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

Part 3-14: Examinations and measurements — Error and repeatability of the attenuation settings of a variable optical attenuator

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

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Dispositifs d'interconnexion et composants passifs à fibres optiques - Procédures fondamentales d'essais et de mesures - Partie 3-14: Examens et mesures - Erreur et répétabilité des positions d'affaiblissement d'un affaiblisseur optique variable (CEI 61300-3-14:2014)

Lichtwellenleiter - Verbindungselemente und passive Bauteile - Grundlegende Prüf- und Messverfahren - Teil 3-14: Untersuchungen und Messungen - Abweichung und Reproduzierbarkeit der Einstellung eines einstellbaren optischen Dämpfungsgliedes (IEC 61300-3-14:2014)

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Foreword

The text of document 86B/3816/FDIS, future edition 3 of IEC 61300-3-14, prepared by SC 86B “Fibre optic interconnecting devices and passive components” of IEC/TC 86 “Fibre optics" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61300-3-14:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-08-14
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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 61300-1	-	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 1: General and guidance	EN 61300-1	-
IEC 61300-3-4	-	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-4: Examinations and measurements - Attenuation	EN 61300-3-4	-

CONTENTS

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

Part 3-14: Examinations and measurements – Error and repeatability of the attenuation settings of a variable optical attenuator

1 Scope

This part of IEC 61300 provides a method to measure the error and repeatability of the attenuation value settings of a variable optical attenuator (VOA). There are two control technologies for VOAs, manually controlled and electrically controlled. This standard covers both control technologies of VOAs and also covers both single-mode and multimode fibre VOAs.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 61300-3-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4:Examinations and measurements – Attenuation*

3 General description

A variable optical attenuator is adjusted sequentially through a series of nominal attenuation settings prescribed in the relevant specification. For an electrically controlled VOA, the attenuation is set by applying electrical voltage or current to the device.

There are two categories of VOAs:

– those that can be adjusted to nominal attenuation levels;
– those that have no information on the nominal attenuation levels.

Some manually controlled VOAs have a scaled dial to indicate the nominal attenuation levels. Some electrically controlled VOAs have a table (or equation) indicating the applied voltage (or current) corresponding to nominal attenuation levels. This measurement method of attenuation error and repeatability can only be applied to VOAs which can be adjusted to nominal attenuation levels.

In this type of measurement, the attenuation value is measured at each setting. This sequence of measurements is repeated a number of times as prescribed in the relevant specification. The error of the attenuator at each setting is then given by the difference between the mean of the measured values and the nominal value. The repeatability at each setting is given by a value of plus and minus three times the standard deviation of the measurements.

Generally the nominal attenuation levels are provided in different two ways, i.e. absolute or relative attenuation calibration levels. Figure 1a characterizes an attenuator which is calibrated to read the actual or measured attenuation. Figure 1b characterizes an attenuator for which the manufacturer provides the calibration results relative to a zero-point setting. When the attenuator is adjusted to read zero, the actual or measured attenuation will be some value greater than zero.

