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INTERNATIONAL STANDARD

Fibre optic interconnecting devices and passive components – Basic test and measurement procedures –
Part 3-7: Examinations and measurements – Wavelength dependence of attenuation and return loss of single mode components

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FOREWORD

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International Standard IEC 61300-3-7 has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2000. It constitutes a technical revision.

Changes from the previous edition of this standard are to reflect changes made to IEC 61300-1 and covers unidirectional and bi-directional methods of measurement.

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

FDIS	Report on voting
86B/2771/FDIS	86B/2803/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- withdrawn,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.

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

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

Part 3-7: Examinations and measurements – Wavelength dependence of attenuation and return loss of single mode components

1 Scope

This part of IEC 61300-3 describes the various methods available to measure the wavelength dependence of attenuation $A(\lambda)$ and return loss $RL(\lambda)$, of single-mode passive optical components (POC) used in fibre-optic (FO) telecommunications. It is not, however, applicable to dense wavelength division multiplexing (DWDM) devices. Measurement methods of wavelength dependence of attenuation of DWDM devices are described in IEC 61300-3-29. Definition of WDM device types is given in IEC 62074-1.

Three measurement cases are herein considered:

- Measurement of $A(\lambda)$ only;
- Measurement of $RL(\lambda)$ only;
- Measurement of $A(\lambda)$ and $RL(\lambda)$ at the same time.

These measurements may be performed in one direction (unidirectional) or bi-directionally.

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 (including any amendments) applies.

IEC 61300-3-29, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-29: Examinations and measurements – Measurement techniques for characterising the amplitude of the spectral transfer function of DWDM components*

IEC 62074-1, *Fibre optic WDM devices – Part 1: Generic specification*

3 Abbreviations and acronyms

For the purposes of this document, the following abbreviations and acronyms apply:

A	attenuation
$A(\lambda)$	wavelength dependent attenuation
ASE	amplified spontaneous emission
BBD	broadband detection
BBS	broadband source

BD	branching devices
CWDM	coarse wavelength division multiplexing
DFB	distributed feedback (laser)
DOP	degree of polarization
DUT	device under test
DWDM	dense wavelength division multiplexing
DWS	discrete wavelength source
ECL	external cavity (tuneable) laser
EDFL	erbium-doped fibre laser
FA	fibre amplifier
FP	Fabry-Perot (laser)
G(λ)	test system constant
IL	insertion loss
IL(λ)	wavelength dependent insertion loss
λ	wavelength
NLS	narrowband light sources
OPM	optical power meter
OSA	optical spectrum analyser
$P_i(\lambda)$	wavelength dependent power incident on the DUT
$P_r(\lambda)$	wavelength dependent power reflected by the DUT (from the input port of the DUT)
$P_t(\lambda)$	wavelength dependent power transmitted through the DUT
$P_G^{RL}(\lambda)$	wavelength dependent reflected power measured for the determination of the test set-up constant
$P_{Gi}^{RL}(\lambda)$	wavelength dependent incident power measured for the determination of the test set-up constant
$P_i^A(\lambda)$	wavelength dependent power incident on the DUT in case of the wavelength dependent attenuation measurement

$P_i^{RL}(\lambda)$ wavelength dependent power incident on the DUT in case of the wavelength dependent return loss measurement

PDL polarization dependent loss

POC passive optical components

PON passive optical network

RBD reference branching device

RBW resolution bandwidth

RL return loss

$RL(\lambda)$ wavelength dependent return loss

RTM reference test method

SMSR side mode suppression ratio

SOA semiconductor amplifier

SOP state of polarization

T termination

TJ temporary joint

TND tuneable narrowband detection (system)

TLS tuneable narrowband light source

TN-OTDR tuneable OTDR

WDM wavelength division multiplexing

4 General

4.1 General description

$A(\lambda)$ and $RL(\lambda)$ are expressed in decibels (dB), transmitted by or reflected from a device under test (DUT) resulting from its insertion within a fibre-optic (FO) telecommunication system. $A(\lambda)$ and $RL(\lambda)$ are obtained by comparing the optical power incident on the DUT with the optical power

- transmitted at the output port of the DUT;
- reflected from the input port of the DUT.

The DUT is inverted in order to get a bi-directional measurement. Measurements should be taken in both directions and averaged expect where the device is intentionally not bidirectional no averaging shall be done.

The term “return loss” should not be used as equivalent to reflectance. Both have completely different meanings.

4.2 Spectral conditions

$A(\lambda)$ and $RL(\lambda)$ measurements are made over a wavelength range defined in the DUT specifications. The DUT spectral characteristics also defined in the DUT specifications should be used in turn to define the spectral characteristics of the measurement system, such as its wavelength resolution (spectral difference between two adjacent data points) and uncertainty (spectral uncertainty around each data point) which in turn will define the bandwidth of the measurement system.

4.3 Definition

4.3.1 Attenuation

$A(\lambda)$ refers to the power decrease of light transmitted by the DUT as a function of wavelength. It is expressed as follows:

$$A(\lambda) = -10 \times \log\left[\frac{P_t(\lambda)}{P_i(\lambda)}\right] \text{ [dB]} \qquad (1)$$

where

$P_t(\lambda)$ is the optical power, as a function of wavelength, transmitted through the input port of the DUT and measured at the output port of the DUT, expressed in watt;

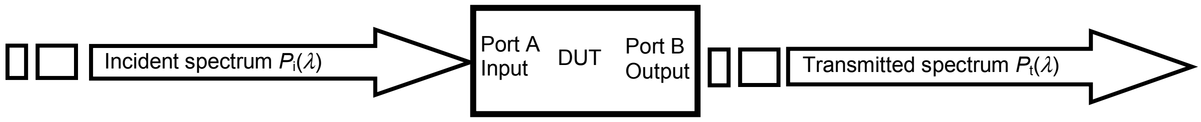
$P_i(\lambda)$ is the optical power, as a function of wavelength, incident on and measured at the input port of the DUT, expressed in watt;

for bi-directional measurement,

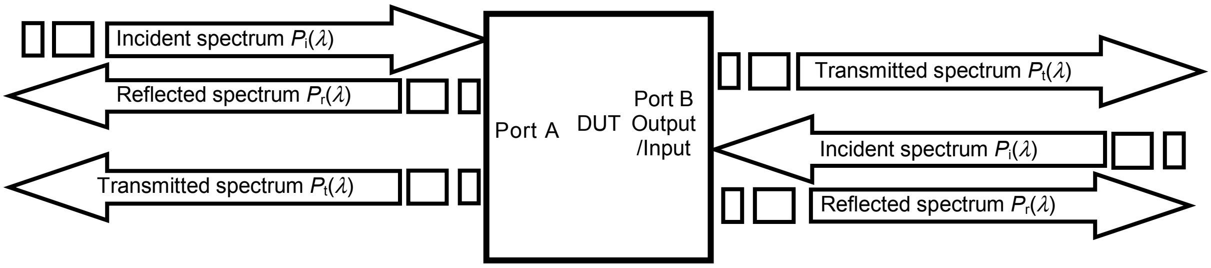
$P_t(\lambda)$ is the optical power, as a function of wavelength, transmitted through the output port of the DUT and measured at the input port of the DUT, expressed in watt;

$P_i(\lambda)$ is the optical power, as a function of wavelength, incident on and measured at the output port of the DUT, expressed in watt.

