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INTERNATIONAL STANDARD

colour inside

Fibre optic communication subsystem test procedures – Part 2-2: Digital systems – Optical eye pattern, waveform and extinction ratio measurement

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 2-2: Digital systems – Optical eye pattern, waveform and extinction ratio measurement

FOREWORD

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International Standard IEC 61280-2-2 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This fourth edition cancels and replaces the third edition published in 2008 and constitutes a technical revision.

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

a) additional definitions;

b) clarification of test procedures.

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

CDV	Report on voting
86C/1043/CDV	86C/1074/RVC

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.

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- withdrawn,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.

The contents of the corrigendum of February 2015 have been included in this copy.

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.

FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 2-2: Digital systems – Optical eye pattern, waveform and extinction ratio measurement

1 Scope

The purpose of this part of IEC 61280 is to describe a test procedure to verify compliance with a predetermined waveform mask and to measure the eye pattern and waveform parameters such as rise time, fall time, modulation amplitude and extinction ratio.

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 61280-2-3, *Fibre optic communication subsystem test procedures – Part 2-3: Digital systems – Jitter and wander measurements*

3 Terms and definitions

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

3.1
amplitude histogram
graphical means to display the power or voltage population distribution of a waveform

3.2
contrast ratio
ratio of the nominal peak amplitude to the nominal minimum amplitude of two adjacent logical ‘1’s when using return-to-zero transmission

3.3
duty cycle distortion
DCD
measure of the balance of the time width of a logical 1 bit to the width of a logical 0 bit, indicated by the time between the eye diagram nominal rising edge at the average or 50 % level and the eye diagram nominal falling edge at the average or 50 % level

3.4
extinction ratio
ratio of the nominal 1 level to the nominal 0 level of the eye diagram

3.5
eye diagram
type of waveform display that exhibits the overall performance of a digital signal by superimposing all the acquired samples on a common time axis one unit interval in width

3.6
eye height
difference between the 1 level, measured three standard deviation below the nominal 1 level of the eye diagram, and 0 level, measured three standard deviations above the nominal 0 level of the eye diagram

3.7
eye mask
constellation of polygon shapes that define regions where the eye diagram may not exist, thereby effectively defining the allowable shape of the transmitter waveform

3.8
eye width
time difference between the spread of the two crossing points of an eye diagram, each measured three standard deviations toward the centre of the eye from their nominal positions

3.9
jitter
deviation of the logical transitions of a digital signal from their ideal positions in time manifested in the eye diagram as the time width or spread of the crossing point

3.10
observed jitter transfer function
OJTF
ratio of the displayed or measured jitter relative to actual jitter, versus jitter frequency, when a test system is synchronized with a clock derived from the signal being measured

3.11
reference receiver
description of the frequency and phase response of a test system, typically a fourth-order Bessel-Thomson low-pass, used to analyze transmitter waveforms with the intent of achieving consistent results whenever the test system complies with this expected response

3.12
signal-to-noise ratio
SNR
similar to Q-factor, the ratio of the difference of the nominal 1 and 0 level of the eye diagram to the sum of the standard deviation of both the 1 level and the 0 level of the eye diagram

3.13
unit interval
for the NRZ signal, the unit interval is one bit period or the inverse of the signalling rate

