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G.661

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SERIES G: TRANSMISSION SYSTEMS AND MEDIA

Transmission media characteristics – Characteristics of optical components and sub-systems

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Definition and test methods for the relevant generic parameters of optical fibre amplifiers

ITU-T Recommendation G.661

Superseded by a more recent version

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION G.661

DEFINITION AND TEST METHODS FOR THE RELEVANT GENERIC PARAMETERS OF OPTICAL FIBRE AMPLIFIERS

Summary

This Recommendation intends to provide the definitions of the relevant parameters common to the different types of optical fibre amplifiers and the test methods of said parameters to be followed, as far as applicable, for optical fibre amplifiers covered by ITU-T Recommendations.

Source

ITU-T Recommendation G.661 was revised by ITU-T Study Group 15 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 8th of November 1996.

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the 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.

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.

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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The ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. The ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, the ITU had/had not 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.661

DEFINITION AND TEST METHODS FOR THE RELEVANT GENERIC PARAMETERS OF OPTICAL FIBRE AMPLIFIERS

(revised in 1996)

The ITU-T,

considering

a) that Optical Fibre Amplifiers (OFAs) of different designs for different applications are going to be widely used in telecommunication networks;

b) that different Recommendations are being prepared concerning the generic characteristics and the system aspects of OFAs;

c) that the definition of the relevant parameters of these Recommendations, characterizing the transmission, operation, reliability and environmental properties of the OFA device seen as a "black box", are preliminarily needed;

d) that the test methods to verify said characteristics are preliminarily needed;

e) that further Recommendations concerning OFAs of different designs and applications could be prepared in the future, when practical use studies have sufficiently progressed, but referring substantially to the same definitions and test methods,

recommends

the definitions of the relevant parameters, common to the different types of OFAs, listed in the following clause 1, and the test methods of said parameters described in the following clause 2, to be followed, as far as applicable, for OFAs covered by ITU-T Recommendations.

1 Definitions

The **optical fibre amplifier (OFA)** is to be considered as a black box, as shown in Figure 1, with at least two optical ports and electrical connections for power supply. The optical ports are usually distinguished as input and output ports and may consist of unterminated fibres or optical connectors.

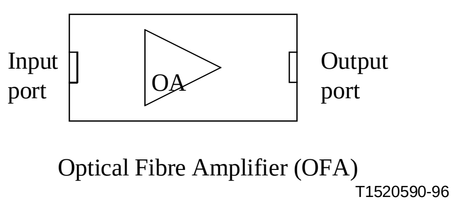

Figure 1/G.661 – The optical fibre amplifier

Hereafter, two different operating conditions will be usually referred to: nominal operating conditions, for a normal use of the OFA, and limit operating conditions, in which all the adjustable parameters (e.g. temperature, gain, pump laser injection current, etc.) are at their maximum values, according to the stated absolute maximum ratings.

NOTE 1 – If one of these parameters is specified for a particular device, it will be generally necessary to provide certain appropriate operating conditions such as temperature, bias current, pump power, etc.

NOTE 2 – The device amplifies signals in a nominal operating wavelength region. In addition, other signals out of the band of operating wavelength could, in some applications, also cross the device. The purpose of these out-of-band signals and their wavelength or wavelength region can be specified explicitly case by case. For OFAs described in the present Recommendation, the operating wavelength will be in the 1550 nm region.

NOTE 3 – All gains are measured as the dB ratio of the output signal over the input signal in a fibre pigtail. If connectors are used, then the signals are measured in fibre pigtails joined to connectors which are connected to the OFA ports. The measured input and output optical power levels refer to the signal only and discriminate against pump or spontaneous emission radiation.

NOTE 4 – There is a correspondence in the numbering of the parameters given in this clause and the corresponding test methods given in clause 2.

NOTE 5 – Except where noted, the optical powers mentioned in the following are intended as average powers.

NOTE 6 – Some additional definitions concerning specific types of OFAs (power, pre- and line-amplifiers) will be given in successive Recommendations.

NOTE 7 – This Recommendation has been prepared from experience with Erbium-doped, silica-based fibre amplifiers, operating in the 1550 nm wavelength region. Future OFAs, based on different active fibres and possibly operating in different wavelength regions, are not intended to be excluded from this Recommendation and may lead to additional definitions and test methods, as well as to modifications of the existing ones.

1.1 small-signal gain: The gain of the amplifier, when operated in linear regime, where it is quite independent of the input signal optical power, at a given signal wavelength and pump optical power level.

NOTE – This property can be described at a discrete wavelength or as a function of wavelength.

1.2 reverse small-signal gain: The small-signal gain measured using the input port as output port and vice versa.

