

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.661

(07/2007)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

Transmission media and optical systems characteristics –
Characteristics of optical components and subsystems

Definitions and test methods for the relevant generic parameters of optical amplifier devices and subsystems

ITU-T Recommendation G.661



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ITU-T Recommendation G.661

Definitions and test methods for the relevant generic parameters of optical amplifier devices and subsystems

Summary

ITU-T Recommendation G.661 provides the definitions of the relevant parameters, common to the different types of optical amplifiers and the test methods of said parameters to be followed, as far as applicable, for optical amplifier devices and subsystems covered by ITU-T Recommendations.

Source

ITU-T Recommendation G.661 was approved on 29 July 2007 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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ITU-T Recommendation G.661

Definitions and test methods for the relevant generic parameters of optical amplifier devices and subsystems

1 Scope

This Recommendation applies to all commercially available optical amplifiers (OAs), optically amplified subsystems and optical network elements (ONEs) containing OAs. It applies to OAs using optically pumped fibres (OFAs based either on rare-earth doped fibres or on the Raman effect), semiconductors (SOAs) and waveguides (POWAs).

This Recommendation provides the definitions of the relevant parameters, common to the different types of OAs, listed in clause 5, and the test methods of said parameters described in clause 6, to be followed, as far as applicable, for OA devices and subsystems covered by ITU-T Recommendations. Parameter definitions applicable specifically to distributed Raman amplifiers, however, can be found in [ITU-T G.665].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.662] ITU-T Recommendation G.662 (2005), *Generic characteristics of optical amplifier devices and subsystems*.

[ITU-T G.663] ITU-T Recommendation G.663 (2000), *Application related aspects of optical amplifier devices and subsystems*.

[ITU-T G.665] ITU-T Recommendation G.665 (2005), *Generic characteristics of Raman amplifiers and Raman amplified subsystems*.

[ITU-T G.680] ITU-T Recommendation G.680 (2007), *Physical transfer functions of optical network elements*.

[IEC 61290] IEC 61290 (all parts), *Basic specification for optical amplifier test methods*.

[IEC 61291-1] IEC 61291-1 (2006), *Optical amplifiers – Part 1: Generic specification*.

Parameters specified for OAs are those characterizing the transmission, operation, reliability and environmental properties of the OA seen as a "black box" from a general point of view. In [ITU-T G.662], a subset of these parameters is specified according to the type and application of the particular OA device or subsystem.

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ASE	Amplified Spontaneous Emission
BER	Bit Error Ratio
Bsp-sp	Spontaneous-spontaneous optical bandwidth

DGD	Differential Group Delay
DOP	Degree of Polarization
EDFA	Erbium-Doped (silica-based) Fibre Amplifier
F	noise Factor
FIT	Failures In Time
FWHM	Full-Width Half-Maximum
MPI	Multi-Path Interference
MTBF	Mean Time Between Failures
NF	Noise Figure
OA	Optical Amplifier
OAR	Optically Amplified Receiver
OAT	Optically Amplified Transmitter
OFA	Optical Fibre Amplifier
ONE	Optical Network Element
OSA	Optical Spectrum Analyser
PDG	Polarization Dependent Gain
PDL	Polarization Dependent Loss
PMD	Polarization Mode Dispersion
POWA	Planar Optical Waveguide Amplifier
PSP	Principal State of Polarization
SNR	Signal-to-Noise Ratio
SOA	Semiconductor Optical Amplifier
SOP	State Of Polarization
TM	Test Method

4 Classification

Different OA application categories are defined depending on the technology used and the utilization of the OA itself. Classification of optical amplifier technologies is also given in IEC/TR 61292-3.

These categories are identified by a capital letter, a number and a lower case letter, as follows:

Capital letter

- A OFAs using silica-based fibres doped with erbium ions to produce an active fibre
- B OFAs using other doped active fibres
- C Raman amplifiers
- D SOA
- E POWA

Number

- 1 Power amplifiers (post-amplifiers or booster amplifiers)
- 2 Pre-amplifiers
- 3 Line amplifiers
- 4 Optically amplified transmitter (OAT)
- 5 Optically amplified receiver (OAR)
- 6 Distributed amplifiers
- 7 Composite distributed and discrete amplifiers

Lower case letter

- a Amplifiers for analogue, single (wavelength) channel transmission
- b Amplifiers for digital, single (wavelength) channel transmission
- c Amplifiers for digital, multichannel (wavelength) transmission

EXAMPLE – Category A2b refers to optical pre-amplifiers for single-channel digital transmission which use a silica-based fibre doped with Erbium ions.

The *power amplifier* is a high saturation-power OA device to be used directly after the optical transmitter to increase its signal power level.

