IEC 61746-2

Edition 1.0 2010-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Étalonnage des réflectomètres optiques dans le domaine temporel (OTDR) –
Partie 2: OTDR pour fibres multimodales

IEC 61746-2:2010-06(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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CALIBRATION OF OPTICAL TIME-DOMAIN REFLECTOMETERS (OTDR) –

Part 2: OTDR for multimode fibres

FOREWORD

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International Standard IEC 61746-2 has been prepared by IEC technical committee 86: Fibre optics.

This bilingual version (2015-12) corresponds to the monolingual English version, published in 2010-06.

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

CDV	Report on voting
86/336/CDV	86/359/RVC

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

The French version of this standard has not been voted upon.

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

A list of all parts of IEC 61746 series, under the general title *Calibration of optical time-domain reflectometers (OTDR)*, can be found on the IEC website.

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

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- withdrawn,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

INTRODUCTION

In order for an optical time-domain reflectometer (OTDR) to qualify as a candidate for complete calibration using this standard, it must be equipped with the following minimum feature set:

a) the ability to measure type A1a or A1b IEC 60793-2-10 fibres;

b) a programmable index of refraction, or equivalent parameter;

c) the ability to present a display of a trace representation, with a logarithmic power scale and a linear distance scale;

d) two markers/cursors, which display the loss and distance between any two points on a trace display;

e) the ability to measure absolute distance (location) from the OTDR's zero-distance reference;

f) the ability to measure the displayed power level relative to a reference level (for example, the clipping level).

Calibration methods described in this standard may look similar to those provided in Part 1 of this series. However, there are differences: mix of different fibre types, use of mode conditioner or different arrangement of the fibres. This leads to different calibration processes as well as different uncertainties analysis.

CALIBRATION OF OPTICAL TIME-DOMAIN REFLECTOMETERS (OTDR) –

Part 2: OTDR for multimode fibres

1 Scope

This part of IEC 61746 provides procedures for calibrating multimode optical time domain reflectometers (OTDR). It covers OTDR measurement errors and uncertainties. The test of the laser(s) source modal condition is included as an optional measurement.

This standard does not cover correction of the OTDR response.

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

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

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

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

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

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions and symbols

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

NOTE For more precise definitions, the references to IEC 60050-731 should be consulted.

3.1
attenuation
A
loss

optical power decrease in decibels (dB)

NOTE If P_{in} (watts) is the power entering one end of a segment of fibre and P_{out} (watts) is the power leaving the other end, then the attenuation of the segment is

$$A = 10\log_{10}\left(\frac{P_{\text{in}}}{P_{\text{out}}}\right) \text{ dB} \quad (1)$$

[IEV 731-01-48, modified]

3.2
attenuation coefficient
α
attenuation (3.1) of a fibre per unit length

[IEV 731-03-42, modified]

3.3
attenuation dead zone
for a reflective or attenuating event, the region after the event where the displayed trace deviates from the undisturbed backscatter trace by more than a given vertical distance ΔF

NOTE The attenuation dead zone (see Figure 1 below) will depend on the following event parameters: reflectance, loss, displayed power level and location. It may also depend on any fibre optic component in front of the event.

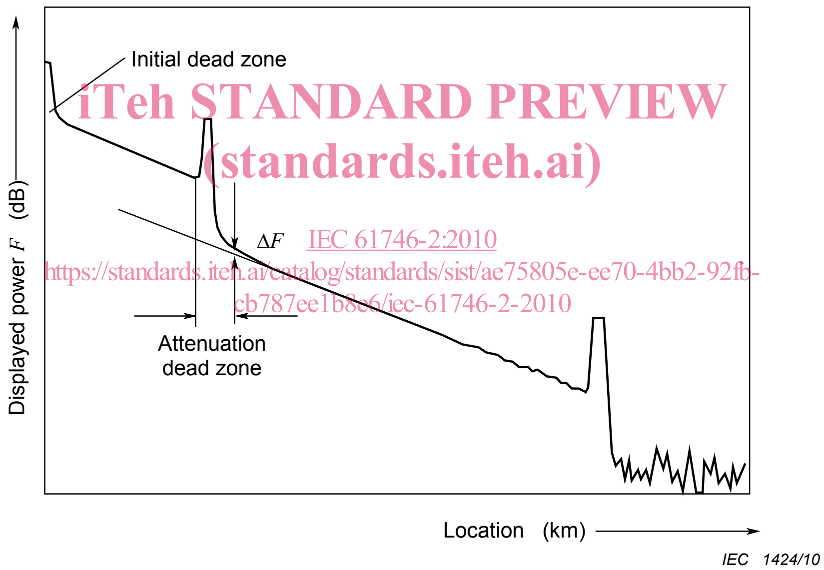

Figure 1 – Definition of attenuation dead zone

3.4
calibration
set of operations which establish, under specified conditions, the relationship between the values indicated by the measuring instrument and the corresponding known values of that quantity

NOTE See ISO *Guide International vocabulary of basic and general terms in metrology.*

3.5
centroidal wavelength
λ_{avg}
power-weighted mean wavelength of a light source in vacuum

[IEC 61280-1-3, definition 2.1.4]

3.6
displayed power level
F
level displayed on the OTDR's power scale

NOTE 1 Unless otherwise specified, F is defined in relation to the clipping level (see Figure 8).

