

INTERNATIONAL STANDARD



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



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2017 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

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

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - www.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

INTERNATIONAL STANDARD



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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.180.01

ISBN 978-2-8322-4077-9

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	10
3 Terms, definitions, symbols and abbreviated terms.....	10
3.1 Terms and definitions.....	10
3.2 Symbols and abbreviated terms	11
4 Background on PMD properties	12
5 Measurement methods	13
5.1 Methods of measuring PMD	13
5.1.1 General	13
5.1.2 Method A: Fixed analyzer with Fourier transformation (FA-FT)	14
5.1.3 Method B: Stokes parameters evaluation (SPE).....	14
5.1.4 Method C: Interferometric	15
5.1.5 Method D: Stokes parameter evaluation using back reflected light.....	15
5.1.6 Method E: Modulated phase-shift technique.....	15
5.1.7 Method F: Polarization phase shift (PPS).....	15
5.1.8 Method G: Wavelength scanning OTDR and SCOA Analysis (WSOSA).....	16
5.2 Document structure.....	16
5.3 Reference test method.....	16
6 Measurement configurations.....	16
6.1 Passive cabling link	16
6.2 Link including amplifiers.....	17
6.3 Link including chromatic dispersion compensating modules	17
6.3.1 General	17
6.3.2 Grating based DCM	17
6.4 Link including ROADMs	17
6.4.1 General	17
6.4.2 Multi-channel point to point configuration.....	18
6.4.3 Single channel configuration.....	18
7 Measurement considerations	18
7.1 General.....	18
7.2 Wavelength range.....	18
7.3 FLD measurement range.....	18
7.4 Measurement dynamic range	19
7.5 Fibre movement.....	19
7.6 Input and output SOP scrambling.....	19
7.6.1 General	19
7.6.2 Polarizers/scramblers	19
7.6.3 The 9-states Mueller set	20
7.6.4 Random scrambling	20
7.7 Polarization dependent loss	20
7.8 Amplifier considerations.....	20
7.8.1 General	20
7.8.2 Optical isolators.....	20
7.8.3 Wavelength range.....	20

7.8.4	Power levels	20
7.8.5	Amplified spontaneous emission (ASE) noise	21
7.9	Considerations on location of equipment	21
8	Apparatus	21
8.1	General	21
8.2	Light source and polarizers	21
8.3	Input optics	22
8.4	Cladding mode stripper	22
8.5	High-order mode filter	22
8.6	Output connection	22
8.7	Output optics	23
8.8	Detector	23
8.9	Computer or test platform	23
8.10	Means to reduce the effects of amplified spontaneous emission	23
9	Sampling and specimens	23
10	Procedure	23
11	Calculation or interpretation of results	24
12	Documentation	24
12.1	Information required for each measurement	24
12.2	Information to be available	24
13	Specification information	25
Annex A (normative)	Fixed analyzer method	26
A.1	Apparatus	26
A.1.1	Block diagrams	26
A.1.2	Light source	28
A.1.3	Analyzer	29
A.1.4	Optional polarization control at the input and output of the link under test	29
A.2	Procedure	29
A.2.1	Wavelength range and increment	29
A.2.2	Complete the scans	30
A.3	Calculations – Fourier transform	31
A.3.1	General	31
A.3.2	Data post processing and Fourier transformation	32
A.3.3	Transform data fitting	32
A.3.4	Spectral range	34
Annex B (normative)	Stokes parameter evaluation method	36
B.1	Apparatus	36
B.1.1	Block diagrams	36
B.1.2	Light source	37
B.1.3	Polarimeter	37
B.2	Procedure	37
B.3	Calculations	38
B.3.1	General	38
B.3.2	Jones matrix eigenanalysis (JME)	38
B.3.3	Poincaré sphere analysis (PSA) DGD calculation	40
Annex C (normative)	Interferometric method	41
C.1	General	41

