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

Transmission media characteristics – Characteristics of
optical components and subsystems

**Generic characteristics of optical amplifier
devices and subsystems**

ITU-T Recommendation G.662

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION G.662

GENERIC CHARACTERISTICS OF OPTICAL AMPLIFIER DEVICES AND SUBSYSTEMS

Summary

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

Source

ITU-T Recommendation G.662 was revised by ITU-T Study Group 15 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 13th of October 1998.

FOREWORD

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As of the date of approval of this Recommendation, the ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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Recommendation G.662

GENERIC CHARACTERISTICS OF OPTICAL AMPLIFIER DEVICES AND SUBSYSTEMS

(revised in 1998)

1 Scope

This Recommendation applies to Optical Amplifier (OA) devices and subsystems to be used in transmission networks. It covers both Optical Fibre Amplifiers (OFAs) and Semiconductor Optical Amplifiers (SOAs).

The object of this Recommendation is to identify those generic characteristics specifiable for the use of OA devices (as power amplifiers, pre-amplifiers or line amplifiers) and OA subsystems (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, G.958, G.692 and G.691 (when published)].

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 (1998), *Definition and test methods for the relevant generic parameters of optical amplifier devices and subsystems.*
- ITU-T Recommendation G.663 (1996), *Application related aspects of optical fibre amplifier devices and subsystems.*
- ITU-T Recommendation G.691¹, *Optical interfaces for single channel SDH systems with optical amplifiers, and STM-64 systems.*
- ITU-T Recommendation G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers.*
- ITU-T Recommendation G.955 (1996), *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.*

¹ Presently at the stage of draft.

3 Terms and definitions

The definitions of the generic parameters of this Recommendation, concerning both OA devices and subsystems, are given in Recommendation G.661. The definitions of most of the relevant parameters of Optically Amplified Transmitters (OATs) and Optically Amplified Receivers (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 OA applications, e.g. in the field of analogue transmission.

3.1 power wavelength band (applicable to power amplifiers only): The wavelength range within which the OA output signal power is maintained in the specified output power range, when OA input signal power is within the specified input power range.

3.2 available signal wavelength band [applicable to pre-amplifiers with optical filter(s) only]: The resulting OA wavelength band including the effect of the optical filter(s).

3.3 tuneable wavelength range [applicable to pre-amplifiers and to optically amplified receivers with tuneable optical filter(s) only]: The wavelength range within which the tuneable optical filter(s) inside the OA can be tuned.

3.4 output optical signal-to-noise ratio (applicable to optically amplified transmitters only): The ratio of the optical signal power to the optical noise power at the OAT output port, measured over a specified optical bandwidth.

3.5 signal linewidth (applicable to optically amplified transmitters only): The signal linewidth of the OAT is dominated by the transmitter laser linewidth, and the definition can be considered equal to that specified in Recommendation G.957 for the specified transmitter laser.

The following parameters from 3.6 to 3.16 are applicable to OAs for multichannel applications, and are defined in IEC 61291-4 (when published).

3.6 Channel gain

3.7 Multichannel gain variation (inter-channel gain difference)

3.8 Gain cross-saturation

3.9 Multichannel gain-change difference (inter-channel gain-change difference)

3.10 Multichannel gain tilt (inter-channel gain-change ratio)

3.11 Channel addition/removal (steady-state) gain response

3.12 Channel addition/removal transient gain response

3.13 Channel addition/removal transient response time constant

3.14 Channel noise figure

3.15 Channel signal-spontaneous noise figure

3.16 Channel allocation

4 Abbreviations

This Recommendation uses the following abbreviations:

ASE Amplified Spontaneous Emission

BA Booster (power) Amplifier

LA	Line Amplifier
NF	Noise Figure
OA	Optical Amplifier
OAM	Operation, Administration and Maintenance
OAR	Optically Amplified Receiver
OAT	Optically Amplified Transmitter
OFA	Optical Fibre Amplifier
PA	Pre-Amplifier
PDG	Polarization-Dependent Gain
PDH	Plesiochronous Digital Hierarchy
PMD	Polarization Mode Dispersion
Rx	(optical) Receiver
SDH	Synchronous Digital Hierarchy
SOA	Semiconductor Optical Amplifier
Tx	(optical) Transmitter

5 Classification of OA devices

OA devices covered by this Recommendation are stand-alone OAs in which both input and output ports are specified.

