BS EN 61300-3-6:2009

BSI British Standards

Fibre optic interconnecting devices and passive components — Basic test and measurement procedures —

Part 3-6: Examinations and measurements — Return loss

British Standards

National foreword

This British Standard is the UK implementation of EN 61300-3-6:2009. It is identical to IEC 61300-3-6:2008. It supersedes BS EN 61300-3-6:2003 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/86, Fibre optics, to Subcommittee GEL/86/2, Fibre optic interconnecting devices and passive components.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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EUROPEAN STANDARD

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English version

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

(IEC 61300-3-6:2008)

Dispositifs d'interconnexion
et composants passifs à fibres optiques -
Méthodes fondamentales d'essais
et de mesures -
Partie 3-6: Examens et mesures -
Affaiblissement de réflexion
(CEI 61300-3-6:2008)

Lichtwellenleiter -
Verbindungselemente
und passive Bauteile -
Grundlegende Prüf- und Messverfahren -
Teil 3-6: Untersuchungen und Messungen -
Rückflussdämpfung
(IEC 61300-3-6:2008)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 61300-3-6:2009 E

Foreword

The text of document 86B/2762/FDIS, future edition 3 of IEC 61300-3-6, prepared by SC 86B, Fibre optic interconnecting devices and passive components, of IEC TC 86, Fibre optics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61300-3-6 on 2009-03-01.

This European Standard supersedes EN 61300-3-6:2003.

The changes with respect to EN 61300-3-6:2003 are to reconsider the constitution of this standard and launch conditions for multimode fibres.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2009-12-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2010-03-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61300-3-6:2008 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60793-2	Series	Optical fibres - Part 2: Product specifications	EN 60793-2	Series
IEC 61300-1	- [1]	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 1: General and guidance	EN 61300-1	2003 [2]
IEC 61300-3-1	- [1]	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-1: Examinations and measurements - Visual examination	EN 61300-3-1	2005 [2]
IEC 61300-3-39	- [1]	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-39: Examinations and measurements - PC optical connector reference plug selection	EN 61300-3-39	1997 [2]

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[1] Undated reference.

[2] Valid edition at date of issue.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES –

Part 3-6: Examinations and measurements – Return loss

FOREWORD

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International Standard IEC 61300-3-6 has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition published in 2003. It constitutes a technical revision. The changes with respect to the previous edition are to reconsider the constitution of the document and launch conditions for multimode fibres.

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

FDIS	Report on voting
86B/2762/FDIS	86B/2792/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 parts of IEC 61300 series, published under the general title, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures* can be found on the IEC website.

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.

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES –

Part 3-6: Examinations and measurements – Return loss

1 Scope

This part of IEC 61300 presents procedures for the measurement of the return loss (RL) of a fibre optic device under test (DUT).

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 (all parts), *Optical fibres – Product specifications*

IEC 61300-1, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 1: General and guidance*

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

IEC 61300-3-39, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-39: Examinations and measurements – PC optical connector reference plug selection*

3 General description

RL, as used in this standard, is the ratio of the power (P_i) incident on, or entering, the DUT to the total power reflected (P_r) by the DUT, expressed in decibels:

$$RL = -10 \times \log\left(\frac{P_r}{P_i}\right) \tag{1}$$

Return loss is a positive number.

Four methods will be presented for measuring optical return loss:

- measurement with an optical continuous wave reflectometer (OCWR) (method 1);
- measurement with an optical time domain reflectometer (OTDR) (method 2);
- measurement with an optical low coherence reflectometer (OLCR) (method 3);
- measurement with an optical frequency domain reflectometer (OFDR) (method 4).

These four measurement methods have different characteristics and different applications in terms of spatial resolution and detectable *RL* (in Annex A, a comparison of return loss detectable by the four different methods is reported).

3.1 Method 1

This technique is the nearest to the theoretical definition of return loss given by equation (1). It measures directly the incident power and the reflected power. It is not affected by instrumental data processing and it gives absolute measurement values, which are not relative to a reference reflection (technique A). This method has some limiting factors: it cannot spatially resolve two different reflections on the line and its dynamic range is limited by the characteristics of the branching device and by the ability to suppress the reflections beyond the one from the DUT.

3.2 Method 2

This method allows measurement of RL from reflection points on an optical line, with a spatial resolution in the metre range and with a dynamic range of more than 75 dB (depending on the pulse width) using an OTDR instrument.

3.3 Method 3

The purpose of this method is to measure reflection profiles of single-mode optical devices with a micrometre spatial resolution and a high dynamic range (> 90 dB) by using optical low-coherence interference.

The reflection profile is defined as a distribution of reflections at individual end-faces and/or connected points in single-mode optical devices. When the reflection at a particular point is $-R$ (dB), the return loss at this point is given by R (dB). This method measures the reflection at a point by detecting the power of a beat signal produced by optical interference between the reflected light and the reference light. When a component with dispersed reflections is analysed, each reflection can be identified and located, provided their separation is greater than the spatial resolution of the measurement system.

3.4 Method 4

The purpose of this procedure is to measure the return loss of single-mode optical devices with a spatial resolution in the centimetre range and high dynamic range (> 70 dB) by using optical frequency domain reflectometry.

One of the prime benefits of this technique is the ability to spatially resolve the desired reflection from undesired ones, such as all of the connectors or unterminated ports on the DUT, without any dead zone. Moreover, the OFDR method is highly reliable and the apparatus can be compact.

Measurement in the frequency domain is based on the ability to convert information in the time domain by means of an inverse Fourier transform. In this way, with a source modulated from some kHz to 1 GHz, it is possible to resolve two reflective points on an optical line separated by some centimetres.

3.5 Selection of reference measurement method

Due to the different characteristics of these methods, and their different application fields, the reference method depends on the type of DUT. For a component with RL ≤ 55 dB, the reference is method 1, for a component with RL > 55 dB, the reference is method 2 using a pulse duration less than 100 ns. In cases in which it is necessary to resolve more reflection points separated by a distance of less than 5 m, the reference shall be method 3.

4 Apparatus and symbols

4.1 Device under test (DUT)

Where the DUT is the mounted connector on one end of a component, the reference mating plug shall be considered one-half of the DUT connection on the temporary joint (TJ) side and have the same end-face finish and minimum performance as the connectors to be measured.