Figure 1 illustrates the process.



a) Unidirectional measurement



b) Bi-directional measurement

IEC 2334/08

Figure 1 – Wavelength dependence of attenuation and return loss

4.3.2 Return loss

$RL(\lambda)$ refers to the power decrease of light reflected by the DUT as a function of wavelength. It is expressed as follows:

$$RL(\lambda) = -10 \times \log\left[\frac{P_r(\lambda)}{P_i(\lambda)}\right] \text{ [dB]} \tag{2}$$

where

$P_r(\lambda)$ is the optical power, as a function of wavelength, reflected by and measured from the input port of the DUT, expressed in watt;

$P_i(\lambda)$ is the optical power, as a function of wavelength, incident on and measured at the input port of the DUT, expressed in watt;

for bi-directional measurement,

$P_r(\lambda)$ is the optical power, as a function of wavelength, reflected by and measured from the output port of the DUT, in units of W;

$P_i(\lambda)$ is the optical power, as a function of wavelength, incident on and measured at the output port of the DUT, in units of W.

Figure 1 illustrates the process.

4.4 Device under test

The DUT may have more than two ports. However, since measurement of $A(\lambda)$ is made across only two ports, be they unidirectional or bi-directional, the DUT in this standard shall be described as having two ports. The same is true for measurement of $RL(\lambda)$, except that in this case, the measurement is made from only one port at a time.

Eight different DUT configurations are herein considered and described in Table B.1 of Annex B. The differences between these configurations are primarily in the terminations of the optical ports. Terminations may consist of bare fibre, connector plug, or receptacle. The various types of product that are herein under consideration are illustrated in Table B.2 of Annex B.

4.5 Measurement methods

The characterization of the DUT spectral response can be carried out on several discrete wavelengths along a wavelength range of interest, continuously over the range or a combination of the above. The way this characterization is performed defines the various test methods.

Four methods, A to D, are described for measuring $A(\lambda)$ and $RL(\lambda)$. The methods are listed below in the order of their introduction. For some methods, multiple configurations are possible.

Table 1 summarizes the different test methods and their main characteristics.

NOTE Different test configurations and methods will result in different accuracies of the attenuation being measured. In cases of dispute, the RTM should be used.

Table 1 – Test methods and characteristics

Method	Name	Light source	Detection system	Example	Comments
A	BBS	BBS	TND	BBS + DUT + OSA	Alternate
B	TLS	To be depolarised + coherence control			
B.1	TLS + BBD	TLS	BBD	TLS + DUT + OPM	
B.1.1	TLS in start-stop-measure mode + BBD	TLS in start-stop-measure mode	BBD	TLS + DUT + OPM	Alternate
B.1.2	TLS in sweep mode + BBD	TLS in sweep mode	BBD	TLS + DUT + OPM	Alternate
B.2	TLS + TND	TLS	TND	TLS + DUT + OSA	
B.2.1	TLS in start-stop-measure mode + TND	TLS in start-stop-measure mode	TND	TLS + DUT + OSA	RTM
B.2.2	TLS in sweep mode + TND	TLS in sweep mode	TND	TLS + DUT + OSA	Alternate
C	Set of *N* NLS	To be depolarised + coherence control			
C.1	*N* NLS + BBD	*N* NLS	BBD	*N* NLS + N x 1 coupler + DUT + OPM	Alternate
C.2	*N* NLS + TND	*N* NLS	TND	*N* NLS + N x 1 coupler + DUT + OSA	Alternate
D	TN-OTDR	TN OTDR	TN-OTDR	TN-OTDR + DUT	Alternate

4.5.1 Method A – Broadband light source (BBS)

In Method A, a broadband light source (BBS) is used with a tuneable narrowband filtering detection system (TND).

A possible implementation of Method A is the use of the BBS with an optical spectrum analyser (OSA). Method A has the advantage of providing all the required wavelength range in a single test and the test sampling rate is defined by the TND. Measurement of the wavelength dependence should be done using the BBS having high quality spectral power density. Use of a suitable TND spectral filter is recommended for an accurate measurement.

4.5.2 Method B – Tuneable narrowband light source (TLS)

In Method B, a tuneable narrowband light source (TLS) is used with two possible different detection systems.

4.5.2.1 Method B.1 – Tuneable narrowband light source and broadband detection system

In Method B.1, a TLS is used with a broadband detection system (BBD).

A possible implementation of Method B.1 is the use of the TLS with an optical power meter (OPM). The TLS can be used in two different modes with the BBD:

a) Method B.1.1 – Step-by-step tuneable narrowband light source and broadband detection system

In this method, the bandwidth of the measurement is defined by the TLS linewidth. A linewidth too narrow will create spurious noise, coherence interference effects and unnecessary amount of data; a linewidth too wide will not provide enough resolution to the DUT spectral response. An estimate of the DUT bandwidth and the application of the Nyquist criterion are required in order to properly define the TLS linewidth.

b) Method B.1.2 – Swept tuneable narrowband light source and broadband detection system

In this method, the bandwidth of the measurement is defined by the bandwidth of the detection system, not by the TLS linewidth. An estimate of the DUT bandwidth and the application of the Nyquist criterion are required in order to properly define the bandwidth of the detection system.

4.5.2.2 Method B.2 – Tuneable narrowband light source and tuneable narrowband detection system

In Method B.2, a TLS is used with a TND. Synchronization between both ends of the measurement system is required. This method is particularly useful for very narrowband components.

A possible implementation of Method B.2 is the use of the TLS with an OSA. The TLS can be used in two different modes with the TND:

a) Method B.2.1 – Step-by-step tuneable narrowband light source and tuneable narrowband detection system

The measurement bandwidth for Method B.2.1 is the same as in Method B.1.1.

b) Method B.2.2 – Swept tuneable narrowband light source and tuneable narrowband detection system

The measurement bandwidth for Method B.2.2 is the same as in Method B.1.2.

4.5.3 Method C – Set of multiple fixed narrowband light sources (NLS)

In Method C, a set of *N* narrowband light sources (NLS) is used with two possible different detection systems. This method is particularly useful when the DUT spectral response is expected to be quite non-uniform and the regions of non-uniformity need to be carefully assessed.

A possible implementation of Method C is the use of a set of *N* DFB lasers with *N* x 1 coupler and/or 1 x *N* splitter on each side of the DUT with one OPM for each DFB.

4.5.3.1 Method C.1 – NLS and BBD

Method C.1 is a variation of Method B.1 in which the TLS is replaced by the set of *N* NLS.

4.5.3.2 Method C.2 – NLS and TND

Method C.2 is a variation of Method B.2 in which the TLS is replaced by the set of *N* NLS.

4.5.4 Method D – Tuneable OTDR

In Method D, a tuneable narrowband light is emitted by TN-OTDR and appropriate detection by the TN-OTDR is used.

4.5.5 Reference method

The reference test method (RTM) for measuring $A(\lambda)$ and $RL(\lambda)$ shall be Method B.2.1.

5 Apparatus

The following subclauses describe the test set-up components.

5.1 Wavelength source

The following subclauses describe the various available sources for performing the measurements.

5.1.1 Method A – Broadband light source

The BBS is used in Method A. The BBS emits a broadband light over a wavelength range with various characteristics depending on its type. The BBS may be a white light source, an LED (surface emitted or edge emitted), a superluminescent LED (SLED) or an amplified spontaneous emission (ASE) source from an optical fibre amplifier (FA) or from a semiconductor amplifier (SOA).