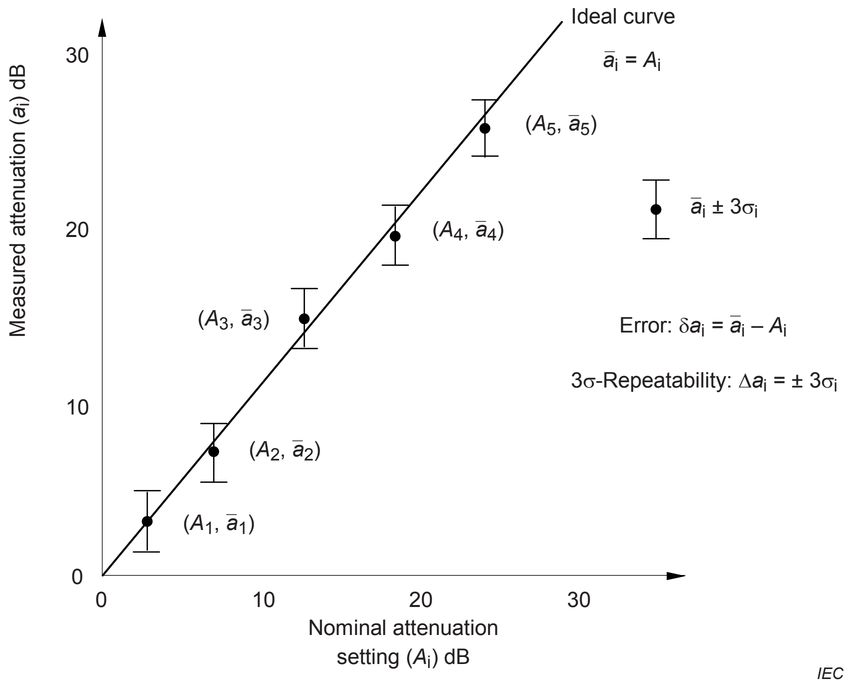

Figure 1a – Absolute calibration of attenuation

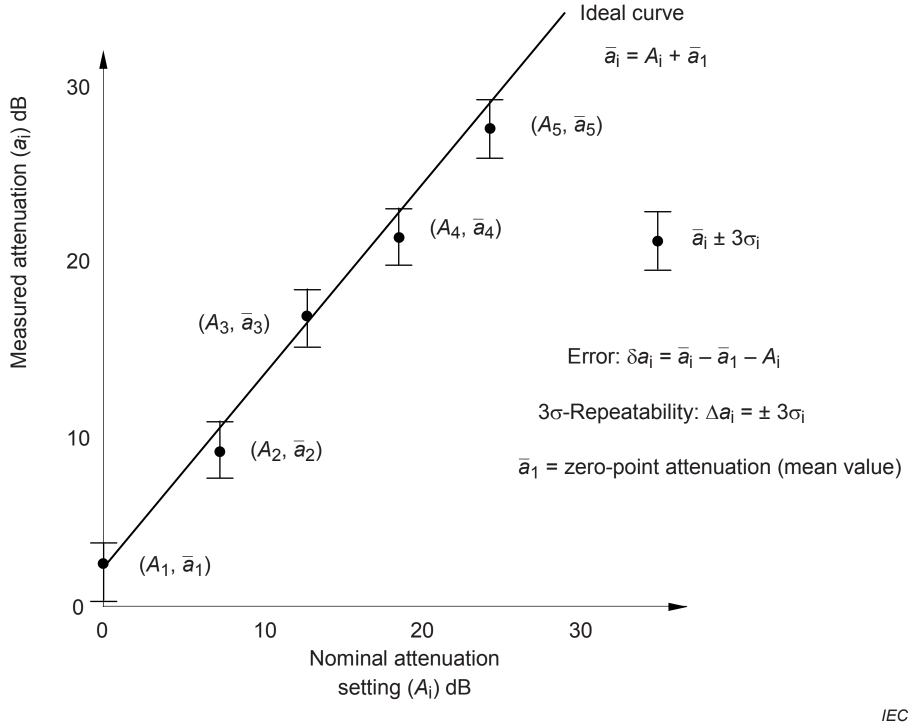

Figure 1b – Calibration relative to zero-point setting

Figure 1 – Measured versus nominal attenuation

4 Apparatus

4.1 Light source (S) and launch conditions

The output power of the light source shall be sufficiently high to permit a sufficiently large measurement dynamic range with the optical detector used. The output power stability shall be less than or equal to 0,05 dB over one hour. The dynamic range of the source/detector combination shall be at least 10 dB greater than the absolute value of the maximum attenuation value to be measured. However the output power into the fibre shall not exceed the maximum operating input power rating of the VOA to be tested.

The wavelength and spectral width of the light source shall correspond to the operating wavelength range and calibration settings of the VOA to be measured.

For the measurement of single-mode VOAs, polarization dependent loss (PDL) may influence the error and repeatability of attenuation values. Unless otherwise specified, random polarization states shall be used or the PDL shall also be characterized.

Other requirements of the light source and launch conditions shall be in accordance with IEC 61300-3-4. An excitation unit shall be used to satisfy the launch condition defined in IEC 61300-1, if necessary. Moreover cladding modes shall be stripped as typically achieved by the fibre coating, so that they do not affect the measurement.

4.2 Detector (D)

A high dynamic range optical power meter should be used for the detector. Its wavelength range shall be wider than the operating wavelength range of the VOA to be measured. In order to make measurements with low uncertainty, the linearity of the optical power meter is most important for the error and repeatability of VOA measurements. The minimum resolution of the detector shall be ≤0,01 dB.

Other requirements of detector shall be in accordance with IEC 61300-3-4.

4.3 Reference fibre (RF)

In order to measure the output power of the light source, a reference fibre is used. The reference fibre shall be of the same performance as the pigtail fibre of the VOA to be measured.

4.4 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 of the device under test (DUT) to the measurement system is not achievable by a standard connector. It may, for example, be a precision V-groove, vacuum chuck, a micromanipulator, or a fusion or mechanical splice. The temporary joint shall be stable to within ±10 % of the measurement uncertainty required in dB over the time taken to measure P_0 and P_n. A suitable refractive index matching material may be used to improve the stability of the TJ.

