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# TECHNICAL REPORT

## Fibre optic interconnecting devices and passive components – Part 04: Example of uncertainty calculation: Measurement of the attenuation of an optical connector



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## FOREWORD

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IEC 62627-04, which is a technical report, has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

| Enquiry draft | Report on voting |
|---|---|
| 86B/3374/DTR | 86B/3427/RVC |

Full information on the voting for the approval of this technical report 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 the parts in the IEC 62627 series, published under the general title *Fibre optic interconnecting devices and passive components* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability 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- withdrawn,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 publication may be issued at a later date.

# INTRODUCTION

The IEC 61300-3 series is a library of measurement methods for fibre optic passive components.

These standards describe the necessary equipment and procedures to measure a specific quantity. The uncertainty budget of every measurement is a key parameter, which should be determined by applying dedicated statistical methods as extensively presented in reference documents like ISO/IEC Guide 98-3:2008.

This technical report shows a possible simple application of these methods for the determination of the measurement uncertainty of optical low loss connector attenuation measurements as defined in IEC 61300-3-4. A detailed analysis of the main uncertainty contributions for single and for repeated measurements is shown, and a full mathematical development of the uncertainty budget is given in Annex B. The difference in uncertainty estimation for the measurement of an optical connection compared to the measurement of an optical connector against a reference connector is also discussed.

The reference document for general uncertainty calculations is ISO/IEC Guide 98-3:2008 and this report does not intend to replace it, it only represents an example and should be used in combination with ISO/IEC Guide 98-3:2008. A brief introduction to the determination of a measurement uncertainty according to ISO/IEC Guide 98-3:2008is given in Annex A.

Uncertainty calculations should preferably be performed using a linear representation of the relevant quantities. In this document all calculations are performed using linear scales but results are also presented in logarithmic scale, since logarithmic units such as dB or dBm are in common use in fibre optics. This analysis assumes uncorrelated quantities, which is usually an acceptable assumption when considering simple attenuation measurements.



All numbers presented in this document are related to this particular example and should not be taken as standard values.

# FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS –

# Part 04: Example of uncertainty calculation: Measurement of the attenuation of an optical connector

## 1 Scope

This Technical Report represents a selected example that concerns the measurement of the attenuation of passive optical components (IEC 61300-3-4), particularly focussed on insertion method B for low-loss optical connectors assembled on SM optical fibre (according to IEC 60793-2-50, Type B1.3).

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

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



IEC 61755-1, *Fibre optic connector optical interfaces – Part 1: Optical interfaces for single mode non-dispersion shifted fibres – General and guidance*

IEC 61755-3-9, *Fibre optic interconnecting devices and passive components – Fibre optic connector optical interfaces – Part 3-9: Optical interface, 2,5 mm and 1,25 mm diameter cylindrical PC ferrule for reference connector, single mode fibre*

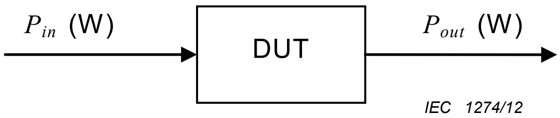
IEC 61755-3-10, *Fibre optic interconnecting devices and passive components – Fibre optic connector optical interfaces – Part 3-10: Optical interface, 2,5 mm and 1,25 mm diameter cylindrical APC ferrule for reference connector, single mode fibre*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement- Part 3 Guide to the expression of uncertainty in measurement (GUM)*

## 3 Measurement of attenuation

### 3.1 General

Attenuation measurement is intended to give a value for the decrease of useful power, expressed in decibels, resulting from the insertion of a device under test (DUT), within a length of optical fibre cable as shown in Figure 1.




$$A[\text{dB}] = -10 \cdot \log\left(\frac{P_{out}}{P_{in}}\right)$$

where

$P_{in}$ and $P_{out}$ are expressed in W

attenuation, $A$, is expressed in dB

**Figure 1 – Schematic representation of an attenuation measurement**

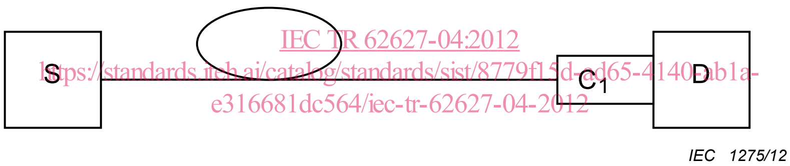
## 3.2 Attenuation measurement for optical connectors

The most common method used for the attenuation measurement of optical connectors is defined in IEC 61300-3-4 as “insertion method B”. This technical report concentrates on the uncertainty estimation for this particular method.

Insertion method B is based on the use of an input connector (measurement plug) for the measurement of $P_{in}$ (reference power).

Light source (S) and power meter (D) properties shall be as defined in IEC 61300-3-4. For the scope of this document, the source shall be of type S4 or S5 (single mode source at 1 310 nm or 1 550 nm)






**Key**

S light source

D detector

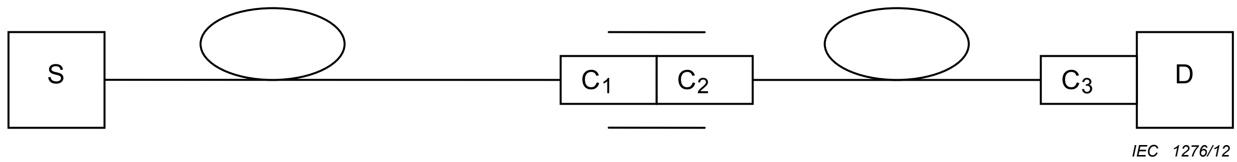
$C_1$ measurement plug

**Figure 2 – Measurement of $P_{in}$**

A DUT connector ($C_2$), assembled on a patchcord, is then connected to $C_1$, with the second connector $C_3$ placed in front of the detector (see Figure 2 and Figure 3). Any change in the measured power can be attributed to the additional connection between $C_1$ and $C_2$ under the assumptions that:

The attenuation caused by the additional fibre length of the patchcord is negligible.

The situation at the plug – detector interface is the same for $P_{in}$ as for $P_{out}$ measurements.




**Key**

S light source

D detector

$C_1$ measurement plug

$C_2$ plug connected to C1

$C_3$ second connector

**Figure 3 – Measurement of $P_{out}$**

Based on the above assumptions, the connection ($C_1 – C_2$) attenuation (also called Insertion Loss) can be calculated as follows:

$A$[dB] = $- 10 \log (P_{out\,W} / P_{in\,W})$ for power measurement values expressed in W (1a)

$A$[dB] = $P_{in} - P_{out}$ for power measurement values expressed in dBm (1b)



### 3.3 Insertion loss measurement using a reference connector

Although the attenuation measurement is the measurement of the additional loss caused by the insertion of an optical connection in the line, and therefore comprises of 2 optical connector plugs and one adapter, it is common use in the industry to use this type of measurement to verify the quality of one single optical connector by performing attenuation measurement using reference connectors and adapters.

Reference connectors and adaptors are components with tightened tolerances and give more reproducible results when the same connector is measured in different laboratories using different reference connectors and adapters. These types of components are currently in the process of standardization (IEC 61755-3-9 and IEC 61755-3-10).

## 4 Uncertainty estimation

### 4.1 General

The relative uncertainty of the attenuation $A$ is derived from the uncertainty of the reference power $P_{in}$ and of $P_{out}$ measurements and by considering supplementary contributions, which will be discussed in the next clauses.

In addition, we shall consider following two situations:

a) The attenuation measurement of a connection ($C_1 – C_2$).

b) The attenuation measurement of one connector ($C_2$) using a reference connector plug ($C_1$). In this case, the attenuation value is attributed to $C_2$ and measurement may vary when changing reference connector and or adaptor, thus representing one additional source of uncertainty.

### 4.2 Uncertainty calculation

For the calculation of the uncertainty of attenuation measurement according to IEC 61300-3-4, method B, the following equation is valid (for details of the calculation, see Annex B and more particularly Formula (B.1b)):

$$u_A \approx \sqrt{2 \cdot u_{TypeA}{}^2 + 2 \cdot u_{PDR}{}^2 + 2 \cdot u_{Displ}{}^2 + u_{Lin}{}^2 + u_{Unif}{}^2 + 2 \cdot u_{P_{stab}}{}^2 + 2 \cdot u_{PDL}{}^2 + u_{mating}{}^2 + u_{ref}{}^2} \quad (2)$$

where

$u_{TypeA}$ is the type A relative uncertainty in case of repeated measurements of optical power, or is given by the relative repeatability $\Delta P_{rep}$ of the power meter in case of a single measurement, namely $u_{TypeA} = \Delta P_{rep} / \sqrt{3}$ ;

$u_{Pstab}$ is the relative uncertainty arising from the stability of the optical source;

$u_{PDR}$ is the relative uncertainty arising from the polarization dependency of the responsivity of the power meter;

$u_{PDL}$ is the relative uncertainty arising from the polarization dependant losses of the fibre and of the connector;

$u_{Displ}$ is the relative uncertainty arising from the finite display resolution of the power meter;



$u_{Lin}$ is the relative uncertainty arising from the non-linearity of the power meter;



$u_{Unif}$ is the relative uncertainty arising from the uniformity of the power meter and from possible reflection effects between the detector and the ferrule;



$u_{ref}$ is the uncertainty due to the use of different reference connectors. This contribution is only relevant when measuring the attenuation of a single connector by comparison with a reference connector;

$u_{Mating}$ is the relative uncertainty related to the repeatability of the connector mating.

In order to separate uncertainties due to the power meter, due to the light source and due to the device under test (DUT), the following definitions are useful:

$$u_{instr}{}^2 = 2 \cdot u_{PDR}{}^2 + 2 \cdot u_{Displ}{}^2 + u_{Lin}{}^2 + u_{Unif}{}^2 + 2 \cdot u_{TypeA}{}^2 \quad (3)$$

$$u_{source}{}^2 = 2 \cdot u_{Pstab}{}^2 \quad (4)$$

$$u_{DUT}{}^2 = u_{mating}{}^2 + 2 \cdot u_{PDL}{}^2 + u_{\mathrm{Re}\,f}{}^2 \quad (5)$$

Formula (2) can then be simplified to the following form using Formulas (3) to (5):

$$u_A = \sqrt{u_{instr.}{}^2 + u_{source}{}^2 + u_{DUT}{}^2} \quad (6)$$

### 4.3 Evaluation of uncertainty

In Table 1 to Table 4 the uncertainties evaluated in the case of a single measurement of attenuation performed on grade B (according to IEC 61755-1) optical connectors assembled on single mode fibre (B1.3 according to IEC 60793-2-50) are presented. The presented values