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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Fibre optic communication subsystem test procedures – Part 2-9: Digital systems – Optical signal-to-noise ratio measurement for dense wavelength-division multiplexed systems

Procédures d'essai des sous-systèmes de télécommunications à fibres optiques – Partie 2-9: Systèmes numériques – Mesure du rapport signal sur bruit optique pour les systèmes multiplexés à répartition en longueur d'onde dense

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FOREWORD

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International Standard IEC 61280-2-9 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics

This second addition cancels and replaces the first edition published in 2002 and constitutes a technical revision. The main changes from the previous edition are as follows:

- A paragraph has been added to the Scope describing the limitations due to signal spectral width and wavelength filtering.
- Annex B has been added to further explain error in measuring noise level due to signal spectral width and wavelength filtering.

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

CDV	Report on voting
86C/823/CDV	86C/864/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 the parts in the IEC 61280 series, 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 maintenance result 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- withdrawn,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.

INTRODUCTION

At the optical interfaces within wavelength-division multiplexed (WDM) networks, it is desirable to measure parameters that provide information about the integrity of the physical plant. Such parameters are necessary to *monito*r network performance as an integral part of network management. They are also necessary to assure proper system operation for *installation and maintenance* of the network.

Ideally, such parameters would directly correspond to the bit error ratio (BER) of each channel of a multichannel carrier at the particular optical interface. Related parameters such as Q-factor or those calculated from optical eye patterns would provide similar information, that is, they would correlate to the channel BER. However, it is difficult to obtain access to these parameters at a multichannel interface point. It is necessary to demultiplex the potentially large number of channels and make BER, Q-factor, or eye-diagram measurements on a per-channel basis.

In contrast, useful information about the optical properties of the multichannel carrier is readily obtained by measuring the optical spectrum. Wavelength-resolved signal and noise levels provide information on signal level, signal wavelength, and amplified spontaneous emission (ASE) for each channel. Spectral information, however, does not show signal degradation due to wave-shape impairments resulting from polarization-mode dispersion (PMD), and chromatic dispersion. Also, intersymbol interference and time jitter are not revealed from an optical signal to noise ratio (OSNR) measurement. In spite of these limitations, OSNR is listed as an interface parameter in ITU-T Rec. G.692 [1][1], as an optical monitoring parameter in ITU-T Rec. G.697 [2] and in ITU-T G Rec. Sup. 39 [3].

1 Figures in brackets refer to the bibliography.

FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 2-9: Digital systems – Optical signal-to-noise ratio measurement for dense wavelength-division multiplexed systems

1 Scope

This part of IEC 61280 provides a parameter definition and a test method for obtaining optical signal-to-noise ratio (OSNR) using apparatus that measures the optical spectrum at a multichannel interface. Because noise measurement is made on an optical spectrum analyzer, the measured noise does not include source relative intensity noise (RIN) or receiver noise.

Three implementations for an optical spectrum analyser (OSA) are discussed: a diffraction-grating-based OSA, a Michelson interferometer-based OSA, and a Fabry-Perot-based OSA. Performance characteristics of the OSA that affect OSNR measurement accuracy are provided.

A typical optical spectrum at a multichannel interface is shown in Figure 1. Important characteristics are as follows.

- The channels are placed nominally on the grid defined by ITU Recommendation G.694.1.[4]
- Individual channels may be non-existent because it is a network designed with optical add/drop demultiplexers or because particular channels are out of service.
- Both channel power and noise power are a function of wavelength.

For calculating the OSNR, the most appropriate noise power value is that at the channel wavelength. However, with a direct spectral measurement, the noise power at the channel wavelength is included in the signal power and is difficult to extract. An estimate of the channel noise power can be made by interpolating the noise power value between channels.

The accuracy of estimating the noise power at the signal wavelength by interpolating the noise power at an offset wavelength can be significantly reduced when the signal spectrum extends into the gap between the signals and when components such as add-drop multiplexers along the transmission span modify the spectral shape of the noise. These effects are discussed in further detail in Annex B, and can make the method of this document unusable for some situations. In such cases, where signal and noise cannot be sufficiently separated spectrally, it is necessary to use more complex separation methods, like polarization or time-domain extinction, or to determine signal quality with a different parameter, such as RIN. This is beyond the scope of the current document.