Where the DUT is an entire component assembly terminated with pigtails with or without connectors, reference plugs with pigtails and, as required, reference adapters are to be added to those ports with connector terminations so as to form complete connector assemblies with pigtails. Reference mating plugs shall then be considered one-half of the TJ and have the same end-face finish and minimum performance as the connectors to be measured. All unused ports shall be terminated as stated in 4.2.5.

Unless otherwise specified, reference plugs shall meet the requirements of IEC 61300-3-39. The reference adapters shall meet the appropriate IEC connector interface dimensions and ensure a high degree of repeatability and reproducibility. It is recommended that the test adapters be tested and visually inspected after every 100 matings and replaced after 500 matings.

4.2 Method 1: measurements with OCWR

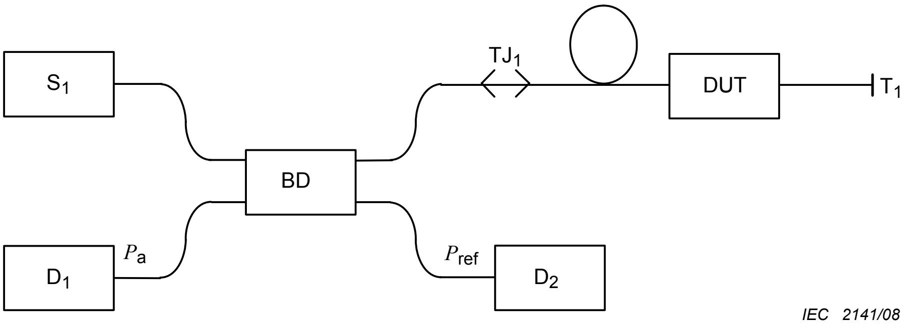


Figure 1 – Measurement set-up of return loss OCWR method

The circuit in Figure 1 is representative of, but is not the only circuit that may be used for OCWR return loss measurement. The requirements are that the values measured satisfy the following two conditions:

- P_a (power measured by the detector D_1) shall be proportional to the power reflected from the DUT, P_r, plus the reflected power originating in the measurement circuit outside of the DUT, P_0:

$$P_a = C_1 \times P_r + P_0 \qquad \text{(mW)} \qquad (2)$$

- P_{ref} (power measured by the detector D_2) shall be proportional to the power incident on the DUT, P_i:

$$P_{ref} = C_2 \times P_i \qquad \text{(mW)} \qquad (3)$$

where

P_r is the power reflected from the DUT (equation (1));

P_i is the power incident on the DUT (equation (1));

P_0 is the system reflected power originating in the measurement circuit;

C_1 is the branching device transfer coefficient;

C_2 is the splitting ratio of the branching device.

The following is a list of the apparatus and components used in the measurement of return loss using an OCWR (see Figure 1).

4.2.1 Branching device (BD)

The splitting ratio of the BD shall be stable and be insensitive to polarization (< 0,1 dB). The directivity shall be at least 10 dB higher than the maximum return loss to be measured (see 5.4.4).

4.2.2 Detector (D_1, D_2 and D_3)

The detector used consists of an optical detector, the associated electronics, and a means of connecting to an optic fibre. The optical connection may be a receptacle for an optical connector, a fibre pigtail or a bare fibre adapter.

The detectors linearity needs to 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. Care shall be taken to suppress the reflected power from the detector D_2 during the measurement.

Where, during the sequence of measurements, a detector is disconnected and reconnected, the coupling efficiency for the two measurements shall be maintained.

4.2.3 Source (S_1 and S_2)

The source consists of an optical emitter, associated drive electronics, an excitation unit, and a fibre connector or fibre pigtail. A second source S_2 may be used for calibration, as illustrated in Figure 6. Where a second source is used, the central wavelength and spectral width of S_2 shall be the same as S_1.

4.2.4 Temporary joint (TJ)

A temporary joint is a joint that is made to connect the DUT into the measurement circuit. Examples of temporary joints are a connector, splice, vacuum chuck or micro-manipulator. The loss of the TJ shall be stable and the TJ shall have a return loss of at least 10 dB greater than the maximum return loss to be measured (see 5.4.4).

Where a return loss greater than 50 dB is to be measured, a fusion splice is advised in order to guarantee the prescribed measurement precision.

4.2.5 Termination (T)

Fibre terminations marked T shall have a high return loss. Three types of terminations are suggested:

- angled fibre ends: the value of the angle depends on the fibre type; however, it shall be higher than 12°;
- the application of an index match material to the fibre end;
- attenuation in the fibre, for example, with a mandrel wrap (not applicable to multimode fibre).

Where attenuation is used as a termination, it may be applied between components. For example, the measurement of P_0 in Figure 5 may be made by applying attenuation between TJ_1 and the DUT in Figure 8.

The fibre termination shall have a return loss of at least 20 dB greater than the maximum return loss to be measured.

Where a return loss greater than 50 dB is to be measured, the “attenuation in the fibre” termination technique is advised in order to guarantee the prescribed measurement precision.

4.3 Method 2: measurements with OTDR

The measurement set-up for the RL measurement using an OTDR is shown in Figure 2. The following is a list of the apparatus and components used in the measurement.

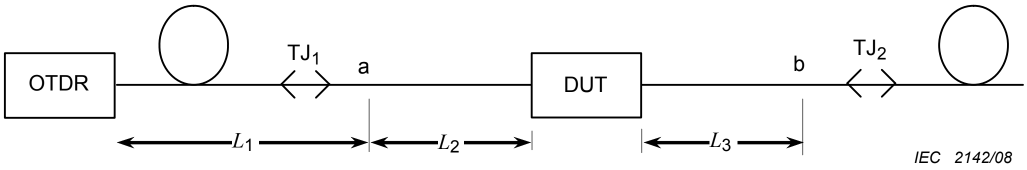


Figure 2 – Measurement set-up of return loss with OTDR method

Another implementation is possible based on comparing the OTDR reflection from the DUT to a calibrated or known return loss.

4.3.1 Optical time domain reflectometer (OTDR)

An instrument able to measure the optical power backscattered along a fibre as a function of time. With this instrument, it is possible to measure several characteristics of an optical line (attenuation, splice loss, splice location, fibre uniformity, breaks) by looking at the fibre from only one end. The return loss from a discontinuity in the fibre is one of the parameters that can be measured.

