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OF ITU

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TRANSMISSION MEDIA CHARACTERISTICS

**GENERIC CHARACTERISTICS OF OPTICAL
FIBRE AMPLIFIER DEVICES
AND SUB-SYSTEMS**

ITU-T Recommendation G.662

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(Previously "CCITT Recommendation")

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FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation G.662 was prepared by ITU-T Study Group 15 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 10th of July 1995.

NOTE

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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CONTENTS

	<i>Page</i>
1 Scope	1
2 References	1
3 Terms and definitions	1
3.1 Power wavelength band (for BA only)	1
3.2 Available signal wavelength band (for PA with optical filter(s) only)	1
3.3 Tuneable wavelength range (for PA and OAR with tuneable optical filter(s) only).....	1
3.4 Output signal-to-noise ratio (for OAT only)	2
3.5 Signal linewidth (for OAT only).....	2
4 Abbreviations	2
5 Classification of OFA devices	2
6 Classification of OFA sub-systems	4
7 Characteristics of BAs	5
8 Characteristics of PAs	5
9 Characteristics of LAs	5
10 Characteristics of OATs	6
11 Characteristics of OARs	6

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SUMMARY

This Recommendation intends to provide those generic characteristics needed for the specification of Optical Fibre Amplifiers as devices and sub-systems, primarily for applications in digital transmission. The maximum compatibility with Recommendations on line systems and equipments is pursued.

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Recommendation G.662

GENERIC CHARACTERISTICS OF OPTICAL FIBRE AMPLIFIER DEVICES AND SUB-SYSTEMS

(Geneva, 1995)

1 Scope

This Recommendation applies to Optical Fibre Amplifier (OFA) devices and sub-systems.

The object of this Recommendation is to identify those generic characteristics specifiable for the use of OFA devices (as power amplifiers, pre-amplifiers or line amplifiers) and OFA sub-systems (as optically amplified transmitters or optically amplified receivers), primarily for applications in digital transmission, ensuring the maximum compatibility with Recommendations on line systems and equipments (Recommendations G.955, G.957 and G.958).

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; all 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.

- ITU-T Recommendation. G.661 (1993), *Definition and test methods for the relevant generic parameters of optical fibre amplifiers.*
- ITU-T Recommendation. G.955 (1993), *Digital line systems based on the 1544 kbit/s and the 2048 kbit/s hierarchy on optical fibre cables.*
- ITU-T Recommendation. G.957 (1995), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*
- ITU-T Recommendation. G.958 (1994), *Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables.*

3 Terms and definitions

The definitions of the generic parameters of this Recommendation, concerning the OFA aspects of both OFA devices and sub-systems, are given in Recommendation G.661. The definitions of most of the relevant parameters of OATs and OARs are shared with those of conventional transmitters and receivers, and are given in Recommendation G.957. The definitions of some additional parameters are given in the following.

NOTE – Further definitions may be needed in the future according to the evolution of OFA applications, e.g. in the fields of analogue and multi-wavelength transmission.

3.1 power wavelength band (for BA only): The wavelength range within which the OFA output signal power is maintained in the specified output power range, when OFA input signal power is within the specified input power range.

3.2 available signal wavelength band (for PA with optical filter(s) only) The resulting OFA wavelength band including the effect of the optical filter(s).

3.3 tuneable wavelength range (for PA and OAR with tuneable optical filter(s) only): The wavelength range within which the tuneable optical filter(s) inside the OFA can be tuned.

Superseded by a more recent version

3.4 Output signal-to-noise ratio (for OAT only)

Under study.

3.5 Signal linewidth (for OAT only)

Under study.

4 Abbreviations

For the purposes of this Recommendation, the following abbreviations are used:

ASE	Amplified Spontaneous Emission
BA	Booster (power) Amplifier
LA	Line Amplifier
NF	Noise Figure
OAM	Operation Administration and Maintenance
OAR	Optically Amplified Receiver
OAT	Optically Amplified Transmitter
OFA	Optical Fibre Amplifier
ORL	Optical Return Loss
PA	Pre-Amplifier
PDG	Polarization-Dependent Gain
PDH	Plesiochronous Digital Hierarchy
PMD	Polarization Mode Dispersion
Rx	(optical) Receiver
SDH	Synchronous Digital Hierarchy
Tx	(optical) Transmitter

5 Classification of OFA devices

OFA devices covered by the present Recommendation can be divided in the following three categories.