The BBS shall cover the specified wavelength range. The wavelength range shall be wide enough to cover the specified DUT bandwidth and the output power high enough for $A(\lambda)$ and $RL(\lambda)$ to be measured. The spectral power density stability shall be better than ±0,05 dB during 8 h consecutive.

The test set-up specifications shall meet the detailed requirements of the DUT $A(\lambda)$ and $RL(\lambda)$ as defined in the DUT specifications. As a consequence, the BBS requirements shall be carefully defined in order to make sure that Method A and set-up will meet those specifications. The main BBS characteristics are shown in Clause B.1 of Annex B.

5.1.2 Method B – Tuneable narrowband light source

The TLS is used in Method B. The TLS emits a narrowband light that can be spectrally tuned over a wavelength range with various characteristics depending on its type. The TLS may be a BBS with a tuneable filter, an external cavity tuneable laser (ECL), a tuneable DFB laser (DFB) and a tuneable erbium-doped fibre laser (EDFL). Clause B.2 of Annex B describes the main characteristics of various TLS types.

The test set-up specifications and the selection of the particular sub-sets of Method B shall meet the detailed requirements of the DUT $A(\lambda)$ and $RL(\lambda)$ as defined in the DUT specifications. As a consequence, the TLS requirements shall be carefully defined in order to make sure that the selected test method and set-up will meet those specifications. In general, the main TLS specifications that should be carefully considered are (see Clause B.3 of Annex B):

- centre wavelength;
- side-mode suppression ratio (SMSR), when applicable;
- linewidth; in relation with coherence interference effects, polarization dependent loss (PDL) effects and spurious reflections, and Nyquist criterion;
- power stability at any operating wavelength; ≤ ±0,05 dB over a continuous 8 h period.

Coherence control shall be applied to the narrowband light source used in TN-OTDR in order to avoid coherence interference effects.

5.1.3 Method C – Set of *N* narrowband light sources

The wavelength of each NLS and the total wavelength range of the set is set to cover the specified wavelengths and total wavelength range together with the detection system. In all cases, $N \times 1$ couplers or switches are used where *N* is equal to the number of NLS used.

Method C is based on a set of *N* discrete wavelengths. The wavelengths may be emitted by the following sources:

- Fabry-Perot (FP) laser
- DFB laser.

The same TLS requirements typically apply to each narrowband light source used in the wavelength set.

Coherence control shall be applied to avoid coherence interference effects.

5.1.4 Method D – Tuneable OTDR

The source light emitted by the TN-OTDR shall have the same characteristics as the TLS.

5.1.5 Depolarizer

In all cases, the TLS output shall be depolarized in order to get $A(\lambda)$ and $RL(\lambda)$ independent of any particular state of polarization (SOP) i.e. the averaged value over all possible SOPs. Active and passive depolarization methods exist such as the use of polarization scrambler or a serial set of circulating couplers. Coherence control shall be applied to the TLS in order to prevent coherence interference effects during the measurement.

For Method B, C and D, the measurement results shall be the averaged $A(\lambda)$ and $RL(\lambda)$ as a function of the state of polarization (SOP). This is particularly critical because these methods use narrowband polarized light sources and as such the test results may be obtained at different unknown SOP after the DUT.

The following are two approaches for obtaining the averaged value of $A(\lambda)$ and $RL(\lambda)$:

- Direct approach. A depolarizer based on active or passive device is connected at the output port of the source in order to reduce its degree of polarization (DOP). This allows the direct measurement of the averaged $A(\lambda)$ and $RL(\lambda)$ as a function of the state of polarization (SOP).
- Indirect approach. The measurement of $A(\lambda)$ and $RL(\lambda)$ as a function of the state of polarization (SOP) and to obtain the average value of $A(\lambda)$ and $RL(\lambda)$ from the measurement results.

5.2 Detection system

The following subclauses describe the various options for the detection system in relation with the methods described above.

5.2.1 Method A, Method B.2 and Method C.2 tuneable narrowband detection spectrum

The TND typically uses an OSA measuring the output optical power at every wavelength over the specified wavelength range and with a resolution bandwidth (RBW). The RBW is specified at –3 dB and is a spectral characteristic of the filtering design used in an OSA. The RBW may be variable but shall be specified in accordance with the required DUT bandwidth and fulfilling the Nyquist criterion. In order to avoid false interpretation of detectable artefacts in the measured DUT spectral response, the optical rejection ratio (ORR) shall be specified at a certain wavelength difference from the centre wavelength. An example of such specification could be –20 dB at 0,1 nm away from the centre wavelength; other values may be specified such as –30 dB at 0,2 nm away from the centre wavelength, better defining the required spectral response of the filter used in the OSA. If a global assessment of the OSA RBW performance is desired, the overall filter shape response of the OSA may be required. This is typically achieved by comparing the envelope of a DFB against one obtained from a high-resolution interferometer.

The power dynamic range and sensitivity shall be high enough for *A* and *RL* to be measured in accordance with the DUT specification. The amplitude uncertainty due to polarization dependance of the OSA shall be less than desired uncertainty of $A_{DUT}(\lambda)$ to be measured.

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

5.2.2 Method B.1 and Method C.1 broadband detection spectrum

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

The BBD wavelength range shall be wide enough and power sensitivity high enough for $A(\lambda)$ and $RL(\lambda)$ to be measured. The BBD response shall be linear. Since all of the measurements are differential, it is however not necessary that the calibration be absolute. Care should be taken to suppress the reflected power and minimize polarization sensitivity from the BBD during the measurement.

Where, during the sequence of measurements, the BBD is disconnected and reconnected, the coupling efficiency for the two measurements shall be maintained. Use of a large area detector to capture all of the light emanating from the DUT is recommended.

5.3 Branching devices

The branching devices (BD) are used in order to branch the DUT to the source and the detection system in pigtailed or connectorized configuration depending on their individual connection design.

BD configurations may be 1X1 connector jumper (also called patchcord), splice, bare-fibre adaptor, vacuum chuck or micro manipulator. Another configuration may also be a 2X1 coupler used for $RL_{DUT}(\lambda)$ measurements.

BD splitting ratio shall be stable and uniform with wavelength. The amplitude uncertainty due to PDL of the BD shall be less than desired uncertainty of $A_{DUT}(\lambda)$ to be measured. $A_{BD}(\lambda)$ shall be low enough to allow the minimum $RL_{DUT}(\lambda)$ to be measured. $RL_{BD}(\lambda)$ should be at least 20 dB higher than the maximum $RL_{DUT}(\lambda)$ to be measured. The directivity should be at least 10 dB higher than the maximum $RL_{DUT}(\lambda)$ to be measured.

BD shall be selected in accordance with the DUT detail specifications.

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

5.4 Termination

Table A.1 in Annex A illustrates a number of DUT configurations for terminations. Terminations (RL_∞) shall have a high *RL*. Three RL_∞ types may be considered:

- angled fibre ends such as the use of angled-polished connector (APC);
- application of an index matching material to the fibre end;
- sufficient fibre attenuation, for example with a mandrel wrap.

RL_∞ shall have an *RL* at least 20 dB greater than the maximum $RL_{DUT}(\lambda)$ to be measured.

Reference plugs with pigtails, and as required, reference adaptos, shall be added to the DUT ports with connector terminations so as to form complete connector assemblies with pigtails.