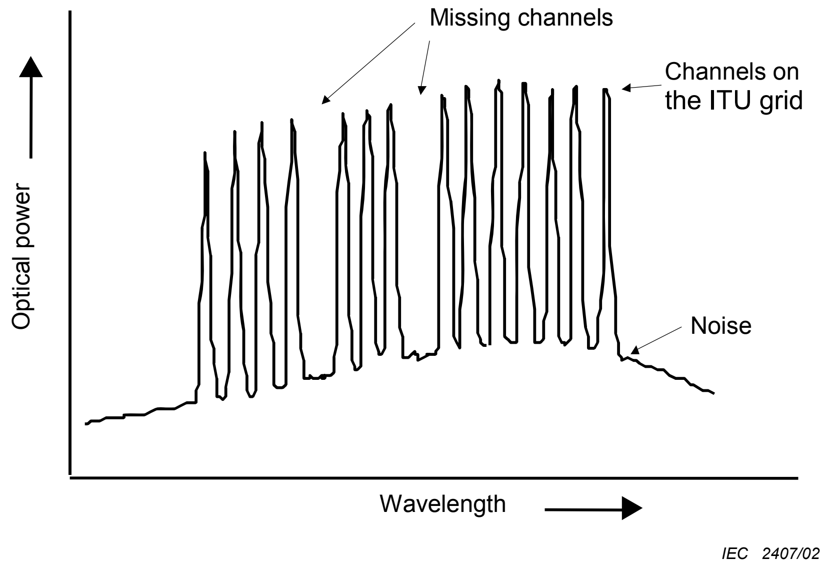

Figure 1 – Typical optical spectrum at an optical interface in a multichannel transmission system

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 61290-3-1, *Optical amplifiers – Test methods – Part 3-1: Noise figure parameters – Optical spectrum analyzer method*

IEC 62129, *Calibration of optical spectrum analyzers*

3 Terms and definitions

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

3.1
optical signal-to-noise ratio
OSNR
ratio in decibels, from the optical spectrum, defined by the equation

$$\text{OSNR} = 10\text{Log}\frac{P_i}{N_\text{i}} + 10\text{Log}\frac{B_\text{m}}{B_\text{r}} \quad \text{dB,} \qquad (1)$$

where

P_i is the optical signal power, in watts, at the i-th channel,

B_r is the reference optical bandwidth, and

N_i is the interpolated value of noise power, in watts, measured in the noise equivalent bandwidth, B_m, given by

$$N_i = \frac{N(\lambda_i - \Delta\lambda) + N(\lambda_i + \Delta\lambda)}{2} \qquad (2)$$

at the i-th channel, where

λ_i is the wavelength of the i-th channel, and

$\Delta\lambda$ is the interpolation offset equal to or less than one-half of the ITU grid spacing.

(The units for B_m and B_r may be in frequency or wavelength but must be consistent.) Typically, the reference optical bandwidth is 0,1 nm. See Figure 2.

NOTE The noise equivalent bandwidth of a filter is such that it would pass the same total noise power as a rectangular passband that has the same area as the actual filter, and the height of which is the same as the height of the actual filter at its centre wavelength.

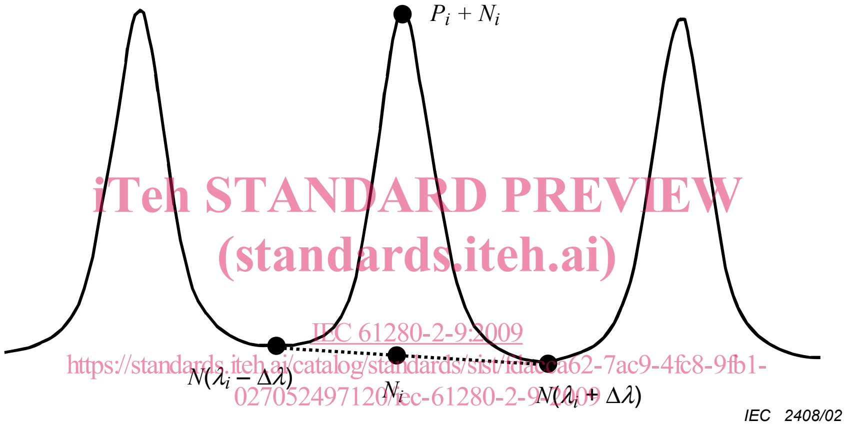

Figure 2 – OSNR for each channel as derived from direct measurements of the optical spectrum

4 Apparatus

4.1 General

The required apparatus is an optical spectrum analyzer (OSA) with the performance necessary to measure the signal and noise powers required for Equation (1). Three common ways to implement an OSA are with a diffraction grating, a Michelson interferometer, and a Fabry-Perot etalon.

