs d'onde utilisées pour la mesure de l'affaiblissement soient représentatives des longueurs d'onde sur lesquelles les systèmes de transmission fonctionnent. Pour le câblage de bâtiments et dans beaucoup d'autres applications, cette mesure est effectuée à des longueurs d'onde nominales de 1 310 nm et 1 550 nm.

Si d'autres longueurs d'onde sont à utiliser pour la transmission, des longueurs d'onde d'essai supplémentaires peuvent également être exigées. Par exemple, si des applications de DWDM utilisant la bande L (1 565 nm à 1 625 nm) doivent être utilisées, il est recommandé de procéder également aux essais à 1 625 nm. Si un réseau optique passif pour FTTH est soumis aux essais, des essais à 1 490 nm peuvent être exigés.

Si le câblage en essai est utilisé pour des systèmes CWDM qui couvrent une plage étendue de longueurs d'onde, alors soit il convient de soumettre le câblage à essai à chaque longueur d'onde individuellement, soit une mesure de l'affaiblissement spectral peut être effectuée pour couvrir toute la plage de longueurs d'onde considérée en utilisant une source lumineuse optique à large bande appropriée et un analyseur de spectre optique, au lieu de la source lumineuse optique et de l'appareil de mesure de la puissance. Voir Annexe K pour plus d'informations.

Il est recommandé de procéder aux essais par OTDR sur un câblage unimodal en utilisant au moins deux longueurs d'onde. Cela permet d'identifier l'affaiblissement dû à la courbure de la fibre en comparant les traces aux deux longueurs d'onde. Pour de plus amples informations sur la mesure de l'affaiblissement par courbure, voir I.4.2. Souvent, les longueurs d'onde nominales utilisées sont 1 310 nm et 1 550 nm pour des chemins plus courts (< 40 km) ou 1 550 nm et 1 625 nm pour des chemins plus longs. Les mesurages à une longueur d'onde de 1 650 nm, qui est parfois utilisée pour des canaux de maintenance, sont également très efficaces pour détecter la présence de courbures.

Si le câblage en essai inclut des éléments à longueurs d'onde sélectives (des dispositifs WDM, DWDM ou CWDM et des filtres optiques, par exemple), la largeur spectrale de la source lumineuse optique doit être compatible avec celle des bandes de transmission de ces éléments. Cela peut exiger des sources du rayonnement lumineux à largeur spectrale très étroite. En variante, la réponse spectrale du système peut être évaluée en utilisant une source lumineuse optique à large bande et un analyseur de spectre optique en utilisant la procédure décrite à l'Annexe K.

Pour les mesurages LSPM, la largeur spectrale de la source lumineuse optique unimodale doit satisfaire aux exigences du Tableau 6, lorsqu'elle est mesurée conformément à l'IEC 61280-1-3.

Tableau 6 – Exigences spectrales

Longueur d'onde centroïdale nm	Plage de largeurs spectrales nm
1 310 ± 30 (sur des fibres B-652 et B-657)	≤ 5 (valeur efficace) pour la diode laser ≤ 40 (valeur efficace) pour une LED à émission latérale
1 550 ± 30 (sur des fibres B-652 et B-657)	≤ 5 (valeur efficace) pour la diode laser ≤ 40 (valeur efficace) pour une LED à émission latérale

6.3 Cordon d'injection

À l'exception de la méthode par OTDR, le cordon d'injection doit avoir une longueur de 2 m à 10 m. Pour la longueur du cordon d'injection OTDR, voir l'Annexe E.

Le connecteur ou l'adaptateur terminant le cordon d'injection doit être compatible avec le câblage (type d'extrémité, par exemple) et il convient que la terminaison soit de classe de référence pour réduire le plus possible l'incertitude des résultats de mesure.

La taille de cœur nominale de la fibre optique qui compose le cordon d'injection doit être identique à celle qui compose le câblage en essai.

Les fibres optiques unimodales prises en charge par le présent document et utilisées dans le cordon d'injection unimodal sont appelées B-652 et B-657 dans l'IEC 60793-2-50.

