INTERNATIONAL STANDARD

IEC 60728-6

Second edition
2003-07

Cable networks for television signals, sound signals and interactive services –

Part 6: Optical equipment



Reference number
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CABLE NETWORKS FOR TELEVISION SIGNALS, SOUND SIGNALS AND INTERACTIVE SERVICES –

Part 6: Optical equipment

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International Standard IEC 60728-6 has been prepared by technical area 5: Cable networks for television signals, sound signals and interactive services, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This second edition cancels and replaces the first edition published in 2001 of which it constitutes a technical revision.

The text of this standard is based on

FDIS	Report on voting
100/680/FDIS	100/697/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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- withdrawn;
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Standards of the IEC 60728 series deal with cable networks for television signals, sound signals and interactive services including equipment, systems and installations:

- for headend-reception, processing and distribution of sound and television signals and their associated data signals, and
- for processing, interfacing and transmitting all kinds of interactive multimedia signals using all applicable transmission media.

They cover all kinds of networks that convey modulated RF carriers such as

- CATV-networks;
- MATV-networks and SMATV-networks;
- individual receiving networks;

and all kinds of equipment, systems and installations installed in such networks.

The scope of these standards extends from antennas and special signal source inputs to headend or other interface points, to networks as a whole up through system outlets, or terminal inputs where no system outlet exists.

The standardization of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals, etc.) is excluded.

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CABLE NETWORKS FOR TELEVISION SIGNALS, SOUND SIGNALS AND INTERACTIVE SERVICES –

Part 6: Optical equipment

1 Scope

This part of IEC 60728 lays down the measuring methods, performance requirements and data publication requirements of optical equipment of cable networks for television signals, sound signals and interactive services.

This standard

- applies to all optical transmitters, receivers, amplifiers, directional couplers, isolators, multiplexing devices, connectors and splices used in cable networks;
- covers the frequency range 5 MHz to 3 000 MHz;

  NOTE The upper limit of 3 000 MHz is an example, but not a strict value. The frequency range or ranges, over which the equipment is specified, shall be published.
- identifies guaranteed performance requirements for certain parameters;
- lays down data publication requirements with guaranteed performance;
- describes methods of measurement for compliance testing.

All requirements and published data relate to minimum performance levels within the specified frequency range and in well-matched conditions as might be applicable to cable networks for television signals, sound signals and interactive services.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-1, *Environmental testing. Part 1: General and guidance*

IEC 60068-2, (all parts), *Environmental testing – Part 2: Tests*

IEC 60169-2, *Radio-frequency connectors – Part 2: Coaxial unmatched connector*

IEC 60169-24, *Radio-frequency connectors – Part 24: Radio-frequency coaxial connectors with screw coupling, typically for use in 75 ohm cable distribution systems (Type F)*

IEC 60417-DB:2002*, *Graphical symbols for use on equipment*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60617 (all parts) [DB]*, *Graphical symbols for diagrams*

* "DB" refers to the IEC on-line database.

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IEC 60728-1, *Cabled distribution systems for television and sound signals – Part 1: Methods of measurement and system performance*

IEC 60728-2, *Cabled distribution systems for television and sound signals – Part 2: Electromagnetic compatibility of equipment*

IEC 60728-3, *Cabled distribution systems for television and sound signals – Part 3: Active coaxial wideband distribution equipment*

IEC 61280-2-2, *Fibre optic communication subsystem basic test procedures – Part 2-2: Test procedures for digital systems – Optical eye pattern, waveform, and extinction ratio*

IEC 61280-4-2, *Fibre optic communication subsystem basic test procedures – Part 4-2: Fibre optic cable plant – Single-mode fibre optic cable plant attenuation*

IEC 61282-4, *Fibre optic communication system design guides – Part 4: Guideline to accommodate and utilize nonlinear effects in single-mode fibre optic systems*

IEC 61290-1-3, *Optical fibre amplifiers – Basic specification – Part 1-3: Test methods for gain parameters – Optical power meter*

IEC 61290-3, *Optical fibre amplifiers – Basic specification – Part 3-1: Test methods for noise figure parameters*

IEC 61290-3-2, *Optical fibre amplifiers – Part 3-2: Test methods for noise figure parameters – Electrical spectrum analyzer*

IEC 61290-5, *Optical fibre amplifiers – Basic specification – Part 5: Test methods for reflectance parameters*

IEC 61291-1, *Optical fibre amplifiers – Part 1: Generic specification*

IEC 61931, *Fibre optics – Terminology*

IEC 80416, *Basic principles for graphical symbols for use on equipment*

ITU G.692, *Optical interfaces for multichannel systems with optical amplifiers*

EN 300019-1-3, *Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-3: Classification of environmental conditions; Stationary use at weatherprotected locations*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the definitions given in IEC 60728-1, IEC 61931 and the following terms and definitions apply.

