BS EN 61280-2-9:2009

BSI British Standards

# Fibre optic communication subsystem test procedures —

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



*raising standards worldwide™*

British Standards

## National foreword

This British Standard is the UK implementation of EN 61280-2-9:2009. It is identical to IEC 61280-2-9:2009. It supersedes BS EN 61280-2-9:2002 which is withdrawn.

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.



ISBN 978 0 580 60148 4

ICS 33.180.20

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2009

## Amendments issued since publication

| Amd. No. | Date | Text affected |
|---|---|---|

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

# EN 61280-2-9

April 2009

ICS 33.180.20

Supersedes EN 61280-2-9:2002

English version

## Fibre optic communication subsystem test procedures - Part 2-9: Digital systems - Optical signal-to-noise ratio measurement for dense wavelength-division multiplexed systems
(IEC 61280-2-9:2009)

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
(CEI 61280-2-9:2009)

Prüfverfahren für Lichtwellenleiter-Kommunikationsuntersysteme - Teil 2-9: Digitale Systeme - Messung des optischen Signal-Rausch-Verhältnisses für dichte Wellenlängen-Multiplex-Systeme
(IEC 61280-2-9:2009)

This European Standard was approved by CENELEC on 2009-04-01. 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.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

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

**Central Secretariat: avenue Marnix 17, B - 1000 Brussels**



Ref. No. EN 61280-2-9:2009 E

## Foreword

The text of document 86C/823/CDV, future edition 2 of IEC 61280-2-9, prepared by SC 86C, Fibre optic systems and active devices, of IEC TC 86, Fibre optics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61280-2-9 on 2009-04-01.

This European Standard supersedes EN 61280-2-9:2002.

The main changes from EN 61280-2-9:2002 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 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) | 2010-01-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2012-04-01 |

Annex ZA has been added by CENELEC.

## Endorsement notice

The text of the International Standard IEC 61280-2-9:2009 was approved by CENELEC as a European Standard without any modification.

# Annex ZA
(normative)

## Normative references to international publications with their corresponding European publications

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.

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 61290-3-1 | -[1] | Optical amplifiers - Test methods - Part 3-1: Noise figure parameters - Optical spectrum analyzer method | EN 61290-3-1 | 2003[2] |
| IEC 62129 | -[1] | Calibration of optical spectrum analyzers | EN 62129<br>+ corr. December | 2006[2]<br>2006 |

[1] Undated reference.

[2] Valid edition at date of issue.

CONTENTS

# 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.

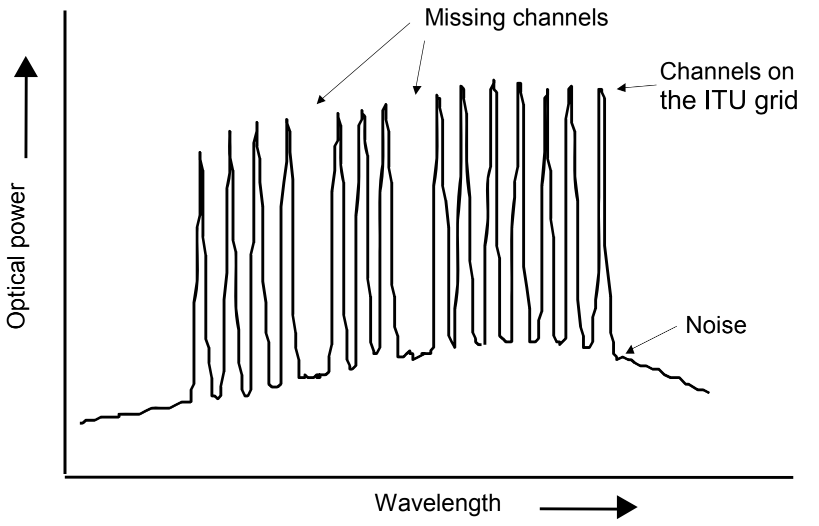


**Figure 1 – Typical optical spectrum at an optical interface in a multichannel transmission system**

## 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

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

where

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

$B_\mathrm{r}$ is the reference optical bandwidth, and

$N_\text{i}$ is the interpolated value of noise power, in watts, measured in the noise equivalent bandwidth, $B_\text{m}$, given by

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

at the $i$-th channel, where

$\lambda_i$ 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 $B_\text{m}$ and $B_\text{r}$ 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.