Patchcords with direct connection to the light source may be used and the use of TJs is not mandatory.

5 Measurement procedure

5.1 Measurement set-up

Figure 2 shows the measurement set-up.

The position of the fibres during the measurement shall remain fixed between the measurement of P_0 and P_n to avoid changes in attenuation due to bending losses.

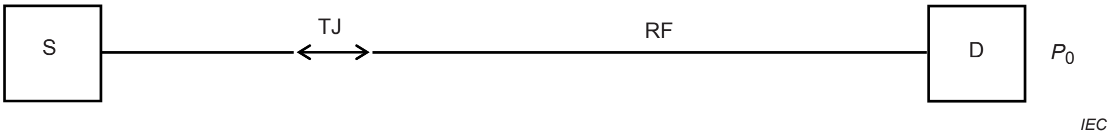

Figure 2a – Measurement of reference power

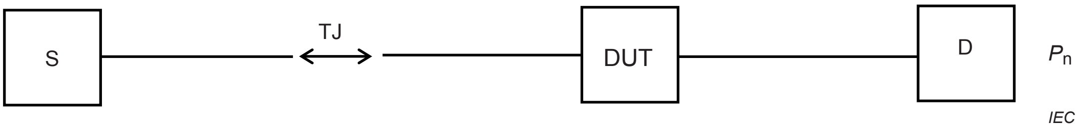

Figure 2b – Measurement of attenuation

Figure 2 – Measurement set-up

5.2 Measurement procedure

The measurement procedure is as follows:

a) Assemble the measurement set-up as shown in Figure 2a and measure P_0.

b) Insert the VOA to be measured (DUT) into the measurement set-up as shown in Figure 2b.

c) Adjust the DUT to the lowest attenuation level and record the power level of P_1.

d) Increase the attenuation of the DUT to the next lowest attenuation level and record the power level of P_2.

e) Continue to measure and record the power levels of P_3, P_4, ...P_n, increasing the attenuation levels to the next higher attenuation level for each step.

f) Repeat steps c) to e) and record a second set of readings $P_1(2)$ to $P_n(2)$.

g) Repeat step f) for the number of times *m* specified in the relevant specification.

6 Calculation

6.1 Attenuation error for VOAs with absolute calibration

Calculate the error of the ith attenuation setting using the following equation:

$$\delta a_i = \overline{a}_i - A_i \text{ (dB)} \qquad (1)$$

where

$$a_i(n) = -10 \log_{10}\left[P_i(n) / P_0\right] \text{ (dB)} \qquad (2)$$

$$\overline{a}_i = \frac{1}{m}\sum_{j=1}^{m} a_i(j) \text{ (dB)} \quad (3)$$

and where A_i is the i[th] nominal attenuation setting (dB).

6.2 Attenuation error for VOAs with relative calibration

Calculate the error of the i[th] attenuation setting using the following equation:

$$\delta a_i = \overline{a}_i - \overline{a}_1 - A_i \text{ (dB)} \quad (4)$$

where $\overline{a}_1$ is the mean value of the zero point attenuation.

6.3 Maximum deviation of attenuation from setting for all attenuation levels

The maximum deviation of attenuation from setting for all attenuation levels can be calculated using the following equation:

$$\delta a_{max} = \max_{i=1-n}\left(\left|\delta a_i\right|\right) \text{ (dB)} \quad (5)$$

6.4 Repeatability of attenuation

Calculate the 3σ-repeatability of attenuation by

$$\Delta a_i = \pm 3\,\sigma_i \text{ (dB)} \quad (6)$$

where σ_i is the standard deviation of the measurements calculated by the following equation:

$$\sigma_i = \frac{1}{n}\sum_{j=1}^{n}(a_i(j) - \overline{a}_i)^2 \text{ (dB)} \quad (7)$$

A minimum of $m = 10$ measurements at each setting are recommended to provide a reasonable estimate of σ_i.

7 Measurement report

The following values shall be described in the measurement report. Annex A shows an example of a sample measurment record.

– i[th] nominal attenuation level, A_i;
– error of the i[th] attenuation levels, $\delta \boldsymbol{a}_i$;
– maximum deviation of attenuation from setting for all attenuation levels, $\delta \boldsymbol{a}_{max}$;
– repeatability of ith attenuation levels, $\Delta \boldsymbol{a}_i$.

It is recommended that a chart plotting the measurement result such as those shown in Figure 1a or Figure 1b is included in the measurement report.