NOTE 2 Usually, the OTDR power scale displays five times the logarithm of the received power, plus a constant offset.

3.7
distance
D
spacing between two features

NOTE Usually expressed in metres.

3.8
distance sampling error
ΔL_{sample}
maximum distance (3.7) error attributable to the distance between successive sample points

NOTE 1 Usually expressed in metres.

NOTE 2 The distance sampling error is repetitive in nature; therefore, one way of quantifying this error is by its amplitude.

3.9
distance scale deviation
ΔS_L
difference between the average displayed distance (3.7) $< D_{otdr} >$ and the correspondent reference distance (3.27) D_{ref} divided by the reference distance (3.27)

NOTE 1 Usually expressed in m/m.

NOTE 2 ΔS_L is given by the following formula

$$\Delta S_L = \frac{< D_{otdr} > - D_{ref}}{D_{ref}} = \frac{< D_{otdr} >}{D_{ref}} - 1 \qquad (2)$$

where $< D_{otdr} >$ is the displayed distance on a fibre averaged over at least one sample spacing.

3.10
distance scale factor
S_L
average displayed distance (3.7) divided by the correspondent reference distance (3.27)

NOTE 1 S_L is given by the following formula

$$S_L = \frac{< D_{otdr} >}{D_{ref}} \qquad (3)$$

where $< D_{otdr} >$ is the displayed distance between two features on a fibre (actual or simulated) averaged over at least one sample spacing.

3.11
distance scale uncertainty
$u_{\Delta SL}$
uncertainty of the distance scale deviation (3.9)

NOTE 1 Usually expressed in m/m.

NOTE 2 $u_{\Delta SL}$ is given by the following formula

$$u_{\Delta SL} = u\left(\frac{< D_{otdr} >}{D_{ref}} - 1\right) = u\left(\frac{< D_{otdr} >}{D_{ref}}\right) \quad (4)$$

NOTE 3 In the above formula, $u()$ is understood as the standard uncertainty of ().

3.12
dynamic range at 98 % (one-way)
amount of fibre attenuation (3.1) that causes the backscatter signal to equal the noise level at 98 % (3.24)

NOTE It can be represented by the difference between the extrapolated point of the backscattered trace (taken at the intercept with the power axis) and the noise level expressed in decibels, using a standard category A fibre (see IEC 60793-2-10).

3.13
encircled flux
EF

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

3.14
group index
N
factor by which the speed of light in vacuum has to be divided to yield the propagation velocity of light pulses in the fibre

3.15
location
L
spacing between the front panel of the OTDR and a feature in a fibre

NOTE Usually expressed in metres

3.16
location deviation
ΔL
displayed location (3.15) of a feature L_{otdr} minus the reference location (3.28) L_{ref}

NOTE 1 Usually expressed in metres.

NOTE 2 This deviation is a function of the location.

3.17
location offset
ΔL_0
constant term of the **location deviation** (3.16) model

NOTE 1 Usually expressed in metres.

NOTE 2 This is approximately equivalent to the location of the OTDR front panel connector on the instrument's distance scale.

NOTE 3 For a perfect OTDR, the location offset is zero.

3.18
location offset uncertainty
$u_{\Delta L0}$
uncertainty of the location offset (3.17)

3.19
location readout uncertainty
$u_{Lreadout}$
uncertainty of the location (3.15) measurement samples caused by both the distance sampling error (3.8) and the uncertainty type A of the measurement samples

3.20
loss deviation
ΔA
difference between the displayed loss of a fibre component A_{otdr} and the reference loss (3.29) A_{ref}, in dB

NOTE 1 ΔA is given by the following formula

$$\Delta A = A_{otdr} - A_{ref} \quad (5)$$

NOTE 2 The loss deviation usually depends on the displayed power level, F.

3.21
loss uncertainty
$u_{\Delta A}$
uncertainty of the loss deviation (3.20), in dB

3.22
loss scale deviation

ΔS_A
difference between the displayed loss of a fibre component A_{otdr} and the reference loss (3.29) A_{ref}, divided by the reference loss (3.29), in dB/dB

NOTE 1 ΔS_A is given by the following formula

$$\Delta S_A = \frac{A_{otdr} - A_{ref}}{A_{ref}} \quad (6)$$

NOTE 2 Refer to 7.1 for more details.