OA devices covered by this Recommendation can be divided in the following three categories:

- The *Booster power Amplifier (BA)* is a high saturation-power OA device to be used directly after the optical transmitter to increase its signal power level.
- The *Pre-Amplifier (PA)* is a very low noise OA device to be used directly before an optical receiver to improve its sensitivity.
- The *Line Amplifier (LA)* is a low noise OA 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.

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

NOTE 2 – The OA devices defined in these three categories may or may not include Operation, Administration and Maintenance (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 OA device of these three categories, if OAM functions are explicitly considered.

In the following, the characterization criterion of the OA device is provided in a way to ensure, as far as possible, the compatibility with Recommendations G.955 for Plesiochronous Digital Hierarchy (PDH) and G.957 for 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 OA device 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.

Future optical amplifiers (e.g. semiconductor optical amplifiers) or optical amplifiers based on active fibres other than Erbium-doped silica-based fibres are not intended to be excluded from this Recommendation.

According to this criterion, an OA 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 OA device shall be specified at reference points R' and S', before and after the OA device, respectively. It is understood that, since the OA device is not a regenerator or a terminal equipment, these are fictitious R and S points.

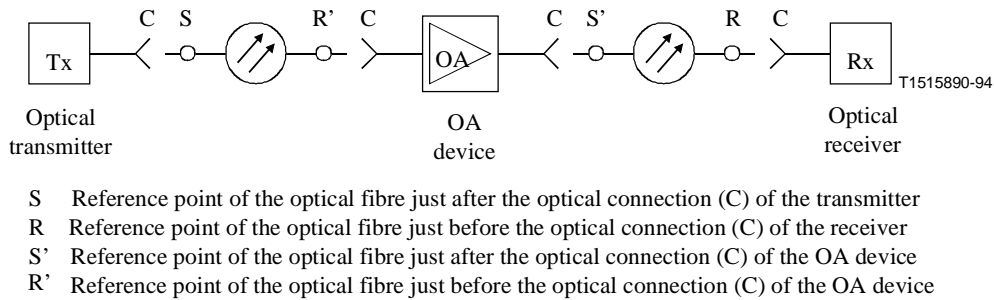


Figure 1/G.662 – Scheme of insertion of an OA device

A PA may include an optical filter, e.g. to minimize the contribution of OA device noise to the total noise at the output of the optical receiver, or to separate signals in some multiwavelength 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 OA 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.

6 Classification of OA subsystems

OA subsystems covered by this Recommendation are OAs integrated either with the optical transmitter or with the optical receiver, in which either the output or the input port, respectively, is specified only.

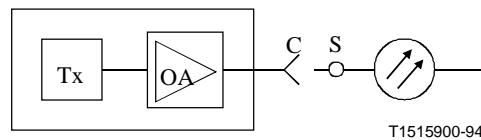
NOTE – Different OA subsystems can exist in which the OA is integrated with other optical functions (such as optical multiplexing, dispersion compensation, etc.). These OA subsystems are not intended to be excluded and could be considered in new dedicated Recommendations and/or in the existing ones as soon as they become sufficiently mature.

OA subsystems covered by this Recommendation can be divided in the following two categories:

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

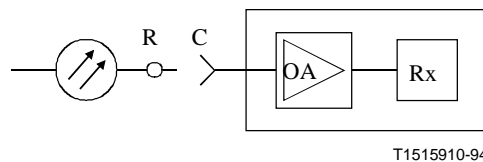
Both kinds of integration imply that the connection between the transmitter or the receiver and the OA is proprietary and shall not be specified. Consequently a reference point S only can be defined for the specification of the OAT output characteristics after the OA, as shown in Figure 2, and a reference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



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

Figure 2/G.662 – Scheme of insertion of an OAT



R Reference point of the optical fibre just before the optical connection (C) of the OAR

Figure 3/G.662 – Scheme of insertion of an OAR

7 Characteristics of power amplifiers

7.1 Single-channel applications

The following is the minimum list of relevant parameters for the specification of an OA device used as BA for single-channel applications:

- Input power range.
- Output power range.

- c) Power wavelength band.
- d) Signal-spontaneous noise figure.
- e) Input reflectance.
- f) Output reflectance.
- g) Pump leakage to input (applicable to OFAs only).
- h) Maximum reflectance tolerable at input.
- i) Maximum reflectance tolerable at output.
- j) Maximum total output power.