6 Procedure

The methods herein described are intended to define procedures from which $A(\lambda)$ and $RL(\lambda)$ can be derived.

In each of the following methods, it may be possible to improve the measurement accuracy by using variants of the basic methods. Phase-sensitive detection of a mechanically modulated source is an example of an improved test set-up when high loss components are to be characterized.

Also, power fluctuation of the optical source can be monitored over time and used to systematically adjust the DUT spectral response, using the terminated output port of the RBD.

NOTE The measurement precision is dependent on the DUT PDL and on the detection system when a Method B or Method C is used.

6.1 Method A – broadband light source

6.1.1 Attenuation-only

6.1.1.1 Reference measurement

Connect BBS to TND as shown in Figure 2a. Depending on DUT configuration, the connection may be either direct or with an adaptor. If possible, direct connection should be preferred as it is less uncertain.

Following Figure 2a, measure and record optical output power levels $P_t^{ref}(\lambda)$ over the wavelength range.

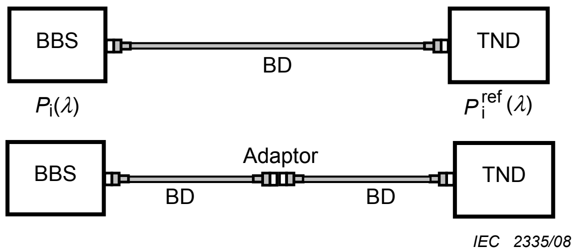


Figure 2a – Attenuation reference measurement

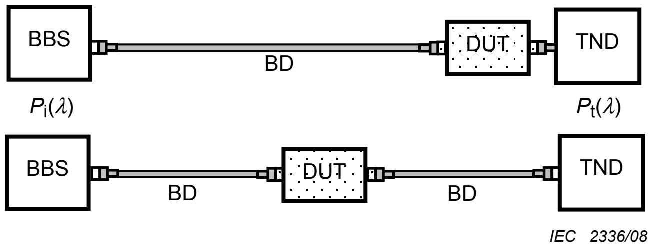


Figure 2b – Attenuation measurement

Figure 2 – Method A – Attenuation-only measurement

6.1.1.2 Attenuation measurement

Insert the DUT as shown in Figure 2b; measure and record optical output power levels $P_t(\lambda)$ over the wavelength range.

Calculate $A(\lambda)$as follows:

$$A(\lambda) = -10 \times \left[\log \frac{P_t(\lambda)}{P_i(\lambda)} - \log \frac{P_t^{ref}(\lambda)}{P_i(\lambda)} \right] \text{ [dB]} \qquad (3)$$

6.1.1.3 Bidirectional measurement

Invert the DUT in order to perform a bidirectional measurement and the measurements taken in both directions should be averaged. No averaging shall be done when the device is intentionally non-bidirectional.

6.1.2 Return-loss-only

6.1.2.1 Reference measurement

Connect BBS and NBD to 2 ×1 BD as shown in Figure 3a. Depending on DUT configuration, the connection may be either direct or with an adaptor. If possible, direct connection should be preferred as it is less uncertain. Make sure to terminate the single output branch of the 2 × 1 BD, as shown in Figure 3a.

Following Figure 3a, measure and record optical output power levels $P_r^{ref}(\lambda)$ over the wavelength range.

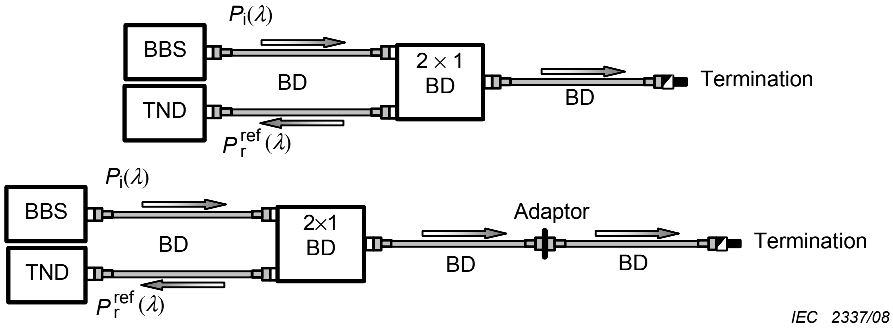


Figure 3a – Return loss reference measurement

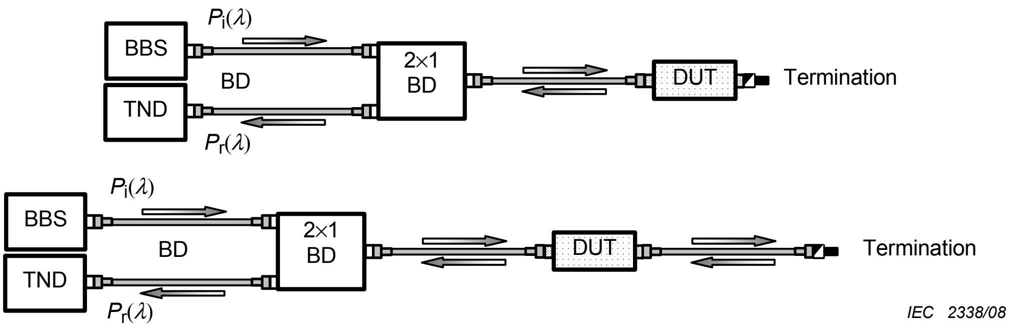


Figure 3b – Return loss measurement

Figure 3 – Method A – Return-loss-only measurement

6.1.2.2 Return loss measurement

Insert the DUT as shown in Figure 3b; measure and record optical output power levels $P_r(\lambda)$ over the wavelength range.

Calculate $RL(\lambda)$as follows:

$$RL(\lambda) = -10 \times \left[\log \frac{P_r(\lambda)}{P_i(\lambda)} - \log \frac{P_r^{ref}(\lambda)}{P_i(\lambda)} \right] \text{ [dB]} \qquad (4)$$

6.1.2.3 Bidirectional measurement

Invert the DUT in order to perform a bidirectional measurement and the measurements taken in both directions should be averaged. No averaging shall be done when the device is intentionally non-bidirectional.

6.1.3 Attenuation and return loss

6.1.3.1 Reference measurement

Connect BBS and two NBDs to 2 × 1 BD as shown in Figure 4a. Depending on DUT configuration, the connection may be either direct or with an adaptor. If possible, direct connection should be preferred as it is less uncertain. Make sure to use an APC connector with the second NBD on the side of the single output branch of the 2 × 1 BD, as shown in Figure 4a.

Following Figure 4a, measure and record both optical output power levels $P_t^{ref}(\lambda)$ and $P_r^{ref}(\lambda)$ over the wavelength range.

