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Edition 3.0 2021-07

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

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

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FOREWORD

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

This third edition cancels and replaces the second edition published in 2009. This edition constitutes a technical revision.

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

a) reduction of the number of alternative methods proposed to bring in-line with industry practice;
b) re-statement of the equations for insertion loss and return loss using logarithmic forms more common in the industry;
c) additional recommendations with respect to the creation of fibre terminations;

d) additional discussion on the characterization of the optical sources used in this document;

e) simplification of bi-directional testing;

f) removal of separate return loss only measurement procedures.

The text of this International Standard is based on the following documents:

Draft	Report on voting
86B/4337/CDV	86B/4425A/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the 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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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 methods available to measure the wavelength dependence of attenuation and return loss of two-port, single mode passive optical components. 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.

There are two measurement cases described in this document:

a) measurement of attenuation only;

b) measurement of attenuation and return loss at the same time.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-731, *International Electrotechnical Vocabulary (IEV) – Part 731: Optical fibre communication* (available at www.electropedia.org)

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

IEC 61755-2-4, *Fibre optic interconnecting devices and passive components – Connector optical interfaces – Part 2-4: Connection parameters of non-dispersion shifted single-mode physically contacting fibres – Non-angled for reference connection applications*

IEC 61755-2-5, *Fibre optic interconnecting devices and passive components – Connector optical interfaces – Part 2-5: Connection parameters of non-dispersion shifted single-mode physically contacting fibres – Angled for reference connection applications*

IEC TR 61931, *Fibre optic – Terminology*

IEC 62074-1, *Fibre optic interconnecting devices and passive components – Fibre optic WDM devices – Part 1: Generic specification*

3 Terms, definitions, abbreviated terms and quantity symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-731, IEC TR 61931 and IEC 62074-1 apply.

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

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

3.2 Abbreviated terms

APC	angled physical contact
ASE	amplified spontaneous emission
BBD	broadband detector
BBS	broadband light source
BD	branching device
BPON	broadband passive optical network
CC	coherent control
CWDM	coarse wavelength division multiplexing
DFB	distributed feedback
DOP	degree of polarization
DUT	device under test
DWDM	dense wavelength division multiplexing
ECL	external cavity laser
EDFA	erbium doped fibre amplifier
EDFL	erbium doped fibre laser
EPON	ethernet passive optical network
FBG	fibre Bragg grating
FEC	forward error correction
FP	Fabry-Perot
GPON	gigabit Ethernet passive optical network
IR	infra-red
LD	laser diode
LED	light emitting diode
NLS	narrow band light source
OADM	optical add drop multiplexer
OFA	optical fibre amplifier
OPM	optical power meter
OSA	optical spectrum analyzer
PDL	polarization dependent loss
PON	passive optical network
RA	reference adapter
RBD	reference branching device
RBW	resolution bandwidth
RL	return loss
RP	reference plug
RTM	reference test method
SLED	super light emitting diode
SMSR	side mode suppression ratio

SOP	state of polarization
SSE	source spontaneous emission
TJ	temporary joint
TLS	tuneable laser source
TND	tuneable narrow band detection
TNLS	tuneable narrow band light source
UV	ultra violet
WDM	wave division multiplexing

3.3 Quantity symbols

λ_k	array of n (k = 1 to n) wavelengths to be measured, expressed in nm
$P_i(\lambda_k)$	input optical power to the device under test (DUT) of the k^{th} wavelength to be measured, expressed in dBm
$P_t(\lambda_k)$	output optical power from the output port of the DUT of the k^{th} wavelength to be measured, expressed in dBm
$P_r(\lambda_k)$	output optical power at the input port of the DUT propagating away from the input port of the k^{th} wavelength to be measured, expressed in dBm
$P_r'(\lambda_k)$	output optical power at the branching port of the reference branching device (RBD) propagating away from the input port of the RBD of the k^{th} wavelength to be measured, expressed in dBm
$A(\lambda_k)$	attenuation of the DUT at k^{th} wavelength, expressed in dB
$RL(\lambda_k)$	return loss of the DUT at k^{th} wavelength, expressed in dB
$RL^*(\lambda_k)$	calculated return loss of the DUT at k^{th} wavelength corrected for measurement apparatus RL, expressed in dB
$RL_0(\lambda_k)$	return loss of the measurement apparatus at k^{th} wavelength, expressed in dB

4 General description

4.1 General

Attenuation, $A(\lambda_k)$, is the relative decrease of transmitted optical power due to the insertion or addition of a component within a fibre-optic system. Return loss, $RL(\lambda_k)$, is the relative optical power reflected from a component inserted within a fibre-optic system. $A(\lambda_k)$ and $RL(\lambda_k)$ are expressed in decibels (dB) and are obtained by comparing the optical power incident on the DUT with the optical powers transmitted or reflected at the ports of the DUT. These terms are defined in IEC TR 61931.

4.2 Light source and detector conditions

$A(\lambda_k)$ and $RL(\lambda_k)$ are measured over a wavelength range defined by the DUT specifications. The spectral properties of the measurement system should be selected for the measurement of the attenuation performance specification of the DUT. These properties should include:

- wavelength setting resolution (wavelength difference between two adjacent data points);
- wavelength setting uncertainty;
- 3 dB spectral bandwidth of the light source or the tuneable narrowband detector (TND);
- source spontaneous emission (SSE) noise floor relative to peak power for the light source;
- degree of polarization (DOP).

The following performance guidelines shall be followed.

– The wavelength setting resolution shall be less than half the smallest resolvable attenuation feature. For example, when the attenuation changes over 1 nm the wavelength resolution shall be less than 0,5 nm.
– The 3 dB spectral bandwidth for the light source or the TND shall be less than half the wavelength resolution of the measurement.
– When the DOP of the source is more than 5 %, the polarization dependence of the detection system shall be considered as part of the total insertion loss uncertainty.

