SLOVENSKI STANDARD

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Optična vlakna – 1-48. del: Metode merjenja in preskusni postopki - disperzija z načinom polarizacije (IEC 607993-1-48:2003)*

Optical fibres - Part 1-48: Measurement methods and test procedures - Polarization mode dispersion (IEC 607993-1-48:2003)

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EN 60793-1-48

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Optical fibres
Part 1-48: Measurement methods and test procedures –
Polarization mode dispersion
(IEC 60793-1-48:2003)

Fibres optiques
Partie 1-48: Méthodes de mesure
et procédures d'essai –
Dispersion de mode de polarisation
(CEI 60793-1-48:2003)

Lichtwellenleiter
Teil 1-48: Messmethoden
und Prüfverfahren –
Polarisationsmodendispersion
(IEC 60793-1-48:2003)

This European Standard was approved by CENELEC on 2003-11-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 60793-1-48:2003 E

Foreword

The text of document 86A/849/FDIS, future edition 1 of IEC 60793-1-48, prepared by SC 86A, Fibres and cables, of IEC TC 86, Fibre optics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60793-1-48 on 2003-11-01.

This European Standard is to be read in conjunction with EN 60793-1-1:2003.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2004-08-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2006-11-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annexes A, B, C and ZA are normative and annexes D to K are informative.
Annex ZA has been added by CENELEC.

EN 60793-1-4X consists of the following parts, under the general title: Optical fibres:

- Part 1-40: Measurement methods and test procedures – Attenuation
- Part 1-41: Measurement methods and test procedures – Bandwidth
- Part 1-42: Measurement methods and test procedures – Chromatic dispersion
- Part 1-43: Measurement methods and test procedures – Numerical aperture
- Part 1-44: Measurement methods and test procedures – Cut-off wavelength
- Part 1-45: Measurement methods and test procedures – Mode field diameter
- Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance
- Part 1-47: Measurement methods and test procedures – Macrobending loss
- Part 1-48: Measurement methods and test procedures – Polarization mode dispersion
- Part 1-49: Measurement methods and test procedures – Differential mode delay

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Endorsement notice

The text of the International Standard IEC 60793-1-48:2003 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

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

Publication	Year	Title	EN/HD	Year
IEC 60793-1-1	- [1]	Optical fibres Part 1-1: Measurement methods and test procedures - General and guidance	EN 60793-1-1	2003 [2]
IEC 60793-1-44	2001	Part 1-44: Measurement methods and test procedures - Cut-off wavelength	EN 60793-1-44	2002
IEC 60793-1-50	2001	Part 1-50: Measurement methods and test procedures - Damp heat (steady state)	EN 60793-1-50	2002
IEC 60793-2-50	2002	Part 2-50: Product specifications - Sectional specification for class B single-mode fibres	EN 60793-2-50	2002
IEC 60794-3	2001	Optical fibres cables Part 3: Sectional specification - Outdoor cables	EN 60794-3	2002
IEC 61280	Series	Fibre optic communication subsystem test procedures	EN 61280	Series
IEC/TR 61282-3	2002	Fibre optic communication system design guides Part 3: Calculation of polarization mode dispersion	-	-

[1] Undated reference.

[2] Valid edition at date of issue.

NORME INTERNATIONALE

INTERNATIONAL STANDARD

CEI IEC 60793-1-48

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Fibres optiques –

Partie 1-48: Méthodes de mesure et procédures d'essai – Dispersion de mode de polarisation

Optical fibres –

Part 1-48: Measurement methods and test procedures – Polarization mode dispersion

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OPTICAL FIBRES –

Part 1-48: Measurement methods and test procedures – Polarization mode dispersion

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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 preparation. The 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 the 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 National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.

6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60793-1-48 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

The text of this standard is based on the following documents:

FDIS	Report on voting
86A/849/FDIS	86A/858/RVD

Full information on the voting for the approval of this standard 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.

This standard is to be read in conjunction with IEC 60793-1-1.

