EUROPEAN TELECOMMUNICATION STANDARD

FINAL DRAFT

pr **ETS 300 672**

May 1996

Source: ETSI TC-TM

Reference: DE/TM-01034

ICS: 33.180.30

Key words: transmission, optical, amplification

Transmission and Multiplexing (TM); Relevant generic characteristics of optical amplifier devices and sub-systems

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Foreword

This final draft European Telecommunication Standard (ETS) has been produced by the Transmission and Multiplexing (TM) Technical Committee of the European Telecommunications Standards Institute (ETSI), and is now submitted for the Voting phase of the ETSI standards approval procedure.

Proposed transposition dates	
Date of latest announcement of this ETS (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this ETS (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

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1 Scope

This final draft European Telecommunication Standard (ETS) applies to Optical Amplifier (OA) devices and sub-systems to be used in transmission networks. It covers both Optical Fibre Amplifiers (OFAs) and Semiconductor Optical Amplifiers (SOAs).

The object of this ETS is to specify those generic characteristics relevant for the use of OA devices (as power amplifiers, pre-amplifiers or line amplifiers) and OA sub-systems (as optically amplified transmitters or optically amplified receivers), primarily for applications in digital transmission.

NOTE 1: As far as OFAs are concerned, the present ETS has been prepared from experience with Erbium-doped, silica-based fibre amplifiers, operating in the 1 550 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 ETS and may lead to additional specifications, as well as to modifications of the existing ones.

NOTE 2: The OFA aspects of the present ETS are mainly based on ITU-T Recommendations G.661 [2] and G.662 [3].

2 Normative references

This ETS incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETS only when incorporated in by amendment or revision. For undated references the latest edition of the publication referred to applies.

[1] ETS 300 232 (1993): "Transmission and Multiplexing (TM); Optical interfaces for equipments and systems relating to the Synchronous Digital Hierarchy [ITU-T Recommendation G.957 (1993) modified]".

[2] ITU-T Recommendation G.661 (1993): "Definition and test methods for the relevant generic parameters of optical fibre amplifiers".

[3] ITU-T Recommendation G.662 (1995): "Generic characteristics of optical fibre amplifier devices and sub-systems".

[4] IEC Publication 1290 series (1996): "Basic Specification for optical fibre amplifier test methods".

3 Abbreviations

For the purpose of this ETS, the following abbreviations apply:

ASE	Amplified Spontaneous Emission
BA	Booster (power) Amplifier
F	noise Factor
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
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
SOA	Semiconductor Optical Amplifier
Tx	(optical) Transmitter

4 Definitions of relevant parameters

The definitions of the relevant generic parameters concerning the OA aspects of both OA devices and sub-systems are given in this clause. 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 ETS 300 232 [1].

NOTE 1: Further definitions may be needed in the future according to the evolution of OA applications, e.g. in the fields of analogue and multiwavelength transmission.

NOTE 2: Hereafter two different operating conditions will usually be referred to: nominal operating conditions, for a normal use of the OA, and limit operating conditions, in which all the adjustable parameters (e.g. temperature, gain, pump laser injection current for OFAs, or pump current for SOAs, etc.) are at their maximum values, according to the stated absolute maximum ratings.

NOTE 3: All gains are intended 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 OA ports. The input and output optical power levels refer to the signal only and discriminate against pump or spontaneous emission radiation.

NOTE 4: Except where noted, the optical powers mentioned in the following are intended as average powers.

NOTE 5: The specification for a particular OA of the parameters defined in the following, will generally require provision of certain appropriate operating conditions such as temperature, bias current, pump power, etc.

NOTE 6: The OA amplifies signals in a nominal operating wavelength region. In addition, other out of band signals of the 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 the OFAs described in the present Standard the operating wavelength is in the 1 550 nm region.

The definitions of most of the relevant parameters for OA devices and sub-systems are given in ITU-T Recommendations G.661 [2] and G.662 [3]. For these parameters the definition is not provided explicitly, but the corresponding sub-clauses of those Recommendations are quoted in the following, taking into account that the words "Optical Fibre Amplifier(s) [OFA(s)]" should be replaced by "Optical Amplifier(s) [OA(s)]".

4.1 Small-signal gain

For OA devices only. The gain of the amplifier, when operated in linear regime, where it is quite independent of the input signal optical power, at given signal wavelength and pump optical power level for OFAs, or pump current for SOAs.

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

4.2 Reverse small-signal gain

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.2.

4.3 Maximum small-signal gain

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.3.