An attenuator at the OTDR receiver input may be required to reduce the optical power to a level that does not saturate the OTDR receiver (see 5.5.4).

4.3.2 Fibre sections (L_1, L_2, and L_3)

Sections of fibre that are to be included in an OTDR measurement. Section L_1 is required by most OTDRs to provide separation between the OTDR and the events to be measured. Sections L_2 and L_3 provide the space required for the OTDR to resolve the measurement of the return loss of the DUT. The fibre between points “a” and “b” shall have the same backscatter coefficient (see equation (15)).

Where the DUT is terminated with connectors, the connectors are part of the DUT, they shall fall between sections L_2 and L_3.

4.3.3 Temporary joints (TJ)

A temporary joint is a joint that is made to connect the DUT into the measurement circuit. Examples of temporary joints are a connector, splice, vacuum chuck, or micromanipulator. The temporary joints shall be out of the “a”-“b” zone. The loss of the TJ shall be stable and shall have an RL sufficiently high that it does not affect the OTDR trace in the measurement zone.

In the case in which the temporary joints TJ_1 or TJ_2 fall between “a” and “b”, the absolute value of the loss of these joints as measured by a one-way OTDR measurement shall be less than 0,10 H (see 5.5.4). To obtain this low loss value, it may be necessary to work with several different fibre combinations to match the backscatter characteristics of the pigtails attached to the DUT.

4.4 Method 3: measurements with OLCR

The description of the apparatus shown in Figure 3 indicates only the principle of the method.

NOTE A practical measuring system needs to use various modifications, for example, to make a measurement independently of the state of polarization of the returning signal.

The apparatus consists of the following.

4.4.1 Light source (S)

The source is a broadband light source (LED edge emitting) with a fibre output.

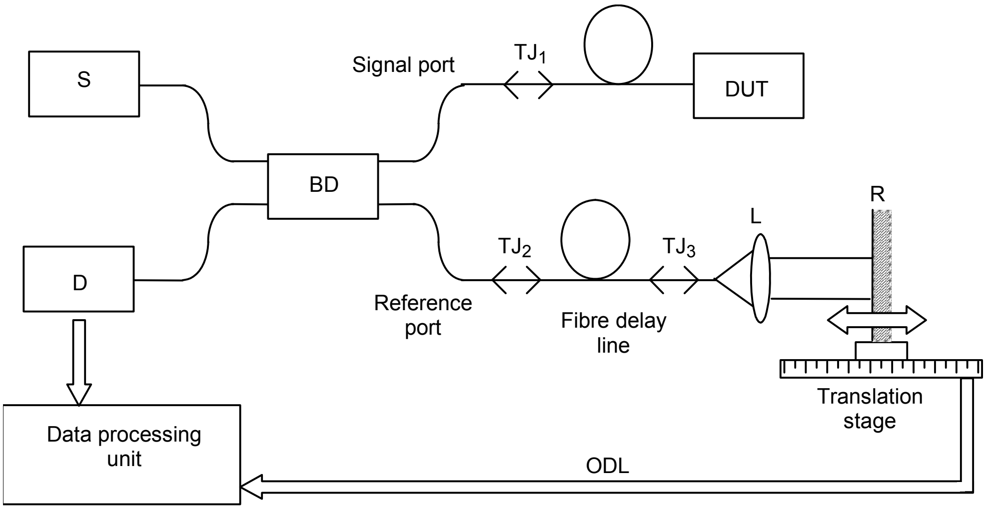
4.4.2 Branching device (BD)

The BD splits light power from the source to the signal and reference ports and couples light power from those ports into the detector.

4.4.3 Optical delay line (ODL)

The ODL changes the time delay of the reference light linearly.

A conventional ODL is composed of a collimator (L) to make the light beam parallel, and a reflector (R) mounted on a translation stage.



IEC 2143/08

Figure 3 – Measurement set-up of return loss with OLCR method

4.4.4 Optical detector (D)

The detector shall be connected to an output end of the branching device.

A detector shall be used, which has sufficient dynamic range. The photocurrent of the detector is fed into the data processing unit.

4.4.5 Temporary joint (TJ)

A temporary joint is a joint that is made to connect the DUT into the measurement circuit. Examples of temporary joints are a connector, splice, vacuum chuck, or micro-manipulator. The loss of the TJ shall be stable.

4.4.6 Data processing unit

The data processing unit collects and processes data from D and controls the optical delay of the reference light.

4.5 Method 4: measurements with an OFDR

The experimental set-up using the OFDR is illustrated in Figure 4 and is formed by the following components.

4.5.1 RF network analyser

The RF network analyser is a vector network analyser able to measure both the intensity and the phase of the reflected power. The RF frequency drift shall be minimized in line with the measurement accuracy.

4.5.2 Optical heads – Source (S) and receiver (D)

An optical emitter at the specified wavelength and an optical detector, both with their properly associated drive electronics and means of connecting to the network analyser and to optical fibres, respectively. The dynamic range of the measurement set-up shall be at least 5 dB greater than the minimum RL to be measured. The system dynamic range is defined as the difference between the largest signal, i.e. 0 dB, and the signal 3 dB above the noise floor as measured in the time domain.

The following factors may give rise to a potential source of errors and could affect the measurement uncertainty:

- laser wavelength drift with the temperature;
- the range in return loss power over which the detector is linear;
- the polarization sensitivity.

