IEC TR 62316

Edition 3.0 2017-07

TECHNICAL REPORT

colour inside

Guidance for the interpretation of OTDR backscattering traces for single-mode fibres

iTeh STANDARD PREVIEW
(standards.iteh.ai)

IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

IEC TR 62316:2017-07(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2017 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

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

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standar
9c35b1a1d5b9/iec-tr-62316-2017

IEC TR 62316

Edition 3.0 2017-07

TECHNICAL REPORT

Guidance for the interpretation of OTDR backscattering traces for single-mode fibres

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.180.10

ISBN 978-2-8322-4553-8

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

GUIDANCE FOR THE INTERPRETATION OF OTDR BACKSCATTERING TRACES FOR SINGLE-MODE FIBRES

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a Technical Report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 62316, which is a Technical Report, has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition published in 2007. It constitutes a technical revision.

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

a) the scope has been extended to include single-mode fibres;

a) backscattered power effects are discussed in case of unidirectional trace, including so-called losers and gainers.

b) example of apparent splice loss evaluation for unidirectional OTDR measurements has been added:

c) description of launch and tail cords have been added;

d) figures have been improved.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
86A/1754/DTR	86A/1768A/RVC

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

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

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

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

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

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

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

GUIDANCE FOR THE INTERPRETATION OF OTDR BACKSCATTERING TRACES FOR SINGLE-MODE FIBRES

1 Scope

IEC 62316, which is a Technical Report, aims to provide guidelines for the interpretation of backscattering traces, as obtained by traditional optical time domain reflectometers (OTDRs) – not including polarization OTDRs – for single-mode fibres. Also, backscattered power effects are discussed in case of unidirectional trace.

Full description of the test measurement procedure can be found in Annex C of IEC 60793-1-40:2001.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

iTeh STANDARD PREVIEW
(standards.iteh.ai)

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

IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

4 Backscattering phenomenon

4.1 Rayleigh scattering

Rayleigh scattering or backscattering originates from fluctuations in the density, and hence in the index of refraction, of the material constituting the wave-guide; optical fibres are made of amorphous silica, and density fluctuations are a consequence of the manufacturing process.

4.2 Fresnel reflections and dead zone fibres

When a light ray reaches a surface at an angle of incidence from the normal to that surface and that surface separates two media of different index of refraction, part of this light ray is refracted in the second medium and part of it is reflected backward into the first medium. This is the Fresnel reflection, which can be very high, depending on the difference in the index of refraction of the two media, on the aspect of the surface, the surface roughness, the angle of incidence and the surface defects. In most situations, strong Fresnel reflections cause non-linearities at the receiver. These non-linearities can overload the receiver resulting in signal clipping, pulse widening, tailing, and ghosts. The corresponding section of the optical time domain reflectometer (OTDR) trace following the intense Fresnel reflection defines the deadzone. This particular deadzone should not be confused with the manufacturer's specification, always defined with a narrow pulse and small Fresnel reflection. The effect of the strong reflection on the deadzone is usually resolved by cleaning the connector responsible for the reflection. The so-called deadzone eliminator (adding a length of fibre after a strong reflection) does not reduce the deadzone nor the strong reflection. It artificially moves the virtual bulkhead connector to another location and assumes the following connector has a low reflection. Depending on the type of photodetector used in the receiver, the tailing due to a strong reflection can be greater than the fibre length inserted between the OTDR and the fibre under test.

5 Measurement of the backscattered power (OTDR)

5.1 General

The power backscattered by an optical fibre is measured by means of OTDRs. They are based on the principle of sending one pulse or typically a train of pulses from one fibre end, and measure the power back-reflected from the fibre at the same end. In OTDR traces, space and time are completely equivalent through the relation:

$$\frac{z}{t}=\frac{c}{n_{\mathrm{g}}(\lambda)} \tag{1}$$

where

z is the distance (in meters);

t is the time (in seconds);

c is the speed of light in vacuum (299 792 458 meters/second);

n_{g} is the group index of refraction (as a function of the wavelength).