The impact of the source SSE noise floor on the uncertainty of the measurement depends strongly on the wavelength dependence of the DUT. For CWDM components, this shall be considered. The total ASE power over the measurement range limits the dynamic range of the measurement.

Additional information can be found in Annex B.

4.3 General explanation of attenuation and return loss

4.3.1 Attenuation

Attenuation, $A(\lambda_k)$, is the relative optical power reduction caused by the insertion of the DUT into an optical path and is illustrated in Figure 1. It is a function of wavelength. It is expressed as shown in Formula (1):

$$A(\lambda_k) = P_i(\lambda_k) - P_t(\lambda_k) \text{ dB)} \quad (1)$$

where

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

$P_t(\lambda_k)$ is the optical power, as a function of wavelength, transmitted through and measured at the output port of the DUT, expressed in dBm.

4.3.2 Return loss

Return loss, $RL(\lambda_k)$ is the optical power reflected by the DUT relative to the incident power. It is a function of wavelength and is illustrated in Figure 1. It is expressed as shown in Formula (2):

$$RL(\lambda_k) = P_i(\lambda_k) - P_r(\lambda_k) \qquad \text{(dB)} \quad (2)$$

where

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

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

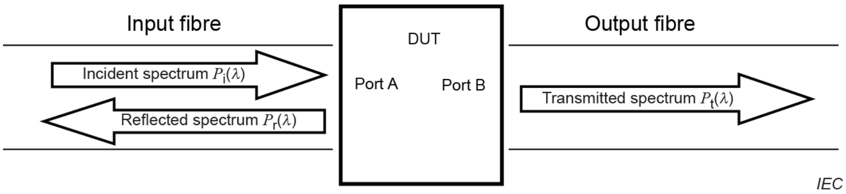


Figure 1 – Generic explanation of attenuation and return loss

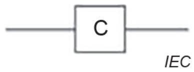
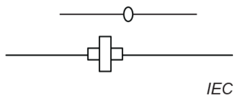
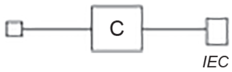
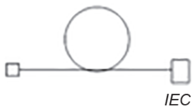
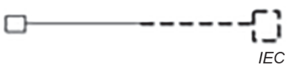
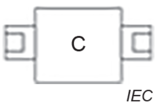
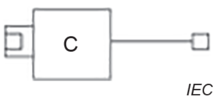
4.4 Device under test (DUT)

The DUT may have more than two ports. Only two ports are relevant for attenuation testing (input and output port) and only one is relevant for return loss testing (input port). It is not a requirement to measure attenuation and return loss at the same time.

Eight two-port DUT configurations are described in Table 1. Port connections may consist of bare fibre, connector plug, or receptacle. IEC 61300-3-4 describes multiple connection methods in detail. This document focuses on type 4 and type 7. If a multiport DUT is to be measured, all unused ports shall be terminated. For additional details, refer to Annex C.

A summary of the applicable DUT can be found in Annex A.

Table 1 – Device under test categories

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

Key

C: optical component

NOTE Type 1 can be measured using a temporary joint replacing optical connectors.

4.5 Measurement methods

The following measurement configurations are defined in Table 2. The applicable reference test method (RTM) is shown in Table 3.

Table 2 – Measurement methods

Method	Name	Light source	Detection system	Example
A	Broadband light source	BBS	TND	BBS + DUT + OSA
B	Tuneable narrow band light source	TNLS	BBD	TLS + DUT + OPM
C	Set of multiple fixed narrow band light sources	NLS	BBD	N x DFB-LD + DUT + OPM

Table 3 – Reference test methods

Resolution bandwidth (RBW)	Wavelength band	RTM	Alternative
< 0,1 nm	Any	Method B	Method A
≥ 0,1 nm	C-band and L-band	Method B	Method A, method C
≥ 0,1 nm	Not C-band and L-band	Method A	Method B, method C

a) Method A – Broadband light source (BBS)

In method A, a broadband light source (BBS) is used with a tuneable narrowband detector (TND). A common implementation is to use an optical spectrum analyzer (OSA) for the TND. In this implementation, the OSA controls the wavelength range, the measurement wavelength and resolution bandwidth. The optical power and bandwidth of the BBS shall be large enough to cover the attenuation of the DUT and the power measurement dynamic range of the OSA.

b) Method B – Tuneable narrowband light source (TNLS)

In method B, a tuneable narrowband light source (TNLS) is used with a broadband detection system (BBD). The most likely implementation of method B is the use of a tuneable laser source (TLS) with an optical power meter (OPM). In this method, the TLS controls the wavelength range, the measurement wavelength and resolution bandwidth. Given the narrow linewidth and high DOP, care shall be taken to minimize the test system background return loss. This will help to avoid coherent interference in the power measurement.

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

In method C, a set of narrowband light sources are used with a broadband detector (BBD). This method is suitable for a DUT which has a small wavelength dependent loss and is specified for operation over a wide wavelength range. A common implementation of method C is the use of a set of fixed laser sources with an N x 1 optical branching device or optical switch. The use of a switch prevents the need to turn off the light sources not in use. This can reduce the time needed for laser power stabilization. An OPM is typically used as the BBD.

5 Apparatus

5.1 General

All methods share a common basic setup:

- optical source;
- source depolarizer (optional);

- return path branching device (for RL measurement);
- temporary joint (TJ);
- fibre;
- reference plug (RP);
- reference adapter (RA);
- termination (for RL measurement);
- power detection system.

