IEC 61280-4-4

Edition 2.0 2017-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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**Fibre optic communication subsystem test procedures –
Part 4-4: Cable plants and links – Polarization mode dispersion measurement for installed links**

**Procédures d'essai des sous-systèmes de télécommunication fibroniques –
Partie 4-4: Installations de câbles et liaisons – Mesure de la dispersion de mode de polarisation pour les liaisons installées**

IEC 61280-4-4:2017-03(en-fr)

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CONTENTS

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-4: Cable plants and links – Polarization mode dispersion measurement for installed links

FOREWORD

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International Standard IEC 61280-4-4 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2006. This second edition constitutes a technical revision.

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

a) theory is removed and replaced with a reference to IEC TR 61282-9;
b) a new method, wavelength scanning OTDR and SOP analysis (WSOSA), is added as Annex G;
c) a brief description of each method is added to Clause 5;
d) Methods E and F are converted to informative Annexes E and F;
e) a new Clause (6) on measurement configurations is added;

f) a new Clause (7) on measurement considerations is added;

g) Clause 10 on procedure is expanded;

h) several of the apparatus diagrams are improved;

i) several clarifications about what is measured and what is calculated have been made in Annex H.

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

CDV	Report on voting
86C/1378/CDV	86C/1419/RVC

Full information on the voting for the approval of this International Standard 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 61280 series, published under the general title *Fibre optic communication subsystem test 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.

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INTRODUCTION

Polarization mode dispersion (PMD) is a statistical parameter. The reproducibility of measurements depends on the particular method, but is limited also by the PMD level of the link and the accessible wavelength range. Gisin [1][1] derived a theoretical limit to this reproducibility independent of the measurement method by assuming ideal measurement conditions.

Originally, the principles of IEC 61280-4-4:2006 were closely aligned with those of IEC 60793-1-48:2003 on optical fibre and optical fibre cable test method, which focuses on aspects related to the measurement of factory lengths. However, IEC 60793-1-48:2007 removed some of the test methods that are no longer of interest to fibre and cable manufacturers. These have been retained as informative Annexes D, E, and F in this document, and a new test method G has been added.

This document also updates test methods A, B and C and adds more information applicable to testing of installed cabling.

NOTE 1 Test methods for factory lengths of optical fibres and optical fibre cables are given in IEC 60793-1-48.

NOTE 2 Test methods for optical amplifiers (OAs) are given in IEC 61290-11-1 and IEC 61290-11-2.

NOTE 3 Test methods for passive optical components are given in IEC 61300-3-32.

NOTE 4 Guidelines for the calculation of PMD for links that include components such as dispersion compensators or optical amplifiers are given in IEC TR 61282-3.

NOTE 5 Further general guidance on PMD measurements and background theory is contained in IEC TR 61282-9.

1 Figures in square brackets refer to the Bibliography.

FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 4-4: Cable plants and links – Polarization mode dispersion measurement for installed links

1 Scope

This part of IEC 61280 provides uniform methods of measuring polarization mode dispersion (PMD) of single-mode installed links. An installed link is the optical path between transmitter and receiver, or a portion of that optical path. These measurements can be used to assess the suitability of a given link for high bit rate applications, or to provide insight on the relationships of various related transmission attributes. This document focuses on the measurement methods and requirements for measuring long lengths of installed cabling that can also include other optical elements, such as splices, connectors, amplifiers, chromatic dispersion compensating modules, dense wavelength division multiplexing or multiplexer (DWDM) components, multiplexers, wavelength selective switches, re-configurable optical add drop multiplexer (ROADMS).

This document focuses on the apparatus, procedures, and calculations needed to complete measurements. IEC TR 61282-9 explains the theory behind the test methods.