4.4 Maximum small-signal gain wavelength

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.4.

4.5 Maximum small-signal gain variation with temperature

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.5.

4.6 (Small-signal gain) wavelength bandwidth

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.6.

4.7 Small-signal gain wavelength variation

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.7.

4.8 Small-signal gain stability

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.8.

4.9 Large-signal output stability

Not for OARs. As in ITU-T Recommendation G.661 [2], subclause 1.9.

4.10 Polarisation-Dependent Gain (PDG)

For OA devices only. The maximum variation of gain due to a variation of the state of polarisation 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.

4.11 Saturation output power (gain compression power)

Not for OARs. The optical output signal power above which the gain is reduced by 3 dB for OFAs, or 1 dB for SOAs, with respect to the small-signal gain at the signal wavelength.

NOTE 1: The wavelength at which the parameter is specified should be stated.

NOTE 2: The optical pump power for OFAs, or the pump current for SOAs, should be stated where applicable.

4.12 Nominal output signal power

Not for OARs. As in ITU-T Recommendation G.661 [2], subclause 1.12.

4.13 Noise Figure (NF)

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.13.

4.14 Forward amplified spontaneous emission (ASE) power level

Not for OARs. Recommendation G.661 [2], subclause 1.14.

4.15 Reverse ASE power level

Not for OATs. As in ITU-T Recommendation G.661 [2], subclause 1.15.

4.16 Input Optical Return Loss (ORL)

Not for OATs. As in ITU-T Recommendation G.661 [2], subclause 1.16.

4.17 Output ORL

Not for OARs. As in ITU-T Recommendation G.661 [2], subclause 1.17.

4.18 Maximum ORL tolerable at input

Not for OARs. As in ITU-T Recommendation G.661 [2], subclause 1.18.

4.19 Maximum ORL tolerable at output

Not for OARs. As in ITU-T Recommendation G.661 [2], subclause 1.19.

4.20 Pump leakage to output

For OFAs only and not for OARs. The pump optical power which is emitted from the OFA output port.

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

4.21 Pump leakage to input

For OFAs only and not for OATs. The pump optical power which is emitted from the OFA input port.

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

4.22 Out-of-band insertion loss [1)]

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.22.

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1) These parameters are strongly wavelength dependent in SOAs.

4.23 Out-of-band reverse insertion loss [1)]

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.23.

4.24 Maximum power consumption

As in ITU-T Recommendation G.661 [2], subclause 1.24.

4.25 Maximum total output power

Not for OARs. As in ITU-T Recommendation G.661 [2], subclause 1.25.

4.26 Operating temperature

As in ITU-T Recommendation G.661 [2], subclause 1.26.

4.27 Optical connections

As in ITU-T Recommendation G.661 [2], subclause 1.27.

4.28 Input power range

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.28.

4.29 Output power range

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.29.

4.30 Polarization Hole Burning (PHB)

Under study.

4.31 Polarization Mode Dispersion (PMD)

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.31.

4.32 Power wavelength band

For power amplifiers only. As in ITU-T Recommendation G.662 [3], subclause 3.1.

4.33 Available signal wavelength band

For pre-amplifiers with optical filter(s) only. As in ITU-T Recommendation G.662 [3], subclause 3.2.

4.34 Tuneable wavelength range

For pre-amplifiers and OARs with tuneable optical filter(s) only. As in ITU-T Recommendation G.662 [3], subclause 3.3.

4.35 Output signal-to-noise ratio

For OATs only. As in ITU-T Recommendation G.662 [3], subclause 3.4.

4.36 Signal linewidth

For OATs only. As in ITU-T Recommendation G.662 [3], subclause 3.5.

4.37 Gain ripple

For OA devices only. The peak to peak variation of the small-signal gain over a given wavelength range, with sub-nanometre resolution in wavelength.

NOTE: This parameter is usually relevant for SOAs only.

4.38 Gain dynamics

The characteristics time and strengths of non-linearities of the gain medium.

NOTE 1: This parameter is usually relevant for SOAs only.

NOTE 2: This definition is under study.

4.39 Gain

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.32.

4.40 Noise factor (F)

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.33.

4.41 Signal-spontaneous noise figure

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.34.

4.42 (Equivalent) spontaneous-spontaneous optical bandwidth ($B_{sp\text{-}sp}$)

Not for OARs. As in ITU-T Recommendation G.661 [2], subclause 1.31.