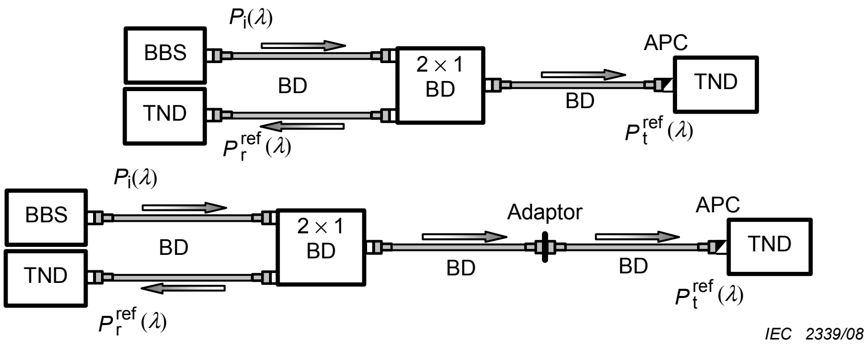


Figure 4a – Attenuation and return loss reference measurement

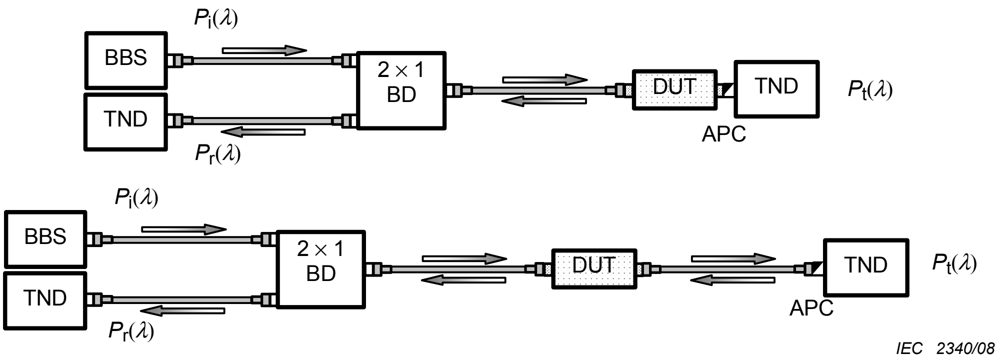


Figure 4b – Attenuation and return loss measurement

Figure 4 – Method A – Attenuation and return loss measurement

6.1.3.2 Attenuation and return loss measurement

Insert the DUT as shown in Figure 4b; measure and record optical output power levels $P_t(\lambda)$ and $P_r(\lambda)$ over the wavelength range.

Calculate $A(\lambda)$ and $RL(\lambda)$ following Equations (3) and (4).

6.1.3.3 Bidirectional measurement

Invert the DUT in order to perform a bidirectional measurement and the measurements taken in both directions should be averaged. No averaging shall be done when the device is intentionally non-bidirectional.

6.2 Method B – Tuneable narrowband light source

In all cases, when Method B is used the TLS must be depolarized in order to obtain a result which is the average over all SOPs and not just at one unknown or inapplicable SOP from the TLS itself without depolarization.

Method B may be used in a number of different configurations (see Table 1 – Test methods and characteristics), such as:

- Method B.1 – TLS with BBD

- Method B.1.1 – step-by-step TLS with BBD in which the measurement is made one wavelength at a time over the wavelength range
- Method B.1.2 – swept TLS with BBD in which the measurement is made continuously over the wavelength range
- Method B.2 – TLS with TND
- Method B.2.1 – step-by-step TLS with TND in which the measurement is made one wavelength at a time over the wavelength range and TLS and TND are synchronized to one another
- Method B.2.2 – swept TLS with TND in which the measurement is made continuously over the wavelength range and TLS and TND are synchronized to one another

In all cases, the measurement set-up and procedure are the same as in Figure 3 and Figure 4 and in 5.1.

6.3 Method C – Set of multiple fixed narrowband light sources

Method C may be used in two different configurations (see Table 1 – Test methods and characteristics), such as:

- Method C.1 – Set of *N* x NLS with BBD
- Method C.2 – Set of *N* x NLS with TND

In all cases, each NLS must be depolarized in order to obtain a result which is the average over all SOPs and not just at one unknown or inapplicable SOP from the NLS itself without depolarization.

The measurement procedure is the same for both configurations.

6.3.1 Attenuation-only

6.3.1.1 Reference measurement

Connect each NLS to the *N* 1 BD or switch and to the BBD or TND as shown in Figure 5a.

Depending on the DUT configuration, the connection may be either direct or with an adaptor. If possible, direct connection should be preferred as it is less uncertain.

Following Figure 5a, measure and record optical output power levels $P^{\text{ref}}_{\text{t,n=1...}N}(\lambda)$ for each NLS over the specified wavelength range.

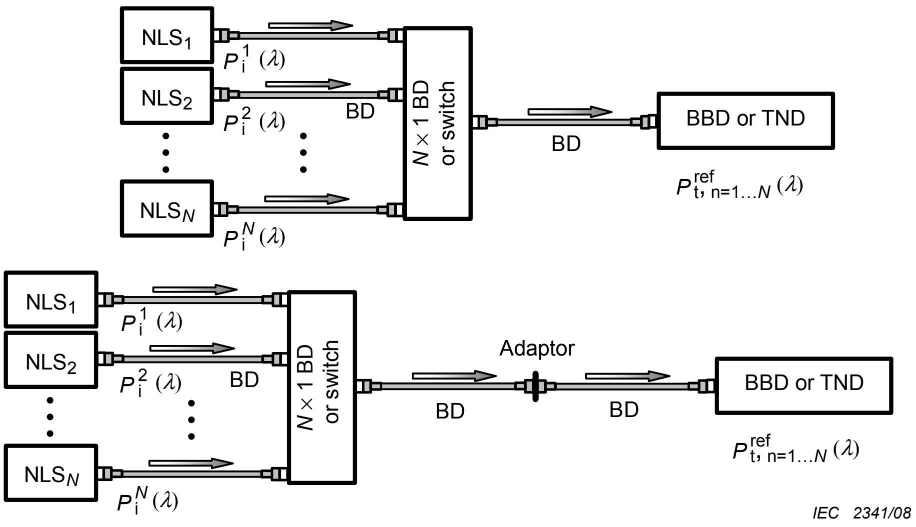


Figure 5a – Attenuation reference measurement

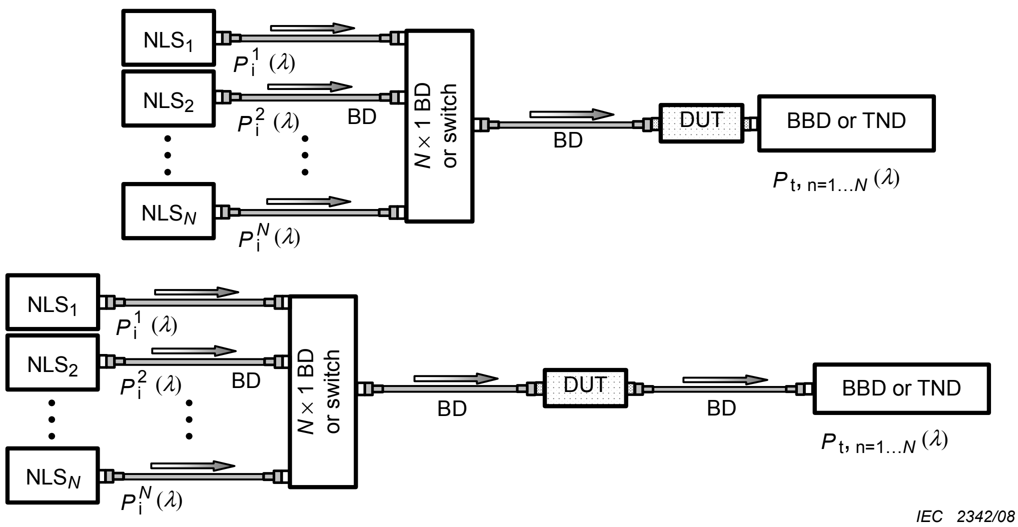


Figure 5b – Attenuation measurement

Figure 5 – Method C – Attenuation-only measurement

6.3.1.2 Attenuation measurement

Insert the DUT as shown in Figure 5b; measure and record optical output power levels $P_{t,n=1...N}(\lambda)$ over the wavelength range for each NLS.

