

TECHNICAL REPORT

IEC TR 61292-2

First edition
2003-01

Optical amplifier technical reports –

**Part 2:
Theoretical background for noise figure evaluation
using the electrical spectrum analyzer**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OPTICAL AMPLIFIER TECHNICAL REPORTS –

**Part 2: Theoretical background for noise figure evaluation
using the electrical spectrum analyzer**

FOREWORD

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IEC 61292-2, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

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

Enquiry draft	Report on voting
86C/418/DTR	86C/474/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

This Technical Report should be read in conjunction with IEC 61290-3-2. To enhance the clarity of this document, some of the text in document 61290-3-2 is repeated here. Definitions of many terms and parameters contained in this Technical Report can be found in IEC 61291-1.

Each abbreviation introduced in this Technical Report is generally explained in the text the first time it appears. However, for an easier understanding of the whole text, a list of the abbreviations used in this Technical Report is given in Annex A.

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OPTICAL AMPLIFIER TECHNICAL REPORTS –

Part 2: Theoretical background for noise figure evaluation using the electrical spectrum analyzer

1 Scope and object

This Technical Report applies to all commercially available optical amplifiers (Oas) including optical fibre amplifiers (OFAs) using active fibres and semiconductor optical amplifiers (SOAs) using semiconductor gain media.

The object of this Technical Report is to provide the theoretical background to Clause 6 (Calculation) of IEC 61290-3-2.

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: *Optical fibre amplifiers – Basic specification – Test methods for noise figure parameters*

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IEC 61290-3-2: *Optical fibre amplifier test methods – Part 3-2: Noise figure parameters – Electrical spectrum analyzer method* IEC TR 61292-2:2003

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

3 Theoretical background of calibration

The calibration setup is shown in Figure 1.

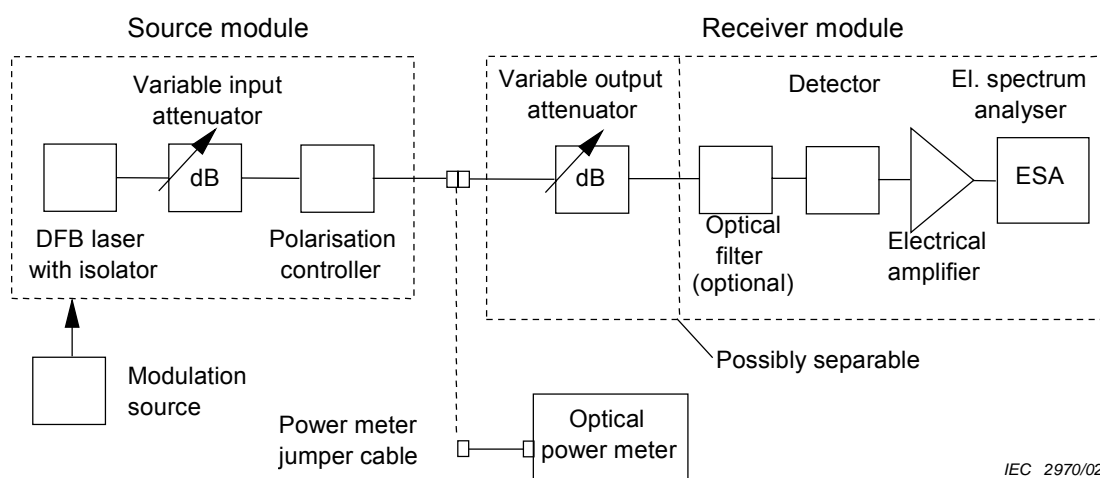


Figure 1 – Noise figure calibration setup

The following quantities are obtained during the calibration process; notice that all noise measurement results are to be understood as ESA power levels after subtraction of the thermal noise level:

$P_{in,0}$ is optical input power at 0 dB setting of input attenuator.

S_0 is electrical power of the modulation signal at 0 dB setting of input attenuator.

N_0 is noise power measured with ESA with input and output attenuator at 0 dB.

N_0' is noise power measured with ESA with input attenuator set to $1/k$ ($k > 1$) and output attenuator set to 0 dB.

N_0 can be expressed as:

$$N_0 = N_{rin,0} + N_{shot,0} \text{ [W]} \quad (1)$$

$N_{rin,0}$ is (frequency-dependent) ESA noise contribution caused by the laser's relative intensity noise (RIN);

$N_{shot,0}$ is (frequency-independent) ESA noise contribution caused by the photodetector's shot noise.

N_0' , obtained after k -fold reduction of the input power, can be expressed as:

$$N_0' = k^2 N_{rin,0} + k N_{shot,0} \quad (2)$$

For subtraction purposes, re-write equation (2) in two different forms:

$$\frac{1}{k^2} N_0' = N_{rin,0} + \frac{1}{k} N_{shot,0} \quad (3)$$

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$$\frac{1}{k} N_0' = k N_{rin,0} + N_{shot,0} \quad (4)$$

Subtraction (3) – (1) yields the shot noise contribution to the ESA noise power:

$$N_{shot,0} \left(\frac{1}{k} - 1 \right) = \frac{1}{k^2} N_0' - N_0$$

$$N_{shot,0} = \frac{N_0' - k^2 N_0}{k(1 - k)} \quad (5)$$

Subtraction (1) – (4) also yields the contribution from the source's RIN to the ESA noise power:

$$N_{rin,0} (1 - k) = N_0 - \frac{1}{k} N_0'$$

$$N_{rin,0} = \frac{k N_0 - N_0'}{k(1 - k)} \quad (6)$$

3.1 Calculation for photocurrent measurement alternative

The effective photodetector responsivity (which includes the loss of the output attenuator at 0 dB attenuation) can be calculated from:

$$r_0 = \frac{I_{pd,0}}{P_{in,0}}$$

Calculate the shot- and RIN contributions using:

$$N_{shot,0} = 2er_0 P_{in,0} RT_x^2 B_e = \frac{2e}{r_0} H_0 P_{in,0} B_e \quad (7)$$

$$S_0 = H_0 m^2 P_{in,0}^2 \quad (8)$$

in which m is the ratio of RMS optical power modulation amplitude to average optical power, and the following was used as receiver transfer function:

$$H_0 = \frac{S_{esa}}{\Delta P_{in}^2} = r_0^2 T_x^2 R \quad (9)$$

where

r_0 is effective photodetector responsivity in A/W through output attenuator at 0 dB setting; this quantity may depend on the baseband frequency, and

T_x is voltage amplification between resistor R and ESA input; this quantity usually depends on the baseband frequency.

Dividing the two equations yields:

$$\frac{N_{shot,0}}{S_0} = \frac{2e}{r_0} \frac{H_0 P_{in,0} B_e}{H_0 m^2 P_{in,0}^2} = \frac{2e}{r_0} \frac{B_e}{m^2 P_{in,0}} \quad (10)$$

$$N_{shot,0} = \frac{2e}{r_0} \frac{B_e S_0}{m^2 P_{in,0}} \quad (11)$$

3.2 Calculation of source RIN

The following derivation can be used to estimate the laser RIN:

$$N_{rin,0} = H_0 B_e P_{in,0}^2 RIN_{source} \quad (12)$$

$$N_{shot,0} = 2er_0 P_{in,0} RT_x^2 B_e = \frac{2e}{r_0} H_0 P_{in,0} B_e \quad (13)$$