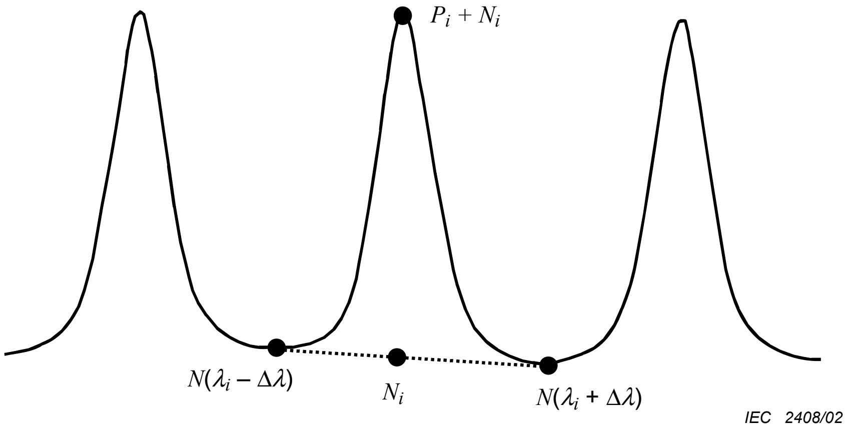


**Figure 2 – OSNR for each channel as derived from direct measurements of the optical spectrum**

## 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.

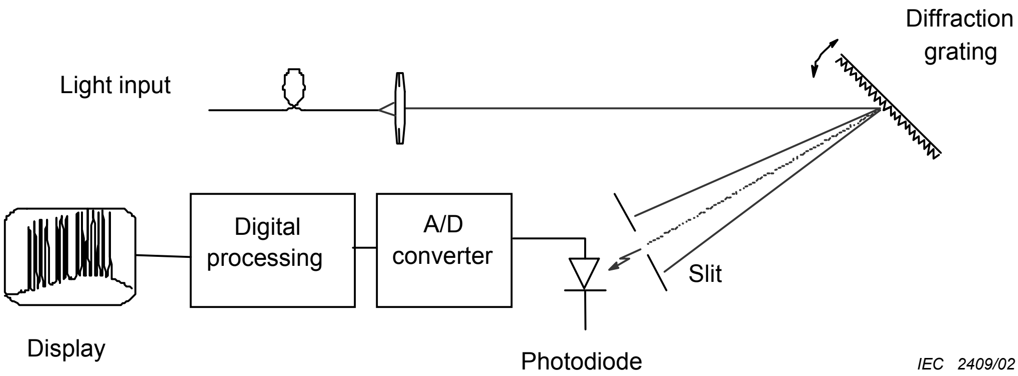


**Figure 3 – Diffraction grating-based OSA**

### 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.

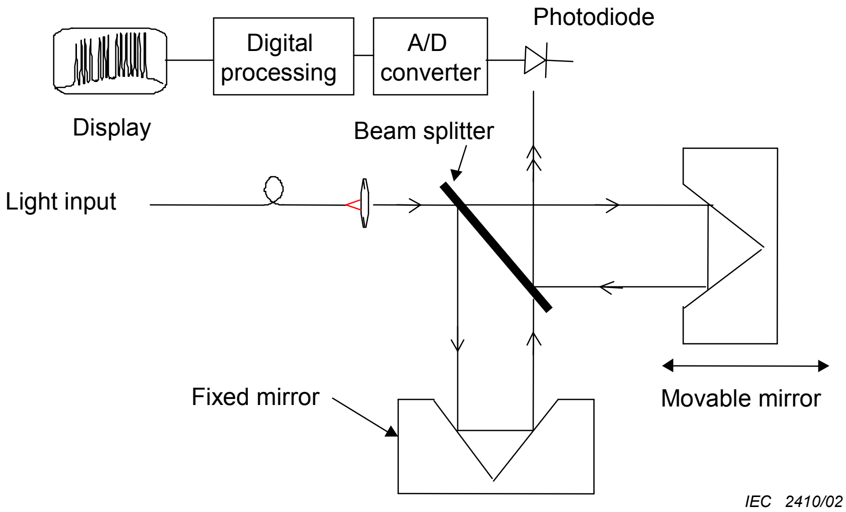


**Figure 4 – Michelson interferometer-based OSA**

### 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.

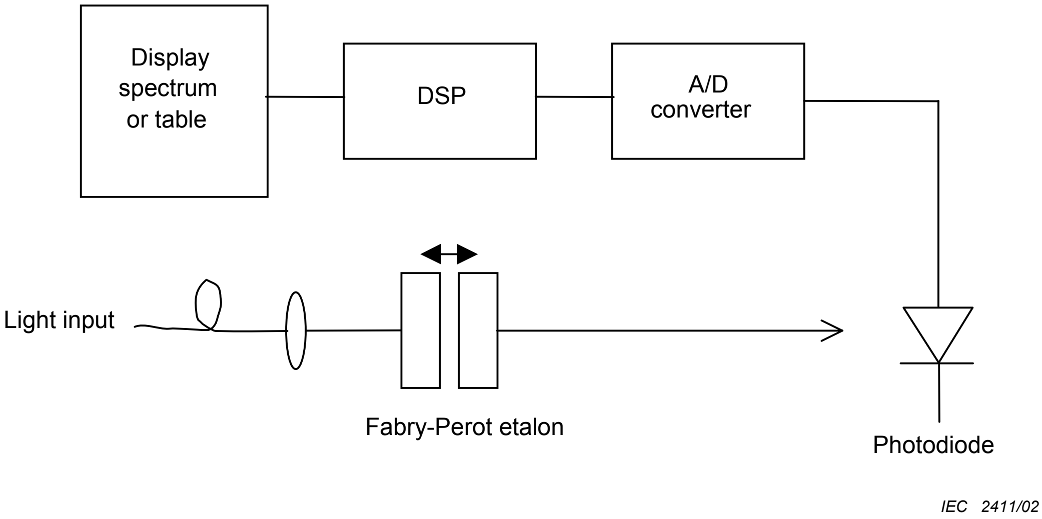


**Figure 5 – Fabry-Perot-based OSA**

### 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.

When the signal spreads spectrally into the range between the channels, as due to high modulation rates, then the resolution must be sufficiently narrow to exclude the signal power from the noise measurement enough to allow the desired accuracy for the given level of noise. For example in the above case, if the OC-192 (STM-64) signals are spaced 0,2 nm apart (25 GHz grid), then the spectral power outside an 0,1-nm-RBW signal measurement would all be included in the noise measurement with 0,1-nm RBW. This 17 % of the signal power would result in a best measurable OSNR of only about 7 dB. The topic is also discussed in Annex B.

### 4.5.5 Resolution bandwidth accuracy

The accuracy of the noise measurement is directly impacted by the accuracy of the OSA's RBW. For best accuracy, the OSA's *noise equivalent bandwidth*, $B_m$, must be calibrated. RBW, in general, differs from $B_M$ due to the non-rectangular shape of the optical spectrum analyzer's filter characteristic. The procedure for calibrating $B_m$ is given in IEC 61290-3-1, where it is referred to as *optical bandwidth*.

