BS EN 61290-3-3:2014

BSI Standards Publication

# Optical amplifiers — Test methods

## Part 3-3: Noise figure parameters — Signal power to total ASE power ratio

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## National foreword

This British Standard is the UK implementation of EN 61290-3-3:2014. It is identical to IEC 61290-3-3:2013.

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.

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

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# EN 61290-3-3

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English version

## Optical amplifiers - Test methods - Part 3-3: Noise figure parameters - Signal power to total ASE power ratio

(IEC 61290-3-3:2013)

Amplificateurs optiques -
Méthodes d'essais -
Partie 3-3: Paramètres du facteur de bruit -
Rapport puissance du signal sur puissance totale d'ESA
(CEI 61290-3-3:2013)

Lichtwellenleiter-Verstärker –
Prüfverfahren -
Teil 3-3: Rauschzahlparameter -
Verhältnis der Signalleistung zur Gesamt-ASE-Leistung
(IEC 61290-3-3:2013)

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

**CEN-CENELEC Management Centre: Avenue Marnix 17, B - 1000 Brussels**



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## Foreword

The text of document 86C/1121/CDV, future edition 1 of IEC 61290-3-3, 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 approved by CENELEC as EN 61290-3-3:2014.

The following dates are fixed:

| | | |
|---|---|---|
| • latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2014-09-12 |
| • latest date by which the national standards conflicting with the document have to be withdrawn | (dow) | 2016-12-12 |

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

## Endorsement notice

The text of the International Standard IEC 61290-3-3:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

| | |
|---|---|
| IEC 61290-3-1 | NOTE Harmonized as EN 61290-3-1. |
| IEC 61290-3-2 | NOTE Harmonized as EN 61290-3-2. |

# Annex ZA
(normative)

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

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.

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 | - | Optical amplifiers - Test methods - Part 3: Noise figure parameters | EN 61290-3 | - |
| IEC 61291-1 | 2012 | Optical amplifiers - Part 1: Generic specification | EN 61291-1 | 2012 |

CONTENTS

# OPTICAL AMPLIFIERS – TEST METHODS –

## Part 3-3: Noise figure parameters – Signal power to total ASE power ratio

## 1 Scope and object

This part of IEC 61290-3 applies to all commercially available single channel optical amplifiers (OAs), including OAs using optically pumped fibres (OFAs) based on either rare-earth doped fibres or on the Raman effect, semiconductor optical amplifier modules (SOA modules) and planar optical waveguide amplifiers (POWAs). More specifically, it applies to single channel OAs placed before optical receivers, where there are no optical bandpass filtering elements placed between the OA and the receiver.

The object of this part of IEC 61290-3 is to establish uniform requirements for accurate and reliable measurement of the ratio of the signal output power to the total ASE power generated by the OA in the optical bandwidth of the receiver. This quantity is a measure of the spontaneous-spontaneous beat noise at the receiver, and is correlated to the spontaneous-spontaneous noise factor of the OA, $F_{sp\text{-}sp}$, as defined in IEC 61290-3 and IEC 61291-1.

IEC 61290-3-1 describes a measurement method, using an optical spectrum analyzer, OSA, for the signal-spontaneous noise factor $F_{sig-sp}$ but does not describe a method for measuring $F_{sp\text{-}sp}$. IEC 61290-3-2 describes a measurement method, using an electrical spectrum analyzer (ESA), for the total noise factor $F_{sp\text{-}sp} + F_{sig\text{-}sp}$. However, this method does not allow $F_{sp\text{-}sp}$ to be measured separately, and therefore does not provide a means of directly quantifying the effect of spontaneous-spontaneous beat noise at the receiver. This part of IEC 61290-3 complements IEC 61290-3-1 and IEC 61290-3-2 in that it provides such a means.

Two measurement methods are provided for the ratio of the signal output power to the total ASE power. The first method uses an OSA, while the second method uses a bandpass filter and an optical power meter.