The group index of refraction, to be supplied by the fibre manufacturer, takes into account the wave-guiding properties of the fibre and the different materials used for the cladding and the core. It also adjusts the speed of light in the studied material. The group index of refraction n_g is related to the phase index n or n_p (which is measured on a fibre and its fundamental attribute) by using the following expression:

iTeh STANDARD PREVIEW
(standards.iteh.ai)

$$n_{\mathrm{g}}=n_{\mathrm{p}}-\lambda\frac{dn_{\mathrm{p}}}{d\lambda} \tag{2}$$

5.2 Representation of the backscattered power

IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/fecead06-1a06-4186-91ea-9c35b1a1d5b9/iec-tr-62316-2017

A possible schematic representation of the OTDR power $P(z)$ at wavelength λ backscattered by a point z along an optical fibre is:

$$P(z)=C\frac{\lambda^2}{(\omega(z))^2}P_{\mathrm{i}}\tau_{\mathrm{w}}10^{-\frac{2}{10}\alpha z} \tag{3}$$

where

P_i is the input OTDR pulse power into the fibre;

τ_w is the input OTDR pulse width (in seconds);

z is the distance at which the backscattered power is generated;

α is the attenuation in m^{-1}. Multiply α_{dB} by 0,00023 to obtain α, and α_{dB} is the attenuation in dB/km (assumed constant to simplify the equation);

$\omega(z)$ is the fibre mode field diameter (MFD) at point z;

C is a proportionality factor, which depends on several parameters such as the fibre material or the refractive index value. For step-index single-mode fibre, this factor is expressed by:

$$C=\frac{3c\alpha_{\mathrm{s}}}{16\pi^2 n_{\mathrm{eff}}{}^2 n_{\mathrm{g}}} \tag{4}$$

where

c is the speed of light in vacuum;

α_s is the Rayleigh scattering coefficient in m^{-1};

n_{eff} is the effective refractive index of the fundamental mode, which is a number quantifying the phase delay per unit length in a wave guide, relative to the phase delay per unit length in vacuum;

n_{g} is the group index of refraction.

Equation (3) shows the relation between the backscattered power, the pulse width, the attenuation coefficient and the MFD. The optical reflected power, as given by Equation (3), is conventionally represented on a logarithmic graph: it therefore appears as a (theoretically) straight line, whose slope is the attenuation coefficient of the fibre, α, as better explained in Clause 6 below.

Note that Equation (3) is valid for short pulse width, i.e. $\tau_{\mathrm{w}}\alpha << 1$, which applies in most practical cases.

5.3 Noise and perturbations

Normally, the fluctuations of fibre parameter and receiver linearity affect the backscatter traces; the trace can therefore appear as a perturbed line. The linear signal decreases exponentially – as from Equation (3); over long distance, the signal to noise ratio (SNR) decreases as a function of distance. As the backscatter signal approaches the noise floor, non-linearities can appear. A practical way to improve the SNR, also known as dynamic range, is to increase averaging time or increase the pulse width.

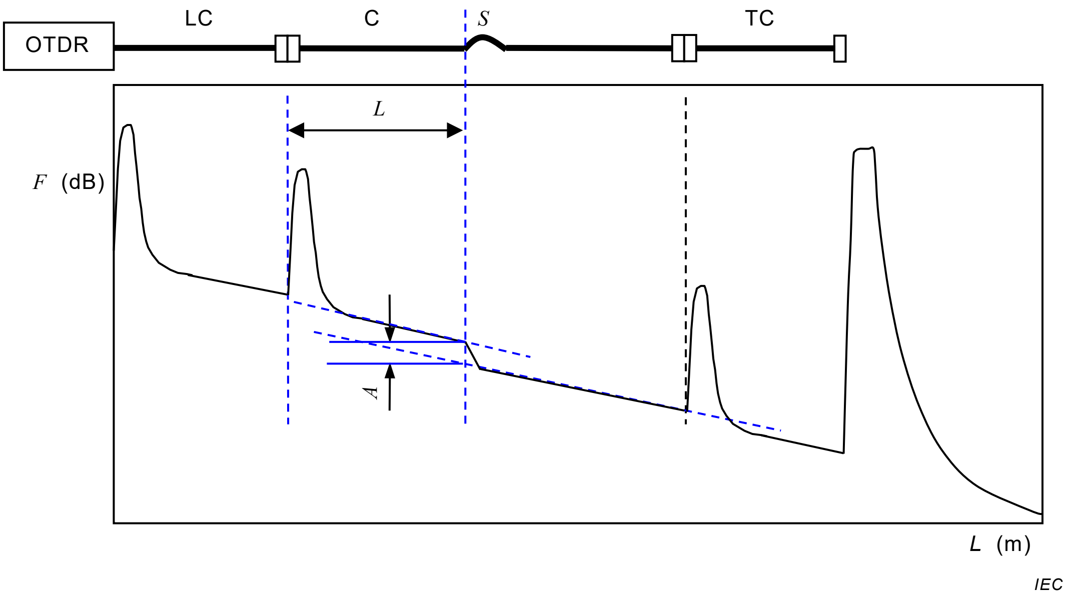
Any event, such as a splice, connector, macro-bend, micro-bend, can be detected by the OTDR and appear as a perturbation. Micro-bends are more evident at long wavelengths such as 1625 nm, far from the cut-off wavelength where the MFD is larger and the confinement of light in the fibre is reduced.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