5.2 Optical source

5.2.1 Method A – Broadband light source (BBS)

A BBS is used for the source in method A. The BBS emits light over a continuous wavelength range with various characteristics depending on its type. Examples of a BBS are a white light source (i.e. tungsten lamp), a light emitting diode (LED), a super-luminescent LED (SLED) or an optical fibre amplifier (OFA) without an input optical signal.

The wavelength range shall be wide enough to cover the entire specified DUT wavelength operating range. The output power shall be high enough for $A(\lambda_k)$ and $RL(\lambda_k)$ to be measured. The spectral power density instability shall be smaller than ±0,05 dB as observed for at least 30 min.

5.2.2 Method B – Tuneable narrowband light source (TNLS)

A TNLS emits a narrow spectrum of light that can be spectrally tuned over the specified wavelength range. There are various characteristics depending on its type. Examples of applicable TNLS technologies are a BBS with a tuneable filter, an external cavity tuneable laser, a tuneable DFB laser diode and a tuneable erbium-doped fibre laser. The wavelength accuracy and spectral bandwidth shall be specified. Typical values are provided in Annex B.

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

Method C is based on a set of N discrete wavelengths. The wavelengths may be emitted by sources such as a Fabry-Perot (FP) laser diode (LD) or distributed feedback (DFB) LD.

The set of NLS shall cover the specified wavelength range to be measured. When using a $N \times 1$ fibre optic branching device or fibre optic switch, N is equal to the number of wavelengths to be measured and NLS used.

When a TLS is used as the NLS, the requirement for a TLS is same as that for a NLS.

5.3 Depolarizer

The measurement results [$A(\lambda_k)$ and $RL(\lambda_k)$] shall be averaged as a function of the state of polarization (SOP). Sources based on lasers will be highly polarized (DOP is nearly equal to 100 %) while sources like LED and BBS will be highly depolarized (DOP is less than 5 %). For sources with high DOP, a depolarizer will be required. The depolarizer shall reduce the DOP to < 5 %.

There are two approaches for obtaining the polarization averaged value of $A(\lambda_\mathrm{k})$ and $RL(\lambda_\mathrm{k})$.

- Direct approach: A depolarizer based on an active or passive device is connected at the output port of the source in order to reduce its DOP. This allows direct measurement of the averaged $A(\lambda_k)$ and $RL(\lambda_k)$. The averaging time of the power detection system shall be greater than 2 times the quoted de-polarization time.

- Indirect approach: Measure $A(\lambda_k)$ and $RL(\lambda_k)$ as a function of the state of polarization (SOP) to obtain the average value of $A(\lambda_k)$ and $RL(\lambda_k)$ from the measurement results. This requires multiple measurements be made and recorded. In this case, the role of the depolarizer is fulfilled by a polarization controller that either deterministically sets a chosen sequence of SOP or randomly scans many SOP.

5.4 Power detection systems

5.4.1 Method A – Tuneable narrowband detection (TND)

The measurement system shall be stable within specified limits over the measuring time. For measurements where the connection to the detector shall be separated between measurements, the repeatability specification shall be less than 0,02 dB.

The TND (typically an OSA) measures the output optical power at a specified wavelength over the wavelength range. Generally, an OSA has an optical filter function inside. The resolution bandwidth (RBW) is typically specified at –3 dB or the full width at half the maximum. The RBW shall be specified in accordance with the wavelength setting interval. In order to avoid false interpretation of artefacts in the measurement, the optical rejection ratio shall be specified. An example of such specification could be –20 dB at 0,1 nm away from the centre wavelength. If a detailed assessment of the OSA RBW is required, the filter shape of the OSA should be measured. This is typically achieved by measuring the envelope of a DFB known to have a spectrum much narrower than the OSA RBW.

The power measurement range and sensitivity shall be high enough for $A(\lambda_k)$ and $RL(\lambda_k)$ to be measured in accordance with the DUT specification. The amplitude uncertainty due to polarization dependence of the OSA shall be less than the desired uncertainty to be measured.

5.4.2 Method B and C – Broadband detection (BBD)

The broadband detection system (BBD) measures an integrated optical power over a wide range. A typical BBD consists of an optical power sensor, a mechanism for coupling a fibre to it and associated detection electronics. These devices are most commonly referred to as an OPM.

The performance of the measurement system shall be stable within specified limits over the measuring time. For measurements where the connection to the detector shall be separated between measurements, the repeatability specification shall be less than 0,02 dB. A detector with a large sensitive area may be used to achieve this.

The power measurement range of the BBD shall cover the peak power of the light source and intended attenuation of the DUT. The minimum detectable power is recommended to be more than 10 dB smaller than the optical power to be measured. The amplitude uncertainty due to polarization dependence of the OPM shall be less than the desired uncertainty to be measured.

The preferred OPM parameters are given in Table 4.

Table 4 – Preferred OPM parameters

Type	Maximum nonlinearity dB	Relative uncertainty dB
Single mode	±0,01 (attenuation ≤ 10 dB) ±0,05 (10 dB < attenuation ≤ 60 dB)	≤ 0,02
In order to ensure that all light exiting the fibre is detected by the OPM, the sensitive area of the detector and the relative position between it and the fibre should be compatible with the numerical aperture of the fibre. NOTE Common sources of relative uncertainty are polarization dependence and interference with reflections from the OPM and fibre connector surfaces. The sensitivity of the power meter to such reflections can be characterized by the parameter spectral ripple, determined as the periodic change in responsivity versus the wavelength of a coherent light source.		

5.5 Branching device (BD)

The branching device is used to connect the light source to the DUT. It will split the reflected light from the DUT to the return loss detection system.

