

PD IEC/TR 61282-13:2014



BSI Standards Publication

Fibre optic communication system design guides

Part 13: Guidance on in-service PMD and
CD characterization of fibre optic links

bsi.

...making excellence a habit.™

National foreword

This Published Document is the UK implementation of IEC/TR 61282-13:2014.

The UK participation in its preparation was entrusted by Technical Committee GEL/86, Fibre optics, to Subcommittee GEL/86/3, Fibre optic systems and active devices.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2014.
Published by BSI Standards Limited 2014

ISBN 978 0 580 84230 6
ICS 33.180.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 May 2014.

Amendments/corrigenda issued since publication

Date	Text affected
-------------	----------------------



TECHNICAL REPORT



**Fibre optic communication system design guides –
Part 13: Guidance on in-service PMD and CD characterization of fibre optic links**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE



ICS 33.180.01

ISBN 978-2-8322-1572-2

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

CONTENTS

FOREWORD.....4

INTRODUCTION.....6

1 Scope.....7

2 Normative references7

3 Symbols, acronyms and abbreviated terms.....7

4 Background9

5 Non-intrusive fibre characterization12

 5.1 PMD measurement via polarization-sensitive spectral analysis12

 5.1.1 Introductory remark12

 5.1.2 Measurement principle.....13

 5.1.3 Methods for measuring $\Delta\tau_{eff}$ via polarization analysis.....15

 5.1.4 Measurement accuracy.....19

 5.1.5 Measurement set-up example21

 5.2 CD and PMD measurements based on high-speed intensity detection22

 5.2.1 Introductory remark22

 5.2.2 Asynchronous waveform sampling24

 5.2.3 RF spectral analysis29

 5.3 CD and PMD measurements based on high-speed coherent detection32

 5.3.1 Introductory remark32

 5.3.2 Heterodyne detection.....33

 5.3.3 Direct detection with optical CD or PMD compensation.....33

 5.3.4 Electronic CD and PMD compensation in intradyne coherent receiver.....35

6 Semi-intrusive fibre characterization with special probe signals37

 6.1 CD measurement using multi-tone probe signal37

 6.1.1 Introductory remark37

 6.1.2 Differential phase shift method with narrowband probe signals37

 6.1.3 Issues of transmitting alien probe signals41

 6.1.4 Exemplary procedure for in-service CD measurements42

 6.2 PMD measurement with special probe signals.....43

 6.2.1 Introductory remark43

 6.2.2 Probe signal generator for PMD measurements43

Bibliography.....45

Figure 1 – Out-of-service fibre characterization with broadband optical probe signal.....9

Figure 2 – In-service fibre characterization with non-intrusive method.....10

Figure 3 – Semi-intrusive in-service fibre characterization using narrowband probe signal.....11

Figure 4 – Rayleigh PDF for $\Delta\tau_{eff}$ compared with Maxwellian PDF for $\Delta\tau$14

Figure 5 – PMD-induced polarization rotation within the spectrum of a modulated signal15

Figure 6 – Set-up for measuring PMD-induced polarization rotations in optical signals.....16

Figure 7 – Modified set-up for measuring PMD-induced polarization rotations.....16

Figure 8 – Sequence of polarization transformations leading to a scan with $P_p \approx P_s$ at $\nu=0$ (left) and corresponding power ratios (right)17