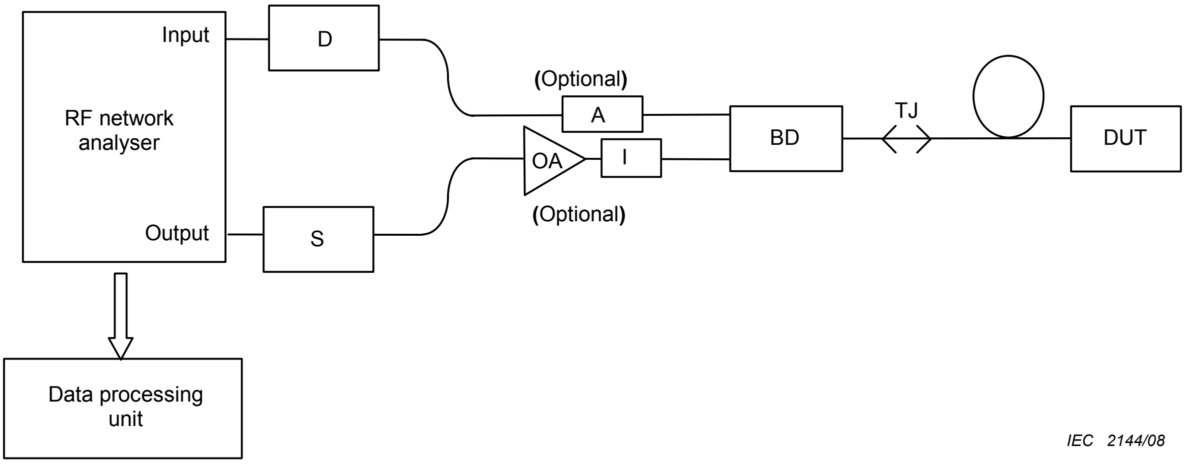


Figure 4 – Measurement set-up of return loss with OFDR method

4.5.3 Optical variable attenuator (A) (optional)

In cases in which the reflection used as reference and the measured one are very different, the optical detector response may not be sufficiently linear over all the measurement range. In this case, it may be necessary to introduce a variable attenuator into the measurement system as shown in Figure 4.

4.5.4 Optical amplifier (OA) (optional)

An optical amplifier, used as a booster, may be added after the source in order to increase the emitted optical power and to enhance the dynamic range of the apparatus.

4.5.5 Isolator (I) (optional)

An optical isolator may be placed in front of the source, if it is not already built in, in order to limit the reflected power which could degrade the source performances.

4.5.6 Branching device (BD)

The splitting ratio is 50 % and the BD is insensitive to the polarization variations (< 0,1 dB).

The directivity of the BD can affect the measurement accuracy and shall be specified accordingly.

4.5.7 Temporary joint (TJ)

A temporary joint is a joint made to connect the DUT to the branching device. Examples of TJs are connectors, splices or micro-manipulators. The loss of the TJ shall be stable with an insertion loss of less than 0,5 dB. The spacing between the TJ and the DUT shall be greater than the resolution of the measurement.

4.5.8 Computer

A computer for performing the inverse Fourier transform on the swept vector will be required if the facility is not included in the network analyser.

5 Procedure

5.1 Launch conditions

The launch condition shall be specified in accordance with Annex B of IEC 61300-1.

Unless otherwise specified, the launch conditions can be obtained by means of a mode filter, the objective of which is to remove unwanted transient higher modes and reduce measurement inaccuracies.

For single-mode measurements, the mode filter shall include two 50 mm diameter loops of fibre.

Mode filters shall be placed between the temporary joint and the DUT.

5.2 Pre-conditioning

If the DUT is the mounted connector on one end of a component, the connector end-face shall be cleaned according to the manufacturer’s instructions and visually examined according to IEC 61300-3-1.

5.3 DUT output port

The output ports of the device under test shall be terminated to suppress reflections, particularly when the length of the DUT output fibre is shorter than the spatial resolution of the chosen method.

5.4 Method 1: measurement with OCWR

5.4.1 Definition of the OCWR measurement

The return loss measured using the OCWR method (see equation (10)) is the total return loss between TJ_1 and T_1 as observed from TJ_1 (Figure 1).

Measured values of power P, used in this procedure, are in linear units such as “mW”.

5.4.2 Set-up characterization

In order to perform the measurement, it is necessary to characterize the system by measuring the parameters P_0 and G (defined in the following subclauses: 5.4.2.1 and 5.4.2.2). These parameters are related to the power reflected by the system and to the attenuation of the power reflected from the DUT as it is measured by the detector D_1.

5.4.2.1 Measurement of the system reflected power

System reflected power P_0 is determined using a measurement in which the reflected power from the DUT has been removed.

- Remove the reflected power from the DUT either by replacing the DUT with a termination that has high return loss (Figure 5), or by adding a large attenuation, for example, a mandrel wrap, between the DUT and TJ_1 (Figure 8).

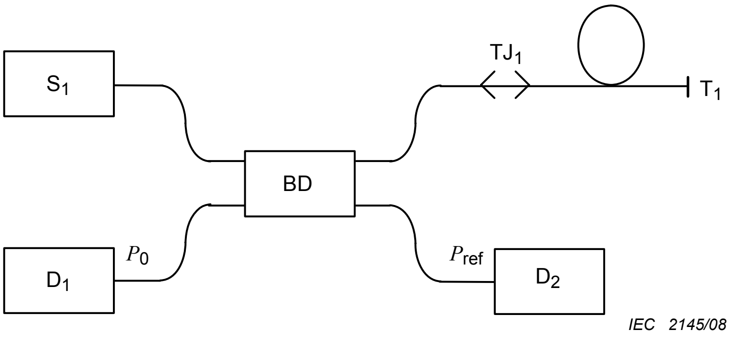


Figure 5 – Measurement set-up of the system reflected power

- The total power reflected (P_0) and the reference power (P_{ref}) are measured by means of the detectors D_1 and D_2.
- The normalized value of the system reflected power is given by:

$$P_0' = \frac{P_0}{P_{ref}} \tag{4}$$

5.4.2.2 Evaluation of the system constant *G*

Two techniques for evaluating the system constant G are presented.

a) Technique A

- Replace S_1 with a termination T_2, and connect source S_2 in place of T_1. Measure P_{aa}.
- Without turning the source S_2 off, cut the fibre at “cp”, connect detector D_3 and measure P_b.