3.1.1
optical transmitting unit; optical transmitter; Tx (abbreviation)
transmit fibre optic terminal device accepting at its input port an electrical signal and providing at its output port an optical carrier modulated by that input signal

NOTE For the purposes of this standard, optical transmitters may have more than one input port accepting electrical RF signals.

[IEC 61931, definition 2.9.6]

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3.1.2
optical receiving unit; optical receiver; Rx (abbreviation)
receive fibre optic terminal device accepting at its input port a modulated optical carrier, and providing at its output port the corresponding demodulated electrical signal (with the associated clock, if digital)

NOTE For the purposes of this standard, optical receivers may have more than one output port providing electrical RF signals.

[IEC 61931, definition 2.9.7]

3.1.3
optical amplifier
optical waveguide device containing a suitably pumped, active medium which is able to amplify an optical signal

[IEC 61931, definition 2.7.75]

3.1.4
(optical) isolator
two port non-reciprocal optical device intended to suppress backward reflection, while having minimum insertion loss in the forward direction, based on Faraday effect

NOTE 1 An isolator is commonly used to prevent return reflections along a transmission path.

NOTE 2 An isolator is generally polarization dependent; however fibre optic polarization independent isolators exist.

[IEC 61931, definition 2.6.30]

3.1.5
(optical (fibre)) splice
permanent, or semi permanent, joint whose purpose is to couple optical power between two optical fibres

[IEV 731-05-05 modified]
[IEC 61931, definition 2.6.8]

3.1.6
fibre optic branching device; (optical) (fibre) branching device;
(optical) (fibre) coupler (deprecated)]

optical fibre device, possessing three or more optical ports, which shares optical power among its ports in a predetermined fashion, at the same wavelength or wavelengths, without wavelength conversion

NOTE The ports may be connected to fibres, sources, detectors, etc.

[IEC 61931, definition 2.6.21]

3.1.7
directional branching device; directional coupler (deprecated)
device which distributes an optical signal among the output ports in a predetermined fashion only when light is launched into one preselected input port

[IEC 61931, definition 2.6.22]

NOTE For the purposes of this standard, directional coupler is the preferred term because this is also the term for its electrical equivalent.

3.1.8
multiplexing device; WDM device
wavelength selective branching device (used in WDM transmission systems) in which optical signals can be transferred between two predetermined ports, depending on the wavelength of the signal

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[IEC 61931, definition 2.6.51]

3.1.9
reference output level of an optical receiver
offset x by which the electrical output level of an optical receiver can be calculated from the optical input level at a modulation index of m = 0,05 using following equation:

$$U = 2\ P_{\text{opt,RX}} + x\ \text{dB}(\mu\text{V}) \quad (1)$$

where

U is the electrical output level in dB(μV)

$P_{\text{opt,RX}}$ is the optical input level in dB(mW)

x is the reference output level in dB(μV)

3.1.10
optical modulation index
optical modulation index is defined as

$$m = \frac{\phi_{\text{h}} - \phi_{\text{l}}}{\phi_{\text{h}} + \phi_{\text{l}}} \quad (2)$$

where ϕ_{h} is the highest and ϕ_{l} is the lowest instantaneous optical power of the intensity modulated optical signal. This term is mainly used for analogue systems.

NOTE This definition does not apply to systems where the input signals are converted and transported as digital baseband signals. In this case, the terms modulation depth or extinction ratio defined in 2.6.79 and 2.7.46 of IEC 61931 must be used. A test procedure for extinction ratio is described in IEC 61280-2-2.

3.1.11
noise figure
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 optical amplifier (OFA), expressed in dB

[IEC 61291-1]

NOTE The noise figure of optical amplifiers depends on the optical input power and on the wavelength used.

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3.1.12
relative intensity noise
RIN
ratio of the mean square of the intensity fluctuations in the optical power of a light source to the square of the mean of the optical output power. The RIN is usually expressed in dB(Hz^{-1}) resulting in negative values then

NOTE The value for the RIN can be calculated from the results of a carrier-to-noise measurement for the system (see 4.18).