1.3 maximum small-signal gain: The highest small-signal gain that can be achieved under nominal operating conditions.

1.4 maximum small-signal gain wavelength: The wavelength at which the maximum small-signal gain occurs.

1.5 maximum small-signal gain variation with temperature: The change in small-signal gain for temperature variation within a specified range.

1.6 (small-signal gain) wavelength bandwidth: The wavelength range within which the small-signal gain is less than N dB below the maximum small-signal gain.

NOTE – A value of N = 3 has been proposed.

1.7 small-signal gain wavelength variation: The peak-to-peak variation of the small-signal gain over a given wavelength range.

1.8 small-signal gain stability: The degree of small-signal gain fluctuation expressed by the ratio (in dB) of the maximum and minimum small-signal gain, for a certain specified test period, under nominal operating conditions.

1.9 large-signal output stability: The degree of output optical power fluctuation expressed by the ratio (in dB) of the maximum and minimum output signal optical powers, for a certain specified test period, under nominal operating conditions and a specified large input signal optical power.

1.10 polarization-dependent gain (PDG): The maximum variation of gain due to a variation of the state of polarization of the input signal at nominal operating conditions.

NOTE – A source of PDG in OFAs is the polarization dependent loss of the passive components used inside.

1.11 saturation output power (gain compression power): The optical output signal optical power above which the gain is reduced by 3 dB with respect to the small-signal gain at the signal wavelength.

NOTE – The wavelength at which the parameter is specified must be stated.

1.12 nominal output signal power: The minimum output signal optical power for a specified input signal optical power under nominal operating conditions.

1.13 noise figure (NF): The decrease of the Signal-to-Noise Ratio (SNR), at the output of an optical detector with unitary quantum efficiency, due to the propagation of a shot-noise-limited signal through the OFA, expressed in dB.

NOTE 1 – The operating conditions at which the noise figure is specified must be stated.

NOTE 2 – This property can be described at a discrete wavelength or as a function of wavelength.

NOTE 3 – The noise degradation due to the OFA is attributable to different contributions, e.g. signal-spontaneous beat noise, spontaneous-spontaneous beat noise, internal reflections noise, signal shot noise, spontaneous shot noise. Each of these contributions depends on various conditions which should be specified for a correct evaluation of the noise figure.

NOTE 4 – By convention, the noise figure is a positive number.

1.14 forward amplified spontaneous emission (ASE) power level: The optical power in a specified bandwidth associated to the ASE exiting from the output port under nominal operating conditions.

NOTE 1 – This parameter is particularly important for OFAs used as pre-amplifiers or in-line amplifiers and it depends mainly on the filter used.

NOTE 2 – The operating conditions (e.g. the gain and input signal optical power) at which the ASE level is specified must be stated.

1.15 reverse ASE power level: The optical power in a specified bandwidth associated to the ASE exiting from the input port under nominal operating conditions.

1.16 input optical return loss (ORL): The fraction of incident optical power at operating wavelength reflected by the input port of the OFA, under nominal operating conditions, expressed in dB.

1.17 output ORL: The fraction of incident optical power at operating wavelength reflected by the output port of the OFA, under nominal operating conditions, expressed in dB.

1.18 maximum ORL tolerable at input: The maximum reflection seen from the input port for which the device still meets its specifications.

NOTE – The measurement is performed with a given input signal optical power.

1.19 maximum ORL tolerable at output: The maximum reflection seen from the output port for which the device still meets its specifications.

NOTE – The measurement is performed with a given input signal optical power.

1.20 pump leakage to output: The pump optical power which is emitted from the OFA output port.

NOTE – The measurement is performed with a given input signal optical power.

1.21 pump leakage to input: The pump optical power which is emitted from the OFA input port.

NOTE – The measurement is performed with a given input signal optical power.

1.22 out-of-band insertion loss: OFA insertion loss for a signal at the specified out-of-band wavelength(s).

1.23 out-of-band reverse insertion loss: OFA insertion loss for a signal at the specified out-of-band wavelength(s), measured using the input port of the OFA as output port and vice versa.

1.24 maximum power consumption: Electrical power needed and absorbed by the OFA operating within the absolute maximum ratings.

1.25 maximum total output power: The highest optical power level at the output port of the OFA operating within the absolute maximum ratings.

1.26 operating temperature: The temperature range within which the OFA can be operated and still meets all its specified parameters values.

1.27 optical connections: The connector and/or the fibre type used as input and output ports of the OFA.

NOTE – Optical connections do not necessarily need to be specified.