The splitting ratio of the BD shall be stable during the measurement time. The wavelength dependent loss and return loss of the BD should be smaller than the DUT to be measured. The uncertainty due to polarization dependence loss of the BD shall be less than the desired uncertainty of $A(\lambda_n)$ to be measured and in general < 0,05 dB. The return loss should be at least 10 dB greater than the maximum $RL(\lambda_k)$ to be measured. The directivity should be at least 10 dB greater than the maximum $RL(\lambda_k)$ to be measured.

5.6 Termination

A termination is a device, process or manipulation which induces the maximum attenuation possible. Terminations shall also have a large return loss. Common terminations are:

a) angled fibre ends such as the use of an angled physical contact (APC) connector or angled cleave (the angle should be more than 8°);
b) application of a refractive index matching material to the fibre end in air;
c) high return loss achieved with a mandrel wrap (tightly coiling the fibre per the manufacturer's recommendation).

The termination return loss shall be 15 dB greater than the maximum $RL(\lambda_k)$ to be measured. Unless otherwise specified, all unused DUT ports (input or outputs) shall be terminated during the RL measurement.

5.7 Temporary joint (TJ)

This is a method, device, or mechanical fixture for temporarily aligning two fibre ends into a stable, reproducible, low-loss joint. It is used when direct connection between the DUT and the measurement system is not achievable by a standard connector. Examples are a precision V-groove, vacuum chuck, micromanipulator, fusion splice or mechanical splice. The attenuation of the temporary joint shall be stable to within 10 % of the required measurement uncertainty in dB over the time taken to measure P_i, P_t and P_r. A suitable refractive index matching material may be used to improve the stability of the TJ.

5.8 Test patch cord

The test patch cord connects the DUT to the test system using a temporary joint. It shall belong to the same category of fibre used by the DUT. Fibres shall be in accordance with IEC 60793-2-50.

5.9 Reference plugs (RPs)

Where reference plugs are required to form complete connector assemblies in any of the test methods, the reference plugs become a part of the DUT during the measurement of attenuation. RPs shall be specified in the relevant specification. IEC 61755-2-4 for non-angled connector plugs and IEC 61755-2-5 for angled connector plugs shall be referred to.

5.10 Reference adapters (RAs)

Where reference adapters are required to form complete connector assemblies in any of the test methods, the reference adapters become a part of the DUT during the measurement of attenuation. RAs shall be specified in the relevant specification. IEC 61755-2-4 for non-angled connector plugs and IEC 61755-2-5 for angled connector plugs shall be referred to.

6 Procedure

6.1 Method A – Broadband light source

6.1.1 Method A1 – Attenuation only

6.1.1.1 General

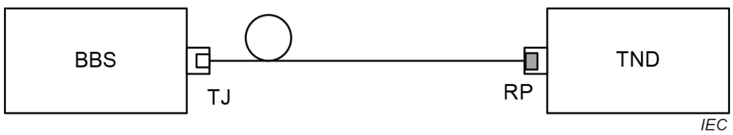
The procedure showed in 6.1.1 shall be used for measuring attenuation and is shown in Table 5. Generate a wavelength of λ_k (k = 1 to n), where n indicates the number of wavelengths where optical power is to be measured. The RBW of the TND is set as per the guidance in 5.4.1. The BBS is energized and allowed to stabilize per the manufacturer's specification.

Table 5 – Steps of method A1, attenuation only

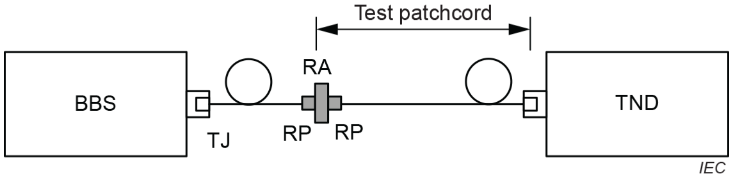
Step	Purpose	Result
1	Reference measurement	$P_i(\lambda_k)$
2	DUT measurement	$P_t(\lambda_k)$
3	Calculation	$A(\lambda_k)$

6.1.1.2 Method A1 – Attenuation-only, reference step 1

Connect the BBS to the TND as shown in Figure 2. The connection may be direct or with an adapter. Measure and record the optical output power levels $P_i(\lambda_k)$ for all pre-defined wavelengths of λ_k (k = 1 to n).



a) Type 4 DUT

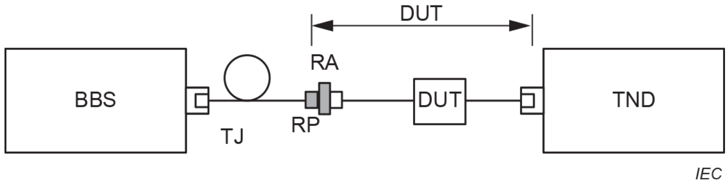


b) Type 7 DUT

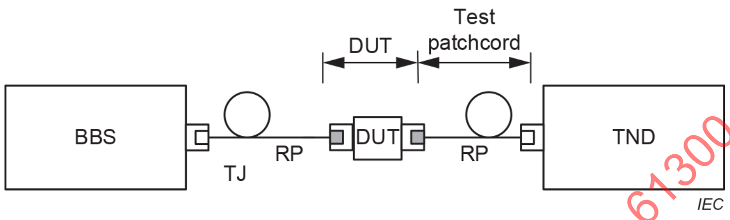
Figure 2 – Method A1, attenuation-only, reference measurement set-up

6.1.1.3 Method A1 – Attenuation-only, DUT measurement step 2

Insert the DUT as shown in Figure 3. Measure and record the optical output power levels $P_t(\lambda_k)$ over all the pre-defined wavelengths.



a) Type 4 DUT



b) Type 7 DUT

Figure 3 – Method A1, attenuation-only, DUT measurement set-up

6.1.1.4 Method A1 – Attenuation-only, calculation step 3

Calculate $A(\lambda_k)$ in accordance with Formula (1).