3.23
mode conditioner
a fibre set that converts any power distribution submitted at its input to an output power distribution that fully comply with encircled flux limits

NOTE For the purposes of this standard, the encircled flux limits are defined by the IEC 61280-4-1.

3.24
noise level at 98 %
upper limit of a range which contains at least 98 % of all noise data points

3.25
non-linearity
NL_{loss}
difference between the maximum and minimum values of the loss deviation (3.20) ΔA for a given range of power levels, in dB

NOTE 1 This is the non-linearity of a logarithmic power scale.

NOTE 2 Non-linearity is one contribution to loss deviation; it usually depends on the displayed power level and the location.

3.26
received power level
P
power received by the OTDR's optical port

3.27
reference distance
D_{ref}
distance (3.7) precisely determined by measuring equipment with calibration traceable to international or national standards

NOTE Usually expressed in metres.

3.28
reference location
L_{ref}
location (3.15) precisely determined by measuring equipment with calibration traceable to international or national standards

NOTE Usually expressed in metres.

3.29
reference loss
A_{ref}
loss of a fibre optic component precisely determined by measuring equipment with calibration traceable to international or national standards

3.30
rms dynamic range (one-way)
amount of fibre attenuation (3.1) that causes the backscatter signal to equal the rms noise level (3.31)

NOTE Assuming a Gaussian distribution of noise, the rms dynamic range can be calculated adding 1,56 dB to the one way dynamic range. See 3.31.

3.31
rms noise level
the quadratic mean of the noise

NOTE 1 On a general basis, the rms noise level cannot be read or extracted from the logarithm data of the OTDR. This is because the linear to logarithm conversion used to display the power level on a dB scale removes the negative part of the noise.

NOTE 2 Assuming a Gaussian distribution of noise, a relation between the noise level and the RMS noise level can be found using the following formula

$$Noise_{98} - Noise_{rms} = 5 \times \log_{10}(2,05375) = 1,56 \text{ dB} \quad (7)$$

where $Noise_{98}$ is the noise level at 98 %, e.g. in dB;

$Noise_{rms}$ is the rms noise level, e.g. in dB;

2,05375 is the value of the reverse standard normal distribution for 98 %.

3.32
sample spacing
distance of consecutive data points digitized by the OTDR

NOTE 1 Usually expressed in metres.

NOTE 2 Sample spacing may be obtainable from instrument set-up information. Sample spacing may depend on the measurement span and other OTDR instrument settings.

3.33
spectral width
$\Delta\lambda_{FWHM}$
full-width half-maximum (FWHM) spectral width of the source

[IEC 61280-1-3, definition 3.2.3 modified]

4 Preparation for calibration

4.1 Organization

The calibration laboratory should satisfy requirements of ISO/IEC 17025.

There should be a documented measurement procedure for each type of calibration performed, giving step-by-step operating instructions and equipment to be used.

4.2 Traceability

The requirements of ISO/IEC 17025 should be met.

All standards used in the calibration process shall be calibrated according to a documented program with traceability to national standards laboratories or to accredited calibration laboratories. It is advisable to maintain more than one standard on each hierarchical level, so that the performance of the standard can be verified by comparisons on the same level. Make sure that any other test equipment which has a significant influence on the calibration results is calibrated. Upon request, specify this test equipment and its traceability chain(s). The re-calibration period(s) shall be defined and documented.

4.3 Preparation

Perform all tests at an ambient room temperature of 23 °C ± 3 °C, unless otherwise specified. Give the test equipment a minimum of 2 h prior to testing to reach equilibrium with its environment. Allow the OTDR a warm-up period according to the manufacturer's instruction.

4.4 Test conditions

The test conditions usually include the following OTDR external conditions: date, temperature, connector-adapter combination and use of a lead-in fibre.

Perform the calibration in accordance with the manufacturer's specifications and operating procedures. Where practical, select a range of test conditions and parameters so as to emulate the actual field operating conditions of the OTDR under test. Choose these parameters so as to optimize the OTDR's accuracy and resolution capabilities (for example, view windows, zoom features, etc.), as specified by the manufacturer's operating procedures.

The test conditions usually include the following OTDR parameters: averaging time, pulse width, sample spacing, centre wavelength. Unless otherwise specified, set the OTDR group index to exactly 1,46.

NOTE 1 The calibration results only apply to the set of test conditions used in the calibration process.

NOTE 2 Because of the potential for hazardous radiation, be sure to establish and maintain conditions of laser safety. Refer to IEC 60825-1 and IEC 60825-2.

4.5 Documentation

Calibration certificates shall include the following data and their uncertainties: