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TECHNICAL REPORT

colour inside

Fibre optic communication system design guidelines – Part 14: Determination of the uncertainties of attenuation measurements in fibre plants

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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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Fibre optic communication system design guidelines –
Part 14: Determination of the uncertainties of attenuation measurements in fibre plants

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CONTENTS

FOREWORD 5
INTRODUCTION 2
1 Scope 9
2 Normative references 9
3 Terms, definitions and abbreviated terms 9
3.1 Terms and definitions 9
3.2 Abbreviated terms 11
4 Overview of uncertainty 11
4.1 What is uncertainty? 11
4.2 Origin of uncertainties 12
4.3 What may not be considered as uncertainty? 12
5 Fibre cabling attenuation measurement 12
5.1 ~~Measurement~~ Test methods 12
5.2 Sources of uncertainty to be considered 12
5.2.1 Analysis 12
5.2.2 Uncertainties due to the environment 15
5.2.3 Uncertainties due to operator skills 15
5.2.4 Uncertainties due to ~~measurement~~ test methods 15
5.2.5 Uncertainties due to measuring instruments 15
5.2.6 Uncertainties due to the setup 17
5.2.7 Uncertainties due to cabling 17
6 Uncertainties estimation 18
6.1 Measurement model 18
6.2 Accumulation of uncertainties 20
7 General representation of the equation using sensitivity coefficients 20
8 Calculation 24
8.1 Combined standard uncertainty 24
8.2 Expanded uncertainty 24
8.3 Determination of the coverage factor k 24
8.3.1 General approach 24
8.3.2 Discussion 24
8.3.3 Typical values of degree of freedom 25
Annex A (~~normative~~ informative) Mathematical basis 27
A.1 General 27
A.2 Type A evaluation of uncertainty 27
A.3 Type B evaluation of uncertainty 28
A.4 Determining the combined standard uncertainty 28
A.5 Reporting 29
Annex B (informative) ~~Measurement~~ Test methods 30
B.1 ~~Measurement~~ Test methods as per IEC 61280-4-1 and 61280-4-2 30
B.1.1 General 30
B.1.2 Measurement configuration 30
B.1.3 One-cord reference configuration 30
B.1.4 Two-cord reference configuration 31
B.1.5 Three-cord reference configuration 31

B.2 ~~Measurement~~ Test methods ~~as per~~ defined in methods defined in ISO/IEC 14763-3:2014 31
B.2.1 General 31
B.2.2 Channels 32
B.2.3 Links 33
Annex C (~~normative~~ informative) Uncertainties evaluation 34
C.1 Type A uncertainties 34
C.1.1 General 34
C.1.2 Evaluation of optical source instability and associated uncertainties 34
C.2 Type B uncertainties 34
C.2.1 General 34
C.2.2 Evaluation of the power meter noise 34
C.2.3 Elements to be considered for power meter stability analysis 35
C.2.4 Evaluation of the centre wavelength dependence 35
C.2.5 Spectral width dependence 37
C.2.6 Evaluation of the uncertainties due to MM launch conditions 37
C.2.7 Evaluation of the PDL 38
C.2.8 Uncertainty of absolute power measurement 39
Annex D (~~normative~~ informative) Typical values of uncertainties 40
Annex E (informative) Linear to dB scale conversion of uncertainties 42
E.1 Definition of decibel 42
E.2 Conversion of relative uncertainties 42
Bibliography 43

Figure 1 – Fishbone analysis 14
Figure 2 – Measurement model 18
Figure B.1 – Measurement configuration 30
Figure B.2 – One-cord reference measurement 30
Figure B.3 – Two-cord reference measurement 31
Figure B.4 – Three-cord reference measurement 31
Figure B.5 – Measurement on channel 32
Figure B.6 – Channel reference measurement 32
Figure B.7 – Link measurement configuration 33
Figure B.8 – Link reference measurement 33
Figure C.1 – Typical spectral response of a fibre 36
Figure C.2 – Uncertainties due to the launch conditions for a given loss 38