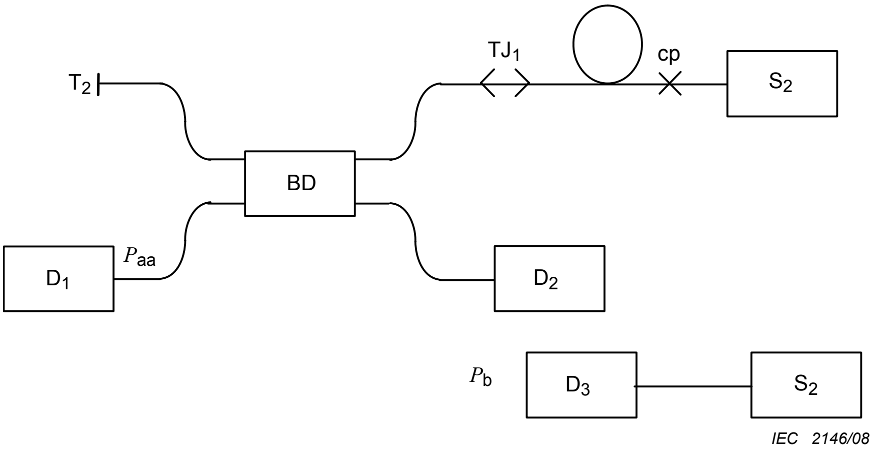


Figure 6 – Measurement set-up of the branching device transfer coefficient

- The factor C_1 is given by:

$$C_1 = \frac{P_{aa}}{P_b} \tag{5}$$

- Connect detector D$_3$ as shown in Figure 7 and measure P_c and P_R.

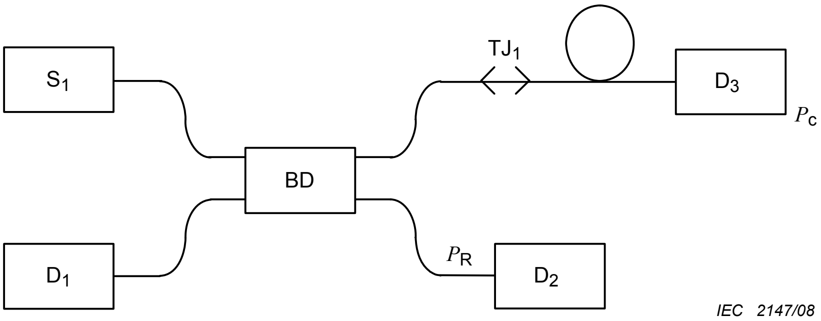


Figure 7 – Measurement set-up of the splitting ratio of the branching device

- The factor C_2 is given by:

$$C_2 = \frac{P_R}{P_c} \tag{6}$$

- The system constant G is derived as follows:

$$G = 10 \text{ x} \log\left(\frac{C_1}{C_2}\right) \qquad \text{(dB)} \tag{7}$$

Detector calibration – differences in the calibration of the three detectors that are used will cancel if this procedure is followed.

b) Technique B

In this method, the system constant G is based on a termination of known return loss, RL_c.

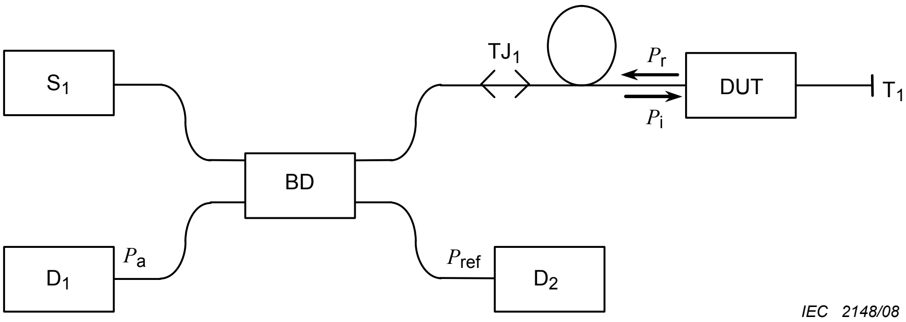
- Replace the DUT in Figure 1 with a fibre termination of known return loss, RL_c.

- Determine P_a', equation (11).
- Determine P_0', equation (4).
- Substitute P_a', P_0', and RL_c in equation (10) and evaluate G.

$$G = RL_C + 10 \text{ x } \log\left[P_a' - P_0'\right] \quad \text{(dB)} \tag{8}$$

5.4.3 Measurement procedure

The measurement of return loss with an OCWR is illustrated in Figure 8 and it is performed by means of the following steps.



IEC 2148/08

Figure 8 – Measurement set-up of return loss with an OCWR

- Connect the DUT to the system and suppress the reflection from the end of the line with the termination T_1.
- Acquire the total reflected power (from the system and from the DUT), P_a, by the detector D_1 and the reference power P_{ref}.
- Using P_a and P_{ref} to express P_r and P_i (relationship (2) and (3)), equation (1) shall be written as:

$$\begin{aligned} RL &= -10 \text{ x } \log\left[\frac{(P_a - P_0)\cdot C_2}{C_1 \cdot P_{ref}}\right] = -10 \text{ x } \log\left[\frac{P_a}{P_{ref}} - \frac{P_0}{P_{ref}}\right] + 10 \text{ x } \log\left(\frac{C_1}{C_2}\right) = \\ &= -10 \text{ x } \log\left[\frac{P_a}{P_{ref}} - \frac{P_0}{P_{ref}}\right] + G \end{aligned} \quad \text{(dB)} \tag{9}$$

Therefore the DUT return loss RL is derived as:

$$RL = -10 \times \log\left[P_a' - P_0'\right] + G \quad \text{(dB)} \tag{10}$$

where

$P_a' = \frac{P_a}{P_{ref}}$ is the normalized value of P_a; (11)

$P_0' = \frac{P_0}{P_{ref}}$ is the normalized value of P_0 (equation (4));

G (dB) is the system constant (equation (7)).

In equation (10), P_a' and P_0' have been normalized with P_{ref}. The value of P_{ref} used to normalize P_a is the value from the measurement illustrated in Figure 8. The value of P_{ref} used to normalize P_0 is the value from Figure 5. This allows the measurements of P_a and P_0 to be made at different times, and for drift in the amplitude of the source to have occurred between these measurements.

5.4.4 Accuracy considerations

The following factors are potential sources of error in the measurement of return loss.

- temporary joints TJ_1 and TJ_2. The error due to a difference in the loss of these joints is twice the difference in their loss.
- BD splitting ratio dependence to the polarization variations in the source. This dependence could cause a change in the relative reference power, P_{ref}, between P_0 and P_a measurement.
- system reflected power. The system reflected power P_0 is the power reaching detector D_1 from sources in the circuit other than the DUT (see Figure 1). The effect that errors in P_0 have on return loss is a function of the magnitude of ΔP, being the difference between P_a and P_0 expressed in decibels:

$$\Delta P = 10 \times \log(P_a) - 10 \times \log(P_0) \qquad \text{(dB)} \qquad (12)$$

At large values of ΔP, relatively large errors in ΔP will have a negligible effect on return loss. For example, an error in P_0 of 5 dB that changed ΔP from 25 dB to 30 dB would produce an error of only 0,014 dB in return loss. The accuracy of this method decreases as P_a becomes comparable to or less than P_0. At small values of ΔP, however, even small errors in ΔP are significant. For example an error of 0,5 dB that changed ΔP from 0,5 dB to 1,0 dB would produce an error of 3,0 dB in return loss.