## 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 61290-3, *Optical amplifiers – Test methods – Part 3: Noise figure parameters*

IEC 61291-1:2012, *Optical fibre amplifiers – Part 1: Generic specification*

## 3 Terms, definitions and abbreviations

### 3.1 Terms and definitions

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

**3.1.1**
**signal input power**
$P_{in}$
power of the optical signal at the input to the OA

**3.1.2**
**signal output power**
$P_{out}$
power of the optical signal at the output of the OA

**3.1.3**
**signal wavelength**
$\lambda_{s}$
wavelength of the signal optical carrier

[SOURCE: IEC 61291-1:2012, definition 3.2.2.1.1]

**3.1.4**
**signal gain**
$G$
gain of the OA at the signal wavelength, defined as the ratio of the output signal power to the input signal power

**3.1.5**
**amplified spontaneous emission band**
ASE band
$B_{ASE}$
wavelength band that contains at least 99 % of the total ASE power generated by OA

**3.1.6**
**ASE centre wavelength**
$\lambda_{C}$
centre wavelength of the ASE band

**3.1.7**
**ASE power**
$P_{ASE}$
ASE power generated by the OA within the ASE band

**3.1.8**
**signal to total ASE power ratio**
*Sig_ASE*
ratio of the output signal power to the total ASE power within $B_{ASE}$

**3.1.9**
**spontaneous–spontaneous noise factor**
$F_{sp-sp}$
ratio of the electrical SNR due to spontaneous-spontaneous beat noise at the OA output to the electrical SNR due to shot noise at the OA input

Note 1 to entry: See also IEC 61290-3 for a detailed formula for of $F_{sp-sp}$.

## 3.2 Abbreviations

APD avalanche photo diode

AFF ASE flattening filter

ASE amplified spontaneous emission

| | |
|---|---|
| CD | chromatic dispersion |
| DFB | distributed feedback |
| EDFA | erbium-doped fibre amplifier |
| ESA | electrical spectrum analyzer |
| FWHM | full width half maximum |
| NF | noise figure |
| OA | optical amplifier |
| OFA | optical fibre amplifier |
| OSA | optical spectrum analyzer |
| PDG | polarization dependent gain |
| PMD | polarization mode dispersion |
| POWA | planar optical waveguide amplifier |
| RBW | resolution band width |
| SNR | signal to noise ratio |
| SOA | semiconductor optical amplifier |
| VOA | variable optical attenuator |
| WDM | wavelength division multiplexing |

## 4 Background

In recent years, high-speed transmission links beyond 10 Gb/s have been commercially introduced. These links (as well as some high-end 10-Gb/s links, such as submarine links) require high sensitivity receivers, e.g. avalanche photo diode (APD) receivers, which operate in a limited input optical power dynamic range. In addition, specialized optical components such as chromatic dispersion (CD) compensators and polarization mode dispersion (PMD) compensators may be placed on the receiver module, thus introducing considerable optical insertion loss.

In multi-channel wavelength division multiplexed (WDM) links a multi-channel OA is often placed at the end of the link before the WDM signal is demultiplexed into individual channels. The total output power of the multi-channel OA is typically such that the optical power per channel is in the range of 0 dBm to 5 dBm. This power is then attenuated by the demultiplexer, and further attenuated by the specialized optical components mentioned above. Thus, the optical power reaching the receiver may be below the required input optical power dynamic range. In this case, a single channel OA may be placed on the receiver module to boost the optical power reaching the receiver.

In such a situation, there is typically no optical bandpass filter between the single channel OA and the receiver, so that all the amplified spontaneous emission (ASE) noise generated by the amplifier reaches the receiver. This can result in a significant level of spontaneous-spontaneous beat noise at the receiver. One way to characterize this noise is through the spontaneous-spontaneous noise factor, $F_{\text{sp-sp}}$, as defined in IEC 61290-3 and IEC 61291-1. Another way to characterize the spontaneous-spontaneous beat noise is through the signal to total ASE power ratio, $Sig\_ASE$, at the OA output, given by the following:

$$Sig\_ASE = \frac{P_{\text{out}}}{P_{\text{ASE}}} \tag{1}$$

where $P_{\text{out}}$ is the signal output power of the OA, and $P_{\text{ASE}}$ is the ASE power generated by the OA within the ASE band, given by

$$P_{\mathrm{ASE}} = \int_{B_{\mathrm{ASE}}} \rho_{\mathrm{ASE}}(\lambda) d\lambda \quad (2)$$

where $B_{\mathrm{ASE}}$ is the ASE band of the OA defined as a wavelength band that contains at least 99 % of the total ASE power generated by OA.