8 Details to be specified

8.1 General

The following details, as applicable, shall be specified in the relevant specification and/or recorded in the measurement report.

8.2 Light source and launch condition

- Type of light source
- Centre wavelength
- Spectral width
- Output power
- Power stability during measurement
- Type of measurement method of polarization dependency (when used)
- Type of mode filter and launch condition (when used)

8.3 Detector

- Type of detector
- Dynamic range of sensitivity
- Linearity of sensitivity
- Polarization dependency of sensitivity

8.4 Reference fibre

- Category of reference fibre
- Fibre length
- Fibre jacket type

8.5 Temporary joint

- Type of temporary joint
- Nominal return loss of temporary joint
- Nominal attenuation of temporary joint

8.6 DUT

- Device performance specifications versus actual performance

8.7 Measurement procedure

- Attenuation settings measured
- Number of measurements at each setting (m)

8.8 Measurement uncertainty

8.9 Others

- Deviations from this measuring procedure

Annex A
(informative)

Example of a sample measurment record

The following example is for illustration only and does not indicate recommended apparatus or measuring conditions.

- Source description: 1 307 nm Fabry-Perot laser source
- Excitation unit description: None
- Detector description: InGaAs power sensor
- Reference fibre: Cut-back section of attenuator input port
- Reference connector set: None
- Temporary joint: Fusion splice
- Reference fibre lengths: 0,25 m
- Pigtail fibre length of VOA: 1 m
- Preconditioning procedure: Standard atmospheric conditions for 24 h as per IEC 61300 -1
- Attenuation settings to be measured: Minimum setting, 10 dB, 20 dB, 30 dB, 40 dB, 50 dB and 60 dB
- Number of measurements at each setting: m = 10
- Deviations from this test procedure: P_0 measured by cut-back of attenuator input port
- Device performance specifications versus actual performance: see Table A.1 below

Table A.1 – Device performance specifications versus actual performance

Setting (i)	Nominal values			Measured values		
	Attenuation A_i dB	Error δa_i dB	Repeatability Δa_i ±dB	Attenuation a_i dB	Error δa_i dB	Repeatability Δa_i ±dB
1	1,4	<0,5	<0,3	1,7	+0,3	0,11
2	10	<0,5	<0,3	9,8	–0,2	0,16
3	20	<0,5	<0,4	19,7	–0,3	0,23
4	30	<0,5	<0,4	30,0	0,0	0,30
5	40	<0,5	<0,5	40,3	+0,3	0,33
6	50	<0,5	<0,5	50,4	+0,4	0,39
7	60	<0,5	<0,6	60,4	+0,4	0,41
Maximum	–	–	–	–	+0,4	0,41

Annex B
(informative)

Measurement method of hysteresis characteristics

B.1 General

For electrically controlled VOAs, the hysteresis characteristics of attenuation are sometimes important. The hysteresis characteristics can be measured as follows.

B.2 Measurement procedure

The measurement procedure is as follows:

a) Proceed using steps a) and b) in 5.2.

b) Adjust the DUT to the lowest attenuation level and record the power level of P_1.

c) Increase the attenuation of the DUT to the next lowest attenuation level and record the power level of P_2.

d) Continue to measure and record the power levels of P_3, P_4, ...P_n, increasing the attenuation levels to the next higher attenuation level for each step.

e) After measuring and recording the power level of $P_n(1)$, decrease the attenuation of the DUT to the next lower attenuation level and record the power of $P'n\text{-}1(1)$. Repeat steps of (f) for the number of times m specified in the relevant specification.

f) Continue to measure and record the power levels of $P'n\text{-}2(1)$ to $P'1(1)$, decreasing the attenuation levels to the next lower attenuation level for each step.

g) Repeat steps b) to f) and record a second set of readings $P_1(2)$ to $P_n(2)$ and $P'n\text{-}1(2)$ to $P'1(2)$.

h) Repeat step g) for the number of times m specified in the relevant specification.

B.3 Calculation

The hysteresis of the attenuation is calculated in the following equation:

$$\delta a_{\text{hys}} = \max_{1 \le i \le n-1}\left(\left| \bar{a}_{\text{i}} - \bar{a}'_{\text{i}} \right| \right) \text{ (dB)} \quad \text{(B.1)}$$

where

$$a'_{\text{i}}(n) = -10\log\left[P'_{\text{i}}(n)/P_0\right] \text{ (dB)} \quad \text{(B.2)}$$

$$\bar{a}_{\text{i}} = \frac{1}{m}\sum_{\text{j}=1}^{\text{m}} a_{\text{i}}'(j) \text{ (dB)} \quad \text{(B.3)}$$

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