### 4.5.6 Dynamic range

The dynamic range of an OSA is a measure of the OSA's ability to make measurements of low-level signals and noise that are close in wavelength to large signals. It is important to note that narrowing the RBW does not necessarily correlate to better dynamic range. RBW is a measure of the 3-dB bandwidth or noise equivalent bandwidth of its filter characteristic. Dynamic range, on the other hand, is a measure of the steepness of the filter characteristic and the OSA noise floor. Dynamic range is defined as the ratio, in dB, of the filter transmission characteristic at the centre wavelength, $\lambda_i$, and at one-half a grid spacing away, $\lambda_I \pm \Delta\lambda$.

Figure 6 shows two channels of a multichannel spectrum, the OSA filter characteristic, the OSA sensitivity limit, and the transmission system noise that is to be measured. At the noise measurement wavelength, the dynamic range must be significantly higher than the OSNR for accurate measurements. The uncertainty contribution can be predicted from the following equation:

$$\text{Uncertainty in OSNR} = 10 \log(1+10^{-D/10}) \text{ dB}, \tag{4}$$

where $D$ is the value in dB by which the OSA dynamic range exceeds the actual OSNR. For example, for an OSNR of 30 dB, a dynamic range of 40 dB (at ½ the ITU grid spacing) will cause an error of 0,42 dB.