Care should be taken to define $B_{\mathrm{ASE}}$ such that it excludes other sources of noise not related to ASE. In particular, $B_{\mathrm{ASE}}$ should exclude possible pump leakage power exiting the OA output port. For example, for a C-band EDFA pumped by a 1 480 nm pump, $B_{\mathrm{ASE}}$ should not include wavelengths below 1 500 nm. This guarantees that $B_{\mathrm{ASE}}$ includes at least 99 % of the ASE generated within the EDFA on the one hand, while excluding possible 1 480 nm pump leakage power on the other.

NOTE 1 In many OAs, and especially in OFAs, the ASE is polarization independent. In some OAs, such as some types of SOA modules, the ASE may be polarization dependent. $P_{\mathrm{ASE}}$ refers to the total power in both polarization directions.

While there is no direct relation between $Sig\_ASE$ and $F_{\text{sp-sp}}$, it is clear that there is a correlation between them, and that both quantities can be used to quantify the effect of spontaneous-spontaneous beat noise at the receiver. The higher is $Sig\_ASE$, the lower is the spontaneous-spontaneous beat noise (and the lower $F_{\text{sp-sp}}$), and vice-versa.

In this standard, a measurement method for $Sig\_ASE$ is presented. Annex A provides a brief technical discussion of the various OA parameters that can affect and determine the $Sig\_ASE$ value.

NOTE 2 All quantities in this standard are in linear units, unless specifically defined otherwise.

## 5 Apparatus

### 5.1 Measurement using an OSA

This subclause describes the apparatus used for measuring $Sig\_ASE$ using an OSA. Figure 1 shows the test set-up used for OSA calibration, as well as for measuring the signal input power and the source spontaneous emission power. Figure 2 shows the test set-up used to measure the signal output power and the ASE power.

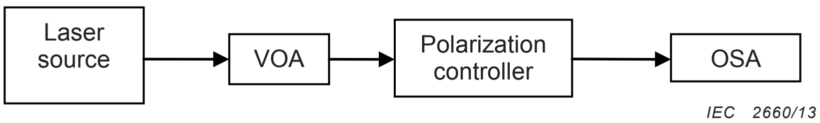



**Figure 1 – Test set-up for OSA calibration and for measuring signal input power and source spontaneous emission power**

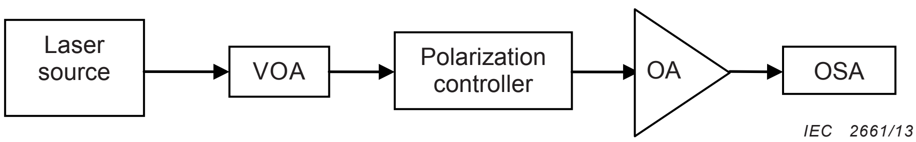



**Figure 2 – Test set-up for measuring signal output power and ASE power using an OSA**

The test equipment listed below, with the required characteristics, is needed.

a) A laser source with the following characteristics:
   1) Either a tuneable laser or a set of discrete lasers able to support the range of signal wavelengths for which the OA under test is to be tested.
   2) An achievable output power such that the input signal power to the OA under test is above the maximum specified input signal power.
   3) A single line output with a side mode suppression ratio of at least 40 dB.
   4) A FWHM linewidth <0,01 nm.
   5) Output power stability <0,05 dB.
b) VOA – A variable optical attenuator (VOA) with a dynamic range sufficient to support the required range of input signal power levels at which the OA under test is to be tested. The reflectance from each port of the device should be <–50 dB.

   NOTE 1 If the output power of the laser source can be varied over the required dynamic range, then the VOA may not be needed.
c) Polarization controller – a device capable of transforming any input polarization state to any output polarization state. The reflectance from each port of the device should be <–50dB.

   NOTE 2 If the polarization dependent gain (PDG) of the an OFA or POWA is <0,3 dB, the polarization controller may not be needed.
d) OSA – the OSA shall have the following characteristics:
   1) Polarization sensitivity less than 0,1dB.
   2) Power stability better than 0,1dB.
   3) Wavelength accuracy better than 0,05 nm.
   4) The resolution bandwidth (RBW) of the OSA should be set to a value in the range of 0,2 nm to 1 nm, preferably 0,5 nm.
   5) Reflectance from the input port of the OSA should be <–50 dB.