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 60793-1-44, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 61300-3-35, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-35: Examinations and measurements – Visual inspection of fibre optic connectors and fibre-stub transceivers*

IEC TR 61282-9, *Fibre optic communication system design guides – Part 9: Guidance on polarization mode dispersion measurements and theory*

IEC TR 62627-01, *Fibre optic interconnecting devices and passive components – Part 01: Fibre optic connector cleaning methods*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

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 Symbols and abbreviated terms

c	velocity of light in vacuum (299792458 m/s)
h	coupling length (also called h-parameter)
L	length of the link
t_c	optical source coherence time (Method C)
$\delta\lambda$	wavelength increment (interval, spacing or step size)
$\delta\nu$	optical frequency increment (interval, spacing or step size)
$\Delta\lambda$	optical source spectral width or linewidth (FWHM unless noted otherwise)
$\Delta\theta$	rotation angle on the Poincaré sphere
$\delta\tau$	differential arrival times of different polarization components
$\delta\tau_{\text{max}}$	maximum measurable $\delta\tau$
$\delta\tau_{\text{min}}$	minimum $\delta\tau$ value that can be measured
$\Delta\tau$	differential group delay value
$<\Delta\tau>$	average DGD over a wavelength range or PMD_{average} value
$<\Delta\tau^2>^{1/2}$	RMS DGD over a wavelength range or PMD_{RMS} value
$\Delta\tau_{\text{max}}$	maximum $\Delta\tau$ value that can be measured
$\Delta\omega$	angular frequency variation in Method B
λ	test wavelength used to measure PMD
λ_0	central wavelength of the light source
ν	optical light frequency
σ_R	second moment of Fourier transform data
σ_0	RMS width of the squared autocorrelation envelope
σ_x	RMS width of the squared cross-correlation envelope
σ_ε	RMS width of interferogram
ω	angular optical frequency
ASE	amplified spontaneous emission
DCF	(chromatic) dispersion compensating fibre
DCM	(chromatic) dispersion compensating module
DGD	differential group delay
DOP	degree of polarization
DUT	device under test
DWDM	dense wavelength division multiplexing or multiplexer
FA	fixed analyzer
FA-FT	fixed analyzer-Fourier transform (PMD test method)
FBG	fibre Bragg grating
FET	field effect transistor
FWHM	full-width half-maximum
GINTY	general interferometric analysis (PMD test method)
INTY	interferometry (PMD test method)
I/O-SOP	input-output state of polarization
JME	Jones matrix eigenanalysis (PMD test method)

LED	light emitting diode
NLE	non-linear effect
OA	optical amplifier
OSA	optical spectrum analyzer
PDL	polarization dependent loss
PIN (diode)	positive intrinsic negative (diode layers)
PMD	polarization mode dispersion
PPS	polarization phase shift
PSA	Poincaré sphere analysis
PSP	principal SOP
RBW	resolution bandwidth
RMC	random mode coupling
RMS	root mean-square
ROADM	re-configurable optical add drop multiplexer
RTM	reference test method
SMF	single-mode fibre
SOP	state of polarization
SPE	Stokes parameter evaluation (PMD test method)
TINTY	traditional interferometric analysis (PMD test method)
WSOSA	wavelength scanning OTDR and SOP analysis (PMD test method)
WSS	wavelength selective switch

4 Background on PMD properties

PMD causes an optical pulse to spread in the time domain. This dispersion could impair the performance of a telecommunications system. The effect can be related to differential phase and group velocities and corresponding arrival times, $\delta\tau$, of different polarization components of the signal. For a sufficiently narrow band source, the effect can be related to a differential group delay (DGD), $\Delta\tau$, between pairs of orthogonally polarized principal states of polarization (PSP) at a given wavelength. For broadband transmission, the delays bifurcate and result in an output pulse that is spread out in the time domain. In this case, the spreading can be related to the root-mean square (RMS) of DGD values.

In long fibre spans, DGD varies randomly both in time and wavelength since it depends on the details of the birefringence along the entire fibre length. It is also sensitive to time-dependent temperature and mechanical perturbations on the fibre. For this reason, a useful way to characterize PMD in long fibres is in terms of an average DGD value over an appropriately large optical frequency range, either RMS $<\Delta\tau^2>^{1/2}$, the RMS DGD over this frequency range, or MEAN $<\Delta\tau>$, the (linear) mean of the DGD over this same frequency range. In principle, the average DGD value (RMS $<\Delta\tau^2>^{1/2}$ or MEAN $<\Delta\tau>$) does not undergo large changes for a given fibre from day to day or from source to source, unlike the parameters $\delta\tau$ or $\Delta\tau$. In addition, the average DGD value is a useful predictor of transmission performance.