The *pre-amplifier* is a very low noise OA device to be used directly before an optical receiver to improve its sensitivity.

The *line amplifier* is a low noise OA device to be used between passive fibre sections to increase the distance covered before regeneration is necessary or in correspondence with a point-multipoint connection to compensate for branching losses in the optical access network.

The OAT is an OA subsystem in which a power amplifier is integrated with an optical transmitter, resulting in a higher power transmitter.

The OAR is an OA subsystem in which a pre-amplifier is integrated with an optical receiver, resulting in a higher sensitivity receiver.

The *distributed amplifier* is a device configuration that provides amplification over an extended length of the optical fibre used for transmission, as by Raman pumping, and is thus distributed over part or all of the transmission span.

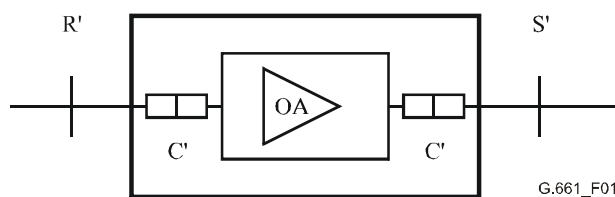
The *composite distributed and discrete amplifiers* are defined in [ITU-T G.665].

5 Definitions

The list of parameter definitions of OAs, given in the following part of this clause, is divided into two parts: the first part lists those parameters relevant for OA devices, namely power, pre-, line-, distributed amplifiers and ONEs containing OAs; the second part lists the parameters relevant for optically amplified, elementary subsystems, namely the optically amplified transmitter (OAT) and the optically amplified receiver (OAR).

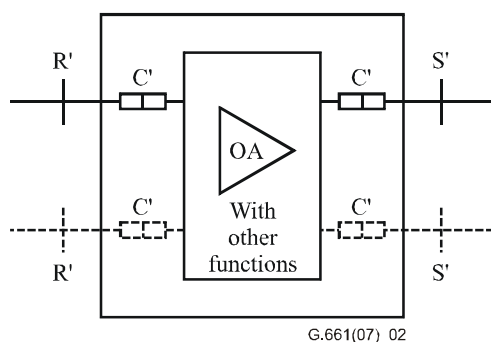
Where the value of a parameter is given for a particular device, it will be necessary to specify certain appropriate operating conditions such as temperature, bias current, pump optical power, etc. In this clause, two different operating conditions are referred to: *nominal operating conditions*, which are those suggested by the manufacturer for normal use of the OA, and *limiting operating conditions*, in which all the parameters adjustable by the user (e.g., temperature, gain, pump laser injection current, etc.) are at their maximum values, according to the *absolute maximum ratings* stated by the manufacturer.

The OA is considered as a "black box", as shown in Figure 1. The OA device has two optical ports, namely an input and an output port. The ONE, as shown in Figure 2, contains one or more OAs, which can be located at the input as well as at the output. The location and number of OAs depends on their function in the ONE. Some ONE examples are described in [ITU-T G.680]. Each ONE has, at a minimum, one input and one output. The ONE is considered as a "black box". The OAT and OAR are considered as an OA integrated with a transmitter or a receiver, respectively. Both kinds of integration imply that the connection between the transmitter or the receiver and the OA is proprietary and not to be specified. Consequently, only the optical output port can be defined for the OAT (after the OA, as shown in Figure 3) and only the optical input port can be defined for the OAR (before the OA, as shown in Figure 4). The optical ports may consist of unterminated fibres or optical connectors. Electrical connections for power supply (not shown in Figures 1 to 4) are also necessary. Following this "black box" approach, the loss of both pairs of connectors directly associated with the device (labelled C or C' in Figures 1 to 4) and the corresponding uncertainty will be included within the values of gain, noise figure and other parameters of the OA device.



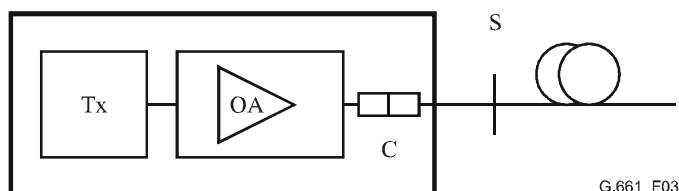
S' Reference point in the optical fibre just after the optical connection (C') of the OA device.
R' Reference point in the optical fibre just before the optical connection (C') of the OA device.

Figure 1 – OA device reference diagram



S' Reference point in the optical fibre just after the optical connection (C') of the ONE device.
R' Reference point in the optical fibre just before the optical connection (C') of the ONE device.

Figure 2 – ONE device reference diagram



S Reference point in the optical fibre just after the optical connection (C) of the OAT.

Figure 3 – OAT reference diagram