7.2 Multichannel applications

The following is the minimum list of relevant parameters for the specification of an OA device used as BA for multichannel applications:

- a) Channel allocation.
- b) Total input power range.
- c) Channel input power range.
- d) Channel output power range.
- e) Channel signal-spontaneous noise figure.
- f) Input reflectance.
- g) Output reflectance.
- h) Pump leakage to input (applicable to OFAs only).
- i) Maximum reflectance tolerable at input.
- j) Maximum reflectance tolerable at output.
- k) Maximum total output power.
- l) Channel addition/removal (steady-state) gain response.

8 Characteristics of pre-amplifiers

8.1 Single-channel applications

The following is the minimum list of relevant parameters for the specification of an OA device used as PA for single-channel applications:

- a) Input power range.
- b) Output power range.
- c) Small-signal gain wavelength band.
- d) Available signal wavelength band.
- e) Tuneable wavelength range.
- f) Signal-spontaneous noise figure.
- g) Input reflectance.
- h) Output reflectance.
- i) Pump leakage to output (applicable to OFAs only).
- j) Maximum reflectance tolerable at input.

- k) Maximum reflectance tolerable at output.
- l) Maximum total output power.
- m) Small-signal gain.

8.2 Multichannel applications

The following is the minimum list of relevant parameters for the specification of an OA device used as PA for multichannel applications:

- a) Channel allocation.
- b) Total input power range.
- c) Channel input power range.
- d) Channel output power range.
- e) Channel signal-spontaneous noise figure.
- f) Input reflectance.
- g) Output reflectance.
- h) Pump leakage to output (applicable to OFAs only).
- i) Maximum reflectance tolerable at input.
- j) Maximum reflectance tolerable at output.
- k) Maximum total output power.
- l) Channel addition/removal (steady-state) gain response.
- m) Channel gain.
- n) Multichannel gain variation (inter-channel gain difference).

9 Characteristics of line amplifiers

9.1 Single-channel applications

The following is the minimum list of relevant parameters for the specification of an OA device used as LA for single-channel applications:

- a) Input power range.
- b) Output power range.
- c) Saturation output power.
- d) Small-signal gain wavelength band.
- e) Signal-spontaneous noise figure.
- f) Input reflectance.
- g) Output reflectance.
- h) Maximum reflectance tolerable at input.
- i) Maximum reflectance tolerable at output.
- j) Maximum total output power.
- k) Small-signal gain.
- l) Polarization Mode Dispersion (PMD).

9.2 Multichannel applications

The following is the minimum list of relevant parameters for the specification of an OA device used as LA for multichannel applications:

- a) Channel allocation.
- b) Total input power range.
- c) Channel input power range.
- d) Channel output power range.
- e) Channel signal-spontaneous noise figure.
- f) Input reflectance.
- g) Output reflectance.
- h) Maximum reflectance tolerable at input.
- i) Maximum reflectance tolerable at output.
- j) Maximum total output power.
- k) Channel addition/removal (steady-state) gain response.
- l) Channel gain.
- m) Multichannel gain variation (inter-channel gain difference).
- n) Multichannel gain-change difference (inter-channel gain-change difference).
- o) Multichannel gain tilt (inter-channel gain-change ratio).
- p) Polarization Mode Dispersion (PMD).

10 Characteristics of optically amplified transmitters

10.1 Single-channel applications

The following is the minimum list of relevant parameters for the specification of an OA subsystem used as OAT for single-channel applications:

- a) Bit rate.
- b) Application code.
- c) Operating signal wavelength range.
- d) (Signal) output power range.
- e) Signal linewidth.
- f) Side mode suppression.
- g) Extinction ratio.
- h) Output optical signal-to-noise ratio.
- i) Output reflectance.
- j) Maximum reflectance tolerable at output.
- k) Maximum total output power.

10.2 Multichannel applications

The following is the minimum list of relevant parameters for the specification of an OA subsystem used as OAT for multichannel applications:

Under study.

11 Characteristics of optically amplified receivers

11.1 Single-channel applications

The following is the minimum list of relevant parameters for the specification of an OA subsystem used as OAR for single-channel applications:

- a) Bit rate.
- b) Application code.
- c) Operating signal wavelength range.
- d) Sensitivity.
- e) Overload.
- f) Dispersion penalty due to optical path.
- g) Tunable wavelength range.
- h) Input reflectance.
- j)i) Maximum reflectance tolerable at input.

11.2 Multichannel applications

The following is the minimum list of relevant parameters for the specification of an OA subsystem used as OAR for multichannel applications:

Under study.

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