Table 1 – Source of uncertainty (raw list) 13
Table 2 – Uncertainties due to measuring instruments 16
Table 3 – Uncertainties due to the setup 17
Table 4 – Uncertainties due to cabling 17
Table 5 – Sensitivity coefficients for IEC 61280-4-1 and IEC 61280-4-2 methods 22
Table 6 – Sensitivity coefficients for ISO/IEC 14763-3:2014 methods 23
Table 7 – Values of k_{95} for different values of ν 25
Table 8 – Typical values of ν_i 26

Table C.1 – Spectral attenuation coefficients 36
Table C.2 – Sensitivity coefficients 37
Table D.1 – Typical values of uncertainties 40

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIBRE OPTIC COMMUNICATION SYSTEM DESIGN ~~GUIDES~~ GUIDELINES –

Part 14: Determination of the uncertainties of attenuation measurements in fibre plants

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 61282-14, which is a Technical Report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This publication contains an attached file titled "Supplemental Data for Section 8" in the form of an Excel spread sheet. This file is intended to be used as a complement and does not form an integral part of the standard.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

a) in the title: replacement of "guide" by "guidelines";
b) text adaptation to allow both standard grade B and reference grade connectors for termination of test cords;
c) addition of values needed for calculation of uncertainties, when standard grade connectors are used, to Annex D;
d) correction of minor inconsistencies in Equation (18) and after.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
86C/1572/DTR	86C/1584/RVDTR

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 document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61282 series, published under the general title *Fibre optic communication system design guides*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The determination of the uncertainty of every measurement is a key activity, which should be performed by applying dedicated methods as extensively presented in reference documents such as ISO/IEC Guide 98-3:2008, *Guide to the uncertainty of measurement (GUM)*.

This document shows a practical application of these methods for the determination of the measurement uncertainty of the attenuation of fibre optic cabling using optical light sources and power meters as defined in IEC 61280-4-1 and IEC 61280-4-2.

It includes the review of all contributing factors to uncertainty (such as launch conditions, spectral width, stability of source, power meter polarization, resolution, linearity, quality of test cord ~~reference~~ connectors~~, etc.~~) to determine the overall measurement uncertainty. This part of IEC 61282 applies to the measurement of single mode or multimode fibres without restrictions to the fibre parameters, including mode field diameter, core diameter and numerical aperture. However, numerical values given in Clause C.2 and typical values given in Annex D are not valid for multimode fibres types A2, A3 and A4.

The list of uncertainties presented in this document is related to this particular application and should be reconsidered if measurement conditions are not compliant to measurement requirements defined by IEC 61280-4-1 and IEC 61280-4-2.

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

This document is associated with a calculation spreadsheet (Excel) containing practical calculations.

FIBRE OPTIC COMMUNICATION SYSTEM DESIGN ~~GUIDES~~ GUIDELINES –

Part 14: Determination of the uncertainties of attenuation measurements in fibre plants

1 Scope

This part of IEC 61282, which is a Technical Report, establishes the detailed analysis and calculation of the uncertainties related to the measurement of the attenuation of both multimode and single mode optical fibre cabling using optical light sources and power meters.

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 61280-4-1:2009, *Fibre-optic communication subsystem test procedures – Part 4-1: Installed cable plant – Multimode attenuation measurement*

IEC 61280-4-2:2014, *Fibre-optic communication subsystem test procedures – Part 4-2: Installed cable plant – Single-mode attenuation and optical return loss measurement*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement* (GUM:1995)

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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

3.1.1
attenuation
L
reduction of optical power induced by transmission through a medium such as cabling~~, given as L (dB)~~

$$L_{dB} = 10 \times \log_{10}(P_{in}/P_{out})$$

where

P_{in} and P_{out} are the power, typically measured in mW, into and out of the cabling

Note 1 to entry: Attenuation is expressed in dB.

3.1.2
calibration
set of operations that establish, under specified conditions, the relationship between the values of quantities indicated by a measuring instrument and the corresponding values realized by standards

3.1.3
encircled flux
EF
fraction of the radial-weighted cumulative near field power to the total radial-weighted output power as a function of radial distance from the optical centre of the core

3.1.4
measurement repeatability
measurement precision under a set of repeatability conditions of measurement

3.1.5
measurement reproducibility
reproducibility
measurement precision under reproducibility conditions of measurement

3.1.6
polarization dependent loss
PDL
maximum variation of ~~insertion loss due~~ attenuation to a variation of the state of polarization (SOP) over all the SOPs

Note 1 to entry: PDL is expressed in dB.