The term PMD is used both in the general sense of two polarization modes having different group velocities (one having the fastest velocity and corresponding earliest arrival time and the other the slowest velocity and corresponding latest arrival time, the difference between the two arrival times being the DGD), and in the specific sense of the average DGD value (RMS $<\Delta\tau^2>^{1/2}$ or MEAN $<\Delta\tau>$). The latter gives us the strict definition of PMD for the purposes of this document. Although the DGD $\Delta\tau$ or pulse broadening $\Delta\delta$ is preferably averaged over frequency, for certain situations it can be averaged over time, or temperature. There are two metrics of averaged DGD, that is PMD:

$$PMD_{\mathrm{MEAN}} = \langle \Delta\tau \rangle \quad (1)$$

$$PMD_{\mathrm{RMS}} = \langle \Delta\tau^2 \rangle^{1/2} \quad (2)$$

The expression in Equation (1) is the PMD definition in term of the linear average of the DGD values. The expression in Equation (2) is the PMD definition in term of RMS average of the DGD values.

For many links, the DGD values are randomly distributed closely as a Maxwell distribution. Under the assumption of a perfect fit with a Maxwell distribution, the linkage between the two metrics, linear average DGD and RMS DGD is given by Equation (3).

$$< \Delta\tau > = \left(\frac{8}{3\pi}\right)^{1/2} < \Delta\tau^2 >^{1/2} \quad (3)$$

NOTE Equation (3) applies if the distribution of DGD values is Maxwellian. This assumption may not be valid if there are highly birefringent elements (relative to the rest of the link) in the optical path. A multiplier of 3 to 3,7 (see IEC TR 61282-3), depending on probability limits accepted by the link owner, is applied to the PMD_{AVG} value to determine the maximum DGD, which is specified for ITU-T compliant links. This multiplier is based on a Maxwell assumption and reflects a very long tail of that distribution. If the link includes a highly birefringent element, both the PMD_{AVG} and PMD_{RMS} metrics will increase relative to the actual tail of the DGD distribution (implying that a reduced multiplier could be used), but Equation (3) will not be maintained because the DGD distribution will begin to resemble one based on the square root of a non-central chi-square distribution with three degrees of freedom. In these cases, the PMD_{RMS} value will generally be larger relative to the PMD_{AVG} value indicated by Equation (3). This condition is indicated by “flat tops” on the fringe envelopes from the time domain measurement methods such as Method C and by bimodal DGD distributions from the frequency domain measurement methods such as Method B.

The expected value operator in the above equations refers to the long term expected value across all wavelengths. In practice, a finite wavelength range at a particular point of time and condition are sampled and some form of mean of the data is calculated. The expected value of these calculated means is equal to the long-term expected values, assuming ergodicity over time, wavelength, and condition. If this assumption is not valid, the result will vary depending on the particular wavelengths that are sampled. For ergodic conditions, the reproducibility of the measurement will vary with wavelength range and PMD level [1].

NOTE Ergodic: of or relating to a process in which every sequence or sizable sample is equally representative of the whole.

5 Measurement methods

5.1 Methods of measuring PMD

5.1.1 General

Seven basic methods of measuring PMD are given. Details specific to Methods A, B, C and G are given in normative annexes. Details specific to Methods D, E, and F are given in informative annexes. Methods A, B, C and G are in widespread commercial use and have been implemented in field test equipment. Methods A, B and C are also applicable to testing of fibres and cables in a factory environment as detailed in IEC 60793-1-48:2007. For some methods, multiple approaches of analyzing the measured results are also provided.

- Method A Fixed analyzer (FA)
  - Fourier transform (FT)
- Method B Stokes parameter evaluation (SPE)
  - Jones matrix eigenanalysis (JME)
  - Poincaré sphere analysis (PSA)