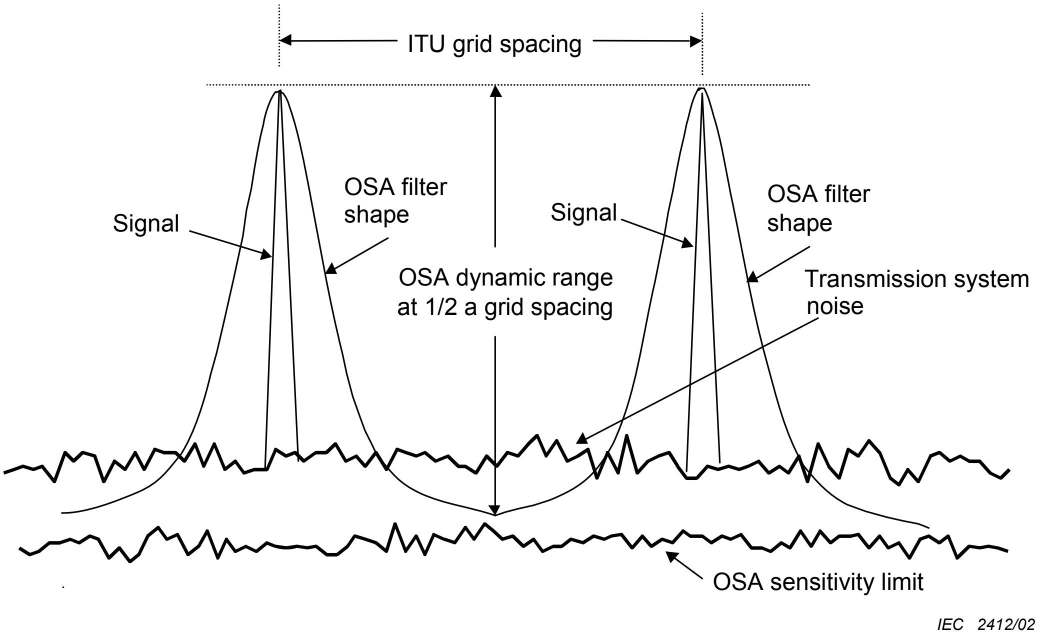


**Figure 6 – Illustration of insufficient dynamic range as another source of measurement uncertainty**

In general, either the OSA sensitivity limit or dynamic range will limit the value of OSNR that can be measured. Typically, a Michelson interferometer-based OSA will be limited by the sensitivity limit and a diffraction grating-based OSA by the dynamic range.

#### 4.5.7 Scale fidelity

Scale fidelity, also called display linearity, is the relative error in amplitude that occurs over a range of input power levels. Scale fidelity directly contributes to the OSNR measurement uncertainty.

#### 4.5.8 Polarization dependence

Typically, the signal, $P_i$ will be highly polarized while the noise, $N_\mathrm{i}$ is unpolarized. OSA polarization dependence will directly contribute to uncertainty in signal measurement.

#### 4.5.9 Wavelength data points

The minimum number of data points collected by the OSA shall be at least twice the wavelength span divided by the noise equivalent bandwidth.

## 5 Sampling and specimens

The device under test (DUT) is a multichannel fibre-optic transmission system or network. The measurement apparatus is connected to the network at any point by directly connecting to the optical fibre or via a broadband monitoring port. Measurement points following wavelength-selective components such as an add-drop multiplexer may be inappropriate due to the noise filtering effect described in Annex B.

## 6 Procedure

a) Connect the OSA to the transmission fibre or a monitor port.

b) Choose RBW values sufficiently wide to accurately measure the signal power and with sufficient dynamic range to measure the noise at $\pm\Delta\lambda$ from the peak channel wavelength where $\Delta\lambda$ is half the ITU grid spacing or less if this gives a more accurate OSNR value due to noise filtering. (See annexes, Table A.2 and Subclause 4.5.6.)

c) Set the wavelength range to accommodate all channels plus at least a half grid spacing below the lowest channel and above the highest channel.

d) Measure the power level at the signal peak for the *i*-th of *n* channels. This value is $P_i$+$N_\text{i}$ (refer to Figure 2).

e) Measure the noise at ±$\Delta\lambda$ from the signal peak wavelength. Use a calibrated RBW with noise equivalent bandwidth, $B_\text{m}$. The measured values are $N(\lambda_i - \Delta\lambda)$ and $N(\lambda_i + \Delta\lambda)$.

f) Calculate the interpolated value of noise at each channel wavelength (Equation (2)):

$$N_\text{i} = \frac{N(\lambda_i - \Delta\lambda) + N(\lambda_i + \Delta\lambda)}{2} \tag{5}$$

g) Calculate $P_i$ by subtracting $N_\text{i}$ from the value obtained in step d).

h) Repeat steps d) through g) for all $n$ channels.