3.1.13
noise equivalent power
NEP
value of the radiant power at the input of an optical detector which produces at the output a signal-to-noise ratio equal to one, for a given wavelength, modulation frequency and equivalent noise bandwidth

[IEV 731-06-40]

[IEC 61931, definition 2.7.61]

NOTE The NEP can be calculated from the carrier-to-noise ratio C/N (see 4.18) of a receiver using:

$$NEP = \frac{mP}{\sqrt{2B}} 10^{-\frac{1}{20} C/N} \quad (3)$$

where

m is the optical modulation index;

P is the received optical power;

B is the bandwidth.

The NEP shall be expressed in units of W/√Hz.

3.1.14
equivalent input noise current density
notional input noise current density which, when applied to the input of an ideal noiseless device, would produce an output noise current density equal in value to that observed at the output of the actual device under consideration

NOTE It can be calculated from the carrier-to-noise ratio C/N (see 4.18) of a device or system using:

$$I_r = \sqrt{\frac{C}{Z\, 10^{\frac{1}{10} C/N}}} \quad (4)$$

where

C is the power of the carrier at the input of the device or system;

Z is its input impedance.

The equivalent input noise current density shall be expressed in units of A/√Hz.

3.1.15
responsivity
ratio of an optical detector's electrical output to its optical input at a given wavelength

[IEV 731-06-36 modified]

NOTE 1 The responsivity is generally expressed in amperes per watt or volts per watt of incident radiant power.

NOTE 2 Sensitivity is sometimes used as an imprecise synonym for responsivity.

NOTE 3 The wavelength interval around the given wavelength may be specified.

[IEC 61931, definition 2.7.56]

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3.1.16
chromatic dispersion; total dispersion (deprecated)
spreading of a light pulse per unit source spectrum width in an optical fibre caused by different group velocities of the different wavelengths composing the source spectrum.

NOTE The chromatic dispersion may be due to the following contributions: material dispersion, waveguide dispersion, profile dispersion.

[IEC 61931, definition 2.4.54]

3.1.17
wavelength
distance covered in a period by the wavefront of a harmonic plane wave.

[IEC 61931, definition 2.2.9]

NOTE The wavelength λ of light in vacuum is given by

$$\lambda = \frac{c}{f} \tag{5}$$

where

c is the speed of light in vacuum ($c \approx 2{,}99792 \times 10^8$ m/s);

f is the optical frequency.

Although the wavelength in dielectric material such as fibres is shorter than in vacuum, only the wavelength of light in vacuum is used.

3.1.18
chirping
rapid change of the emission wavelengths of a directly intensity-modulated optical source as a function of the intensity of the modulating signal

NOTE 1 Chirping should not be confused with long-term wavelength drift.

NOTE 2 Due to the fibre chromatic dispersion, using a single-mode laser, chirping can cause either degradation or improvement of the total bandwidth.

[IEC 61931, definition 2.7.44]

3.1.19
polarization
orientation of the electric field vector of the electromagnetic radiation

[IEC 61931, definition 2.1.44]

3.1.20
linewidth
spectral bandwidth of an individual mode of a laser, defined as the difference between those optical frequencies at which the amplitude reaches or first falls to half of the maximum amplitude

3.1.21
coherence length
propagation distance over which propagating light may be considered to be coherent radiation

[IEV 731-01-17 modified]

NOTE The coherence length in a medium of refractive index n is approximately

$$\lambda_0^{\,2}/(n \cdot \Delta\lambda)$$

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where

λ_0 is the central wavelength;

$\Delta\lambda$ is the spectral linewidth of the source.

[IEC 61931, definition 2.1.67]

3.1.22
coherence time
time over which a propagating light may be considered to be coherent radiation

[IEV 731-01-18]

NOTE 1 The coherence time is equal to coherence length divided by the phase velocity of light in a medium.

NOTE 2 The coherence time is given approximately $\lambda_0^2/(c \cdot \Delta\lambda)$ where λ_0 is the central wavelength, $\Delta\lambda$ is the spectral linewidth and c is the velocity of light in vacuum.