4.43 Amplified Spontaneous Emission (ASE) bandwidth

Not for OARs. The span between the two wavelengths at which a specified decrease of the output ASE from the peak value of the output ASE 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 in the case of OFAs, a suitable extrapolation may be necessary.

4.44 In-band insertion loss

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.37.

4.45 Maximum reflectance tolerable at input and output

For OA devices only. As in ITU-T Recommendation G.661 [2], subclause 1.38.

5 Test methods

The guidelines to be followed for the measurement of most of the parameters defined in clause 4 of this ETS are given in the IEC 1290 series [4]. Table 1 indicates the recommended test methods, collecting the test parameters in homogeneous groups and quoting for each group the relevant IEC 1290 series [4] part number(s).

Table 1: Test methods for parameters defined in clause 4 of this ETS

Group of test parameters	Parameters of clause 4 involved	IEC 1290 series [4] part number: Test Method (TM)
Gain parameters	4.1 to 4.8, 4.10, 4.37, 4.39	1290-1-1: Optical spectrum analyzer TM 1290-1-2: Electrical spectrum analyzer TM 1290-1-3: Optical power meter TM
Optical power parameters	4.9, 4.11, 4.12, 4.25, 4.28, 4.29	1290-2-1: Optical spectrum analyzer TM 1290-2-2: Electrical spectrum analyzer TM 1290-2-3: Optical power meter TM
Noise parameters	4.13 to 4.15, 4.40 to 4.43	1290-3-1: Optical spectrum analyzer TM (under study) 1290-3-2: Electrical spectrum analyzer TM (under study)
Reflectance parameters	4.16 to 4.19	1290-5: Optical spectrum analyzer TM (under study)
Pump leakage parameters	4.20, 4.21	1290-6-1: Optical demultiplexer TM
Insertion loss parameters	4.22, 4.23, 4.44, 4.45	1290-7-1: Filtered power meter TM
NOTE 1: The comparative evaluation of the test methods given in the IEC Basic Specifications is currently under development. When it is available, the chosen reference test methods and possible alternative test methods for each relevant parameter defined in this ETS will be indicated. NOTE 2: The test methods given in the IEC Basic Specifications have been prepared for OFAs only. The extrapolation of these methods to SOAs is under study.		

6 OA classification

OAs can be divided in OA devices and OA sub-systems.

The OA device is a stand-alone OA in which both input and output ports are specified.

The OA sub-system is an OA integrated with either the transmitter or the receiver, in which either the output or the input port, respectively, is specified.

6.1 OA devices

As in ITU-T Recommendation G.662 [3], clause 5, taking into account that the words "Optical Fibre Amplifier(s) (OFA(s))" should be replaced by "Optical Amplifier(s) (OA(s))".

6.2 OA sub-systems

As in ITU-T Recommendation G.662 [3], clause 6, taking into account that the words "Optical Fibre Amplifier(s) (OFA(s))" should be replaced by "Optical Amplifier(s) (OA(s))".

7 Specification parameters

Minimum lists of specification parameters are provided in the following for each kind of OA device and sub-system, quoting the relevant clauses of ITU-T Recommendation G.662 [3], taking into account that the words "Optical Fibre Amplifier(s) (OFA(s))" should be replaced by "Optical Amplifier(s) (OA(s))", and that the pump leakage parameters apply to OFAs only.

7.1 Characteristics of Booster (power) Amplifiers (BAs)

As in ITU-T Recommendation G.662 [3], clause 7.

7.2 Characteristics of Pre-Amplifiers (PAs)

As in ITU-T Recommendation G.662 [3], clause 8.

7.3 Characteristics of Line Amplifiers (LAs)

As in ITU-T Recommendation G.662 [3], clause 9.

7.4 Characteristics of Optically Amplified Transmitters (OATs)

As in ITU-T Recommendation G.662 [3], clause 10.

7.5 Characteristics of Optically Amplified Receivers (OARs)

As in ITU-T Recommendation G.662 [3], clause 11.

Annex A (informative): Bibliography

- ETR 126 (1994): "Transmission and Multiplexing (TM); Applications of optical fibre amplifiers in long distance and optical access networks";

- ITU-T Recommendation G.955 (1993): "Digital line systems based on the 1 544 kbit/s and the 2 048 kbit/s hierarchy on optical fibre cables";

- CCITT Recommendation G.958 (1991): "Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables".

History

Document history			
September 1995	Public Enquiry	PE 91:	1995-09-04 to 1995-12-29
May 1996	Vote	V 102:	1996-05-06 to 1996-08-09