6.4 Cordon de réception ou de fin

La taille de cœur nominale de la fibre optique qui compose le cordon de réception ou de fin doit être identique à celle qui compose le câblage en essai.

La longueur minimale du cordon de réception doit être de 2 m, mais il convient qu'elle ne soit pas trop importante pour éviter que l'affaiblissement de la fibre ait un effet significatif sur le mesurage (moins de 10 m, par exemple).

Le connecteur ou l'adaptateur terminant les cordons de réception ou de fin doit être compatible avec le câblage et il convient que la terminaison soit de classe de référence pour réduire le plus possible l'incertitude des résultats de mesure.

La terminaison d'un cordon de réception au niveau de la connexion avec l'appareil de mesure de la puissance doit être compatible avec celle de l'appareil de mesure de la puissance.

Si un essai unidirectionnel est effectué, aucune exigence relative à la terminaison de classe de référence n'est exigée pour l'extrémité distante du cordon de fin utilisé pour l'essai par OTDR. Si un essai par OTDR bidirectionnel est effectué, le cordon de fin devient le cordon d'injection (voir l'Annexe I) et doit être conforme au 6.3.

6.5 Cordon de remplacement

La taille de cœur nominale de la fibre optique qui compose le cordon de remplacement doit être identique à celle qui compose le câblage en essai.

La longueur minimale du cordon de remplacement doit être de 2 m, sans être trop importante pour éviter que l'affaiblissement de la fibre ait un effet significatif sur le mesurage (moins de 10 m, par exemple).

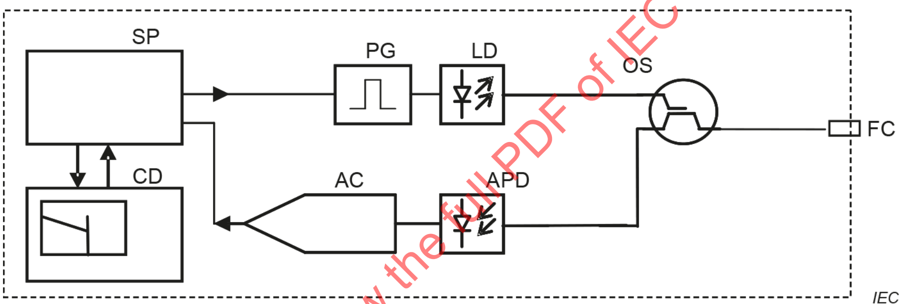
Les connecteurs ou les adaptateurs terminant le cordon de remplacement doivent être compatibles avec le câblage et il convient que les terminaisons soient de classe de référence pour réduire le plus possible l'incertitude des résultats de mesure.

6.6 Appareil de mesure de la puissance – Méthodes LSPM seulement

L'appareil de mesure de la puissance doit être capable de mesurer la plage exigée de niveaux de puissance à des longueurs d'onde normalement associée au câblage, ce qui inclut les considérations relatives à la puissance injectée dans le câblage. L'appareil de mesure de la puissance doit satisfaire aux exigences d'étalonnage de l'IEC 61315. Les dimensions de la surface de détection de l'appareil de mesure de la puissance doivent être suffisantes pour capter toute la puissance provenant de la fibre à laquelle il est connecté. Si une fibre amorce est utilisée, elle doit être suffisamment grande pour recueillir toute la puissance provenant du cordon d'essai.

6.7 Matériel OTDR

La Figure 7 donne une représentation schématique d'un appareillage OTDR typique, avec un seul point de liaison. L'OTDR doit satisfaire aux exigences d'étalonnage de l'IEC 61746-1. L'Annexe E donne des exigences plus détaillées relatives à la longueur du cordon d'injection et à d'autres aspects associés au mesurage par OTDR.