[IEC 61931, definition 2.1.68]

3.1.23
well-cleaved
well-cleaved end of fibre has a clean plane front perpendicular to the axis of the fibre

3.1.24
amplified spontaneous emission
ASE
optical power associated to spontaneously emitted photons amplified by an active medium in an optical amplifier

[IEC 61931, definition 2.7.87]

3.1.25
directivity
in a generic optical branching device, measure of the undesired transfer of a portion of optical power from one input port, when all other ports are optically matched for zero reflection

[IEC 61931, definition 2.6.50]

3.1.26
central wavelength
the average of those wavelengths at which the amplitude of a light source reaches or last falls to half of the maximum amplitude

3.1.27
spectral width
measure of the wavelength range of a spectrum or spectral characteristic

[IEV 731-06-24 modified]

[IEC 61931, definition 2.7.42]

3.1.28
(stimulated) Brillouin scattering
SBS
non-linear scattering of optical radiation characterized by a frequency shift as for the Raman scattering, but accompanied by a lower frequency (acoustical) vibration of the medium lattice. The light is scattered backward with respect to the incident radiation

NOTE In silica fibres the frequency shift is typically around 10 GHz.

[IEC 61931, definition 2.1.88]

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3.1.29
saturation output power (gain compression power)
optical power level associated with the output signal above which the gain is reduced by N dB (typically N=3) with respect to the small-signal gain at the signal wavelength.

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

[IEC 61291-1, definition 3.1.11]

3.1.30
optical return loss; return loss; ORL (abbreviation)
ratio, expressed in dB, of the total reflected power to the incident power from an optical fibre, optical device, or optical system, and defined as:

$$-10\lg\frac{P_r}{P_i}$$

where

P_r is the reflected power;

P_i is the incident power.

NOTE 1 When referring to a reflected power from an individual component, reflectance is the preferred term.

[IEC 61931, definition 2.6.49]

NOTE 2 For the purposes of this standard, the term reflectance is used for optical amplifiers only. The term optical return loss is used for ports of all other types of equipment.

NOTE 3 The term return loss is also used for electrical ports. The definition relates to electrical powers in this case.

3.1.31
cladding mode
mode in which the electromagnetic field is confined in the cladding and the core by virtue of there being a lower refractive index medium surrounding the outermost cladding

[IEV 731-03-60]

[IEC 61931, definition 2.4.10]

3.1.32
slope
gain or attenuation difference at two defined frequencies between any two ports of a device or system

3.1.33
flatness
difference between the maximum and the minimum gain or attenuation reduced by the slope within the specified modulation frequency range of a device or system

3.1.34
small-signal gain
gain of an optical amplifier operated in its linear region where this gain is independent from the optical input power

NOTE This parameter can be given for a single wavelength or as a function of the wavelength.

3.1.35
polarization dependent loss
maximum change in insertion loss for all states of input polarization

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3.1.36
centroidal wavelength
mean or average wavelength of an optical spectrum

3.2 Symbols

The following graphical symbols are used in the figures of this standard. These symbols are either listed in IEC 60617 or based on symbols defined in IEC 60617.



Optical transmitter
[S00213]



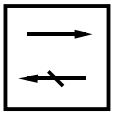
Optical receiver
[S00213]



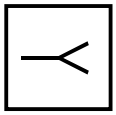
Optical amplifier
[S00127, S01239]



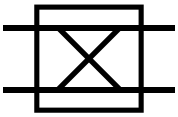
Optical fibre
[S01318]



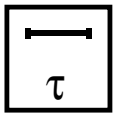
Isolator
[S01175]



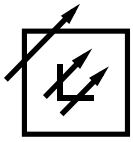
Coupler
[S00059, S01188]



Directional coupler
[S00059, S01193]



Delay line
[S00608]



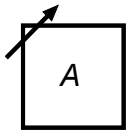
Polarisation control device
[S001430, proposed]



Low-pass filter
[S01248]



Bandpass filter
[S01249]



Variable attenuator
[S01245]



Pulse generator
[S01228]



Sine-wave generator
[S00899, S01403]



Bit pattern generator



Voltmeter
[S00059, S00913]



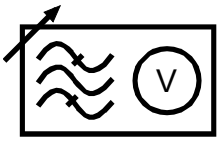
Ammeter
[S00059, S00910]



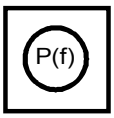
Power meter
[S00059, S00910]



Oscilloscope
[S00059, S00922]



Selective voltmeter
[S00059, S00081,
S00913, S01249]