### 5.2 Measurement using a bandpass filter and an optical power meter

This subclause describes the apparatus used for measuring *Sig_ASE* using a filter and an optical power meter. Figure 3 shows the test set-up used for the filter insertion loss calibration, as well as for measuring the signal input power. Figure 4 shows the test set-up used to measure the signal output power and the ASE power. This measurement method does not allow for the measurement of the laser source spontaneous emission, thus requiring a laser source with low enough spontaneous emission so as not to affect the *Sig_ASE* measurement (see laser source requirements below).

In cases where the OA may emit power outside of $B_{\mathrm{ASE}}$ (for example, pump leakage in the case of an amplifier employing 1 480 nm pumps), then a filter should be placed before the optical power meter to filter out such unwanted components. Such a filter should have an insertion loss ripple of <0,5 dB over $B_{\mathrm{ASE}}$, and should have an extinction ratio of at least 30 dB (relative to the insertion loss within $B_{\mathrm{ASE}}$) for the unwanted wavelength components. This filter should be placed before the optical power meter in Figure 3 and Figure 4.

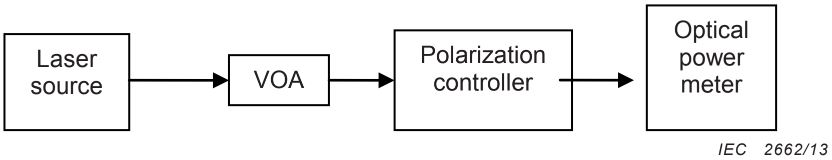



**Figure 3a – Test set-up without bandpass filter**

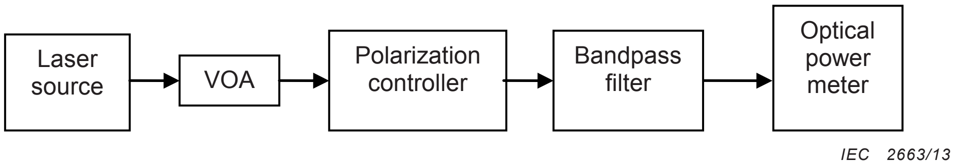



**Figure 3b – Test set-up with bandpass filter**

**Figure 3 – Test set-ups for filter calibration and measuring the signal input power**

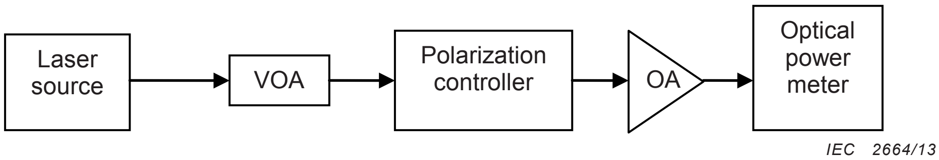



**Figure 4a – Test set-up without bandpass filter**

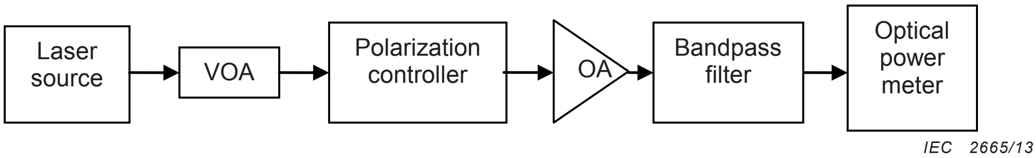



**Figure 4b – Test set-up with bandpass filter**

**Figure 4 – Test set-ups for measuring output signal power and ASE power using a filter and an optical power meter**

The test equipment listed below, with the required characteristics, is needed.

a) A laser source with the following characteristics:
   1) Either a tuneable laser or a set of discrete lasers able to support the range of signal wavelengths for which the OA under test is to be tested.
   2) An achievable output power such that the input signal power to the OA under test is above the maximum specified input signal power.
   3) A single line output with a side mode suppression ratio of at least 40 dB.
   4) A total spontaneous emission power within $B_{\mathrm{ASE}}$ which is at least $X+20$ dB less than the laser output power, where $X$ is the lowest specified $Sig\_ASE$ ratio of the OA.
   5) A FWHM linewidth <0,01 nm.
   6) Output power stability <0,05 dB.
b) VOA – A variable optical attenuator (VOA) with a dynamic range sufficient to support the required range of input signal power levels at which the OA under test is to be tested. The reflectance from each port of the device should be <–50 dB.