Légende

PG	générateur d'impulsions
LD	diode laser
OS	répartiteur optique
FC	connecteur en face avant
APD	photodiode à avalanche
AC	amplificateur et convertisseur
SP	processeur de signal
CD	commande et affichage

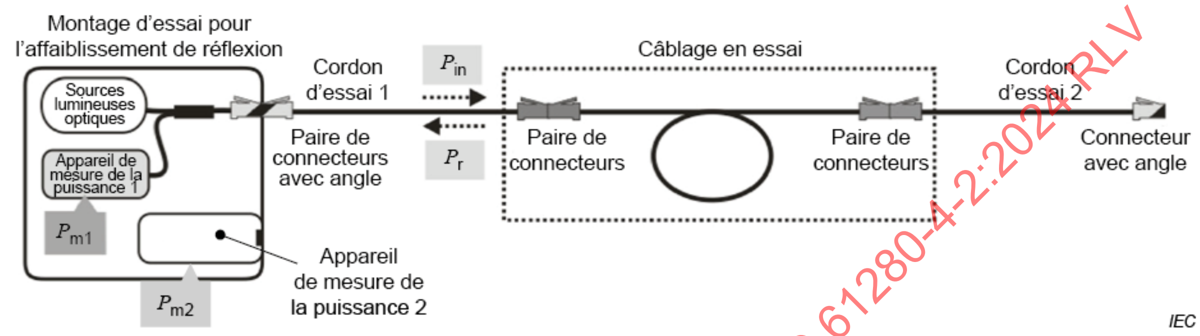
Figure 7 – Représentation schématique d'un OTDR typique

6.8 Montage d'essai pour l'affaiblissement de réflexion

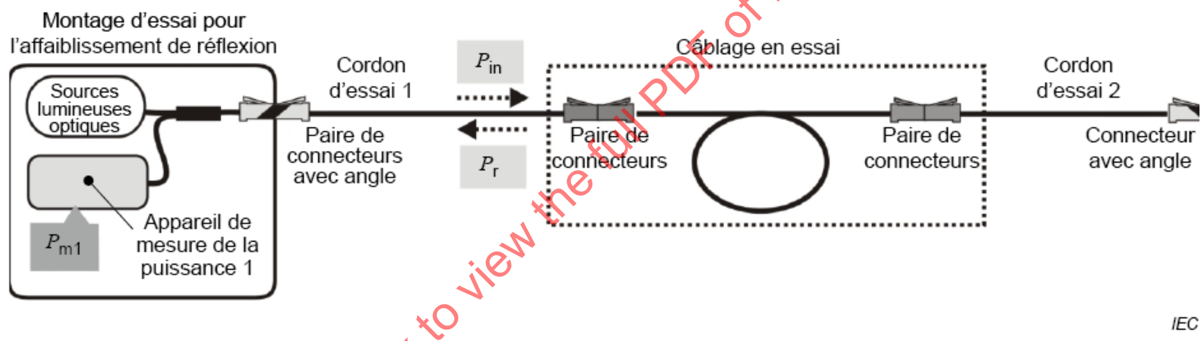
Un montage d'essai pour l'affaiblissement de réflexion comporte généralement une ou plusieurs sources laser stabilisées. Comme le montre la Figure 8, la sortie de la source traverse un coupleur directif vers l'accès de sortie du RLTS qu'il convient d'équiper d'une connexion de basse réflectance. Il convient que sa réflectance soit inférieure à 10 dB par rapport à l'ORL du câblage en essai. Une interface de connecteur avec angle permet généralement d'atteindre cette valeur. L'autre branche du coupleur directif renvoie la lumière réfléchie dans l'appareil de mesure de la puissance interne (P_{m1} dans la Figure 8). Un deuxième appareil de mesure de la puissance (P_{m2} à la Figure 8 a)) avec une interface de connecteur externe est également souvent installé pour mesurer le niveau de puissance qui est délivré au câblage en essai.

D'autres configurations sont possibles sans le deuxième appareil de mesure de la puissance (voir la Figure 8 b)), à condition de calculer la puissance d'entrée du câblage en essai à partir de la mesure d'une réflectance connue ou d'utiliser un deuxième montage d'essai pour l'affaiblissement de réflexion pour mesurer l'entrée de puissance dans le câblage soumis à essai, à condition de pouvoir étalonner l'affaiblissement traversant l'interface du connecteur et le coupleur directif.

Dans une configuration de mesure typique, telle que celle qui est représentée, il est exigé que des cordons d'essai servent d'interface avec le câblage en essai et suppriment les réflexions indésirables en utilisant des connecteurs polis avec angle.



a) Avec un deuxième appareil de mesure de la puissance interne



b) Sans deuxième appareil de mesure de la puissance interne

Figure 8 – Présentation d'un montage d'essai pour l'affaiblissement de réflexion

6.9 Équipement de nettoyage et examen de l'extrémité des connecteurs

L'équipement de nettoyage (incluant l'appareillage, les matières et les substances) et les méthodes de nettoyage à utiliser doivent être conformes à l'IEC TR 62627-01. Les instructions des fabricants de connecteurs doivent être consultées lorsqu'il existe un doute concernant l'adéquation d'un équipement particulier et de méthodes de nettoyage spécifiques.

Un microscope compatible avec la méthode à faible résolution de l'IEC 61300-3-35 est exigé pour vérifier que les faces d'extrémité de la fibre et des connecteurs des cordons d'essai sont propres et ne sont pas endommagées. Des microscopes équipés d'adaptateurs compatibles avec les connecteurs utilisés sont exigés.

L'utilisation d'un microscope vidéo est recommandée pour éviter tout risque de visualisation directe des extrémités de fibres alimentées.

6.10 Adaptateurs

Le cas échéant, les adaptateurs doivent être compatibles avec le modèle de connecteur utilisé et ils doivent permettre d'obtenir les performances exigées des terminaisons de la classe de référence. Pour les connecteurs à férule cylindrique, il convient d'utiliser des manchons en céramique zircone contenus dans l'adaptateur.

7 Procédures

7.1 Généralités

Les exigences relatives aux procédures spécifiques à des méthodes particulières sont présentées de l'Annexe A à l'Annexe G.

Les méthodes LSPM exigent d'effectuer une mesure de référence avant de mesurer le câblage. Il convient d'évaluer les équipements avant de commencer l'essai, afin de vérifier la fréquence à laquelle il convient d'effectuer les mesures de référence. Il convient généralement de procéder à un nouveau mesurage de référence avant que l'appareil ne dérive de plus de 0,1 dB (voir la stabilité en 6.2.1). L'environnement d'essai (en particulier la température) peut avoir une influence sur la fréquence d'un nouveau référencement.

Laisser un laps de temps suffisant pour que la source lumineuse optique se stabilise conformément aux recommandations du fabricant.

7.2 Procédures communes

7.2.1 Précautions relatives aux cordons d'essai

Les connecteurs des cordons d'essai doivent être examinés selon les procédures de l'IEC 61300-3-35. Les extrémités des connecteurs doivent être exemptes de contamination (par exemple, poussières et salissures) et doivent satisfaire aux exigences des tableaux applicables de l'IEC 61300-3-35. En présence de contamination, les extrémités des connecteurs doivent être nettoyées en utilisant l'équipement et les méthodes décrits en 6.9.

NOTE Les exigences en matière de qualité des extrémités des connecteurs dépendent soit des spécifications des connecteurs, soit des exigences de performance du système de communication par fibres optiques, soit des deux à la fois.

Lorsque les cordons d'essai ne sont pas utilisés, il convient de les protéger contre les dommages accidentels en bouchant les extrémités des connecteurs et en rangeant les cordons sans les vriller dans des bobines d'un diamètre supérieur à leur diamètre de courbure minimal.

Avant le début des essais, vérifier les performances optiques de tous les cordons d'essai à utiliser conformément aux procédures de l'Annexe J.

7.2.2 Réalisation des mesures de référence (méthodes LSPM et OCWR seulement)

La puissance de sortie du cordon d'injection doit être mesurée pour chaque longueur d'onde d'essai et être enregistrée dans un format approprié.

Concernant les mesures par OCWR, d'autres niveaux de puissance de référence doivent être relevés et enregistrés selon les exigences de la méthode d'essai utilisée (voir l'Annexe F et l'Annexe G pour plus de détails).

7.2.3 Examen et nettoyage des extrémités des fibres du câblage

Les connecteurs sur des installations de câblage doivent être inspectés en suivant les procédures de l'IEC 61300-3-35. Ils doivent être exempts de contamination (par exemple, poussières et salissures). En présence de contamination, les extrémités des connecteurs doivent être nettoyées en utilisant l'équipement et les méthodes décrits en 6.9, puis de nouveau examinées.

NOTE Les exigences en matière de qualité des extrémités des connecteurs dépendent soit des spécifications des connecteurs, soit des exigences de performance du système de communication par fibres optiques, soit des deux à la fois.

7.2.4 Réalisation des mesures

Comme cela est défini de l'Annexe A à l'Annexe G, les mesures de l'affaiblissement et des ORL entrent dans le cadre d'un processus itératif pour chaque fibre du câblage comprenant:

- la fixation de chacune des fibres aux cordons d'injection et de réception ou de fin;
- l'exécution du mesurage à chaque longueur d'onde;
- la mémorisation ou l'enregistrement des résultats.

Pour les méthodes LSPM, soit l'appareil de mesure de la puissance et le cordon de réception sont déplacés à l'extrémité éloignée du câblage, soit un deuxième appareil de mesure de la puissance et un deuxième cordon de réception peuvent être utilisés à l'extrémité éloignée.

7.2.5 Réalisation des calculs

Effectuer les calculs pour déterminer la différence entre la mesure de référence et les mesures d'essai, et consigner le résultat final, conjointement avec d'autres informations, conformément à l'Article 9.

7.3 Étalonnage

Les appareils de mesure de la puissance et l'équipement de l'OTDR doivent être respectivement étalonnés conformément à l'IEC 61315 et à l'IEC 61746-1.

L'équipement utilisé doit avoir un certificat d'étalonnage valide conforme au système de qualité applicable pendant la période au cours de laquelle l'essai est effectué.

7.4 Sécurité

Tous les essais réalisés sur des systèmes de communications à fibres optiques ou qui emploient un laser dans un montage d'essai doivent être réalisés selon les précautions de sécurité indiquées dans l'IEC 60825-2.

8 Calculs

Pour chaque méthode, les calculs sont indiqués dans les annexes respectives.

9 Documentation

9.1 Informations pour chaque essai

Les informations suivantes doivent être consignées avec chaque essai:

a) procédure et méthode d'essai;

b) résultats de mesure incluant

  – soit l'affaiblissement, soit l'ORL, soit les deux (en dB)

    • la ou les traces de l'OTDR (méthode par OTDR seulement, dans les deux directions lorsque des mesures bidirectionnelles ont été effectuées);

  – la longueur d'onde (en nm);

  – le type de fibre;

  – l'emplacement de la terminaison;

  – l'identifiant de la fibre;

  – l'identifiant du câble;

  – la date de l'essai.

9.2 Informations à fournir

Les informations suivantes doivent être fournies avec chaque essai:

- détails des caractéristiques spectrales de la source lumineuse optique;
- niveau de puissance de référence (en dBm) (méthodes LSPM uniquement);
- registres d'étalonnage avec référence au matériel d'essai;
- détails des cordons d'essai utilisés pour les mesurages;
  – classe de performance des connecteurs de cordon d'essai (classe de référence ou classe normale, par exemple);
  – classe de performance de la fibre dans les cordons d'essai (OSx, par exemple);
  – si la fibre dans les cordons d'essai présente le niveau de performance correspondant à des fibres à macrocourbures améliorées;
  – la longueur des cordons d'essai.

Annexe A
(normative)

Méthode de référence à un seul cordon

A.1 Applicabilité de la méthode d'essai

La mesure par la méthode de référence par un seul cordon inclut l'affaiblissement des deux connexions au câblage en essai. Il s'agit de la RTM pour le mesurage de l'installation câblée de la configuration A (voir 4.2).

Cette méthode a été rédigée pour le cas où une seule fibre est mesurée à la fois. Si des mesurages bidirectionnels sont exigés, les procédures sont répétées par injection par l'autre extrémité.

A.2 Appareillage

La source lumineuse optique, l'appareil de mesure de la puissance et les cordons d'essai utilisés doivent satisfaire aux exigences spécifiées à l'Article 6.

La méthode décrite à l'Annexe A est dite "méthode de référence à un seul cordon", car un seul cordon d'essai (le cordon d'injection) est utilisé pour la mesure de référence. Cependant, un deuxième cordon d'essai (le cordon de réception) est exigé pour la mesure de l'affaiblissement. Il convient de vérifier les performances des cordons d'essai avant le début de l'essai. Pour ce faire, connecter le cordon de réception au cordon d'injection et mesurer l'affaiblissement de la connexion. Voir l'Annexe J pour plus d'informations.

Cette méthode nécessite de relier directement le cordon d'injection à l'appareil de mesure de la puissance pour la mesure de référence. Cela prend pour hypothèse que les connecteurs utilisés dans le câblage sont compatibles avec le connecteur utilisé dans l'appareil de mesure de la puissance.

Cette méthode prend également pour hypothèse ce qui suit:

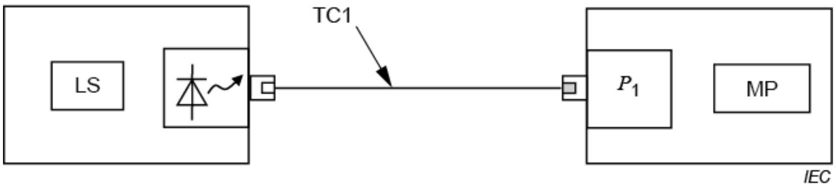
– le connecteur de l'appareil de mesure de la puissance est compatible avec celui du câblage en essai auquel le cordon d'injection est connecté. Le cas échéant, un adaptateur n'ajoutant pas d'incertitude de mesure supplémentaire peut être relié à l'appareil de mesure de la puissance. Une autre méthode (Annexe B) peut être utilisée à condition de reconnaître l'augmentation de l'imprécision de mesure de cette autre méthode, et d'appliquer des limites d'essai modifiées de manière appropriée;
– le cordon d'injection n'est pas déconnecté de la source lumineuse optique entre un mesurage de référence et un mesurage d'essai. Si la conception de l'appareil d'essai ou la conception du câblage en essai rend une telle déconnexion inévitable, l'autre méthode (Annexe B) peut être utilisée, à condition de reconnaître l'augmentation de l'imprécision de mesure de cette autre méthode et d'appliquer des limites d'essai modifiées de manière appropriée.

A.3 Procédure

a) Connecter la source lumineuse optique et l'appareil de mesure de la puissance en utilisant le cordon d'injection (TC1), comme représenté à la Figure A.1.
b) Consigner la puissance optique mesurée, P_1, qui est la mesure de puissance de référence.
c) Déconnecter l'appareil de mesure de la puissance de TC1. Ne pas déconnecter TC1 de la source lumineuse optique sans avoir effectué une nouvelle mesure de référence.
d) Connecter l'appareil de mesure de la puissance au cordon de réception (TC2).

e) Connecter TC1 et TC2 au câblage en essai, comme représenté à la Figure A.2.

f) Consigner la puissance optique mesurée, P_2, qui est la mesure de puissance d'essai.