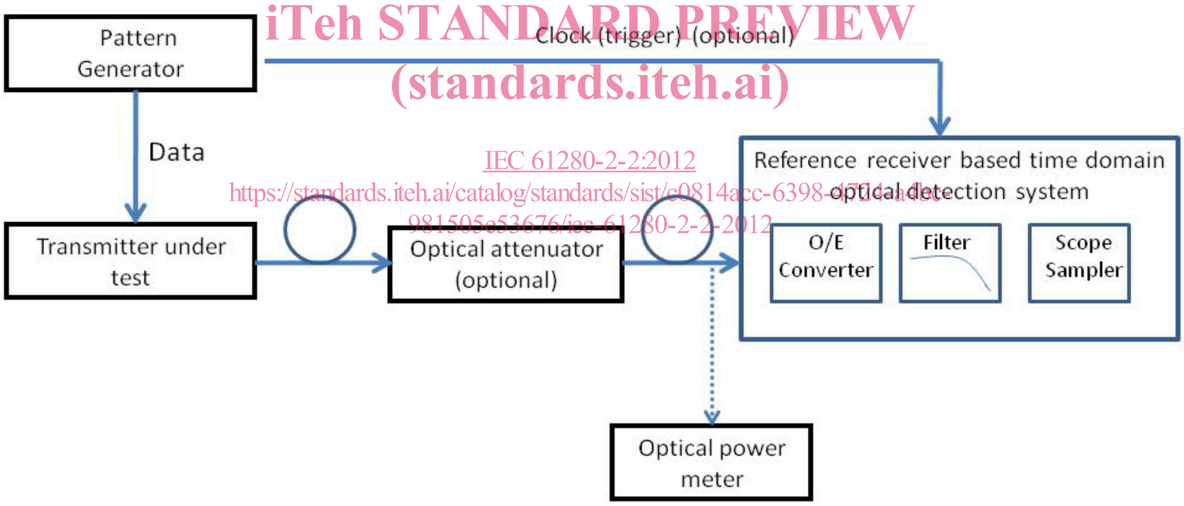
4 Apparatus

4.1 General

The primary components of the measurement system are a photodetector, a low-pass filter, an oscilloscope, and an optical power meter, as shown in Figure 1. Many transmitter characteristics are derived from analysis of the transmitter time-domain waveform. Transmitter waveform characteristics can vary depending on the frequency response and bandwidth of the test system. To achieve consistent results, the concept of a reference receiver is used. The reference receiver definition defines the combined frequency and phase response of the optical-to-electrical converter, any filtering, and the oscilloscope. The reference receiver frequency response is typically a low pass filter design and is discussed in detail in 4.2. At high signalling rates, reference receiver frequency response can be difficult to achieve when configured using individual components. It is common to integrate the reference receiver within the oscilloscope system to achieve reference receiver specifications. Use of a low-pass filter which alone achieves reference receiver specifications often will not result in a test system that achieves the required frequency response.

4.2 Reference receiver definition

A reference receiver typically follows a fourth-order low-pass Bessel response. A well-defined low-pass frequency response will yield consistent results across all test systems that conform to the specification. A low-pass response reduces test system noise and approaches the bandwidth of the actual receiver that the transmitter will be paired with in an actual communications system. As signal transients such as overshoot and ringing, which can lead to eye mask failures, are usually suppressed by the reduced bandwidth of the system receiver, it is appropriate to use a similar bandwidth in a transmitter test system. The Bessel phase response yields near constant group delay in the passband, which in turn results in minimal phase distortion of the time domain optical waveform. The bandwidth of the frequency response typically is set to 0,75 (75 %) of the signalling rate. For example, the reference receiver for a 10,0 GBd signal would have a –3 dB bandwidth of 7,5 GHz. For non-return to zero (NRZ) signals, this response has the smallest bandwidth that does not result in vertical or horizontal eye closure (inter-symbol interference). When the entire test system achieves the fourth-order Bessel low-pass response with a bandwidth of 75 % of the baud rate, this is referred to as a Bessel-Thomson reference receiver. Return-to-zero (RZ) signals require a larger bandwidth reference receiver, but which has not been specified in any standards committees.



IEC 1897/12

Figure 1 – Optical eye pattern, waveform and extinction ratio measurement configuration

4.3 Time-domain optical detection system

4.3.1 Overview

The time-domain optical detection system displays the power of the optical waveform as a function of time. The optical detection system is comprised primarily of a linear optical-to-electrical (O/E) converter, a linear-phase low-pass filter and an electrical oscilloscope. The output current of the linear photodetector must be directly proportional to the input optical power. When the three elements are combined within an instrument, it becomes an optical oscilloscope and can be calibrated to display optical power rather than voltage, as a function of time. More complete descriptions of the equipment are listed in 4.3.2 to 4.3.4.

4.3.2 Optical-to-electrical (O/E) converter

The O/E converter is typically a high-speed photodiode. The O/E converter is equipped with an appropriate optical connector to allow connection to the optical interface point, either directly or via an optical test cord. When low power signals are to be measured, the photodetector may be followed by electrical amplification. The frequency response of the amplification must be considered as it may impact the overall frequency response of the test system.

Precise specifications are precluded by the large variety of possible implementations, but general guidelines are as follows:

a) acceptable input wavelength range, adequate to cover the intended application;

b) input optical reflectance, low enough to avoid excessive back-reflection into the transmitter being measured;

c) responsivity and low noise, adequate to produce an accurately measureable display on the oscilloscope. The photodetector responsivity influences the magnitude of the displayed signal. The photodetector and oscilloscope electronics generate noise. The noise of the test system must be small compared to the observed signal. If the noise is significant relative to the detected optical waveform, some measurements such as eye-mask margin can be degraded. When the photodetector is integrated within the test system oscilloscope, noise performance is specified directly as an RMS optical power level (e.g. 5 mW). The responsivity of the photodetector is used to calibrate the vertical scale of the instrument. Further discussion on the impact of noise is found in 6.1;

d) lower cut-off (–3 dB) frequency, 0 Hz;

e) DC coupling is necessary for two reasons. First, extinction ratio measurements cannot otherwise be performed. Second, if AC-coupling is used, low-frequency spectral components of the measured signal (below the lower cut-off frequency of the O/E converter) may cause significant distortion of the detected waveform;

f) upper cut-off (–3 dB) frequency, greater than the bandwidth required to achieve the desired reference receiver response. Note that –3dB represents a voltage level within the oscilloscope that is 0,707 of the level seen in the filter passband;

g) transient response, overshoot, undershoot and other waveform aberrations so minor as not to interfere with the measurement;

h) output electrical return loss, high enough that reflections from the low-pass filter following the O/E converter are adequately suppressed from 0 Hz to a frequency significantly greater than the bandwidth of the low-pass filter.