NOTE 2 If the output power of the laser source can be varied over the required dynamic range, then the VOA may not be needed.

c) Polarization controller – a device capable of transforming any input polarization state to any output polarization state. The reflectance from each port of the device should be <–50 dB.

NOTE 3 If the polarization dependent gain (PDG) of an OFA or POWA is <0,3 dB, the polarization controller may not be needed.

d) A bandpass filter with the following characteristics:
   1) Either a tuneable filter or a set of discrete filters with centre wavelengths corresponding to the range of signal wavelengths for which the OA under test is to be tested.
   2) 1–dB passband of at least ±20 GHz around the centre wavelength
   3) At least 20 dB attenuation level below the centre wavelength insertion loss for all wavelengths within $B_{ASE}$ except a range of ±100 GHz centred around the centre wavelength.

e) Optical power meter – should have a measurement accuracy of better than ±0,2 dB, irrespective of the signal polarization state.

## 6 Test sample

The OA shall be tested at nominal operating conditions. If the OA is likely to cause laser oscillations due to unwanted reflections, optical isolators should be used to bracket the OA under test. This will minimize the signal instability and the measurement inaccuracy.

Care shall be taken in maintaining the state of polarization of the input signal during the measurement. Changes in the polarization state of the input signal may result in input optical power changes because of the slight polarization dependency expected from all the used optical components, leading to measurement errors.

## 7 Procedure

### 7.1 General

The measurement procedure includes the measurement of the following parameters:

- output signal power – $P_{out}$
- ASE power – $P_{ASE}$

In order to measure $P_{ASE}$, it may be necessary to measure the source spontaneous emission power, $P_{SSE}$ of the laser source, as well as the OA gain, $G$. $P_{ASE}$ is then determined by subtracting $GP_{SSE}$ from the total measured noise power at the OA output. The measurement of $P_{SSE}$ need not be carried out if care is taken to ensure that it is small enough so as not to affect the measurement of $Sig\_ASE$ (see 5.2, a) 4).

### 7.2 Measurement using an OSA

This subclause describes the procedure used for measuring $Sig\_ASE$ using an OSA.

#### 7.2.1 Calibration

##### 7.2.1.1 Calibration of optical bandwidth of the OSA

The optical bandwidth $B_{OSA}$ of the OSA should be accurately calibrated for the RBW at which the measurement is to be performed. This is needed in order to measure the optical power density at each wavelength, and thus the integrated optical power within any desired wavelength band.

NOTE 1 Some OSAs include an automatic function for measuring the integrated optical power in any desired wavelength band. In such cases, it is not necessary to perform this calibration.

To calibrate the optical bandwidth of the OSA, perform the following steps:

a) Connect the test set-up as shown in Figure 1.
b) Set the wavelength of the laser source to $\lambda_c$, the centre of the ASE band.
c) Set the OSA centre wavelength to $\lambda_c$.
d) Set the OSA span to zero.
e) Measure the optical power $P(\lambda_c)$.
f) Set the laser source to a series of wavelengths $\lambda_i$ to cover the wavelength range [$\lambda_c$ – 5 $RBW$, $\lambda_c$ + 5 $RBW$], where the interval $\Delta\lambda_i$ between wavelengths should be smaller than $RBW$ /5. At each wavelength, measure the optical power, $P(\lambda_i)$.
g) Determine the optical bandwidth of the OSA according to the following formula:

$$B_{\mathrm{OSA}} = \frac{1}{P(\lambda_{\mathrm{C}})} \sum_{\mathrm{i}} P(\lambda_{\mathrm{i}}) \Delta\lambda_{\mathrm{i}} \tag{3}$$

#### 7.2.1.2 Calibration of OSA power calibration factor

Follow the steps listed below to calibrate the OSA power calibration factor, $P_{\mathrm{Cal}}$. This factor calibrates the OSA for absolute power.