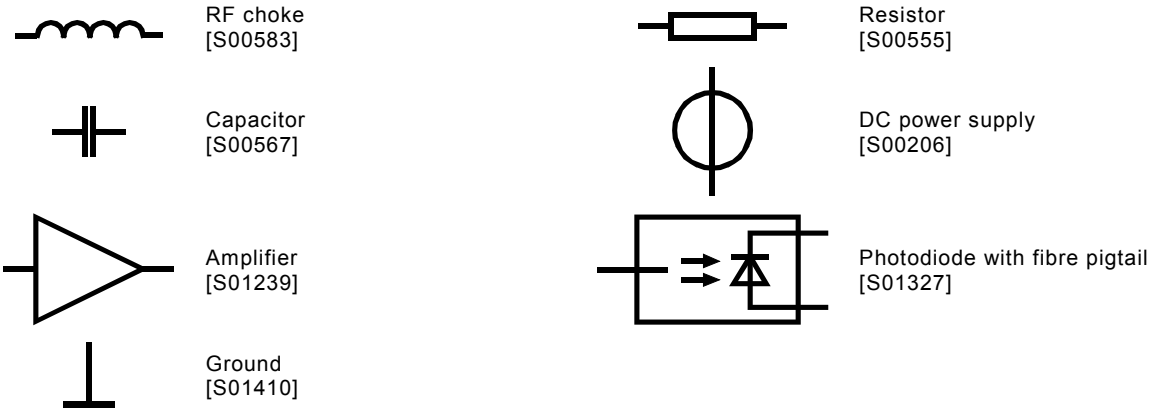


Electrical spectrum analyzer
[S00059, S00910]



Optical spectrum analyzer
[S00059, S00910]

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3.3 Abbreviations

The following abbreviations are used in this standard:

AC	alternating current
AGC	automatic gain control
ALC	automatic level control
ASE	amplified spontaneous emission
CATV	community antenna television (network)
C/N	carrier-to-noise ratio
CSO	composite second order
CTB	composite triple beat
CW	continuous wave
DC	direct current
EMC	electromagnetic compatibility
IF	intermediate frequency
MATV	master antenna television (network)
MTBF	mean time between failure
NEP	noise equivalent power
NF	noise figure
PDL	polarization dependent loss
PRBS	pseudo random bit sequence
RF	radio frequency
RIN	relative intensity noise
SMATV	satellite master antenna television (network)
WDM	wavelength division multiplexing
XM	composite crossmodulation

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4 Methods of measurement

4.1 General measurement requirements

For all methods of measurements described in this clause the following requirements shall be considered.

4.1.1 Input specification

The following conditions shall be obtained from the device specification:

- supply voltage(s);
- control signal(s), if any, with correct impedance, level and frequency.

4.1.2 Measurement conditions

Unless otherwise specified, all measurement shall be carried out under following conditions:

- the ambient or reference point temperature shall be 25 °C ± 5 °C;
- the ambient humidity shall be in the range 40 % to 70 %;
- sufficient care shall be taken to ensure that optical reflection does not impair the accuracy of the measurement;
- during measurement any control input signal(s) shall be held constant.
- test fibres shall have clean and unscratched ends in order to prevent losses of power and reflections.

4.2 Optical power

4.2.1 Purpose

The purpose of this test method is to measure the total average optical power emanating from the end of a test fibre. The test fibre and the coupling means shall be as specified by the manufacturer. The optical power shall be expressed in dB(mW).

4.2.2 Equipment required

a) An **optical power meter** with a range suitable for the expected power. The detector system of the power meter shall have a sufficiently large area to collect all the radiation from the test fibre and a spectral sensitivity compatible with the light source. A minimum accuracy of ±10 % is recommended.

b) A length of **fibre** for connecting the light source to the power meter.

c) A **cladding mode stripper** if the fibre has no cladding mode stripping coating.

d) Test **signal generator(s).**

4.2.3 General measurement requirements

a) The transmitter shall be modulated with at least one modulation carrier at the specified optical modulation index.

b) Cladding modes shall be stripped from the fibre by means of suitable cladding mode stripping techniques.

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4.2.4 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 1.

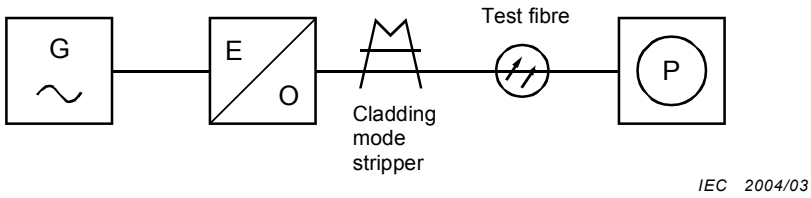


Figure 1 – Measurement of optical power

c) Connect the optical output of the device under test to the detector (a power meter) through the test fibre and the specified coupling means.

d) Measure and record the output power using the power meter.

4.2.5 Potential sources of error

Such sources of error are the following:

- the inaccuracy of the power meter, for example if its dark current is not sufficiently low;
- the attenuation of the test fibre and the specified coupling means.