Calculate $A_{n=1...N}(\lambda)$as follows:

$$A_{n=1...N}(\lambda) = -10 \times \left[\log \frac{P_t(\lambda)}{P_i(\lambda)} - \log \frac{P_t^{ref}(\lambda)}{P_i(\lambda)} \right]_{n=1...N} \text{ [dB]} \quad (5)$$

6.3.1.3 Bidirectional measurement

Invert the DUT in order to perform a bidirectional measurement and the measurements taken in both directions should be averaged. No averaging shall be done when the device is intentionally non-bidirectional.

6.3.2 Return-loss-only

6.3.2.1 Reference measurement

Connect each NLS to the $N \times 1$ BD or switch as shown in Figure 6a.

Connect the $N \times 1$ BD or switch and BBD or TND to 2×1 BD as shown in Figure 6a and terminate the 2×1 BD.

Depending on DUT configuration, the termination may be either direct or with an adaptor, as shown in Figure 6a. If possible, direct connection should be preferred as it is less uncertain.

Following Figure 6a, measure and record optical output power levels $P^{\text{ref}}_{\text{r,n=1...}N}(\lambda)$ over the wavelength range.

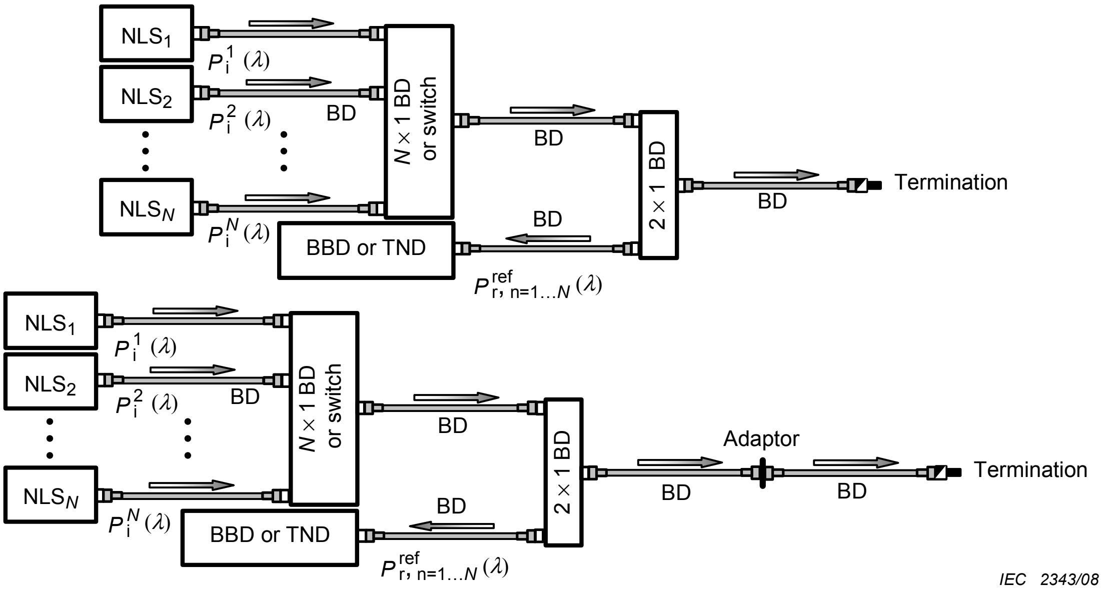


Figure 6a – Return loss reference measurement

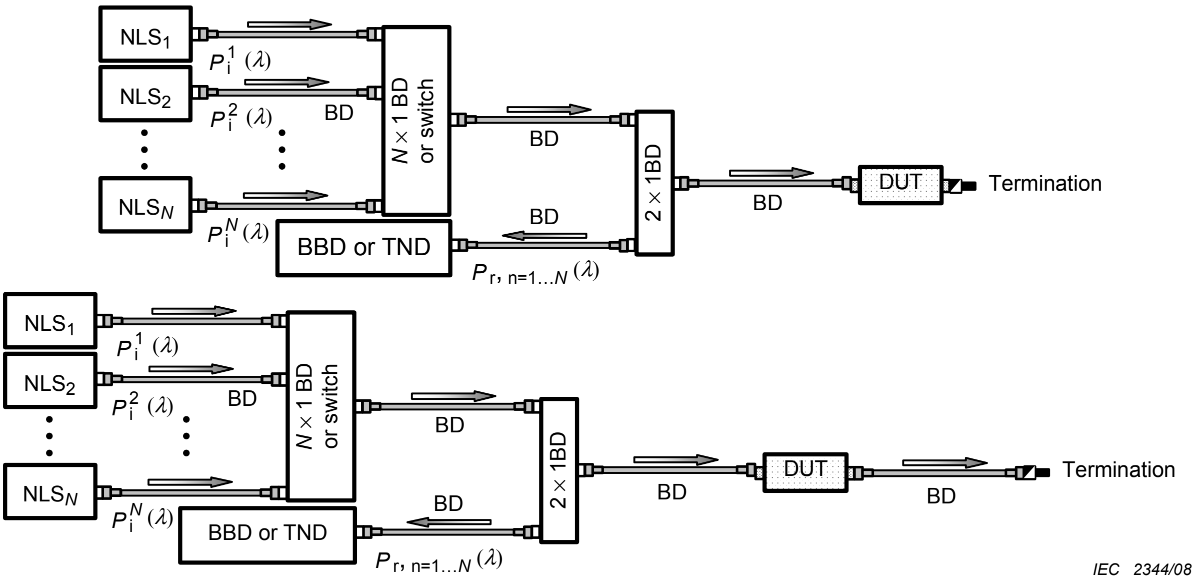


Figure 6b – Return loss measurement

Figure 6 – Method C Return-loss-only measurement

6.3.2.2 Return loss measurement

Insert the DUT as shown in Figure 6b; measure and record optical output power levels $P_{r,n=1...N}(\lambda)$ over the wavelength range.

Calculate $RL(\lambda)$as follows:

$$RL_{n=1...N}(\lambda) = -10 \times \left[\log \frac{P_r(\lambda)}{P_i(\lambda)} - \log \frac{P_r^{ref}(\lambda)}{P_i(\lambda)} \right]_{n=1...N} \quad \text{[dB]} \tag{6}$$

6.3.2.3 Bidirectional measurement

Invert the DUT in order to perform a bidirectional measurement and the measurements taken in both directions should be averaged. No averaging shall be done when the device is intentionally non-bidirectional.

6.3.3 Attenuation and return loss

6.3.3.1 Reference measurement

Connect each NLS to the $N \times 1$ BD or switch, as shown in Figure 7a.

Connect the $N \times 1$ BD or switch and both BBD or TND to 2×1 BD as shown in Figure 7a.

Depending on DUT configuration, the connection may be either direct or with an adaptor, as shown in Figure 7a. If possible, direct connection should be preferred as it is less uncertain. Make sure to use an APC connector with the second BBD or TND on the side of the single output branch of the 2×1 BD, as shown in Figure 7a.