NOTE 2 If the OSA has already been calibrated for absolute power, this calibration step is not required.

a) Connect the test set-up as shown in Figure 1.
b) Set the wavelength of the laser source to $\lambda_c$, the centre of the ASE band.
c) Set the OSA centre wavelength to $\lambda_c$.
d) Measure the optical power at $\lambda_c$, $P_{\mathrm{OSA}}$.
e) Disconnect the OSA, and connect instead a calibrated power meter.
f) Measure the optical power $P_{\mathrm{PM}}$.
g) Determine the OSA power calibration factor according to the following formula:

$$P_{\mathrm{Cal}} = P_{\mathrm{PM}}/P_{\mathrm{OSA}} \tag{4}$$

### 7.2.2 Measurement

Follow the steps listed below to perform the measurement:

a) Connect the test set-up as shown in Figure 1.
b) Set the wavelength of the laser source to the required signal wavelength, $\lambda_s$.
c) Set the VOA such that the signal input power is at the required level.
d) Set the span of the OSA to cover the ASE band.
e) Measure the OSA power at the signal wavelength, $P(\lambda_s)$, and determine the signal input power as $P_{\mathrm{in}} = P(\lambda_s) \times P_{\mathrm{Cal}}$.
f) Measure the optical power at all wavelengths $\lambda_i$ in the ASE band with a resolution of at least $RBW$/5. For each wavelength calculate the optical power density as $\rho(\lambda_i) = P(\lambda_i)/B_{\mathrm{OSA}}$.
g) Measure the total optical power in the ASE band according to the following formula:

$$P_{\mathrm{Tot}} = \sum_{\mathrm{i}} \rho(\lambda_{\mathrm{i}}) \Delta\lambda_{\mathrm{i}} \tag{5}$$

h) Determine the source spontaneous emission power as $P_{\mathrm{SSE}} = P_{\mathrm{Tot}} \times P_{\mathrm{Cal}} - P_{\mathrm{In}}$.

i) Connect the test set-up as shown in Figure 2.

j) Operate the OA at the required operating conditions.

k) Measure the OSA power at the signal wavelength, $P(\lambda_s)$, and determine the signal output power as $P_{out} = P(\lambda_s) \times P_{Cal}$.

l) Determine the signal gain as $G = P_{out}/P_{in}$.

m) Measure the optical power at all wavelengths $\lambda_i$ in the ASE band with a resolution of at least $RBW/5$. For each wavelength calculate the optical power density as $\rho(\lambda_i) = P(\lambda_i)/B_{OSA}$.

n) Measure the total optical power in the ASE band according to the following formula:

$$P_{Tot} = \sum_i \rho(\lambda_i)\Delta\lambda_i \quad (6)$$

o) Determine the ASE power as

$$P_{ASE} = P_{Cal}P_{Tot} - P_{out} - GP_{SSE} \quad (7)$$

NOTE 1 Some OSA may contain an internal integration function that automatically calculates the integrated optical power in a given wavelength band. In this case, steps f), g), m) and n) may be performed using this automatic function.

NOTE 2 The use of the signal gain $G$ to calculate the amplified source spontaneous emission at the OA output may not be totally accurate, since the amplifier gain may be wavelength dependent. However, there are two factors in favour of using this approximation: 1) When an OA is designed to minimize $Sig\_ASE$, the gain is typically quite flat within the wavelength band that contributes the most to $P_{ASE}$; 2) When $Sig\_ASE$ is at its worst, this usually means that $G$ is smaller than the gain at most points within the wavelength band that contributes the most to $P_{ASE}$. Thus, the amplified source spontaneous emission is slightly under-estimated, and $P_{ASE}$ slightly over estimated. This means that the worst measured $Sig\_ASE$ can be viewed as a lower limit to the real $Sig\_ASE$ over all operating conditions of the OA.

### 7.3 Measurement using a bandpass filter and an optical power meter

#### 7.3.1 General

This subclause describes the procedure used for measuring $Sig\_ASE$ using a bandpass filter and an optic power meter.