NOTE This procedure may be done with two RBW settings: one that is sufficiently wide to measure total signal power, the second with sufficient dynamic range to measure noise at ±$\Delta\lambda$ from the peak channel wavelengths.

## 7 Calculations

- For each of the *n* channels, calculate the interpolated value of noise power, $N_i$, using step f) and $P_i$ using step g) in Clause 6.
- For each of the $n$ channels, calculate OSNR from Equation (1).

$$\text{OSNR} = 10\,\text{Log}\frac{P_i}{N_\text{i}} + 10\,\text{Log}\frac{B_\text{m}}{B_\text{r}} \tag{6}$$

## 8 Measurement uncertainty

Measurement uncertainty should be calculated based upon the *ISO/IEC Guide to the expression of uncertainty in measurement*. [5]

Uncertainty contributions that must be considered are as follows:

- modulated signal power (4.5.4 and Annex A);
- OSA noise bandwidth (4.5.5);
- OSA dynamic range (4.5.6);
- OSA scale fidelity (4.5.7);
- OSA polarization dependence (4.5.8).

## 9 Documentation

Report the following information for each test:

- test date
- this standard number
- identification of the transmission system being tested and the test location
- description of the equipment used
- OSNR data
- OSA noise equivalent bandwidth, $B_\text{m}$
- reference bandwidth, $B_\text{r}$

- offset wavelength for noise measurement, $\Delta\lambda$, and ITU grid spacing
- measurement uncertainty

# Annex A
(informative)

## Error in measuring signal level due to signal spectral width

The spectral width of each channel is broadened from that of the CW laser due to several causes:

- laser chirp
- intensity modulation for signal transmission
- modulation to suppress stimulated Brillouin scattering (SBS)
- self-phase modulation (SPM)
- cross-phase modulation

For dense WDM systems in which external modulation is generally used, laser chirp is not a factor. Broadening due to SBS suppression and SPM are typically small compared to the broadening due to the signal modulation at 2,5 Gb/s and higher rates.

Figures A.1 and A.2 show the calculated spectra of an intensity modulated laser for 10 Gb/s and 2,5 Gb/s line rates respectively. The modulation is an NRZ PRBS with a word length of $2^7$-1. Optical and electrical filtering values are indicated in Table A.1. For reference, a typical OSA filter characteristic for a 0,1-nm RBW is also shown.

Because a portion of the signal power is not captured by the OSA, an error in the measured signal power occurs. Figures A.3 and A.4 show the magnitude of the error for 10 Gb/s and 2,5 Gb/s data rates respectively.

**Table A.1 – Filtering used in simulation to determine signal power level error**

| Modulation rate | 10 Gb/s | 2,5 Gb/s |
|---|---|---|
| Electrical filter bandwidth | 30 GHz | 7,5 GHz |
| Optical filter bandwidth | 0,64 nm | 0,36 nm |