4.3 Loss, isolation, directivity and coupling ratio

The measurement of the following parameters is based on the measurement of optical power, and therefore no special methods of measurement are given for these items:

- loss of fibres, connectors, and optical isolators;
- isolation of optical isolators.

NOTE Methods of measurement for the attenuation of fibre optic plants are described in IEC 61280-4-2. A method for measurement of the gain of optical amplifiers is described in IEC 61290-1.

4.3.1 General measurement requirements

The equipment under test shall be tested with a light source suitable for the specified wavelength range.

All optical inputs or outputs not involved during the measurement shall be terminated to make sure that no reflected light can impair the accuracy of the measurement.

4.3.2 Principle of measurement

a) Connect the light source to the power meter and measure the optical output power P_1 of the light source (see 4.2).

b) Connect the device under test to the light source and the optical power meter as shown in Figure 2 and measure the power P_2.

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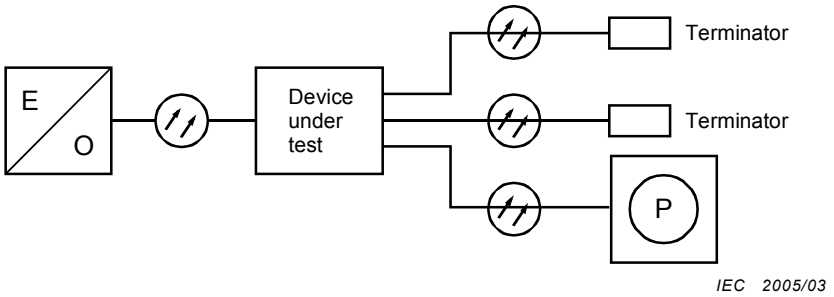


Figure 2 – Measurement of optical loss, directivity and isolation

c) The loss, directivity or isolation is calculated by

$$a = 10 \cdot \lg \frac{P_1}{P_2} \tag{6}$$

4.4 Return loss

4.4.1 Purpose

In general, the return loss is the ratio of the incident optical power P_{in} to the reflected optical power P_{back}, expressed in dB. The purpose of this test is to measure the return loss of an optical equipment. For optical fibre amplifiers, the term reflectance is used which is the reciprocal of the return loss (see IEC 61291-1). Methods of measurement for the reflectance of optical fibre amplifiers are specified in IEC 61290-5.

NOTE A simpler method with reduced accuracy is given in Annex A.

4.4.2 Equipment required

a) A fused **fibre coupler** with a directivity higher than the return loss to be measured.

b) A continuous **light source**.

c) An optical **power meter** with a dynamic range higher than the return loss to be measured.

d) Lengths of **fibre** for connecting the optical equipment.

e) Two **optical terminators** with reflection ideally 20 dB better than the return loss to be measured.

f) A **reference reflector**, which provides a well-known return loss a_{ref}.

4.4.3 General measurement requirements

The length of the fibre for connecting the light source to the coupler shall be longer than the coherence length of the light source.

4.4.4 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 3.

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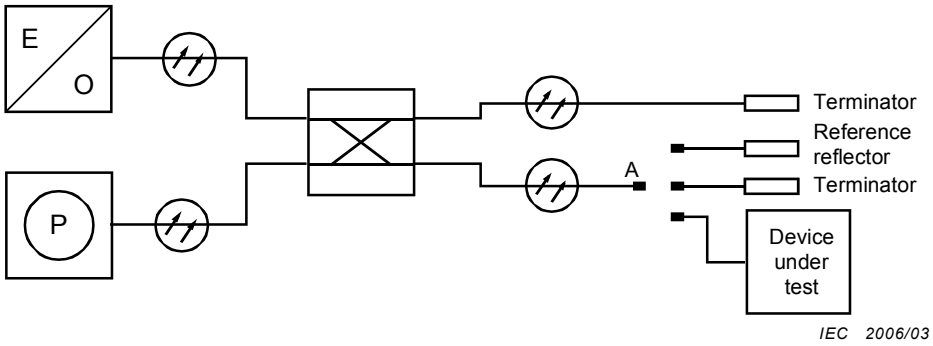


Figure 3 – Measurement of the optical return loss

c) Connect the reference reflector with the known return loss to port A of the coupler and note the reading P_1 of the power meter.

d) Connect the second terminator to port A of the coupler and note the reading P_2 of the power meter.

e) Connect the device under test to port A of the coupler and note the reading P_3 of the power meter. If the device under test has more than one optical port, the other ports shall be terminated with low reflection.