#### 7.3.2 Calibration

Follow the procedure listed below to calibrate the bandpass filter insertion loss:

a) Connect the test set-up as shown in Figure 3a.

b) Set the wavelength of the laser source to the required signal wavelength, $\lambda_s$.

c) Measure the optical power without the bandpass filter, $P_0$, using the optical power meter.

d) Insert the bandpass filter as shown in Figure 3b, with the centre wavelength of the filter equal to $\lambda_s$.

e) Measure the optical power with the bandpass filter, $P_1$, using the optical power meter.

f) Determine the filter insertion loss at the signal wavelength as

$$IL_F(\lambda_S) = P_1 / P_0 \quad (8)$$

#### 7.3.3 Measurement

Follow the steps listed below to perform the measurement:

a) Connect the test set-up as shown in Figure 3(a).

b) Set the wavelength of the laser source to the required signal wavelength, $\lambda_s$.

c) Set the VOA such that the signal input power is at the required level.

d) Measure the signal input power $P_{in}$ using the optical power meter.

e) Insert the OA as shown in Figure 4a.

f) Operate the OA at the required operating conditions

g) Measure the total OA output power, $P_{Tot}$, using the optical power meter.

h) Insert the bandpass filter as shown in Figure 4b, with the centre wavelength of the filter equal to $\lambda_s$.

i) Measure the optical power with the bandpass filter, $P_2$, using the optical power meter.

j) Determine the signal output power as $P_{out} = P_2/IL_F(\lambda_s)$.

k) Determine the ASE power as $P_{ASE} = P_{Tot} - P_{out}$.

## 8 Calculations

*Sig_ASE* may be calculated from Formula (3) using $P_{out}$ and $P_{ASE}$. Note that as with all values and calculations presented in this standard, the values are calculated in linear units. They may be transferred to dB as required.

## 9 Test results

*Sig_ASE* shall be measured for all combinations of signal wavelengths, signal input power levels and OA signal gain levels so as to cover the OA operating range sufficiently, as set in the OA specifications. If the PDG of the OA is above 0,3 dB, then at each operating point a polarization controller should be set to obtain the lowest value of *Sig_ASE*.

At a minimum, the worst case result for *Sig_ASE* shall be provided, along with the signal wavelength, input power level, and OA gain level at which this result was measured.

# Annex A
(informative)

## Signal power to total ASE power ratio – Dependence on signal input power, wavelength and output power

Most OAs are designed to minimize the noise figure (NF), which is related to the ASE in the vicinity of the signal wavelength. However, when designing a single channel OA to be placed on a receiver module, it is desirable to increase the signal power to total ASE power ratio (*Sig_ASE*) as much as possible in order to improve the receiver performance. This means that the total ASE of the OA should be minimized, and not just the ASE in the vicinity of the signal channel. This annex provides a brief technical discussion of the various OA parameters that can affect and determine *Sig_ASE*.

The main parameter that affects *Sig_ASE* is the signal input power. In a typical application, the OA is designed to operate in automatic power control (APC) mode to provide constant signal output power to the receiver. This means that the gain of the amplifier depends on the signal input power. The higher the signal input power, the lower the required gain in order to achieve the desired operating signal output power. Since the ASE power is approximately proportional to the gain, this means that for a given signal output power, *Sig_ASE* will be increased approximately proportionally with the signal input power. At high signal input power (low gain), the ASE ceases to be proportional to the signal input power, and instead is determined by the signal output power. Thus, at high signal input power the *Sig_ASE* increases at a slower rate. An example of the dependence of *Sig_ASE* on signal input power is shown in Figure A.1

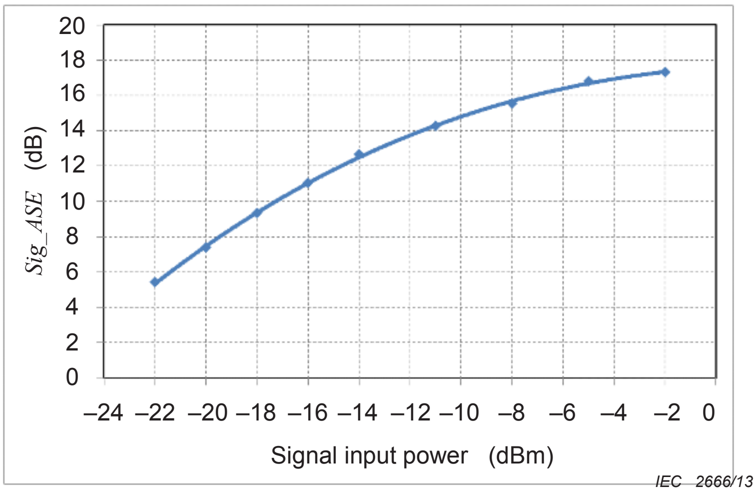
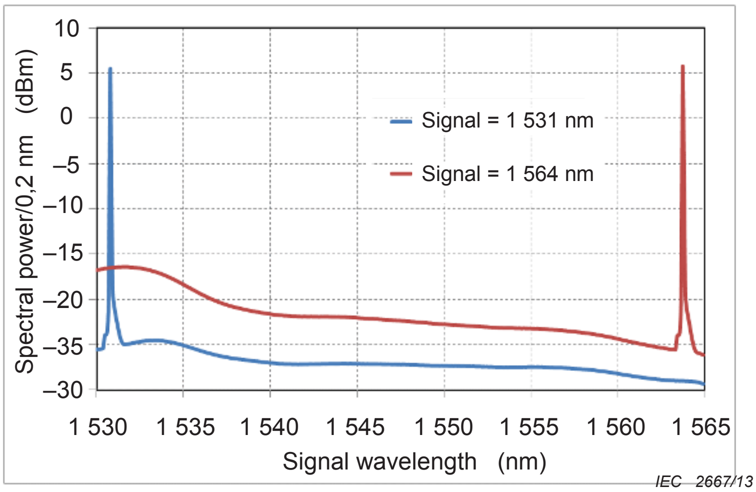