6 Interpretation of a backscattering trace

6.1 General

Figure 1 shows a typical unidirectional OTDR trace of an optical fibre showing a loss A dB, which can be a macrobend loss or splice loss. The reflection at the input face is exaggerated for clarity; normally it is reduced by means of a launch cord with clean connector meeting IEC 61300-3-35.



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	macro bend or splice loss

TC tail cord S macro bend or splice

Figure 1 – Unidirectional OTDR trace showing splice and/or macro bend loss

6.2 Launch cord

The optical fibre within the launch cord at the connection to the cabling under test should be of the same type, in terms of core diameter and numerical aperture, but not necessarily bandwidth, as the optical fibre within the cabling under test.

The length of the launch cord should be longer than the dead zone created by the pulse width selected for a particular length of fibre to be measured. Suppliers of OTDR equipment should recommend lengths. In addition, these lengths should be long enough for a reliable straight line fit of the backscatter trace that follows the attenuation dead zone with standard connector reflectance.

6.3 Tail cord

The optical fibre within the receive or tail cord should be of the same type, nominal core diameter and nominal numerical aperture as the optical fibre within the cabling under test.

The length of the tail cord should be longer than the dead zone created by the pulse width selected for a particular length of fibre to be measured.

6.4 Unidirectional trace

6.4.1 General

iTeh STANDARD PREVIEW
(standards.iteh.ai)
IEC TR 62316:2017
https://standards.iteh.ai/catalog/standards/sist/ffcead06-1a0b-41bb-91ea-9c35b1a1d5b9/iec-tr-62316-2017

The accepted method of determining the attenuation of installed links by OTDR is performing bi-directional OTDR measurements[1] and average both these traces (see IEC 60793-1-40 and IEC 61280-4-2). However, in some situations, it is difficult in practice to perform such bi-directional OTDR measurements, in particular fibre-to-the-home (FTTH) applications. In those cases, OTDR traces obtained by the processing of the optical backscattered light collected from one end only of the fibre can be used, called unidirectional traces. Such unidirectional OTDR traces may be useful to quickly evaluate the optical continuity of a fibre and to estimate the link attenuation coefficient, which reliability, however, can be affected by several effects (such as perturbation changes in the fibre, backscatter coefficient changes, non-linearities, and ghosts).

For unidirectional measurement, the following should be understood and taken care of.

- The main requirement for total single mode unidirectional attenuation measurements using an OTDR is that the launch and tail cords used for the set-up have the same backscatter coefficient. In order to verify this hypothesis, the following test should be performed before using an OTDR for single direction measurement every time when it is not sure the launch and tail cords have the same backscatter coefficient.
- Launch cable test procedure: Connect the launch and tail cords together. Adjust the OTDR pulse width, so that a sufficiently large number of data points and an appropriate signal-to-noise ratio are obtained. Determine the backscatter traces from both fibre ends with averaging OTDR measurements from both directions.
- For each direction A and B, calculate the average loss between launch and receive cords LA and LB. The difference between the losses from both directions should be equal to zero, given the device and measurement uncertainties. This step ensures that the backscatter coefficient of the launch and receive cords are the same, allowing to proceed with total attenuation measurements for single mode links.
- For conformance testing of links and channels, an optical light source and power meter are required.

[1] Further discussions on the same subject can be found in Annex C of IEC 60793-1-40:2001.