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Fibre-optic communication subsystem test procedures –
Part 4-1: Installed cable plant – Multimode attenuation measurement

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FIBRE-OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-1: Installed cable plant – Multimode attenuation measurement

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61280-4-1 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition, published in 2003, and constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

– An additional measurement method based on optical time domain reflectometry (OTDR) is documented, with guidance on best practice in using the OTDR and interpreting OTDR traces.
– The requirement for the sources used to measure multimode fibres is changed from one based on coupled power ratio (CPR) and mandrel requirement to one based on measurements of the near field at the output of the launching test cord.

– Highlighting the importance of, and giving guidance on, good measurement practices including cleaning and inspection of connector end faces.

The text of this standard is based on the following documents:

FDIS	Report on voting
86C/879/FDIS	86C/892/RVD

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

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

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

For the Part 4, the new subtitle will be *Installed cable plant*. Subtitles of existing standards in this series will be updated at the time of the next edition.

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

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

A bilingual version of this publication may be issued at a later date.

FIBRE-OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-1: Installed cable plant – Multimode attenuation measurement

1 Scope

This part of IEC 61280-4 is applicable to the measurement of attenuation of installed fibre-optic cabling using multimode fibre, typically in lengths of up to 2 000 m. This cabling can include multimode fibres, connectors, adapters and splices.

Cabling design standards such as ISO/IEC 11801, ISO/IEC 24702 and ISO/IEC 24764 contain specifications for this type of cabling. ISO/IEC 14763-3, which supports these design standards, makes reference to the test methods of this standard.

In this standard, the fibre types that are addressed include category A1a (50/125 µm) and A1b (62,5/125 µm) multimode fibres, as specified in IEC 60793-2-10. The attenuation measurements of the other multimode categories can be made, using the approaches of this standard, but the source conditions for the other categories have not been defined.

2 Normative references

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

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

IEC 61280-1-3, *Fibre optic communication subsystem basic test procedures – Part 1-3: Test procedures for general communication subsystems – Central wavelength and spectral width measurement*

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

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*

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

IEC 61745, *End-face image analysis procedure for the calibration of optical fibre geometry test sets*

IEC 61746, *Calibration of optical time-domain reflectometers (OTDRs)*

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1 A new edition is in preparation.

3 Terms, definitions, graphical symbols and acronyms

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

3.1 Terms and definitions

3.1.1
attenuation
reduction of optical power induced by transmission through a medium such as cabling, given as L (dB)

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

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

3.1.2
light source power meter
LSPM
test system consisting of a light source (LS), power meter (PM) and associated test cords used to measure the attenuation of installed cable plant

3.1.3
optical time domain reflectometer
OTDR
test system consisting of an optical time-domain reflectometer and associated test cords used to characterize and measure the attenuation of installed cable plant and specific elements within that cable plant

3.1.4
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 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 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 of the cabling under test.

3.1.5
bidirectional measurement
two measurements of the same optical fibre, made by launching light into opposite ends of that fibre

3.1.6
configuration
form or arrangements of parts or elements such as terminations, connections and splices

3.1.7
encircled flux
EF
fraction of cumulative near field power to total output power as a function of radial distance from the optical centre of the core

[from IEC 61280-1-4]

3.1.8
reference grade termination
connector (3.1.9) **plug** (3.1.10) with tightened tolerances terminated onto an optical fibre with tightened tolerances such that the expected loss of a connection formed by mating two such assemblies is less than or equal to 0,1 dB

EXAMPLE: as an example, the core diameter tolerance may need to be ±0,7 micron (ffs). Other fibre tolerances are ffs.

NOTE 1 An adapter (3.1.11), required to assure this performance, may be considered to be part of the reference grade termination where required by the test configuration (3.1.6)

NOTE 2 This definition remains as a point under study. When a more complete definition is available in another document, this definition will be replaced by a reference.

3.1.9
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

{Definition 2.6.1 of IEC/TR 61931}

3.1.10
plug
male-type part of a connector

[Definition 2.6.2 of IEC/TR 61931]

3.1.11
adapter
female-part of a connector in which one or two plugs are inserted and aligned

[Definition 2.6.4 of IEC/TR 61931:1998]

3.1.12
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 Examples include the SG and many harsh environment connectors.

3.1.13
reference test method
RTM
test method used in the resolution of a dispute

3.2 Graphical symbols

The following graphic symbols for different connection options have been adapted from IEC 61930.

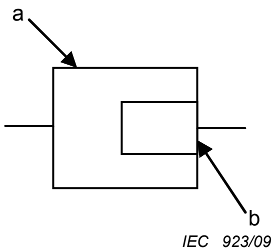

Figure 1a – Socket and plug assembly

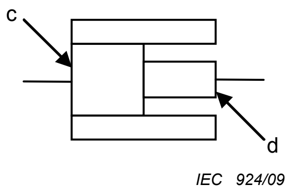

Figure 1b – Connector set (plug, adapter, plug)

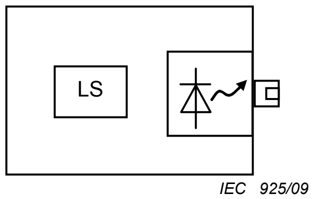

Figure 1c – Light source

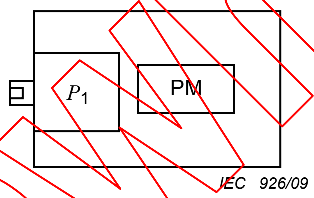

Figure 1d – Power meter

Key

a	socket	d	plug inserted into plug-adapter assembly
b	plug	LS	light source
c	plug-adapter assembly	PM	power meter

Figure 1 – Connector symbols

NOTE 1 In Figure 1b, and elsewhere in this standard, 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 1b, the plug on the left has the adapter pre-attached.