Figure 9 – Sequence of polarization transformations with $P_p \approx P_s$ at $\nu=0$ (left) and corresponding rotation angles (right).....	18
Figure 10 – Apparatus using coherent detection to measure $\Delta\tau_{eff}$	21
Figure 11 – Apparatus for GVD measurements in a transmitted signal using a high-speed receiver with time-domain waveform analysis or, alternatively, RF spectrum analysis	23
Figure 12 – Set-up for determining the sign of the GVD in the fibre link with an additional optical CD element of known GVD magnitude and sign	24
Figure 13 – Asynchronous sampling of the waveform of a 10 Gbit/s NRZ-OOK signal	25
Figure 14 – Asynchronously sampled waveform histograms of a 10 Gbit/s NRZ-OOK signal without dispersion, with 1 000 ps/nm GVD, and with 48 ps DGD	26
Figure 15 – Asynchronous waveform analysis with two successive samples per symbol period	26
Figure 16 – Apparatus for asynchronous waveform analysis with time-delayed dual sampling	27
Figure 17 – Phase portraits of a 10 Gbit/s NRZ-OOK signal with various amounts of GVD and DGD	28
Figure 18 – Phase portraits of a 10 Gbit/s NRZ-OOK signal wherein the time delay between each sample pair is set to half the symbol period.....	29
Figure 19 – RF spectra of directly detected 10 Gbit/s NRZ- and RZ-OOK signals distorted by various amounts of GVD	30
Figure 20 – Magnitude of the clock frequency component in the RF spectra of 10 Gbit/s NRZ- and RZ-OOK signals as a function of GVD.....	30
Figure 21 – Impact of PMD on the RF spectra of directly detected 10 Gbit/s NRZ- and RZ-OOK signals.....	31
Figure 22 – Apparatus for simultaneous GVD and DGD measurements on NRZ- or RZ-OOK signals using separate detectors for upper and lower modulation sidebands	31
Figure 23 – Optical filtering of a 10 Gbit/s NRZ-OOK signal for separate detection of upper and lower modulation sidebands	32
Figure 24 – RF power spectrum of a 10 Gbit/s NRZ-OOK signal detected with an optical heterodyne receiver.....	33
Figure 25 – Apparatus for measuring GVD with calibrated optical CD compensator	34
Figure 26 – Apparatus for measuring PMD with calibrated optical DGD compensator.....	35
Figure 27 – Coherent optical receiver with high-speed digital signal processing and electronic CD and PMD compensation	36
Figure 28 – Spectrum of an amplitude modulated dual-wavelength probe signal	38
Figure 29 – Signal generator and analyser for dual-wavelength probe signal	39
Figure 30 – Four-wavelength probe signal generator using high-speed modulator.....	39
Figure 31 – Example of end-to-end CD measurements in 6 unused WDM channels	40
Figure 32 – In-service CD measurement with broadband probe signal	41
Figure 33 – Modified dual-wavelength probe signal with un-modulated carrier	42
Figure 34 – Probe signal generator for PMD measurements	44

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIBRE OPTIC COMMUNICATION SYSTEM DESIGN GUIDES –**Part 13: Guidance on in-service PMD and
CD characterization of fibre optic 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 preparation. 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, access 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.

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 TR 61282-13, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

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

Enquiry draft	Report on voting
86C/1201/DTR	86C/1236/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 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 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 International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent concerning optical frequency-sensitive analyser given in 5.1.3.4 and concerning CD measurement using multi-tone probe signal given in 6.1.

IEC takes no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured the IEC that he/she is willing to negotiate licences either free of charge or under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with IEC. Information may be obtained from:

Exfo Electro-Optical Engineering Inc.
400 Avenue Grodin
QC G1M 2K2
CANADA

JDS Uniphase Corporation
430 N. McCarthy Blvd.
Milpitas, CA 95035
USA

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. IEC shall not be held responsible for identifying any or all such patent rights.

ISO (www.iso.org/patents) and IEC (<http://patents.iec.ch>) maintain on-line data bases of patents relevant to their standards. Users are encouraged to consult the data bases for the most up to date information concerning patents.

FIBRE OPTIC COMMUNICATION SYSTEM DESIGN GUIDES –

Part 13: Guidance on in-service PMD and CD characterization of fibre optic links

1 Scope

This part of IEC 61282, which is a technical report, presents general information about in-service measurements of polarization mode dispersion (PMD) and chromatic dispersion (CD) in fibre optic links. It describes the background and need for these measurements, the various methods and techniques developed thus far, and their possible implementations for practical applications.

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 60793-1-42, *Optical fibres – Part 1-42: Measurement methods and test procedures – Chromatic dispersion*

IEC 61280-4-4, *Fibre optic communication subsystem test procedures – Part 4-4: Cable plants and links– Polarization mode dispersion measurement for installed links*

3 Symbols, acronyms and abbreviated terms

$D(\lambda)$	group velocity dispersion coefficient at optical wavelength λ
F	frequency of amplitude modulation in CD measurement
L	length of arc of the SOP rotation on the Poincaré sphere
L_f	length of fibre or fibre link
P_p, P_s	optical signal powers in two orthogonal SOPs
\hat{P}	normalized optical power
$\Delta\hat{P}$	normalized optical power difference
S_1, S_2, S_3	Stokes parameter
\hat{S}	normalized Stokes vector
N	number of statistically independent effective DGD measurements
N_t	number of statistically independent effective DGD measurements in time
N_v	number of statistically independent signal wavelengths
c	speed of light in vacuum
Δf	optical frequency interval or spacing
f	electrical signal frequency in dual-wavelength frequency generator
f_{clock}	clock frequency of digital data modulation
Δt	time interval between effective DGD measurements or differential time delay in CD measurement