6.1.2 Method A2 – Attenuation and return loss

6.1.2.1 General

The following procedure shall be used when both $A(\lambda_k)$ and $RL(\lambda_k)$ are to be measured at the same time and is shown in Table 6. It differs from $A(\lambda_k)$ by the inclusion of a 1 x 2 branching device (BD).

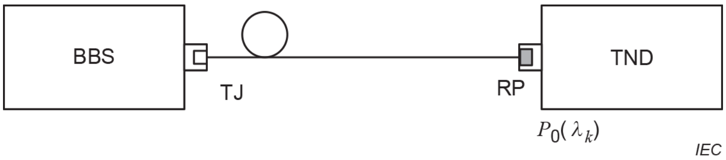
Table 6 – Steps of method A2, attenuation and return loss

Step	Purpose	Result
1	Branching device attenuation measurement	$A_{or}(\lambda_k)$, $P_r'(\lambda_k)$
2	Reference measurement	$P_i(\lambda_k)$
3	System background RL measurement	$P_{r0}(\lambda_k)$, $RL_0(\lambda_k)$
4a	DUT measurement	$P_t(\lambda_k)$, $P_r(\lambda_k)$
4b	Alternate DUT measurement	$P_r(\lambda_k)$
5	Calculation	$A(\lambda_k)$, $RL(\lambda_k)$, $RL^*(\lambda_k)$

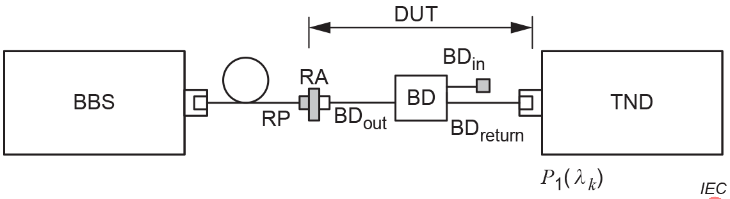
6.1.2.2 Method A – Attenuation of branching device, attenuation step 1

The attenuation of the BD shall first be measured and recorded using the procedure outlined in 6.1.1 for all n wavelengths.

As shown in Figure 4, the BBS is connected to the BD output port (BD_{out}). The BD return port (BD_{return}) is connected to the TND. The attenuation of the return path for all n wavelengths is calculated using the expression $A_{or}(\lambda_k) = P_1(\lambda_k) - P_0(\lambda_k)$ for k = 1 to n. $A_{or}(\lambda_k)$ is required to correct $P_r(\lambda_k)$ and accounts for the attenuation through the branching device. To improve measurement stability, the BD input port (BD_{in}) shall be terminated.



a) Reference



b) Measurement

Figure 4 – Method A2, attenuation and return loss, reference branching device measurement set-up

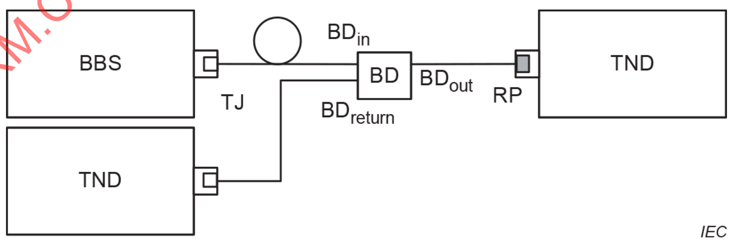
The variable $P_r'(\lambda_k)$ is the correct reflected power, as shown in Formula (3):

$$P_r'(\lambda_n) = P_r(\lambda_n) - A_{or}(\lambda_n) \quad \text{(dB)} \qquad (3)$$

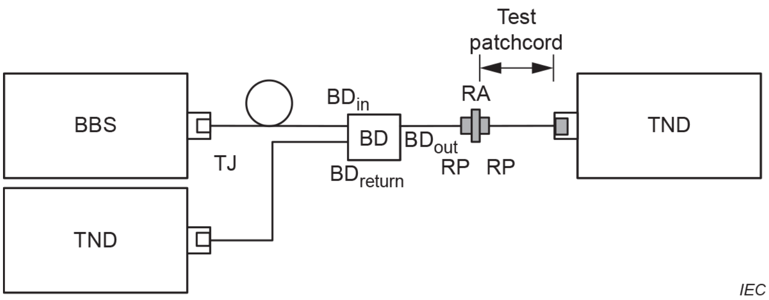
6.1.2.3 Method A – Attenuation and return loss, reference step 2

Connect the BBS and a TND to the BD as shown in Figure 5. Depending on the DUT configuration, the connection may be direct or with an adapter and test patchcord. If the TND is a free air launch type, ensure that an APC connector is used for BD_{out} to reduce reflections.

Following Figure 5, measure $P_i(\lambda_k)$ and record the output optical power level over all n wavelengths.



a) Type 4 DUT



b) Type 7 DUT

Figure 5 – Method A2, attenuation and return loss, reference measurement set-up

6.1.2.4 Method A – System background RL, measurement step 3

This step measures the measurement apparatus contribution to the return loss measurement. Once measured, the intrinsic return loss from the measurement apparatus can be removed from the DUT calculation. Connect the BBS and TND to the RBD as shown in Figure 6. Depending on the DUT configuration, the connection may be direct or with an adapter. If the TND is a free air launch type, ensure that an APC connector is used to reduce reflections. The measurement settings shall be the same as for the reference and measurement steps.

Apply a termination as described in 5.6.