f) The return loss of the device shall be calculated from:

$$a_r = a_{ref} + 10 \lg \frac{P_1 - P_2}{P_3 - P_2} \text{ (dB)} \quad (7)$$

4.4.5 Potential sources of error

Such sources of error are the following:

- the return loss of the connection at port A shall be at least as high as the return loss of the device under test. Otherwise, the dynamic range of the measurement will suffer;
- if the impedance matching of the terminators produces a reflection which is not much less than the reflection of the device under test, the accuracy will suffer;
- the instability of the light source;
- the inaccuracy of the power meter;
- any polarization dependent loss (PDL) of the equipment used. The method of 4.6 can be used in order to measure the influence of polarization on the result.

4.5 Saturation output power of an optical amplifier

4.5.1 Purpose

The purpose of this test method is to measure the mean optical output power of a test fibre whose far end is connected to the optical output port of a saturated optical amplifier. The saturation output power shall be expressed in dB(mW).

4.5.2 Procedure

The gain G of the optical amplifier shall be measured as a function of the optical input power according to IEC 61290-1-3. Plot the gain versus optical input power resulting in a curve shown in Figure 4. At low input levels the small-signal gain is constant. At higher input levels the gain decreases. The saturation output power is reached when the gain lags N dB (if no other value is stated, N should be 3) behind the small-signal gain and can be calculated from $P_{sat} = G_{sat} + P_{in}$ (in dB(mW)).

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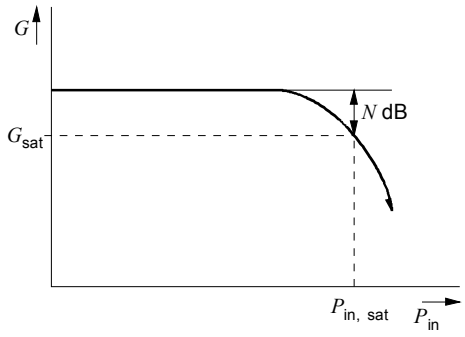


Figure 4 – Optical saturation output power

4.6 Polarization dependent loss

4.6.1 Purpose

The purpose of this test method is to measure the effect of polarization changes on loss or gain under specified conditions. The polarization dependent loss shall be expressed as the logarithmic ratio, in dB, of the maximum and minimum amplitude at the output of a device when the polarization at the input changes over all states of polarization.

4.6.2 Equipment required

a) A **light source** with a wavelength suitable for the device under test. The polarization of the emanating light shall be constant.

b) A **polarization control device** capable of changing the polarization of the test signal by 360 °.

c) An **optical power meter** with a range suitable for the expected power at the output of the device under test. The detector system of the power meter shall have a sufficiently large area to collect all the radiation from the fibre and a spectral sensitivity compatible with the light source. A minimum accuracy of ±10 % is recommended.

d) Lengths of **fibre** for connecting the optical devices. These shall be short enough, straight, unstressed and not birefringent to ensure that the polarization is not changed by them.

e) A **cladding mode stripper** if the fibre has no cladding mode stripping coating.

4.6.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 5.

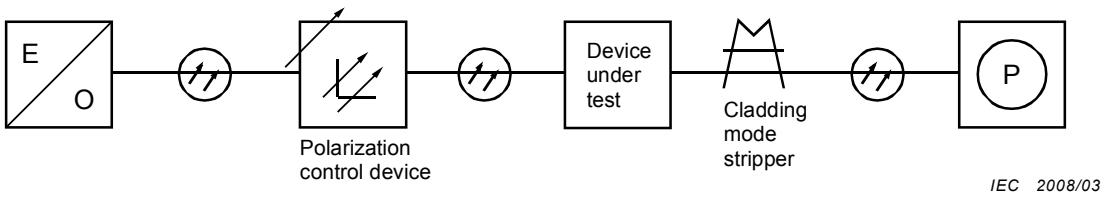


Figure 5 – Measurement of the polarization dependent loss

c) Vary the polarization of the light fed to the device under test covering all states of polarization (in not less than 1 s in the case of optical amplifiers). Record the minimum (P_{min}) and the maximum power (P_{max}) at the output.

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d) The polarization dependent loss PDL is derived as follows:

$$PDL = 10 \lg \frac{P_{max}}{P_{min}} \quad (8)$$

e) If the device under test is an optical amplifier the PDL usually becomes a negative number Then the term polarization dependent gain (PDG) shall be used.