Following Figure 7a measure and record optical output power levels $P_{t,n=1...N}^{ref}(\lambda)$ and $P_{r,n=1...N}^{ref}(\lambda)$ over the wavelength range.

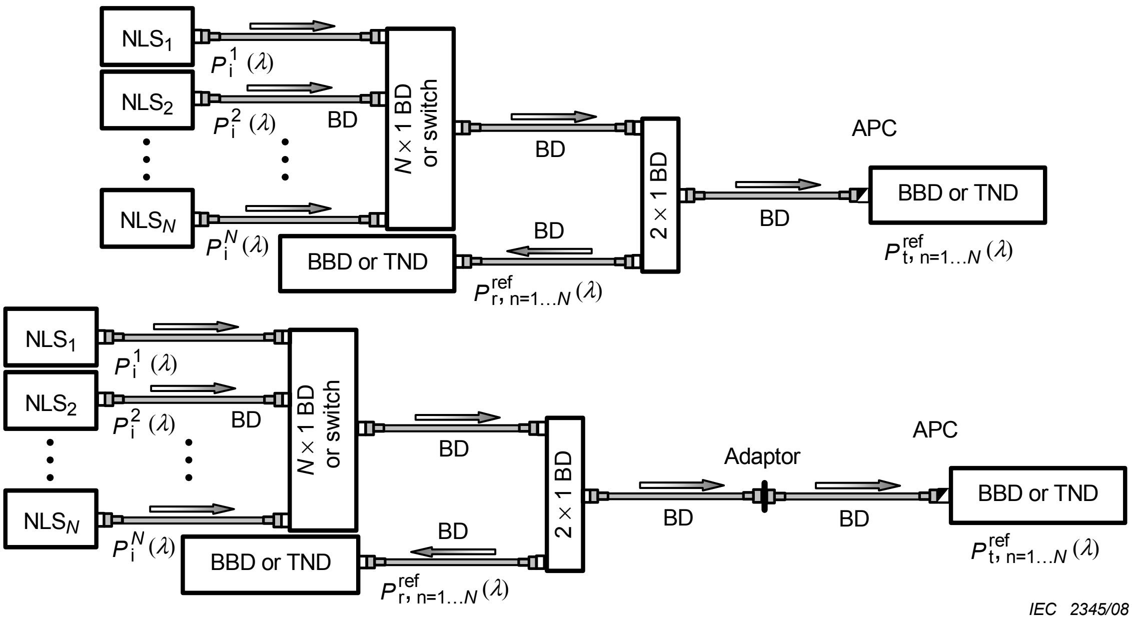


Figure 7a – Attenuation and return loss reference measurement

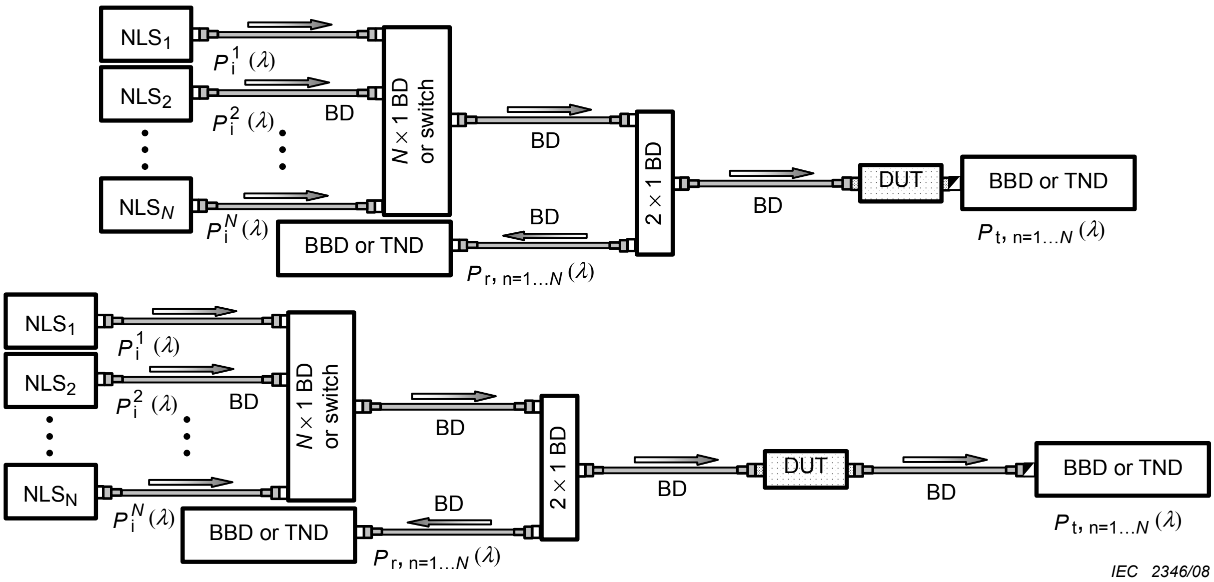


Figure 7b – Attenuation and return loss measurement

Figure 7 – Method C – Attenuation and return loss measurement

Insert the DUT as shown in Figure 7b; measure and record optical output power levels $P_{t,n=1...N}(\lambda)$ and $P_{r,n=1...N}(\lambda)$ over the wavelength range.

Calculate $A_{n=1...N}(\lambda)$ and $RL_{n=1...N}(\lambda)$ following Equations (5) and (6), respectively.

6.3.3.2 Bidirectional measurement

Invert the DUT in order to perform a bidirectional measurement and the measurements taken in both directions should be averaged. No averaging shall be done when the device is intentionally non-bidirectional.

6.4 Test results

The Table 2 and Figure 8 provide examples of test results.

Table 2 – Wavelength dependent attenuation and return loss

Wavelength (nm)	Attenuation (dB)	Return loss (dB)
λ_1	$A(\lambda_1)$	$RL(\lambda_1)$
λ_2	$A(\lambda_2)$	$RL(\lambda_2)$
λ_3	$A(\lambda_3)$	$RL(\lambda_3)$
.	.	.
.	.	.
.	.	.
.	.	.
λ_n	$A(\lambda_n)$	$RL(\lambda_n)$

For each direction of transmission, or for each output port, if applicable, there will be a separate or superposed graph.

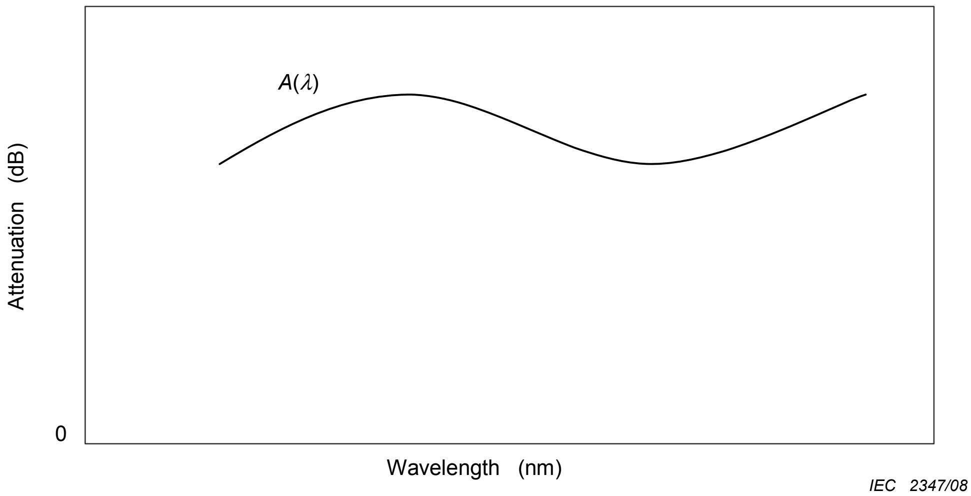


Figure 8 – Wavelength dependent attenuation

7 Details to be specified

The following subclauses describe the details to be provided for each component of the measurement set-up.