Following Figure 6, measure and record the optical output power level $P_{r0}(\lambda_k)$ over all n wavelengths defined in the wavelength array.

$$RL_0(\lambda_n) = P_i(\lambda_n) - P_{r0}(\lambda_n) - A_{or}(\lambda_n) \quad \text{(dB)} \qquad (4)$$

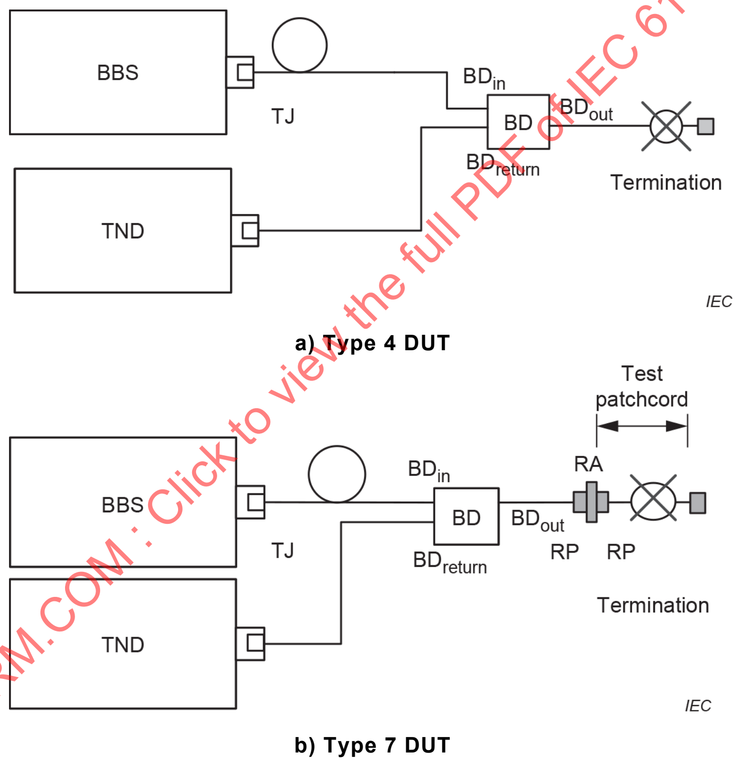
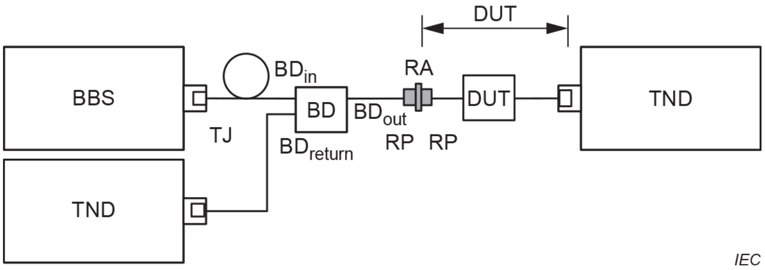


Figure 6 – Method A2, system background measurement set-up

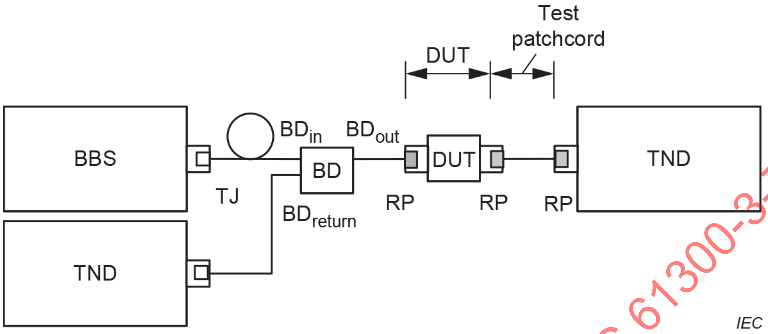
6.1.2.5 Method A2 – Attenuation and return loss, DUT measurement step 4

Step 4 may be used if the total return loss to be measured includes the contribution from the fibre and/or the connector at the output. This procedure may also be used if the return loss from the output side is more than 15 dB larger than the DUT return loss. Annex C calculates the impact of the output return loss using this method.

Insert the DUT as shown in Figure 7. Measure and record the optical output power levels $P_t(\lambda_k)$ and $P_r(\lambda_k)$ over the wavelength array.



a) Type 4 DUT



b) Type 7 DUT

Figure 7 – Method A2, attenuation and return loss, DUT measurement set-up

Care shall be taken at the interface to the TND. When measuring return loss, a termination may be required to block additional reflections from the optical connection to the TND.

6.1.2.6 Method A2 – Attenuation and return loss DUT, calculation step 5

Calculate $A(\lambda_k)$ using Formula (1). Calculate $RL(\lambda_k)$ by Formula (5).

$$RL(\lambda_k) = P_i(\lambda_k) - P_r'(\lambda_k) \quad \text{(dB)} \tag{5}$$

To improve the overall uncertainty of $RL(\lambda_k)$, the instrument RL offset can be corrected for. This is critical if the RL_0 values are < 10 dB relative to the target value to be measured. Then calculate $RL^*(\lambda_k)$ by Formula (6).

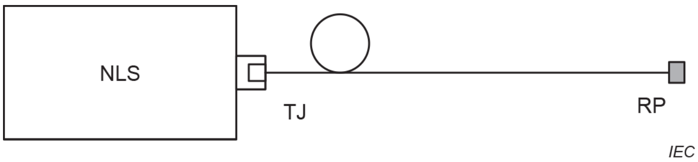
$$RL^*(\lambda_k) = -10 \cdot \log_{10}\left(10^{\frac{-RL(\lambda_k)}{10}} - 10^{\frac{-RL_0(\lambda_k)}{10}}\right) \quad \text{(dB)} \tag{6}$$

Measurement of RL_0 requires the use of a termination. Improper terminations will lead to additional measurement uncertainty.