NOTE 2 Reference grade terminations are shown shaded with grey.

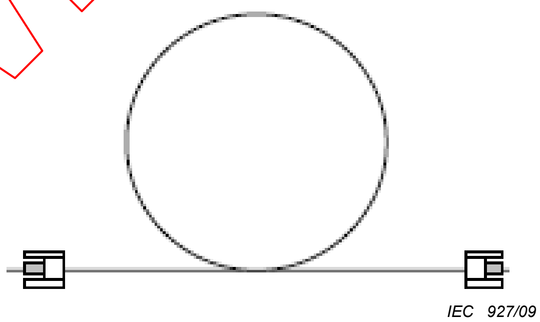

Figure 2 – Symbol for cabling under test

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

NOTE 3 In Figure 2, the cabling is shown with adapters pre-attached and the plugs going into them are associated with reference grade test cord plugs.

3.3 Acronyms

The following acronyms are used:

EF	encircled flux
LSA	least squares approximation
LSPM	light source power meter
OTDR	optical time domain reflectometer
RTM	reference test method

4 Measurement methods

4.1 General

Four measurement methods are designated. The four measurement methods use test cords to interface to the cable plant and are designated as follows:

- one-cord reference method;
- three-cord reference method;
- two-cord reference method;
- optical time domain reflectometer (OTDR) method.

The first three 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 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,' or 'normalization'.

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 includes the attenuation associated with connections at both ends of the cabling under test. The three-cord reference method attempts to exclude the attenuation of the connections of both ends of the cabling under test. The two-cord reference method normally includes the attenuation associated with one of the connections of the cabling under test.

NOTE The maximum allowed cabling attenuation specified (e.g. optical power budget or channel insertion loss) for a transmission system 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 transmission equipment.

The OTDR method emits short light impulses into the cabling and measures the backscattered power as a function of propagation time delay or length along the fibre. This also allows the determination of individual cabling component attenuation values. It does not require a separate reference measurement to be completed. Requirements for the launch cord and tail cord are defined in Annex D.

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 D. The main text also includes related procedures such as connector end face cleaning and inspection.

4.2 Cabling configurations and applicable test methods

This standard assumes that the installed cabling takes one of three 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
A	Adapters attached to plugs or sockets attached to both ends of the cabling
B	Plugs on both ends
C	Mixed, where one end of the cabling is terminated with an adapter and the other end is terminated with a plug

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 equipment with an equipment cord. This corresponds to configuration A. In this case, the one-cord reference method is used to include the losses associated with both end connectors of the cabling. 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.

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.

Table 2 – Test methods and configurations

Configuration	RTM	Alternative method
A	Annex A	Annex B[a]
B	Annex B	–
C	Annex C	Annex B

[a] For situations where pinned/unpinned or plug/socket style connectors are used such as MTRJ, SG or other harsh environment connector but the power meter does not accept the unpinned or plug connector of the launch cord, Figure C.3 may be used.

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

4.3 Overview of uncertainties

4.3.1 General

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

4.3.2 Test cords

A main source of uncertainty involves the connection of the terminated cabling to the test equipment. The attenuation associated with the test cord connections may be different from the attenuation 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 loss is changed as listed in Table F.1.

4.3.3 Launch conditions at the connection to the cabling under test

For all methods, an additional source of uncertainty is related to the characteristic of the optical source at the face of the launch cord. Different regions of the intensity vs. radial position are attenuated differently, depending on how many connections are found in the cabling and the radial offsets between fibre cores at these connection points. Usually, the outer region is attenuated more than the inner region. This is known as differential mode attenuation.

To obtain measurements that are relevant to the types of sources found in transmission equipment, a restricted launch, not an overfilled launch, shall be used. The limits on this restricted launch (see Annex E) are defined to yield attenuation variations of less than ±10 % of the target attenuation for a number of defined conditions when the core diameter of the launch cord fibre is equal to the specification mid-range (the nominal value for the fibre types).

For the OTDR method, the differential mode attenuation occurs not only from the mode coupling resulting from forward transmission through each connection, but also due to the mode coupling resulting from the backscattered power through each connection in the reverse direction. The limits on the near field of the launching cord provide some control on this, but it is not as well quantified as it is for the LSPM methods. There can also be some additional differential mode attenuation at the splitter within the OTDR on the path to the detector that is not subject to an external test. bidirectional testing (see Clause G.6) may reduce this uncertainty.

4.3.4 Optical source

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

- Wavelength of the source – causes fibre attenuation variations between source wavelength and cabling system transmitter wavelength.
- Spectral width – wider spectral widths cause fibre attenuation variations between the source wavelength and the cabling system transmitter wavelength, narrower spectral widths can introduce modal noise.
- Power meter nonlinearity – the linearity error of the power meter.

4.3.5 Output power reference

For methods using 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 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 plant under test. This measurement should be made each time the launch cord is attached to the source, as this coupling may be slightly different each time it is done.