- The *Power (Booster) Amplifier (BA)* is a high saturation-power OFA device to be used directly after the optical transmitter to increase its signal power level.
- The *Pre-Amplifier (PA)* is a very low noise OFA device to be used directly before an optical receiver to improve its sensitivity.
- The *Line Amplifier (LA)* is a low noise OFA device to be used between passive fibre sections to increase the regeneration lengths or in correspondence of a point-multipoint connection to compensate for branching losses in the optical access network.

NOTES

1 The division of OFA devices in these three categories is broad; some further subdivision could be identified in each of these three categories, according to the particular application.

2 The OFA devices defined in these three categories may or may not include OAM functions, which, for BA and PA, may or may not be shared with the line terminals. Suitable modifications may be needed in the definitions of some relevant parameters of the OFA device of these three categories, if OAM functions are explicitly considered.

In the following, the characterization criterion of the OFA device is provided in a way to ensure, as far as possible, the compatibility with the existing Recommendations G.955 and G.957, for Plesiochronous Digital Hierarchy (PDH) and Synchronous Digital Hierarchy (SDH) line systems, respectively. However, some restrictions could be unavoidable: e.g. due to the gain bandwidth characteristics of the active fibres of OFA devices, line systems using OFA devices

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may face restrictions of operating wavelength region and/or wavelength range. In fact, OFA devices presently using Erbium-doped, silica-based fibres as active medium operate in the 1550 nm wavelength region only and in a wavelength range narrower than the ones defined in Recommendations G.955 and G.957.

According to this criterion, an OFA device (BA, PA or LA), inserted along an optical path, shall be considered a separate element placed between the reference points S and R defined in Recommendations G.955 and G.957 for line terminals and regenerators, as shown in the scheme of Figure 1. With reference to this figure, the input and output characteristics of the OFA device shall be specified at reference points R' and S', before and after the OFA device, respectively. It is understood that, since the OFA device is not a regenerator or a terminal equipment, these are fictitious R and S points.

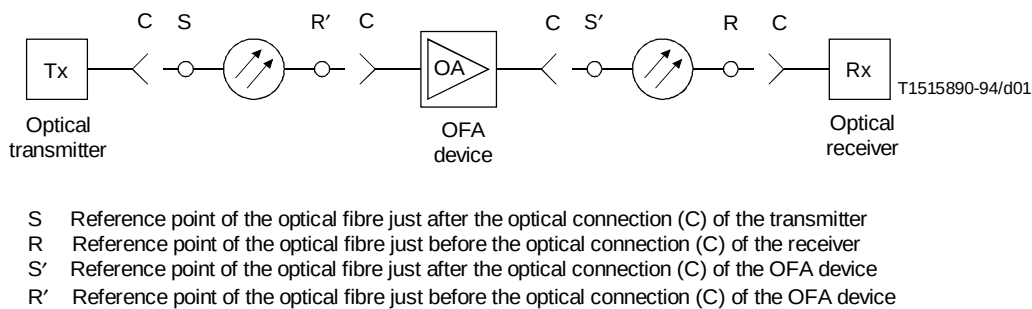


FIGURE 1/G.662

Scheme of insertion of an OFA device

A PA may include an optical filter, e.g. to minimize the contribution of OFA device noise to the total noise at the output of the optical receiver, or to separate signals in some multi-wavelength applications. Such a filter can be tuneable, manually or automatically, to the signal wavelength and, in systems with multiple signals at different wavelengths, filtering may be needed around each wavelength.

According to the definitions of BA, PA and LA, and with reference to Figure 1, the possible configurations of OFA device applications can be schematized as follows (here LA can represent one single line amplifier or two or more cascaded line amplifiers):

- a) Tx + BA + Rx;
- b) Tx + PA + Rx;
- c) Tx + LA + Rx;
- d) Tx + BA + PA + Rx;
- e) Tx + BA + LA + Rx;
- f) Tx + LA + PA + Rx;
- g) Tx + BA + LA + PA + Rx.

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6 Classification of OFA sub-systems

OFA sub-systems covered by this Recommendation can be divided in the following two categories.