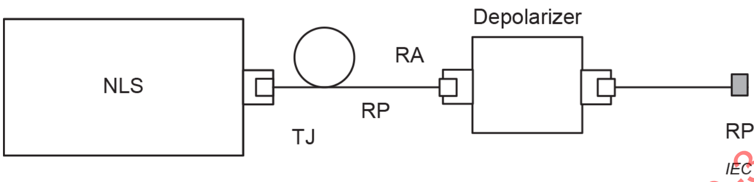
6.2 Method B – Tuneable narrowband light source

6.2.1 General

Method B substitutes a tuneable narrowband light source (TNS) for the BBS and a BBD for the TND. Unless otherwise stated, the calculation and procedure remain the same as for method A. The most common implementation is to use a TLS for the light source and an OPM. In this case, the wavelength is modified to generate the wavelengths of λ_k (k = 1 to n). It is not necessary to change the wavelength calibration value in the OPM as this impact will be referenced out in the calculation. The tuneable laser source is most often paired with a depolarizer to reduce the DOP to < 5 %. See Figure 8.



a) Without depolarizer



b) With depolarizer

Figure 8 – Method B, tuneable narrowband light source with and without depolarizer

6.2.2 Method B – Attenuation only

The procedure and calculations for method B are the same as for method A (6.1.1) and are shown in Table 7.

Table 7 – Steps of method B, attenuation only

Step	Purpose	Result
1	Reference measurement	$P_i(\lambda_k)$
2	DUT measurement	$P_t(\lambda_k)$
3	Calculation	$A(\lambda_k)$

6.2.3 Method B – Attenuation and return loss

The procedure and calculations for method B are the same as for method A (6.1.2) and are shown in Table 8. Given the narrow linewidth, extreme care should be taken with connector cleanliness.

Table 8 – Steps of method B, attenuation and return loss

Step	Purpose	Result
1	Branching device attenuation measurement	$A_{or}(\lambda_k)$, $P_r'(\lambda_k)$
2	Reference measurement	$P_i(\lambda_k)$
3	System background RL measurement	$P_{r0}(\lambda_k)$, $RL_0(\lambda_k)$
4	DUT measurement	$P_t(\lambda_k)$, $P_r(\lambda_k)$
5	Calculation	$A(\lambda_k)$, $RL(\lambda_k)$, $RL^*(\lambda_k)$

6.3 Method C – Set of multiple fixed narrowband light sources

6.3.1 General

Relative to method A, method C substitutes multiple fixed NLSs for the BBS and a BBD for the TND. Unless otherwise stated, the calculation and procedure remain the same as those for method A. The most common implementation is to use a set of fixed laser sources connected to an optical switch and an OPM (see Figure 9). In this case, the wavelength array of λ_k (k = 1 to n) is generated by activation of the switch to select a laser. The switch manufacturer's stabilization times should be followed. It is not necessary to change the wavelength calibration value in the OPM as this impact will be referenced out in the calculation. As in method B, a depolarizer may also be added at the output of the optical switch to reduce the DOP to < 5 %.

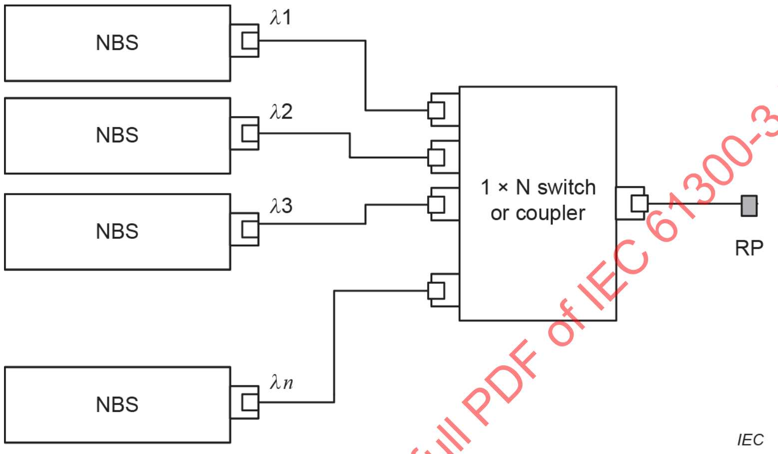


Figure 9 – Method C, multiple fixed narrowband sources set-up

6.3.2 Method C1 – Attenuation only

The procedure and calculations for method C are the same as for method A (6.1.1) and are shown in Table 9. If using an optical coupler, all unused ports shall be terminated.

Table 9 – Steps of method C, attenuation only

Steps	Purposes	Results
1	Reference measurement	$P_i(\lambda_k)$
2	DUT measurement	$P_t(\lambda_k)$
3	Calculate	$A(\lambda_k)$

6.3.3 Method C2 – Attenuation and return loss

The procedure and calculations for method C are the same as those for method A (6.1.2) and are shown in Table 10. For NLS, reflections from poor connections can cause coherent interference and unstable measurements. Fabry-Perot lasers, coherence control settings or LED sources can be used to reduce this.

Table 10 – Steps of method C2, attenuation and return loss

Step	Purpose	Result
1	Branching device attenuation measurement	$A_{or}(\lambda_k)$, $P_r^{'}(\lambda_k)$
2	Reference measurement	$P_i(\lambda_k)$
3	System background RL measurement	$P_{r0}(\lambda_k)$, $RL_0(\lambda_k)$

4	DUT measurement	$P_t(\lambda_k)$, $P_r(\lambda_k)$
5	Calculate	$A(\lambda_k)$, $RL(\lambda_k)$, $RL^*(\lambda_k)$

7 Test results

Table 11 and Figure 10 provide examples of test results.