In the design of a circuit for measuring return loss with a branching device, care must be taken to reduce P_0 to the lowest possible value. Sources of reflected power in the circuit in Figure 1 are listed as follows:

- the branching device BD,
- the termination T_1,
- the fibre to the right of the coupler. A difference in the length of fibre to the right of the coupler will change the value of P_0,
- the temporary joint TJ_1,
- the detectors.

5.5 Method 2: measurement with OTDR

5.5.1 Definition of the OTDR measurement

The OTDR measurement of the reflection at a single point will be the reflectance at the point. Where there are multiple reflections with sufficient distance between them, the OTDR will measure the reflectance of the individual points. Where there are multiple closely spaced reflections, the OTDR will measure the effective reflectance of the sum of the reflections.

A typical OTDR trace for an RL measurement is illustrated in Figure 9. The RL measurement by means of the OTDR is based on the measurement of the height of the spike due to the power reflected in respect to the backscattering level.

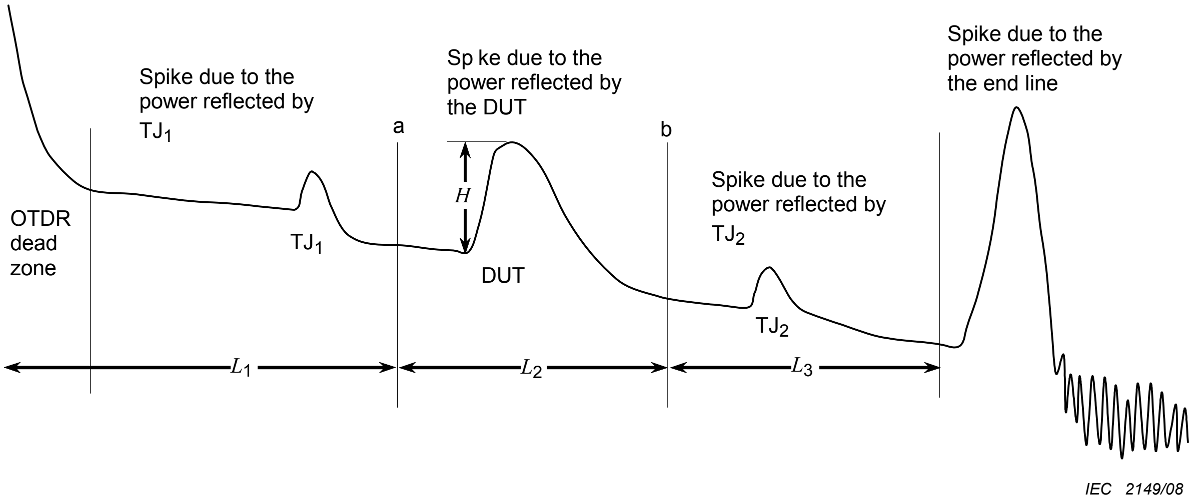


Figure 9 – Typical OTDR trace of the response to a reflection

5.5.2 Evaluation of backscattering coefficient

The backscattering level of the OTDR trace is a constant (K) that includes both the Rayleigh backscattering of the fibre and the OTDR pulse duration. Two techniques for evaluating the system constant are described in the following.

a) Technique A – Termination with a known return loss

- Measure H with a fibre terminated with the known return loss, RL_0.
- Substitute the value of H and RL_0 in equation (13) and determine K as follows:

$$K = 10 \text{ x} \log\left(10^{H/5} - 1\right) + RL_0 \qquad \text{(dB)} \qquad (13)$$

b) Technique B – Evaluation by means of Rayleigh backscattering and pulse duration

The constant K may be evaluated by means of the Rayleigh backscattering coefficient, B, and the pulse duration, t, using the following relationship:

$$K = B - 10 \text{ x} \log(t) \qquad \text{(dB)} \qquad (14)$$

The value in decibels of B is dependent on the time base used for t.

The value of B may be evaluated as follows:

$$B = R_L - 10 \times \log(t_b) - 10 \times \log\left[\frac{\alpha\, v}{1 - e^{-2\alpha L}}\right] \quad \text{(dB)} \qquad (15)$$

where

R_L is the return loss of a length of fibre of length L;

α is the attenuation constant of the fibre;

v is the group velocity;

L is the length of the fibre;

t_b = 1 ns is the time base used in equation (14).

R_L is evaluated, for example, using the measurement procedure in 4.1 where a section of fibre of length L is used as the DUT. If αL << 1, equation (15) becomes

$$B \cong R_\mathrm{L} - 10 \times \log(t_\mathrm{b}) - 10 \times \log\left[\frac{v}{2L}\right] \quad \text{(dB)} \qquad (16)$$

This approximation is valid for single-mode fibres with L << 1 km.

As an example, the following approximations may be used with single-mode fibres type B1 according to IEC 60793-2 for a time base in nanoseconds:

- $B \cong 80$ (dB) at 1 300 nm
- $B \cong 82{,}5$ (dB) at 1 550 nm

5.5.3 Measurement procedure

The following steps shall be performed in order to measure the return loss with the OTDR.

- Set the proper OTDR pulse duration. The choice of the pulse duration depends on the distance of the DUT from point ‘a’ and ‘b’, that is the necessary spatial resolution, and on the range of RL that is to be measured. Table 1 shows the theoretical spatial resolution and the maximum value of RL measurable for several pulse duration values. The true spatial resolution is greater than the theoretical one and depends on the height of the previous reflection spike and on the recovering time of the OTDR trace after the spike. For example, in the case of a pulse of 10 ns, two points on the trace at a distance less than 5 m to 6 m are hardly separated.