4.2 Diffraction grating-based OSA

A simplified diagram of a diffraction grating-based OSA is shown in Figure 3. The expanded input light is incident on a rotatable diffraction grating. The diffracted light comes off at an angle proportional to wavelength and passes through an aperture to a photodetector. The size of the input and output apertures and the size of the beam on the diffraction grating determine the spectral width of the resulting filter and therefore the resolution of the OSA. A/D conversion and digital processing provide the familiar OSA display.

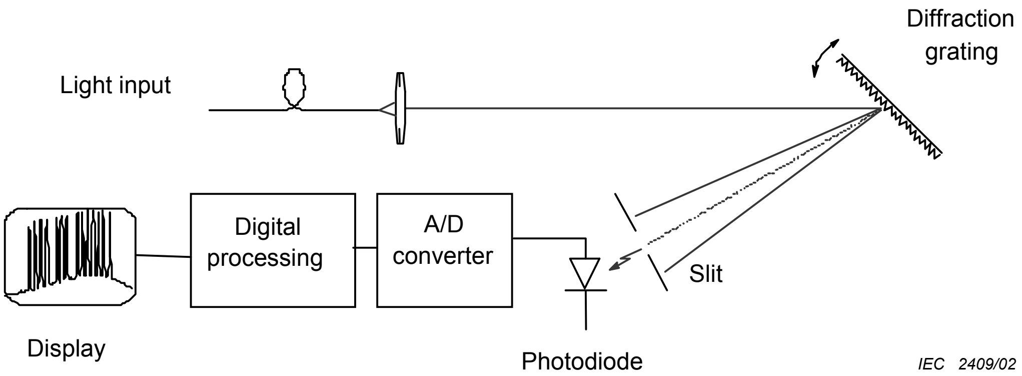

Figure 3 – Diffraction grating-based OSA

4.3 Michelson interferometer-based OSA

Another type of OSA is based on the Michelson interferometer as shown in Figure 4. The input signal is split into two paths. One path is fixed in length and one is variable. The Michelson interferometer creates an interference pattern between the signal and a delayed version of itself at the photodetector. The resulting waveform, called an interferogram, is the autocorrelation of the input signal. A Fourier transform performed on the autocorrelation provides the optical spectrum. The resolution of this type of OSA is set by the differential path delay of the interferometer.