Légende

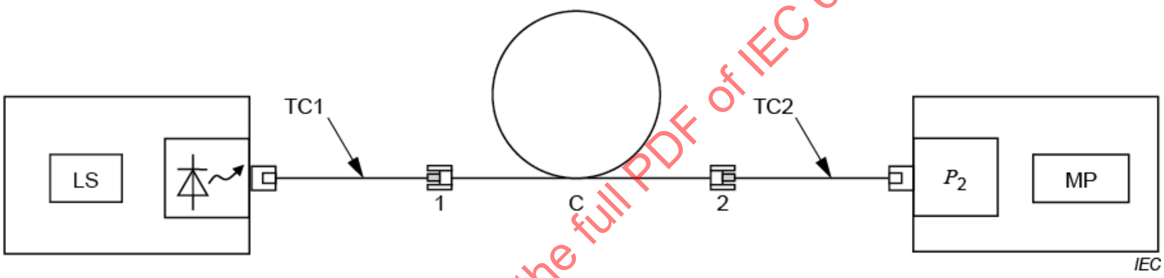
LS source lumineuse optique

TC1 cordon d'injection

MP appareil de mesure de la puissance

P_1 mesure de puissance de référence

Figure A.1 – Mesure de référence à un seul cordon



Légende

LS source lumineuse optique

TC1 cordon d'injection

C câblage en essai

TC2 cordon de réception

MP appareil de mesure de la puissance

1, 2 jeux de connecteurs

P_2 mesure de la puissance d'essai

NOTE Les terminaisons de classe de référence apparaissent en grisé.

Figure A.2 – Mesure d'essai à un seul cordon

A.4 Calcul

L'affaiblissement, A, exprimé en dB, est donné par

$$A = 10 \log_{10}\left(P_1 / P_2\right) \qquad \text{(A.1)}$$

où

P_1 est la puissance de référence en unités linéaires (en W, par exemple);

P_2 est la puissance d'essai en unités linéaires (en W, par exemple).

A.5 Composantes de l'affaiblissement rapporté

Les éléments d'affaiblissement sont identifiés à la Figure A.1 et à la Figure A.2. Ils se composent de l'affaiblissement du câblage, A_c et de deux valeurs d'affaiblissement des connexions, A_1 et A_2, en dB. L'affaiblissement rapporté, A, en dB, est donné par

$$A = A_1 + A_2 + A_c \quad \text{(A.2)}$$

Les différences entre le résultat rapporté par cette méthode et les autres méthodes LSPM sont décrites à l'Annexe H (voir le Tableau H.2).

Annexe B
(normative)

Méthode de référence à trois cordons

B.1 Applicabilité de la méthode d'essai

La méthode de référence à trois cordons s'efforce d'exclure l'affaiblissement des deux connexions au câblage en essai. Il s'agit de la RTM pour le mesurage de l'installation câblée de la configuration B (voir 4.2) et dans certains cas, ou comme l'exigent certaines normes externes, elle peut être utilisée à la place des méthodes d'essai spécifiées à l'Annexe A et à l'Annexe C.

Cette méthode a été rédigée pour le cas où une seule fibre est mesurée à la fois. Si des mesurages bidirectionnels sont exigés, les procédures sont répétées par injection par l'autre extrémité.

B.2 Appareillage

La source lumineuse optique, l'appareil de mesure de la puissance et les cordons d'essai utilisés doivent satisfaire aux exigences spécifiées à l'Article 6. Trois cordons d'essai sont utilisés. Les valeurs d'affaiblissement des connexions entre ces cordons sont déterminantes pour l'incertitude de la mesure. Il convient de vérifier les performances des cordons d'essai avant le début de l'essai. Pour ce faire, connecter le cordon de remplacement et le cordon de réception au cordon d'injection et mesurer l'affaiblissement de la connexion. Voir l'Annexe J pour plus d'informations.

B.3 Procédure

a) Connecter le cordon d'injection (TC1) et le cordon de réception (TC2) à la source lumineuse optique et à l'appareil de mesure de la puissance (voir la Figure B.1).
b) Connecter le cordon de remplacement (TC3) entre TC1 et TC2.
c) Consigner la puissance optique mesurée, P_1, qui est la mesure de puissance de référence.
d) Ne pas déconnecter TC1 de la source lumineuse optique sans avoir effectué une nouvelle mesure de référence.
e) Remplacer le cordon de remplacement par le câblage en essai (en laissant les adaptateurs reliés à TC1 et TC2), suivant les indications de la Figure B.2.
f) Consigner la puissance optique mesurée, P_2, qui est la mesure de puissance d'essai.