**Figure A.1 – The dependence of *Sig_ASE* on signal input power**

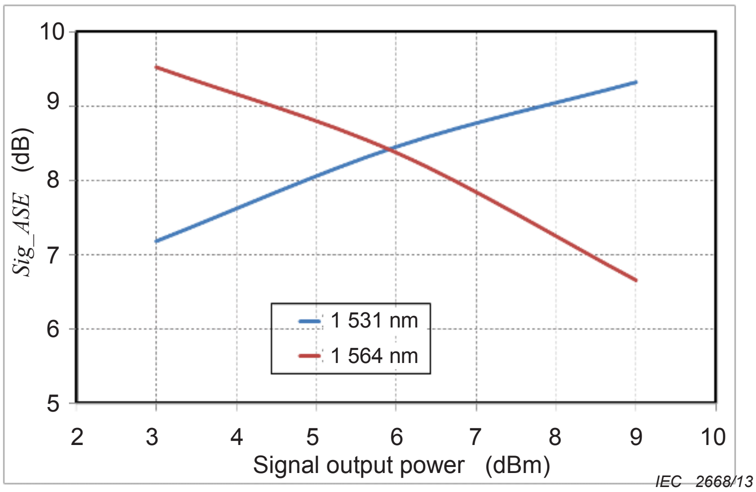
If the single channel OA is specified to operate over a wavelength band, and not just at a specific wavelength, then *Sig_ASE* can also depend on the signal wavelength. For a wider operating wavelength band, the ASE is likely to be less uniform over the band, and wavelength dependence of *Sig_ASE* will be stronger. This is illustrated in Figure A.2, which shows the ASE spectrum for two different signal wavelengths at opposite ends of the C-band. In both cases the signal input and output power are the same, however as can be clearly seen, the *Sig_ASE* ratio is significantly lower in the case of a 1 564 nm signal.




NOTE In both the cases the signal input and output powers are the same.

**Figure A.2 – The ASE spectrum for two different signal wavelengths**

In order to flatten *Sig_ASE* over the specified operating wavelength band, an ASE flattening filter (AFF) can be used. This filter is typically designed such that at the optimal operating signal input and output power, in other words at the optimal signal gain, the *Sig_ASE* is substantially flat as a function of signal wavelength. However, when the operating conditions (signal input and/or output power) differ from the optimal values, then the *Sig_ASE* becomes tilted. This effect is illustrated in Figure A.3, which shows *Sig_ASE* for a constant signal input power and varying output power for two different signal wavelengths at either end of the C-band. When the signal output power is higher than optimal, *Sig_ASE* at 1 531 nm increases, and *Sig_ASE* at 1 564 nm decreases. When the signal output power is lower than optimal, the opposite behaviour occurs.




NOTE A gain-flattening filter, GFF, is used to achieve flat *Sig_ASE* as a function of wavelength for the optimal signal output power (in this case 6 dBm).

**Figure A.3 – *Sig_ASE* as a function of output power for different signal wavelength**

# Bibliography

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

IEC 61290-3-2, *Optical amplifiers – Test methods – Part 3-2: Noise figure parameters – Electrical spectrum analyzer method*

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