Table 1 – OTDR parameters for some pulse duration

Pulse duration ns	**Theoretical spatial resolution** m	**Maximum measurable RL** dB	
		At 1 550 nm	**At 1 300 nm**
100	>10	≈ 63	≈ 60
10	>1	≈ 73	≈ 70
5	>0,5	≈ 75	≈ 72

- From the OTDR trace measure the height H (in decibels) of the spike due to the power reflected from the DUT. In most commercial instruments, the evaluation of H can be performed by using a marker to select two points on the trace.
- The return loss of the DUT shall be as follows:

$$RL = -10 \times \log\left(10^{H/5} - 1\right) + k \qquad (17)$$

NOTE 1 Most OTDRs divide the power in the return signal by two before displaying it. In this equation, the magnitude of the pulse displayed on the OTDR screen is multiplied by two to compensate for the division that the OTDR has made.

NOTE 2 Most OTDRs automatically measure RL using instrument settings fixed by the manufacturer. However, also in this case, it is important to pay attention to the accuracy considerations in 5.4.4.

Equation (17) may be simplified for large values of H:

$$\begin{aligned} RL &= -10 \times \log\left(10^{H/5} - 1\right) + k = -10 \times \log\left[10^{H/5} \cdot \left(1 - 10^{-\mathrm{H}/5}\right)\right] + k = \\ &= -10 \times \log\left(10^{H/5}\right) - 10 \times \log\left(1 - 10^{-H/5}\right) + k = -2\mathrm{x}H - 10 \times \log\left(1 - 10^{-H/5}\right) + k \end{aligned} \quad (\mathrm{dB}) \qquad (18)$$

therefore

$$RL \approx -2 \times H + k \qquad (\mathrm{dB}) \qquad (19)$$

The simplified equation (19) is a good approximation for reflectance (for values of H larger than about 5 dB).

5.5.4 Accuracy considerations

The following factors are potential sources of error in the measurement of return loss:

- evaluation of H. Accuracy in the measurement of H is particularly critical when H is very small. For example, the difference between a measurement of H = 0,5 dB and H = 1 dB is a difference in return loss of 3 dB. The accuracy becomes even worse if H is small and if the DUT attenuation is large at the same time;
- the ability of the detector to accurately respond to short pulses necessary to measure high values of return loss. For short light pulses (<1 μs) the response bandwidth of the OTDR detector can limit the measurement accuracy. In this case, the return loss shall be calibrated against a reference back-reflection element;
- signal saturation. The detector in some OTDRs saturates at large values of H so that accuracy is lost in measuring small values of return loss. In this case, the signal saturation is avoided by adding a variable attenuator between the OTDR and the DUT.

5.6 Method 3: measurement with OLCR

5.6.1 Calibration procedure

The following steps shall be performed in order to calibrate the OLCR.

a) A reflector whose return loss value RL_0 is known is connected via a length of fibre to the signal port. A typical value of RL_0 is 0 dB due to total reflection, or 14,7 dB at fibre end-face right-angled cut in respect to its axis.

b) Another single-mode fibre whose length is approximately equal to the fibre on which the reflector is terminated.

c) Optical delay is changed linearly. In the case of a conventional ODL, the reflector is translated at a constant speed.

d) The detection frequency of the output of D is adjusted to the frequency of the beat signal produced during mirror translation.

e) The output from D is sampled and stored in the data processing unit as a function of the optical delay which is obtained from the position of the reflector in the case of conventional ODL. The peak value in decibels is recorded G_0 (dB) by the processing unit.

5.6.2 Measurement procedure

The following steps shall be performed in order to measure the return loss with the OLCR.

a) The DUT is connected to the signal port in place of the known reflector. If necessary, the single-mode fibre connected to the reference port is changed to be approximately equal to the pigtail length of the DUT.

b) The same procedure from c) to e) of 5.6.1 is carried out again. After completing this procedure, the signal peak for a desired point in the DUT is measured to be G (dB).

c) The return loss of the DUT is calculated by using these values as follows:

$$RL = RL_0 + \left(G - G_0\right) \tag{20}$$

5.6.3 Accuracy considerations

A source of error in the measurement with the OLCR method is the differences in the attenuation between the temporary joints used to connect the line with the known return loss and the one with the DUT. Care shall be taken to minimize these differences.

5.7 Method 4: measurements with OFDR

5.7.1 Calibration procedure

The following steps shall be performed in order to calibrate the OFDR.

a) A reflector, whose return loss value RL_0, is known is connected via a length of single-mode fibre to the measurement system. A typical value of RL_0 is 14,7 dB at fibre end-face right-angled cut in respect to its axis.

b) If a variable attenuator is inserted (to avoid the saturation of the optical detector from the reflected signal) the attenuation value A_r shall be recorded.

c) From the acquired frequency spectrum by means of the inverse Fourier Transform, the time domain signal of the reflection is evaluated and its value R_0 in linear units is recorded.

5.7.2 Measurement procedure

The following steps shall be performed in order to measure the return loss with the OFDR.

a) Substitute the known reflection with the DUT connected through a TJ.

b) If a variable attenuator is inserted, its attenuation is adjusted in order to make the reflected power to be detected high enough, and the attenuation value A shall be recorded.

c) From the acquired frequency spectrum by means of the inverse Fourier Transform, the time domain signal of the reflection is evaluated and its value R in linear units is recorded.

d) The return loss of the DUT is calculated by using these values as follows:

$$RL = RL_0 - 10 \times \log\left(\frac{R}{R_0}\right) + \left(A_0 - A\right) \tag{21}$$

5.7.3 Accuracy considerations

A source of error in the measurement with the OFDR method is the differences in the attenuation between the temporary joints used to connect the line with the known return loss and the one with the DUT. Care shall be taken to minimize these differences.

The data measured in the frequency domain by the OFDR are converted to the time domain using an inverse Fourier transform. Thus, measurement of distances can be derived simply by using the index of refraction of the DUT. The spatial resolution between two reflections depends on the span frequency (F) and on the filtering (f), applied on the frequency data. The filtering is needed because the band-limiting of the frequency domain response causes overshoot and ringing in the time domain response (impulse sidelobes). Filtering improves the dynamic range by reducing the impulse sidelobes at the expense of the resolution.

The spatial resolution (ΔL) can be calculated by the following formula:

$$\Delta L = \frac{c \times f}{2 \times n \times F} \tag{22}$$

where c is the light speed and n is the refractive index. For example, a span of 1 GHz with a windowing factor 1,6 produces approximately 20 cm of spatial resolution. One-half of this span degrades the resolution to 40 cm.