Table 11 – Example report for 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_k	$A(\lambda_k)$	$RL(\lambda_k)$
.	.	.
.	.	.
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.

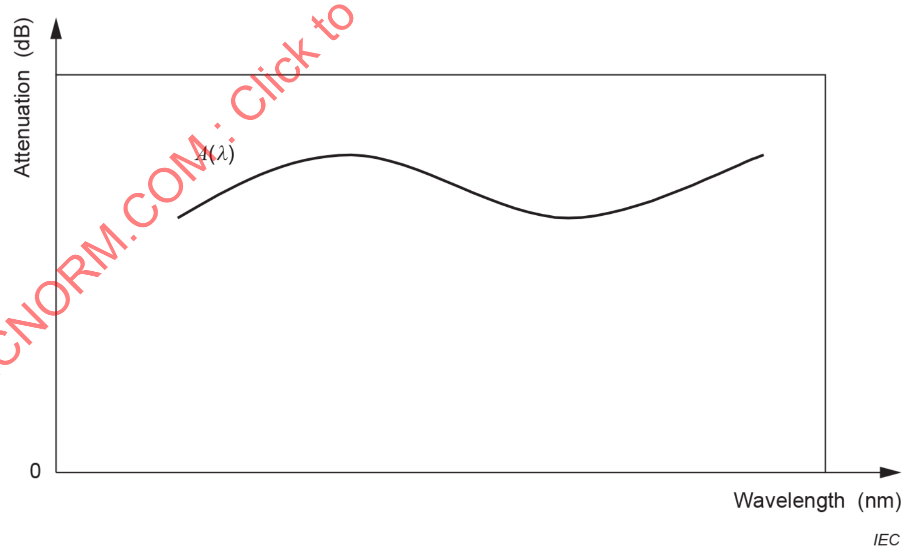


Figure 10 – Example wavelength dependent attenuation plot

8 Details to be reported

8.1 General

Subclauses 8.2 to 8.4 describe the details to be provided for each component of the measurement set-up.

8.2 Total measurement system

- Attenuation measurement uncertainty.
- Return loss measurement uncertainty.

8.3 Source

8.3.1 Broadband light source

- Type of broadband light source.
- Spectral power density.
- Total output optical power stability.
- Spectral bandwidth.
- Type of optical connection.

8.3.2 Tuneable or discrete narrowband light source

- Type of tuneable or discrete narrowband light source.
- Output optical power.
- Output optical power stability.
- Wavelength uncertainty.
- Tuneable wavelength range (only for tuneable narrowband light source).
- Spectral bandwidth.
- Type of optical connection.

8.3.3 Depolarizer

- Maximum loss.
- Maximum PDL.
- Minimum attainable DOP.
- Maximum DOP over the specified wavelength range.
- Speed of changing SOP.
- Type of optical connection.

8.4 Detection system

8.4.1 Optical power meter

- Power accuracy.
- Dynamic range.
- Power linearity.
- Power stability.
- Polarization sensitivity.
- Type of optical connection.

8.4.2 Optical spectrum analyzer

- Wavelength range.
- Wavelength accuracy.
- RBW.
- Averaging times.
- Dynamic range.
- Power linearity.

- Power stability.
- Polarization sensitivity.
- Type of optical connection.

8.4.3 Branching device

- Directivity.
- PDL.
- Type of optical connection.

8.4.4 Termination

- Types of termination used.
- Minimum RL.

8.4.5 Temporary joint

- Method used.
- Attenuation.
- Attenuation stability.

8.4.6 Reference plug

- Type.
- Manufacturer specifications.

8.4.7 Reference adapter

- Type.
- Manufacture specifications.

Annex A
(informative)

Types of passive optical components

Table A.1 is the summary of the application and the number of ports for typical types of passive optical components.

Table A.1 – Functional summary of common passive optical components

Passive optical component type	Most popular application	Number of ports	Comments
Patchcord	General	2	$A(\lambda)$ and $RL(\lambda)$ essentially defined by the connectors
Coupler	General	1 × n	Bidirectional measurement is critical
Wide WDM branching device	PON	1 × 2	Couple/divide 1 310 nm signal upstream with 1 490 nm signal downstream
			Couple/divide combined 1 310 nm signal upstream with 1 490 nm signal downstream with 1 550 nm overlaid analogue video signal downstream
			Bidirectional measurement is critical
		2 × n	Network protection
			Bidirectional measurement is critical
Non-wavelength selective branching device (coupler, splitter)	PON	1 × n	BPON, n ≤ 32 GPON, n ≤ 128 EPON, n ≤ 16 or up to 32 with FEC
			Bidirectional measurement is critical
CWDM multiplexer/ demultiplexer	CWDM network	n × 1 1 × n	Measuring in both directions 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
FBG + circulators	OADM	2 × 2	
Optical circulator	OADM	2 × 1	
Optical filter (bandpass, short wavelength pass, long wavelength pass, notch, gain flattening filter)	WDM	1 × 1	Bidirectional measurement is critical
Optical switch	General	1 × n	Directivity, repeatability and latching are critical
Optical attenuator	General	1 × 1	Bidirectional measurement is critical
Optical isolator	General	1 × 1	High attenuation in reverse direction
Optical power limiter	High power	1 × 1	High attenuation when activated
Optical fuse	High power	1 × 1	Destroyed when at full performance
Mechanical splice	General	1 × 1	Bidirectional measurement is critical
Connector	General, field mountable	1 × 1	Bidirectional measurement is critical
Pigtail	General	1 × 1	