1.28 input power range: Range of optical power levels such that, for any input signal power of the OFA which lies in this range, the corresponding output signal optical power shall lie in the specified output power range, where the OFA performance is ensured.

1.29 output power range: Range of optical power levels in which the output signal optical power of the OFA shall lie, when the corresponding input signal power lies in the input power range, where the OFA performance is ensured.

1.30 polarization hole burning (PHB)

Under study.

1.31 polarization mode dispersion (PMD): The maximum group delay difference between any polarization states on propagation through the OFA.

1.32 gain: In an OFA which is externally connected to an input jumper fibre, the increase of signal optical power from the output end of the jumper fibre to the OFA output port, expressed in dB.

NOTE 1 – The gain includes the connection loss between the input jumper fibre and the OFA input port.

NOTE 2 – It is assumed that the jumper fibres are of the same type as the fibres used as input and output port of the OFA.

NOTE 3 – Care should be taken to exclude the amplified spontaneous emission power from the signal optical powers.

1.33 noise factor (F): The noise figure expressed in linear form.

1.34 signal-spontaneous noise figure: The signal-spontaneous beat noise contribution to the noise figure.

1.35 (equivalent) spontaneous-spontaneous optical bandwidth (B_{sp-sp}): The equivalent optical bandwidth by which the square of the ASE spectral power density, ρ_{ase}, at the signal optical frequency, ν_{sig}, must be multiplied in order to obtain the integral of the squared ASE spectral power density over the full ASE bandwidth, B_{ase}, that is:

$$B_{sp-sp} = \rho_{ase}^{-2}(\nu_{sig}) \cdot \int_{B_{ase}} \rho_{ase}^{2}(\nu)\ d\nu$$

NOTE 1 – The equivalent spontaneous-spontaneous optical bandwidth can be minimized by using an optical filter at the output of the OFA.

NOTE 2 – This parameter is related to the spontaneous-spontaneous beat noise generation and thus it requires the use of the squared ASE spectral power density.

1.36 ASE bandwidth: The span between the two wavelengths at which a specified decrease of the output ASE from the peak value of the output ASE spectrum is observed.

NOTE 1 – A decrease of 30 to 40 dB is considered to be adequate.

NOTE 2 – Due to possible distortion of the measured spectrum, e.g. caused by pump leakage, a suitable extrapolation may be necessary.

1.37 in-band insertion loss: In an electrically unpowered condition, the insertion loss of signal for the OFA at a given input signal wavelength and a given small signal power level.

NOTE 1 – This property can be described at a discrete wavelength or as a function of wavelength.

NOTE 2 – Care should be taken to exclude the output ASE contribution in the measurement of this parameter.

1.38 maximum reflectance tolerable at input and output: The maximum reflectance of two identical reflectors simultaneously placed at both input and output ports of an OFA, for which the OFA still meets its specifications.

NOTE 1 – The measurement is performed with a given input signal optical power.

NOTE 2 – The noise figure is the most sensitive parameter to reflectance.

2 Test methods

According to an agreement with IEC-TC 86-WG 6, the guidelines to be followed for the measurement of most of the parameters defined in clause 1 are given in the IEC *Basic Specification for OFA test methods* 1290 series. Table 1 indicates the recommended test methods, collecting the test parameters in homogeneous groups and quoting for each group the relevant IEC Basic Specification number(s).

Table 1/G.661 – Recommended test methods for parameters defined in clause 1

Group of test parameters	Parameters of clause 1 involved	Test Method (TM) – IEC Basic Specification number
Gain parameters	1.1 to 1.8, 1.10, 1.32	1290-1-1: Optical spectrum analyser TM 1290-1-2: Electrical spectrum analyser TM 1290-1-3: Optical power meter TM
Optical power parameters	1.9, 1.11, 1.12, 1.25, 1.28, 1.29	1290-2-1: Optical spectrum analyser TM 1290-2-2: Electrical spectrum analyser TM 1290-2-3: Optical power meter TM (under study)
Noise parameters	1.13 to 1.15, 1.33 to 1.36	1290-3-1: Optical spectrum analyser TM (under study) 1290-3-2: Electrical spectrum analyser TM (under study)
Reflectance parameters	1.16 to 1.19, 1.38	1290-5-1: Optical spectrum analyser TM (under study)
Pump leakage parameters	1.20, 1.21	1290-6-1: Optical demultiplexer TM
Insertion loss parameters	1.22, 1.23, 1.37	1290-7-1: Filtered power meter TM
NOTE – The comparative evaluation of the Test Methods given in the IEC Basic Specifications is currently under development. When it will be available, the chosen Reference Test Methods and possible Alternative Test Methods for each relevant parameter defined in this Recommendation will be indicated.		

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