The maximum measurable fibre length L_{max} depends on the frequency sampling Δf.

$$L_{\text{max}} = \frac{c}{2 \times n \times \Delta f} \tag{23}$$

As an example, some system data are reported in Table 2.

Table 2 – Example of system data and relevant dynamic range

Optical output power	Frequency span	IF bandwidth	Av. signal	Calibration	System dynamic range
–3 dBm	1 GHz	30 Hz	8	Fresnel	55 dB

To increase the system dynamic range, the use of an optical amplifier at the transmitter end as a power amplifier is suggested (see Figure 4). For example, by using an erbium doped amplifier with an output power of +13 dBm the achieved system dynamic range is ~ 71 dB which allows the measurement of the angled polished connectors terminated in air.

NOTE Measurement performances are dependent upon the lightwave source and the receiver used with the vector network analyser. In addition, the system dynamic range and the noise floor are dependent on the calibration routine and on the signal processing features used (such as IF bandwidth, signal averaging, smoothing, etc.).

6 Details to be specified

6.1 Return loss measurement with OCWR

The following details shall, as applicable, be specified in the detail specifications.

6.1.1 Reference components

- Connector type
- Reference plug performance specification
- Reference adapter performance specification

6.1.2 Branching device

- Splitting ratio
- Directivity

6.1.3 Detector

- Maximum sensitivity at the wavelength of the source
- Linearity
- Stability
- Type of optical connection

6.1.4 Source

- Power output
- Power stability
- Central wavelength
- Spectral width

6.1.5 Temporary joint

- Maximum attenuation
- Maximum return loss

6.1.6 Termination

- Types of termination
- Minimum return loss

6.2 Return loss measurement with OTDR

The following details shall, as applicable, be specified in the detail specifications.

6.2.1 Reference components

- Connector type
- Reference plug performance specification
- Reference adapter performance specification

6.2.2 OTDR

- Central wavelength
- Spectral width
- Pulse duration
- Receiver input attenuator
- Range in return power over which the detector is linear
- Response of the detector to short pulses
- Accuracy of the pulse length

6.2.3 L_1, L_2, and L_3

- Length of each section

6.2.4 Fibre

- Type

6.3 Return loss measurement with OLCR

The following details shall, as applicable, be specified in the detail specifications.

6.3.1 Reference components

- Connector type

- Reference plug performance specification
- Reference adapter performance specification

6.3.2 Source

Spectral width and output power from the light source

6.3.3 Branching device (BD)

- Excess loss and wavelength dependence of the power splitting ratio
- Total delay (total translation of the stage in conventional ODL)
- Linearity of optical detector
- Dispersion of the waveguide used in the measurement system
- Immunity of the measurement system against polarization

6.4 Return loss measurement with OFDR

The following details shall, as applicable, be specified in the detail specifications.

6.4.1 Reference components

- Connector type
- Reference plug performance specification
- Reference adapter performance specification

6.4.2 Vector network analyser

- Start frequency
- Stop frequency
- Frequency span
- Time domain transform (inverse Fourier transform) (optional)

6.4.3 Branching device

- Splitting ratio deviation from 50 %
- Directivity

6.4.4 Source

- Emitting wavelength
- Output power
- Power stability

6.4.5 Detector

- Receiver sensitivity
- Linearity
- Stability

6.4.6 Optical amplifier (optional)

- Saturation gain

6.4.7 Isolator (optional)

- Return loss requirement

6.4.8 Calibration

- Calibration routine
- Standard reflection

6.5 Measurement procedure

- Return loss requirement
- Return loss accuracy
- Deviation from this test procedure

Annex A
(informative)

Comparison of return loss detectable by four different methods

The specific test method(s) to be used should be specified in the relevant specification.

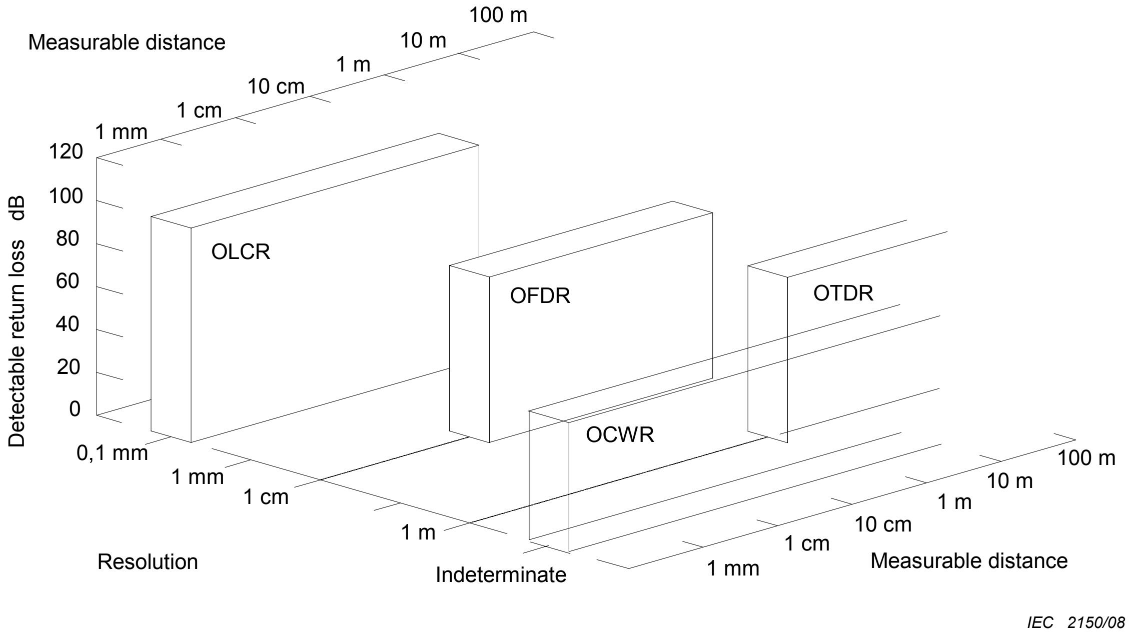


Figure A.1 – Comparison of detectable return loss, resolution and measurable distance for four return loss measurement methods

This graph is to be considered as informative guidance only. Technological improvements may change the values stated in this graph.

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