C.2	Traditional analysis (TINTY).....	42
C.2.1	Apparatus.....	42
C.2.2	Procedure.....	43
C.2.3	Calculations.....	44
C.3	General analysis (GINTY).....	45
C.3.1	Benefit.....	45
C.3.2	Apparatus.....	45
C.3.3	Procedure.....	46
C.3.4	Calculations.....	47
Annex D	(informative) Stokes parameter evaluation method using back-reflected light.....	49
D.1	Utility.....	49
D.2	Apparatus.....	49
D.2.1	Block diagram.....	49
D.2.2	Directional coupler.....	49
D.2.3	Angled connector.....	49
D.2.4	Far-end termination.....	49
D.3	Procedure.....	50
D.4	Calculation and interpretation of results.....	50
Annex E	(informative) Modulation phase-shift method.....	51
E.1	Apparatus.....	51
E.1.1	Overview and block diagrams.....	51
E.1.2	Light source(s).....	52
E.1.3	Modulation.....	53
E.1.4	Polarization control.....	54
E.1.5	Input and output optics.....	54
E.1.6	Optical detector and phase detection electronics.....	55
E.1.7	Reference signal.....	55
E.2	Procedure.....	55
E.2.1	Modulation frequency.....	55
E.2.2	Scan the wavelengths and measure DGD.....	55
E.2.3	Calibration.....	58
E.3	Calculations.....	58
E.3.1	DGD calculations.....	58
E.3.2	PMD calculation.....	59
Annex F	(informative) Polarization phase shift method.....	60
F.1	Apparatus.....	60
F.1.1	Block diagram.....	60
F.1.2	Light source.....	60
F.1.3	Modulation.....	60
F.1.4	Polarization control.....	61
F.1.5	Output optics.....	61
F.1.6	Optical detectors.....	61
F.1.7	Amplitude and phase comparator.....	61
F.1.8	Reference signal.....	62
F.2	Procedure.....	62
F.2.1	Modulation frequency.....	62
F.2.2	Wavelength increment.....	62
F.2.3	Scanning wavelengths and measuring DGDs.....	62
F.2.4	Calibration.....	63

F.3	Calculations	63
F.3.1	Results overview	63
F.3.2	DGD determination	64
F.3.3	PMD calculation.....	65
Annex G (normative) Wavelength scanning OTDR and SOP analysis (WSOSA) PMD test method.....		66
G.1	General.....	66
G.2	Apparatus	66
G.2.1	Block diagram.....	66
G.2.2	Light source.....	67
G.2.3	Launch polarization	67
G.2.4	Polarization scrambling.....	68
G.2.5	Input/output optics	68
G.3	Specimen stability.....	68
G.4	Procedure	68
G.4.1	Set instrument parameters.....	68
G.4.2	Action of the instrument after measurement initiation.....	69
G.5	Calculations	71
G.5.1	Power normalisation	71
G.5.2	Transmission differences	72
G.5.3	Mean-square transmission difference and round trip PMD	73
G.5.4	Determination of PMD.....	74
G.6	Procedures for measuring PMD on installed optical links	74
G.6.1	Instability compensation	74
G.6.2	Approaches to reducing the effects of instabilities	75
Annex H (informative) PMD determination by Method C.....		77
H.1	General.....	77
H.2	Traditional analysis.....	77
H.3	General analysis	79
Bibliography.....		81
Figure 1 – Typical passive cabling link configuration.....		16
Figure 2 – Example configuration of link including amplifiers.....		17
Figure A.1 – Block diagrams for fixed analyzer		28
Figure A.2 – Example of the R-function for the fixed analyzer method.....		31
Figure A.3 – A chirped sine wave.....		33
Figure A.4 – PMD by Fourier analysis		34
Figure B.1 – Block diagram for Method B using a narrowband (tuneable laser) source.....		36
Figure B.2 – Block diagram for Method B using a broadband (ASE) source.....		36
Figure C.1 – Generic set-up for Method C (INTY).....		41
Figure C.2 – Schematic diagram for Method C (TINTY).....		42
Figure C.3 – Typical data obtained by Method C (TINTY).....		44
Figure C.4 – Schematic diagram for Method C (GINTY)		45
Figure C.5 – Typical random-mode-coupling data obtained by Method C (GINTY)		47
Figure C.6 – Typical mixed-mode-coupling data obtained by Method C (GINTY)		47
Figure D.1 – Layout for Method D		49
Figure E.1 – Basic apparatus		51

Figure E.2 – Apparatus layout for polarization modulation..... 52

Figure E.3 – Mueller states on Poincaré sphere 57

Figure E.4 – DGD versus wavelength..... 58

Figure E.5 – DGD in histogram format 58

Figure F.1 – Block diagram for Method F (polarization phase shift method)..... 60

Figure F.2 – DGD versus wavelength for a random mode coupling device 64

Figure G.1 – Illustration of the frequency domain and parameters for WSOSA 66

Figure G.2 – Typical generic experimental implementation for WSOSA..... 67

Figure G.3 – Typical power measurement results..... 71

Figure G.4 – Typical $s(\omega)$ for random I/O-SOP 72

Figure G.5 – Typical transmission difference for a frequency pair and I/O-SOP 73

Figure G.6 – Example of 2-pulse implementation in presence of instabilities..... 76

Table E.1 – Example of Mueller set..... 57

Currently in preview, click buy full version

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**FIBRE OPTIC COMMUNICATION SUBSYSTEM
TEST PROCEDURES –****Part 4-4: Cable plants and links – Polarization mode dispersion
measurement for installed links**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparatory work. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, accept to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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.

A bilingual version of this publication may be issued at a later date.

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

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/>