4.3.3 Linear-phase low-pass filter

A reference receiver is commonly implemented by placing a low-pass filter of known characteristics in the signal path prior to the oscilloscope sampling electronics. The bandwidth and transfer function characteristics of the low-pass filter are designed so that the combined response of the entire signal path including the O/E converter and oscilloscope meets reference receiver specification.

Some measurements of optical waveform parameters are best made without an intentionally reduced bandwidth. Measurements of risetime, falltime, overshoot etc. may be improved with removal of the low-pass filter (see 4.3.4 and 7.11). This may be achieved with electronic switching. The –3 dB bandwidth of the measurement system in this case shall be high enough to allow verification of minimum rise and fall times (for example, one-third of a unit interval), but low enough to eliminate unimportant high-frequency waveform details. For NRZ signals, a bandwidth of 300 % of the signalling rate is a typical compromise value for this type of measurement. RZ signals can require a bandwidth of 500 % of the signalling rate as a typical compromise.

4.3.4 Oscilloscope

The oscilloscope which displays the optical eye pattern typically will have a bandwidth well in excess of the bandwidth of the low-pass filter, so that the oscilloscope is not the bandwidth-limiting item of the measurement system. As signalling rates become very high, the oscilloscope bandwidth may become a more significant contributor to the overall reference receiver response.

The oscilloscope is triggered either from a local clock signal which is synchronous with the optical eye pattern or from a synchronization signal derived from the optical waveform itself (see 4.5).

Figure 2 illustrates oscilloscope bandwidths that are commonly used in eye pattern measurements. Figure 2(a) displays a 10 GBd waveform when the measurement system filter is switched out and the bandwidth exceeds 20 GHz. Figure 2B shows the same signal when measured with the 10 GBd reference receiver in place (~7,5 GHz bandwidth). Note how rise and fall times and eye shape are dependent on measurement system bandwidth.

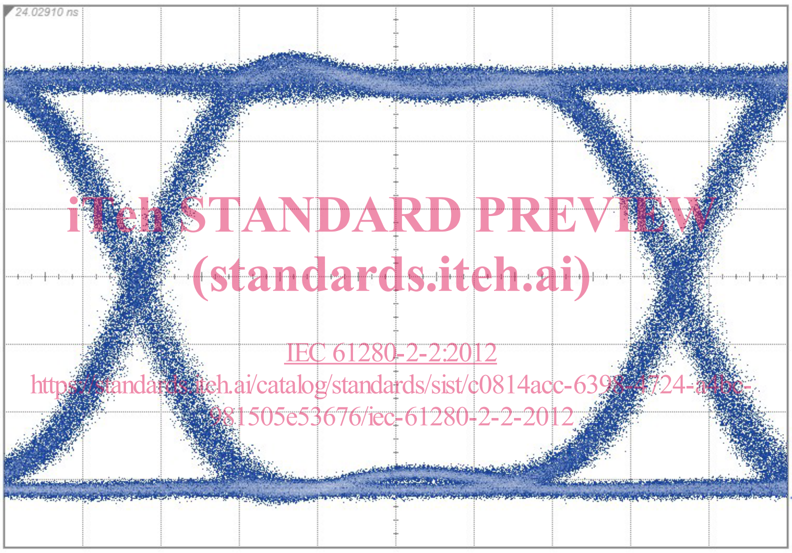


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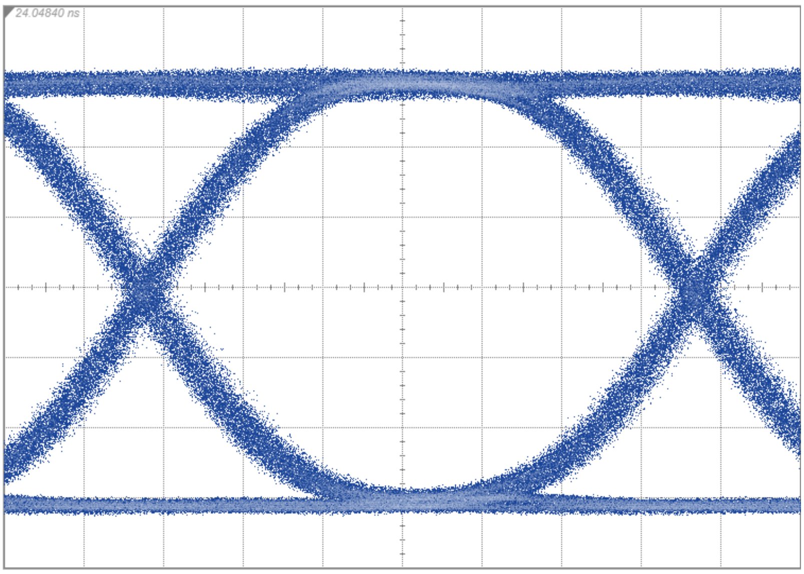
Figure 2(a) – 10 GBd signal measured without filtering



IEC 1899/12

Figure 2(b) – 10 GBd signal measured with a 10 GBd reference receiver

Figure 2 – Oscilloscope bandwidths commonly used in eye pattern measurements