IEC 60793-1-4X consists of the following parts, under the general title *Optical fibres*:

Part 1-40: Measurement methods and test procedures – Attenuation

Part 1-41: Measurement methods and test procedures – Bandwidth

Part 1-42: Measurement methods and test procedures – Chromatic dispersion

Part 1-43: Measurement methods and test procedures – Numerical aperture

Part 1-44: Measurement methods and test procedures – Cut-off wavelength

Part 1-45: Measurement methods and test procedures – Mode field diameter

Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance

Part 1-47: Measurement methods and test procedures – Macrobending loss

Part 1-48: Measurement methods and test procedures – Polarization mode dispersion[1]

Part 1-49: Measurement methods and test procedures – Differential mode delay[2]

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

[1] To be published.

[2] To be published.

INTRODUCTION

Polarization mode dispersion (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 average of DGD values.

In long fibre spans, DGD is random in both 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 the expected value, $<\Delta\tau>$, or the mean DGD over wavelength. In principle, the expected value $<\Delta\tau>$ 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, $<\Delta\tau>$ is a useful predictor of lightwave system performance.

The term “PMD” is used both in the general sense of two polarization modes having different group velocities, and in the specific sense of the expected value $<\Delta\tau>$. The DGD $\Delta\tau$ or pulse broadening $\delta\tau$ can be averaged over wavelength, yielding $<\Delta\tau>_{\lambda}$, or time, yielding $<\Delta\tau>_{\mathrm{t}}$, or temperature, yielding $<\Delta\tau>_{T}$. For most purposes, it is not necessary to distinguish between these various options for obtaining $<\Delta\tau>$.

The coupling length l_c is the length of fibre or cable at which appreciable coupling between the two SOPs begins to occur. If the fibre length L satisfies the condition $L << l_c$, mode-coupling is negligible and $<\Delta\tau>$ scales with fibre length. The corresponding PMD coefficient is

$$\text{“short-length” PMD coefficient} = <\Delta\tau>/L. \quad (1)$$

Fibres in practical systems are nearly always in the $L >> l_c$, regime and mode-coupling is random. If mode-coupling is found to be random, $<\Delta\tau>$ scales with the square root of fibre length, and

$$\text{“long-length” PMD coefficient} = <\Delta\tau>/\sqrt{L} \quad (2)$$

The text provides means for deciding when it is appropriate to use Equations (1) or (2) to calculate the PMD coefficient. Typical units are ps for $\Delta\tau$, km for L, ps/km for short-length PMD, and ps/$\sqrt{\text{km}}$ for long-length PMD. See 5.1 and Annex H for more details on determining the mode-coupling regime.

OPTICAL FIBRES –

Part 1-48: Measurement methods and test procedures – Polarization mode dispersion

1 Scope

This part of IEC 60793 applies to three methods of measuring PMD, which are described in Clause 3. It establishes uniform requirements for measuring the PMD of optical fibre, thereby assisting in the inspection of fibres and cables for commercial purposes.

2 Normative references

The following referenced documents are indispensable for the application 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 60793-1-1, *Optical fibres – Part 1-1: Generic specification – General*

IEC 60793-1-44:2001, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 60793-1-50:2001, *Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state)*

IEC 60793-2-50:2002, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 60794-3:2001, *Optical fibre cables – Part 3: Sectional specification – Outdoor cables*

IEC 61280 (all parts), *Fibre optic communication subsystem basic test procedures*

IEC 61282-3:2002, *Fibre optic communication system design guides – Part 3: Calculation of polarization mode dispersion in fibre optic systems*

3 General

Three methods are described for measuring PMD (see Annexes A, B and C for more details). The methods are listed below in the order of their introduction. For some methods, multiple approaches of analysing the measured results are also provided.