7.1 Source

The following subclauses describe the details to be provided for the various sources used in the measurement set-up.

7.1.1 Broadband source

- Spectral power density
- Total power stability
- Wavelength bandwidth
- Type of optical connection

7.1.2 Tuneable or discrete narrowband light source

- Power output
- Power stability
- Wavelength accuracy
- Wavelength range
- Spectral width
- Type of optical connection

7.1.3 Depolarizer

- Maximum loss
- Maximum PDL
- Minimum attainable DOP
- Maximum wavelength dependency on the DOP

7.2 Detection system

7.2.1 Optical power meter

- Power accuracy
- Dynamic range
- Power linearity
- Power stability
- Polarization sensitivity
- Intrinsic $RL(\lambda)$
- Type of optical connection

7.2.2 Optical spectrum analyser

- Wavelength range
- Wavelength accuracy
- RBW
- Averaging times
- Dynamic range
- Power linearity
- Power stability
- Polarization sensitivity
- Intrinsic $RL(\lambda)$
- Type of optical connection

7.3 Reference branching device

- Power splitting ratio
- Directivity
- PDL
- Intrinsic $A(\lambda)$

7.4 Termination

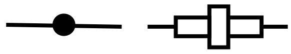
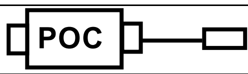
- Types of termination
- Minimum *RL*

Annex A
(informative)

Device under test configurations, terminations and product types

The possible DUT configurations and terminations are described in Table A.1.

Table A.1 – Device under test configurations/terminations

Type	Description	DUT
1	Fibre to fibre (POC)	
2	Fibre to fibre (splice or field-mountable connector set)	
3	Fibre to plug	
4	Plug to plug (POC)	
5	Plug to plug (patchcord)	
6	Single plug (pigtail)	
7	Receptacle to receptacle (POC)	
8	Receptacle to plug (POC)	

The possible product types are shown in Table A.2.

Table A.2 – Possible types of passive optical components (POC)

POC Type	Most popular application	Number of ports	Comments
Patchcord	General	2	$A(\lambda)$ and $RL(\lambda)$ essentially defined by the connectors
Coupler	General	$1 \times N$	Bidirectional measurement is critical
Wide WDM coupler	PON	1×2	Couple 1310-nm signal upstream with 1490-nm signal downstream
			Couple combined 1310-nm signal upstream with 1490-nm signal downstream with 1550-nm overlaid analogue video signal downstream
		$2 \times N$	Network protection
			Bidirectional measurement is critical
Splitter	PON	$1 \times N$	BPON, $N \leq 32$ GPON, $N \leq 128$ EPON, $N \leq 16$ or up to 32 with FEC
			Bidirectional measurement is critical
CWDM multiplexer/ demultiplexer	CWDM network	$N \times 1$ $1 \times N$	Bidirectional measurement is critical Directivity is critical
Fibre bragg grating (FBG)	EDFA gain flattening filter	1×1	May have temperature control
	Dispersion compensator	1×1	Chirp FBG; may have temperature control

Table A.2 (*continued*)

POC Type	Most popular application	Number of ports	Comments
FBG + circulators	OADM	2 × 2	
Circulator	OADM	2 × 1	
TFF	WDM	1 × 1	Bidirectional measurement is critical
3-Port component	WDM	1 × 2	Bidirectional measurement is critical
Optical switch	General	1 × N	Directivity, repeatability and latching are critical
Optical attenuator	General	1 × 1	Bidirectional measurement is critical
			Very lossy at high attenuation
Isolator	General	1 × 1	Very lossy in backward direction
Optical power limiter	High power	1 × 1	Very lossy at high performance
Optical power fuse	High power	1 × 1	Destroyed when at full performance
Mechanical splice	General	1 × 1	Bidirectional measurement is critical
Connector	Field mountable	1 × 1	Bidirectional measurement is critical
	Pigtail	1 × 1	Bidirectional measurement is critical

Annex B
(informative)

Typical light source characteristics

The main characteristics of various light sources used in the test methods are described in this annex.

B.1 Broadband light source

The main characteristics of the BBS used in Method A are described in Table B.1.

Table B.1 – Types of broadband light source (BBS) and main characteristics

Type	Other names	Main characteristics			
		Spectral width nm	Optical power		
			Spectral power density dBm/nm	Uniformity /Flatness dB	Total dBm
White light source	Different types of well known lamps	Very wide(hard UV to far IR)	Very low	None	In the multi-W level
LED	Edge-emitting Surface-emitting	Wide (>100, -3 dB)	Low	Quasi Gaussian	-3 to 0
Super LED	Superluminescent SLED	Relatively wide (>10, -3 dB)	Low but better than LED	Relatively	+3 to +5
ASE source	ASE emitted by an EDFA	C-band (+L-band possible)	-4, high	Yes if gain flattened/2	+12/gain flattened +14/gain unflattened

B.2 Tuneable light source

The main characteristics of the TLS used in Method B are described in Table B.2 for various laser designs.

Table B.2 – Types of tuneable light source (TLS) and main characteristics

	Parameters			Tuneable laser type		
				ECL	EDFL	DFB
Wavelength	Bands			ITU-T	C+L	C+L
	Tuning range (nm)		Typ.	100-140		±1,1/ΔT=20 °C ± 0,01 °C
			Max.	400		±2/on-chip heaters
						±4/double-stage TEC
	Uncertainty (pm)	Absolute		±2,5	±15	±10
		Relative	Typ.	±2	±2,5	No data
			Max.	±10		
	Resolution (pm)	Setting	Typ.	1	1	10
			Max.	10		
	Repeatability (pm)		Typ.	±2,5 – 5	±2,5	±10
			Max.	±100		
	Stability (pm/h)		Typ.	±1	±5	±2
			Max.	±100		
	Linewidth (MHz)	W/O CC		0,1	1000-1300	0,1
		W CC		50-100	-	50-100
Power	Output, (dBm)		Max.	+6	+3	+13
	Stability (dB/h)			±0,02	±0,01	±0,005
	Repeatability (dB)	10 tests		±0,03	±0,015	No data
Noise	Signal to SSE (dB)	± 1 nm from peak @ 0,1 nm RBW	Typ.	55	75-80	No data
			Max.	70		
	Signal to total SSE (dB)			50-60	50	No data
	SMSR (dB)			45	60-70	40
Coherence length (m)				>1000	0,3	10
Tuning speed (nm/s)			Max.	100	50	N/A

Key

ECL: External cavity laser

EDFL: Erbium-doped fibre laser

DFB: Distributed feedback (laser)

CC: Coherence control

C-Band: ITU-T Conventional wavelength band

L-Band: ITU-T Long wavelength band

RBW: Resolution bandwidth (-3 dB)

W: with

W/O: without

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