- The *Optically Amplified Transmitter (OAT)* is an OFA sub-system in which a power amplifier is integrated with the laser transmitter, resulting in a high power transmitter.
- The *Optically Amplified Receiver (OAR)* is an OFA sub-system in which a pre-amplifier is integrated with the optical receiver, resulting in high sensitivity receiver.

Both kinds of integration imply that the connection between the transmitter or the receiver and the OFA is proprietary and shall not be specified. Consequently a reference point S only can be defined for the specification of the OAT output characteristics after the OFA, as shown in Figure 2, and a reference point R only can be defined for the specification of the OAR input characteristics before the OFA, as shown in Figure 3.

As the PA, also the OAR may include an optical filter which can be tuneable, manually or automatically, to the signal wavelength.

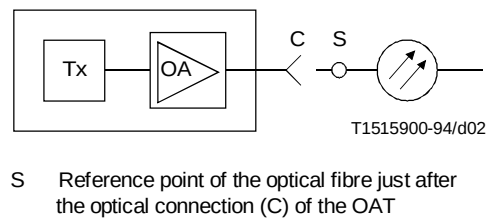


FIGURE 2/G.662

Scheme of insertion of an OAT

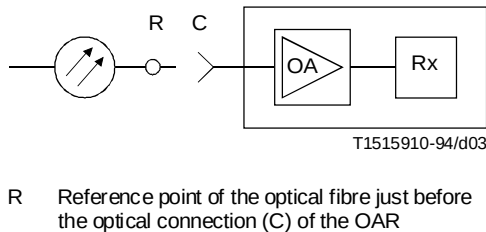


FIGURE 3/G.662

Scheme of insertion of an OAR

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7 Characteristics of BAs

The following minimum list of relevant parameters for the specification of an OFA device used as power amplifier, is given:

- a) input power range;
- b) output power range;
- c) power wavelength band;
- d) Noise Figure (NF);
- e) Polarization-Dependent Gain (PDG);
- f) reverse Amplified Spontaneous Emission (ASE) power level;
- g) input Optical Return Loss (ORL);
- h) pump leakage to input;
- i) pump leakage to output;
- j) maximum ORL tolerable at input;
- k) maximum ORL tolerable at output;
- l) maximum total output power;
- m) small-signal gain.

8 Characteristics of PAs

The following minimum list of relevant parameters for the specification of an OFA device used as pre-amplifier, is given:

- a) input power range;
- b) output power range;
- c) wavelength band;
- d) available signal wavelength band;
- e) tuneable wavelength range;
- f) NF;
- g) PDG;
- h) forward ASE power level;
- i) input ORL;
- j) pump leakage to input;
- k) pump leakage to output;
- l) maximum ORL tolerable at input;
- m) maximum ORL tolerable at output;
- n) maximum total output power;
- o) small-signal gain;
- p) reverse ASE power level (under study).

9 Characteristics of LAs

The following minimum list of relevant parameters for the specification of an OFA device used as line amplifier, is given:

- a) input power range;
- b) output power range;
- c) saturation output power;
- d) wavelength band;

Superseded by a more recent version

- e) NF;
- f) PDG;
- g) forward ASE power level;
- h) reverse ASE power level;
- i) input ORL;
- j) output ORL;
- k) pump leakage to input;
- l) pump leakage to output;
- m) maximum ORL tolerable at input;
- n) maximum ORL tolerable at output;
- o) maximum total output power;
- p) small-signal gain;
- q) Polarization Mode Dispersion (PMD).

10 Characteristics of OATs

The following minimum list of relevant parameters for the specification of an OAT, is given:

- a) bit rate;
- b) application code;
- c) operating signal wavelength range;
- d) maximum (signal) output power;
- e) minimum (signal) output power;
- f) signal linewidth;
- g) side mode suppression;
- h) extinction ratio;
- i) output signal-to-noise ratio;
- j) output ORL;
- k) pump leakage to output;
- l) maximum ORL tolerable at output;
- m) maximum total output power.

11 Characteristics of OARs

The following minimum list of relevant parameters for the specification of an OAR, is given:

- a) bit rate;
- b) application code;
- c) operating signal wavelength range;
- d) sensitivity;
- e) overload;
- f) dispersion penalty due to optical path;
- g) tuneable wavelength range;
- h) input ORL;
- i) pump leakage to input;
- j) maximum ORL tolerable at input;
- k) reverse ASE power level (under study).