Method A **Fixed analyser**

Extrema counting (EC)

Fourier transform (FT)

Method B **Stokes parameter evaluation**

Jones matrix eigenanalysis (JME)

Poincaré sphere analysis (PSA)

State of polarization (SOP)

Method C **Interferometry**

Negligible mode-coupling

Random mode-coupling

All these methods are suitable for laboratory measurements of factory lengths of optical fibre and optical fibre cable. For all methods, changes in the deployment of the specimen can alter the results. For installed lengths, only Method C is appropriate for measurements of installed optical fibre cable that may be moving or vibrating.

All methods require light sources that are controlled at one or more SOPs. All methods require injecting light across a broad spectral region (i.e. 50 nm to 200 nm wide) to obtain a PMD value that is characteristic of the region (i.e. 1 300 nm or 1 550 nm). The methods differ in

a) the wavelength characteristics of the source;
b) the physical characteristics that are actually measured;
c) the analysis methods.

Method A measures PMD by measuring a response to a change of narrowband light across a wavelength range. At the source, the light is linearly polarized at one or more states of polarization. For each state, the change in output power that is filtered through a fixed polarization analyser, relative to the power detected without the analyser, is measured as a function of wavelength. The resulting measured function can be analysed in one of two ways.

- By counting the number of peaks and valleys (extrema counting) of the curve and application of a formula that has been shown [1][3] to agree with the average of DGD values. This analysis is considered as a frequency domain approach.
- By taking the Fourier transform of the measured function. This transform is equivalent to the pulse spreading obtained by the broadband transmission of Method C. Appropriate characterization of the width of the transform function agrees with the average of DGD values.

Method B measures PMD by measuring a response to a change of narrowband light across a wavelength range. At the source, the light is linearly polarized at one or more states of polarization. The Stokes vector of the output light is measured for each wavelength. The change of these Stokes vectors with angular optical frequency (wavelength), ω and with the (optional) change in input state of polarization yields the DGD as a function of wavelength through relationships that are based on the following definitions:

$$\frac{\mathrm{d}s(\omega)}{\mathrm{d}\omega} = \Omega(\omega) \times s(\omega) \tag{3a}$$

[3] Figures in square brackets refer to the bibliography.

$$\Delta\tau(\omega) = \|\Omega(\omega)\| \tag{3b}$$

where

s is the output Stokes vector;

Ω is the polarization dispersion vector in the direction of the PSPs;

$\Delta\tau$ is the DGD.

For both the JME and PSA analysis approaches, three linear SOPs at nominally 0°, 45°, and 90° (orthogonal on the Poincaré sphere) must be launched for each wavelength. For the SOP analysis, only one input state is required.

The JME approach is completed by transforming the output Stokes vectors to Jones matrices [2], appropriate combination of the matrices at adjacent wavelengths, and a calculation using the eigenvalues of the result to obtain the DGD, by application of an argument formula, at the base frequency.

The PSA approach is completed by doing matrix algebra on the normalized output Stokes vectors to infer the output Stokes vector associated with circular birefringence at two adjacent wavelengths, followed by the application of an arcsine formula to obtain the DGD.

The SOP approach is based on a piecewise evaluation of Equation (3a) using the normalized measured Stokes vectors.

The JME and PSA approaches are mathematically equivalent for common assumptions. The SOP approach yields valid results when the transit of the output Stokes vector is well-behaved (negligible mode-coupling) but can produce incorrect results when the output Stokes vector changes rapidly and randomly. The extra measurement time required for the three input states of polarization for JME and PSA result in a more robust measurement.

Method C is based on a broadband light source that is linearly polarized. The cross-correlation of the emerging electromagnetic field is determined by the interference pattern of the output light. The characterization of this pattern is either done by computing the r.m.s width for randomly mode-coupled specimens or by evaluation of the most extreme interferogram "spike" for specimens with negligible mode-coupling. For random mode-coupled specimens, the r.m.s width relates to the average DGD (PMD).

Information common to all three methods is contained in Clauses 3 to 9, and requirements pertaining to each individual method appear in Annexes A, B, and C, respectively.

3.1 Reference test method

Method B, Stokes parameter evaluation (only JME and PSA approaches), is the reference test method (RTM), which shall be the one used to settle disputes.