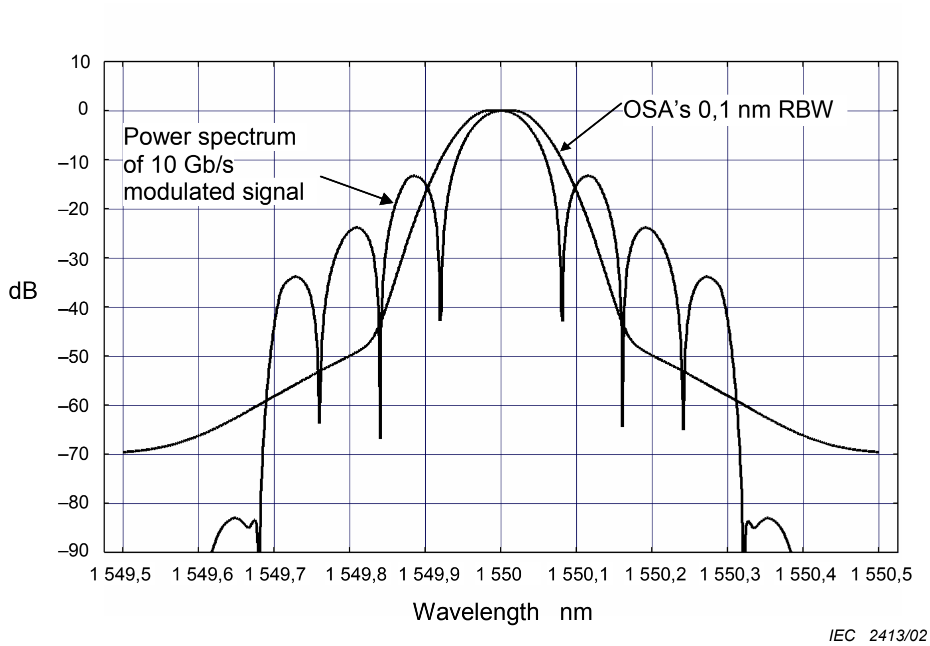


**Figure A.1 – Power spectrum of a 10 Gb/s, $2^7$ – 1 PRBS signal showing the considerable amount of power not captured in a 0,1 nm RBW with 0,64 nm filtering after the signal**

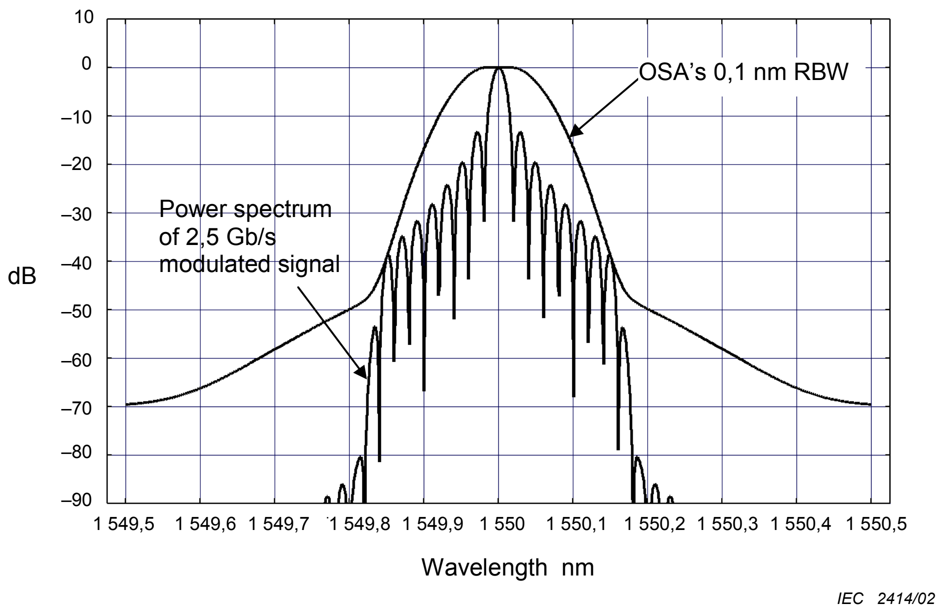


**Figure A.2 – Spectrum of a 2,5 Gb/s $2^7$ – 1 PRBS with 0,36 nm filtering with considerably less power outside the 0,1 nm OSA RBW**