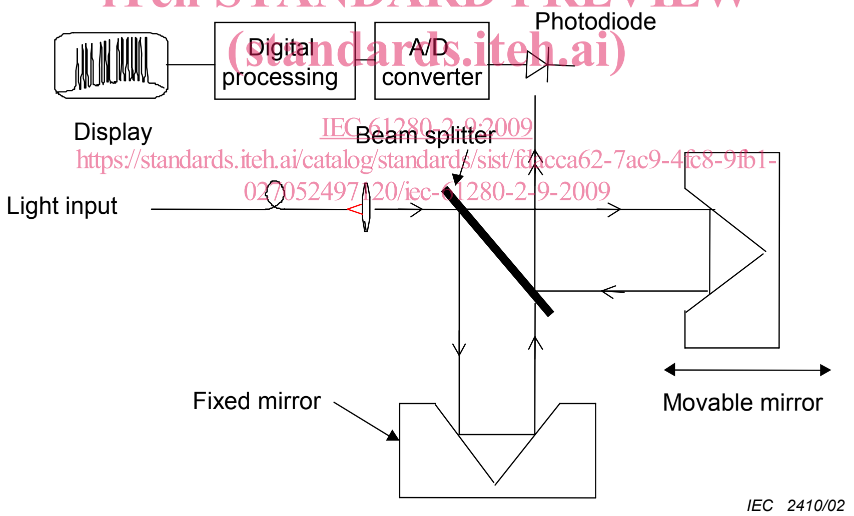

Figure 4 – Michelson interferometer-based OSA

4.4 Fabry-Perot-based OSA

A third type of OSA is based on a Fabry-Perot etalon as shown in Figure 5. The collimated beam passes through a Fabry-Perot etalon, the free spectral range (FSR) of which is greater than the channel plan and the finesse is chosen to give the required resolution bandwidth (RBW). Piezo-electric actuators control the Fabry-Perot mirror spacing and provide spectral tuning. Digital signal processing provides any combination of spectral display or tabular data.

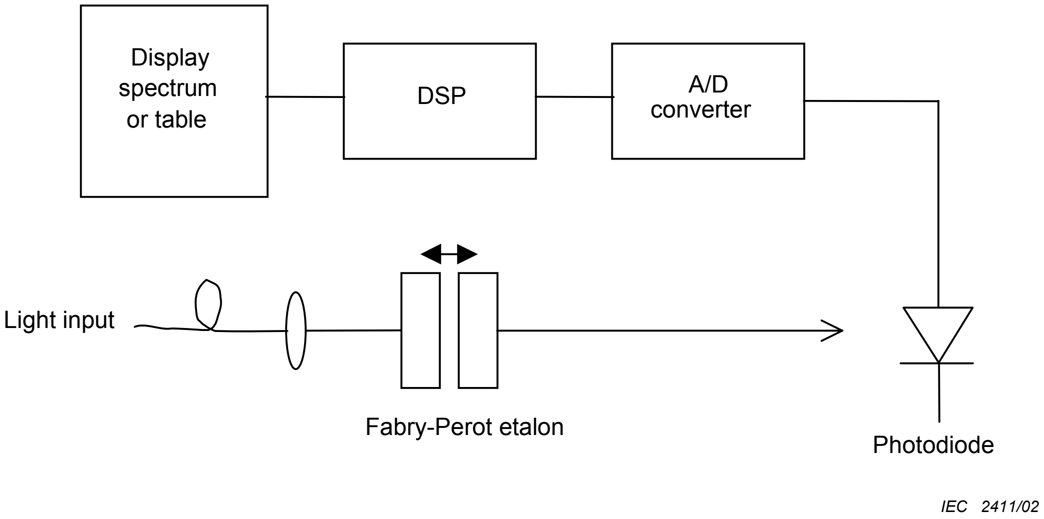

Figure 5 – Fabry-Perot-based OSA

4.5 OSA performance requirements

4.5.1 General

Refer to IEC 62129 for calibration details.

4.5.2 Wavelength range

The wavelength range shall be sufficient to cover the channel plan plus one-half grid spacing on each end of the band to measure the noise of the lowest and highest channels.

4.5.3 Sensitivity

The sensitivity of an OSA is defined as the lowest level at which spectral power can be measured with a specified accuracy. The OSA sensitivity must be sufficient to measure the lowest expected noise level. In terms of OSNR,

$$\text{Required sensitivity (dBm)} = \text{Minimum channel level (dBm)} - \text{OSNR (dB)} \qquad (3)$$

For example, the sensitivity required for a minimum channel level of –10 dBm in order to measure a 35-dB OSNR is

$$-10 \text{ dBm} - 35 \text{ dBm} = -45 \text{ dBm}$$

4.5.4 Resolution bandwidth (RBW)

The relationship of the measured peak power to the total signal power depends on the spectral characteristics of the signal and the resolution bandwidth. The resolution bandwidth must be sufficiently wide to accurately measure the power level of each modulated channel. The proper RBW setting depends on the bit rate. For example, the signal power of a laser modulated at an OC-192 (STM-64) rate with zero chirp will measure 0,8 dB lower with a 0,1-nm RBW than with a wide RBW. This results from the modulation envelope having a portion of its spectral power outside of the 0,1-nm RBW. If the RBW is decreased to 0,05 nm, the signal power will measure 2,5 dB lower. This effect is made worse by the presence of laser chirp and lessened by additional bandwidth limiting in the transmitter laser's modulation circuitry. This subject is treated in more detail in Annex A.