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# INTERNATIONAL STANDARD

# NORME INTERNATIONALE



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



**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**

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



## 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

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CONTENTS

FOREWORD ... 5
1 Scope ... 7
2 Normative references ... 7
3 General description ... 7
3.1 Method 1 ... 8
3.2 Method 2 ... 8
3.3 Method 3 ... 8
3.4 Method 4 ... 8
3.5 Selection of reference measurement method ... 8
4 Apparatus and symbols ... 9
4.1 Device under test (DUT) ... 9
4.2 Method 1: measurements with OCWR ... 9
4.2.1 Branching device (BD) ... 10
4.2.2 Detector ($D_1$, $D_2$ and $D_3$) ... 10
4.2.3 Source ($S_1$ and $S_2$) ... 10
4.2.4 Temporary joint (TJ) ... 10
4.2.5 Termination (T) ... 10
4.3 Method 2: measurements with OTDR ... 11
4.3.1 Optical time domain reflectometer (OTDR) ... 11
4.3.2 Fibre sections ($L_1$, $L_2$, and $L_3$) ... 11
4.3.3 Temporary joints (TJ) ... 11
4.4 Method 3: measurements with OLCR ... 11
4.4.1 Light source (S) ... 12
4.4.2 Branching device (BD) ... 12
4.4.3 Optical delay line (ODL) ... 12
4.4.4 Optical detector (D) ... 12
4.4.5 Temporary joint (TJ) ... 12
4.4.6 Data processing unit ... 12
4.5 Method 4: measurements with an OFDR ... 13
4.5.1 RF network analyser ... 13
4.5.2 Optical heads – Source (S) and receiver (D) ... 13
4.5.3 Optical variable attenuator (A) (optional) ... 13
4.5.4 Optical amplifier (OA) (optional) ... 13
4.5.5 Isolator (I) (optional) ... 14
4.5.6 Branching device (BD) ... 14
4.5.7 Temporary joint (TJ) ... 14
4.5.8 Computer ... 14
5 Procedure ... 14
5.1 Launch conditions ... 14
5.2 Pre-conditioning ... 14
5.3 DUT output port ... 14
5.4 Method 1: measurement with OCWR ... 14
5.4.1 Definition of the OCWR measurement ... 14
5.4.2 Set-up characterization ... 15
5.4.3 Measurement procedure ... 17

5.4.4 Accuracy considerations ....................18
5.5 Method 2: measurement with OTDR....................18
5.5.1 Definition of the OTDR measurement....................18
5.5.2 Evaluation of backscattering coefficient....................19
5.5.3 Measurement procedure ....................20
5.5.4 Accuracy considerations ....................21
5.6 Method 3: measurement with OLCR....................21
5.6.1 Calibration procedure....................21
5.6.2 Measurement procedure ....................21
5.6.3 Accuracy considerations ....................22
5.7 Method 4: measurements with OFDR....................22
5.7.1 Calibration procedure....................22
5.7.2 Measurement procedure ....................22
5.7.3 Accuracy considerations ....................22
6 Details to be specified....................23
6.1 Return loss measurement with OCWR ....................23
6.1.1 Reference components ....................23
6.1.2 Branching device ....................23
6.1.3 Detector....................23
6.1.4 Source....................24
6.1.5 Temporary joint....................24
6.1.6 Termination ....................24
6.2 Return loss measurement with OTDR ....................24
6.2.1 Reference components ....................24
6.2.2 OTDR....................24
6.2.3 $L_1$, $L_2$, and $L_3$....................24
6.2.4 Fibre....................24
6.3 Return loss measurement with OLCR....................24
6.3.1 Reference components ....................24
6.3.2 Source....................25
6.3.3 Branching device (BD) ....................25
6.4 Return loss measurement with OFDR ....................25
6.4.1 Reference components ....................25
6.4.2 Vector network analyser....................25
6.4.3 Branching device ....................25
6.4.4 Source....................25
6.4.5 Detector....................25
6.4.6 Optical amplifier (optional) ....................26
6.4.7 Isolator (optional)....................26
6.4.8 Calibration ....................26
6.5 Measurement procedure ....................26
Annex A (informative) Comparison of return loss detectable by four different methods ....................27

Figure 1 – Measurement set-up of return loss OCWR method....................9
Figure 2 – Measurement set-up of return loss with OTDR method....................11
Figure 3 – Measurement set-up of return loss with OLCR method....................12
Figure 4 – Measurement set-up of return loss with OFDR method....................13
Figure 5 – Measurement set-up of the system reflected power....................15

Figure 6 – Measurement set-up of the branching device transfer coefficient .......................... 16
Figure 7 – Measurement set-up of the splitting ratio of the branching device ......................... 16
Figure 8 – Measurement set-up of return loss with an OCWR ............................................. 17
Figure 9 – Typical OTDR trace of the response to a reflection .............................................. 19
Figure A.1 – Comparison of detectable return loss, resolution and measurable distance for four return loss measurement methods ............................................................... 27

Table 1 – OTDR parameters for some pulse duration ........................................................ 20
Table 2 – Example of system data and relevant dynamic range ........................................... 23

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

## Part 3-6: Examinations and measurements – Return loss

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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,
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# 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:

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

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



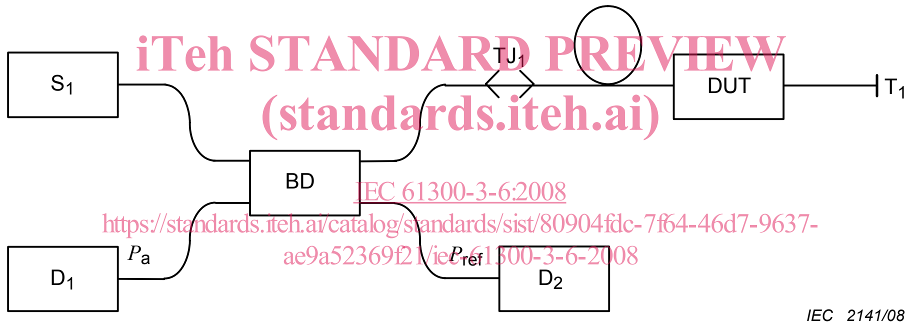


**Figure 1 – Measurement set-up of return loss OCWR method**

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, $P_0$:

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

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

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

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.

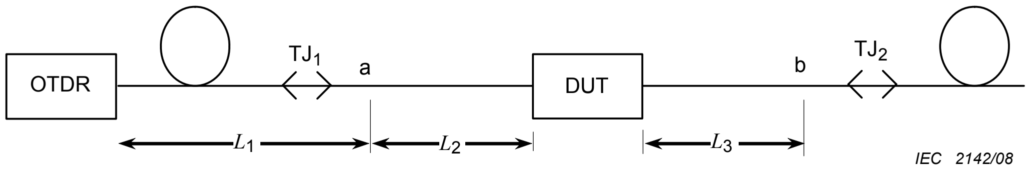


**Figure 2 – Measurement set-up of return loss with OTDR method**

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.

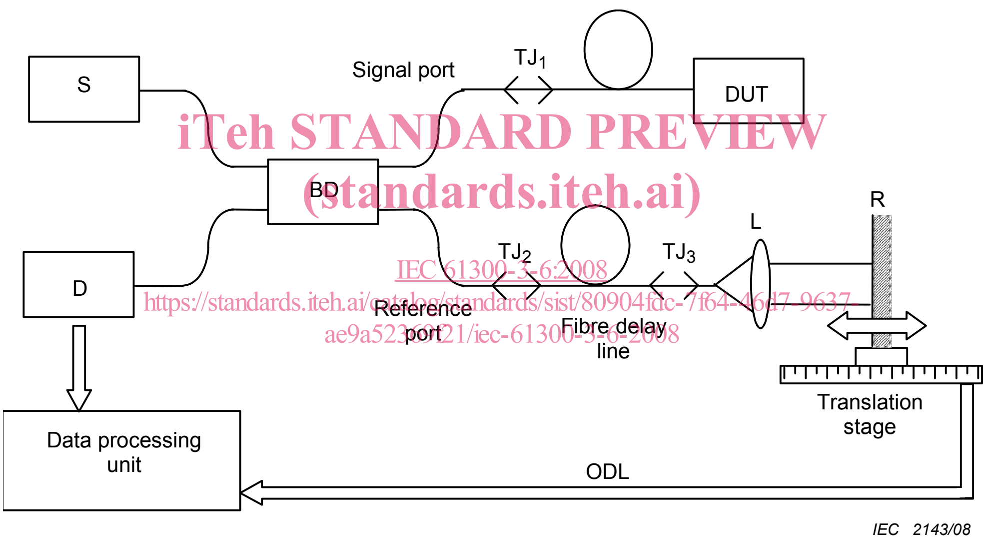




**Figure 3 – Measurement set-up of return loss with OLCR method**

### 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.



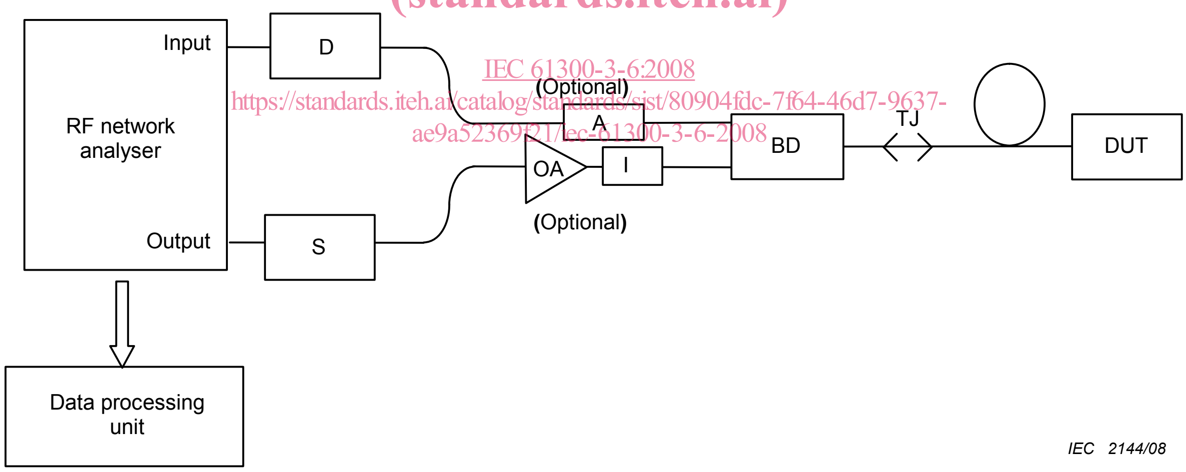


**Figure 4 – Measurement set-up of return loss with OFDR method**

#### 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.