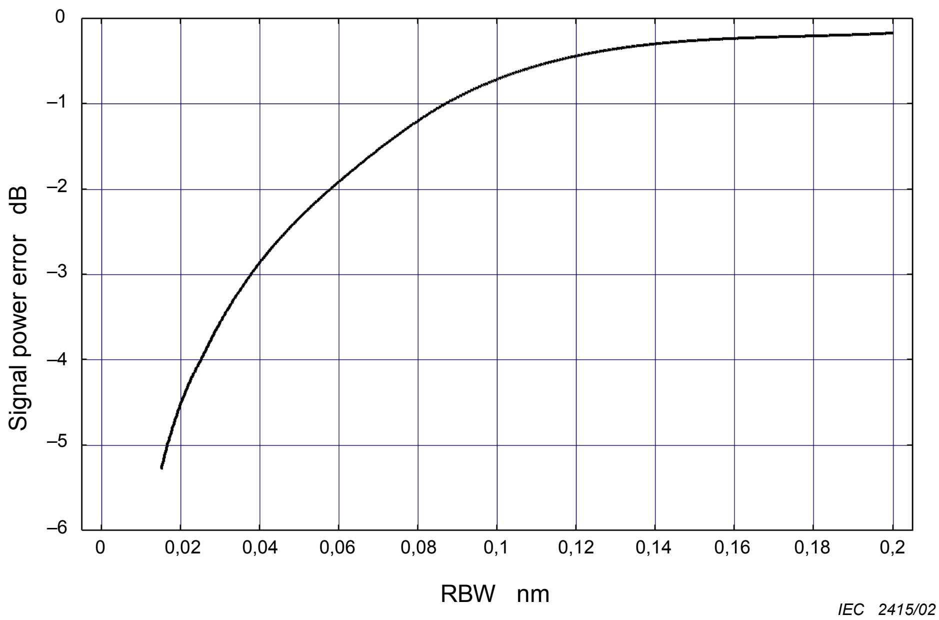


**Figure A.3 – Signal power error versus RBW for a 10 Gb/s modulated signal**

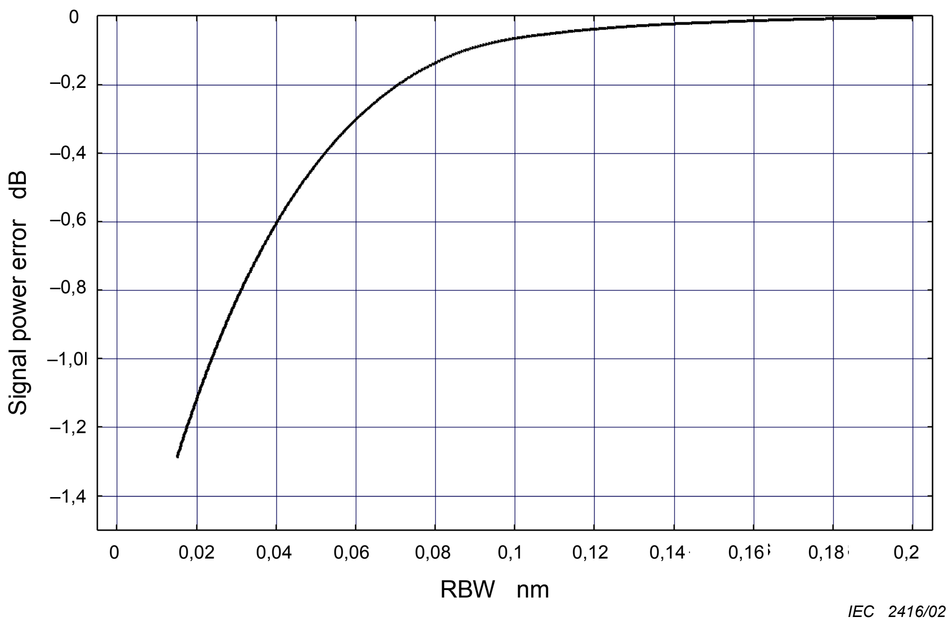


**Figure A.4 – Signal power error versus RBW for a 2,5 Gb/s modulated signal**

To minimize the error in the signal power measurement, a resolution bandwidth of sufficient width should be chosen. Table A.2 shows the RBW values that cause less than 0,1 dB error.

**Table A.2 – RBW to achieve less than 0,1 dB error in signal power**

| Modulation rate | 10 Gb/s | 2,5 Gb/s or lower |
|---|---|---|
| RBW | ≥0,2 nm | ≥0,09 nm |

# Annex B
(informative)

# Error in measuring noise level due to signal spectral width and wavelength filtering

The same signal spectral width discussed in Annex A can also influence the uncertainty of measuring the noise level. When significant power from the signals is present at the mid-point between the channels, then the OSA is unable to distinguish this from the noise power levels using measurements between the channels. This limitation becomes significant when combining higher modulation rates with close channel spacing, like 40 Gb/s signals on a 100 GHz grid. In this case, the noise must be measured with 0,4 nm of the signal, where the signal strength can be comparable to that at 0,1 nm from the 10 GHz signal, as discussed in 4.5.4. The optical filtering from multiplexing would however reduce this, similar to the signal shown in Figure A.1. The degree of this filtering will generally determine whether this OSNR method can measure such signals to the necessary uncertainty.

A second influence of advanced optical networks is the effect of using optical add-drop multiplexers (OADM) and other components that have strong wavelength dependence. Especially the use of reconfigurable OADMs (ROADM) results in channels being separated, and then recombining channels that have been transmitted along different spans. Especially the demultiplexing and “remultiplexing” of channels generally reduces the power level between channels. When this happens, the reduced part of the spectrum cannot be used to estimate the noise level at the signal wavelength. Other complications can also arise, such as adjacent channels originating from different spans with differing contributions to OSNR, so that measuring the noise power between the channels cannot be used for interpolation.