3.1.7
nonlinearity
NL
relative difference, for a power meter, between the response at a given power P and the response at a reference power P_0:

$$nl_{P/P_0} = \frac{r(P)}{r(P_0)} - 1$$

If expressed in decibels, the nonlinearity is:

$$NL_{P/P_0} = 10 \times \log_{10} \frac{r(P)}{r(P_0)} \text{ (dB)}$$

Note 1 to entry: The nonlinearity is equal to zero at the reference power.

3.1.8
uncertainty of measurement
quantified doubt about the result of a measurement

3.1.9
stability
ability of a measuring instrument to keep its performance characteristics within a specified range during a specified time interval, all other conditions being the same

3.1.10
repeatability condition
condition of measurement that includes the same measurement procedure, same operators, same measuring system, same operating conditions and same location, and replicates measurements on the same or similar objects over a short period of time

3.1.11
reproducibility condition
condition of measurement that includes different locations, operators, measuring systems, and replicate measurements on the same or similar objects

3.1.12
standard uncertainty
u
uncertainty of a measurement result expressed as a standard deviation

Note 1 to entry: For further information, see ISO/IEC Guide 98-3.

3.1.13
type A uncertainty
type of uncertainty obtained by a statistical analysis of a series of observations, such as when evaluating certain random effects of measurement

Note 1 to entry: See Annex A and ISO/IEC Guide 98-3.

3.1.14
type B uncertainty
type of uncertainty obtained by means other than a statistical analysis of observations, for example an estimation of probable sources of uncertainty, such as when evaluating systematic effects of measurement

Note 1 to entry: See Annex A and ISO/IEC Guide 98-3.

3.2 Abbreviated terms

~~For the purposes of this document, the following acronyms apply.~~

APC angled physical contact (description of connector style)
CW continuous wave
LSPM light source power meter
OPM optical power meter
NA numerical aperture
PC physical contact (description of connector style that is not angled)

4 Overview of uncertainty

4.1 What is uncertainty?

According to ISO/IEC Guide 98-3:2008 (GUM), the uncertainty of a measurement is the quantified doubt that exists about the result of any measurement. For every measurement, even the most careful, there is always a margin of doubt.

For example, when measuring the attenuation of fibre optic cabling, the operator may observe a variation of the displayed power level on the power meter and be unable to know which value should be recorded. This variation of the displayed value is an element of doubt regarding the result of the measurement.

4.2 Origin of uncertainties

Uncertainties come from measurement devices, the item to be measured, the measurement process, operator skills, references used, and the environment.

4.3 What may not be considered as uncertainty?

Unknown parameters that contribute directly or indirectly to the quantity to be measured cannot be considered as uncertainties. For example, when measuring a cabling, mode field diameter or numerical aperture of different fibres of cabling are unknown; however, mismatch of these parameters causes the measured attenuation.

Also, poor knowledge of measurement conditions generates uncertainties but is not directly an uncertainty. A common example is the wavelength of the optical source: if the wavelength of the source is known with an uncertainty smaller than 1 nm, the measurement condition can be specified precisely. Conversely, if the wavelength of the source is known to be within a range of 40 nm, the possible variation of the attenuation of the device under test should be estimated based on the typical variation of attenuation over the wavelength range for a given length of fibre.

5 Fibre cabling attenuation measurement

5.1 ~~Measurement~~ Test methods

Three attenuation ~~measurement~~ test methods use an optical light source and power meter (LSPM) to measure input and output power levels of the cabling under test to determine the attenuation. These ~~measurement~~ methods are designated respectively, one-cord, three-cord and two-cord ~~reference~~ method.

The main functional difference between these methods is the way the input power level, known as the reference power level (P_{in}), is measured (see Annex B).

Refer to IEC 61280-4-1 and IEC 61280-4-2 for more details.

NOTE ~~Measurement~~ Test methods presented in ISO/IEC 14763-3 have different names and are slightly different. See Clause B.2.

5.2 Sources of uncertainty to be considered

5.2.1 Analysis

An extensive analysis of the source of uncertainties to be considered has been conducted. This resulted in the sorted source of uncertainty given in Table 1.