An example for this in Figure B.1 shows four amplified channels with 200 GHz spacing passed through a multiplexer that has the displayed combined loss curve. The resulting modified spectrum at the output shows how the noise between the channels has been filtered and can no longer be interpolated to provide the noise level at the signal wavelength. In this case, the unmodulated signals are narrower than the passbands, so by using sufficient resolution, noise plateaus are revealed that are not significantly filtered. When this can be done, OSNR measurements are possible by reducing the offset of the interpolation to measure the noise on these plateaus. However when narrower channels are used together with high modulation rates, good OSNR values will not be measurable.

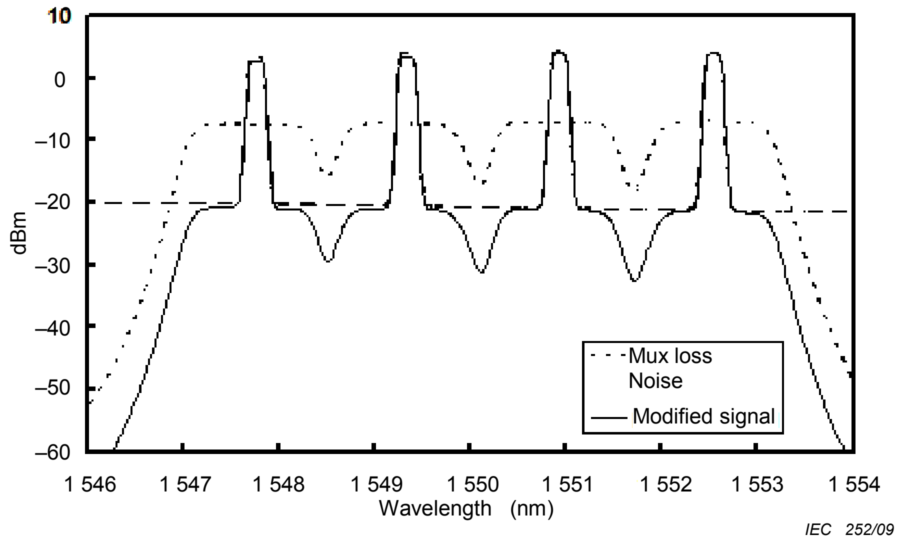


**Figure B.1 – Example for noise filtering between channels for a 200 GHz grid**

The effects discussed in this annex can result in the method of this standard being inappropriate, independent of the instrumentation used. More complex methods such as the use of polarization extinction may then be considered for obtaining OSNR. However, when the time and equipment required to measure the OSNR of multiple channels is higher, the advantage of using spectral OSNR evaluation with respect to channel characterizations like RIN and eye diagrams may be reduced.

# Bibliography

[1] ITU-T Recommendation G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers*

[2] ITU-T Recommendation G.697 (2004), *Optical monitoring for DWDM systems*

[3] ITU-T Supplement 39 to G-series Recommendations (2006): *Optical system design and engineering considerations.*

[4] ITU-T Recommendation G.694.1, *Spectral grids for WDM applications: DWDM frequency Grid*

[5] ISO/IEC MISC UNCERT: 1995, *Guide to the expression of uncertainty in measurement*

*This page deliberately left blank*

*This page deliberately left blank*

# British Standards Institution (BSI)

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level.

It is incorporated by Royal Charter.

## Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover.

**Tel: +44 (0)20 8996 9000  Fax: +44 (0)20 8996 7400**

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

## Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to BSI Customer Services.

**Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001**
**Email: orders@bsigroup.com**

You may also buy directly using a debit/credit card from the BSI Shop on the website **www.bsigroup.com/shop**

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

## Information on standards

BSI provides a wide range of information on national, European and international standards through its Library.

Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre.

**Tel: +44 (0)20 8996 7111**
**Fax: +44 (0)20 8996 7048  Email: info@bsigroup.com**

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.

**Tel: +44 (0)20 8996 7002  Fax: +44 (0)20 8996 7001**
**Email: membership@bsigroup.com**

Information regarding online access to British Standards via British Standards Online can be found at **www.bsigroup.com/BSOL**

Further information about BSI is available on the BSI website at **www.bsigroup.com**

## Copyright



**BSI Group Headquarters**

389 Chiswick High Road London W4 4AL UK

Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards

*raising standards worldwide™*

British Standards