4.6.4 Potential sources of error

Such sources of error are:

- the inaccuracy of the power meter and the polarization control device;
- the amplitude and wavelength instability of the light source.

4.7 Centroidal wavelength and spectral width under modulation

4.7.1 Purpose

The purpose of this test method is to measure the centroidal wavelength λ_0 of the spectrum and the spectral width $\Delta\lambda$ of a transmitter under modulation. The centroidal wavelength and the spectral width shall be expressed in nm. The method described is not suitable for light sources and transmitters with very narrow spectral width (single mode laser) or for measuring the chirping of transmitters (see 4.8).

4.7.2 Equipment required

a) An **optical spectrum analyzer** with a wavelength range suitable for the transmitter to be tested.

b) A length of **fibre** for connecting the transmitter to the optical spectrum analyzer.

c) A test **signal generator** for modulating the transmitter.

4.7.3 General measurement requirements

The transmitters shall be modulated with at least one modulation carrier at the specified optical modulation index.

4.7.4 Procedure

a) Connect the equipment as shown in Figure 6.

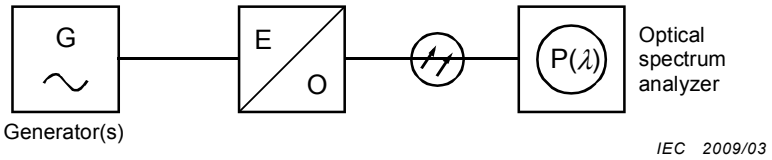


Figure 6 – Measurement of central wavelength and spectral width under modulation

b) Measure the power level of the highest power spectrum using the optical spectrum analyzer.

c) Set the optical spectrum analyzer to a short wavelength and then adjust it to a progressively longer wavelength. Record the wavelength λ_1, at which half of the maximum peak reading is obtained or exceeded for the first time.

d) Set the optical spectrum analyzer to a long wavelength and then adjust it to a progressively shorter wavelength. Record the wavelength λ_2, at which half of the maximum peak reading is obtained or exceeded for the first time.

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e) The centroidal wavelength is calculated from

$$\lambda_0 = \frac{\lambda_1 + \lambda_2}{2} \tag{9}$$

f) The spectral width is calculated from

$$\Delta\lambda = \lambda_2 - \lambda_1 \tag{10}$$

4.7.5 Potential sources of error

Such sources of error are the following:

- the inaccuracy of the optical spectrum analyzer;
- mode partition noise and instability of the transmitter. Instability of the transmitter can often be reduced by reducing optical reflections towards the transmitter, for instance by adding an optical isolator at the output of the transmitter. The impact of mode partition noise and instability of the transmitter can be reduced by averaging a suitable number of measurements;
- using connectors with angled front can lead to wrong wavelength readings if the input of the optical spectrum analyzer is not a fibre;
- any temperature instability of the device.

4.8 Linewidth and chirping of transmitters with single mode lasers

4.8.1 Purpose

The purpose of this test method is to measure the linewidth and the frequency modulation, or chirping, of a transmitter with single mode laser. The linewidth shall be expressed in MHz. The chirping shall be expressed in MHz/mA.

4.8.2 Equipment required

a) An **RF signal generator** which can be gated on and off with a 50 % duty cycle so that the transmitter is operating unmodulated for a time, τ, and then modulated for an identical time. The magnitude and the waveform of the generated signal shall be suitable for the transmitter to be tested. The signal frequency shall be lower than the linewidth of the transmitter to be tested.

b) A **fibre-optic Mach-Zehnder interferometer** with a delay line producing a delay difference τ between the 2 arms and with a polarization controller in one of the arms.

c) An **optical receiver** with a 1 dB bandwidth higher than the expected frequency deviation of the optical output signal of the transmitter to be tested.

d) An electrical **spectrum analyzer** with a bandwidth greater than the expected frequency deviation of the optical output signal of the transmitter to be tested.

e) Lengths of **fibre** for connecting the optical equipment.

f) An **optical isolator**, if not embodied in the transmitter, to prevent reflected light from perturbing the lineshape of the transmitter.

g) An **RF voltmeter** with the same input impedance as the optical transmitter to be measured.

4.8.3 General measurement requirements

The delay time τ (identical to the gating time τ of the signal generator) shall be at least three to five times the coherence time of the transmitter to make sure that the combining signals from the two arms of the interferometer are uncorrelated. For DFB lasers, a typical value is τ = 20 ... 50 µs.

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4.8.4 Procedure

a) Connect the equipment as shown in Figure 7.

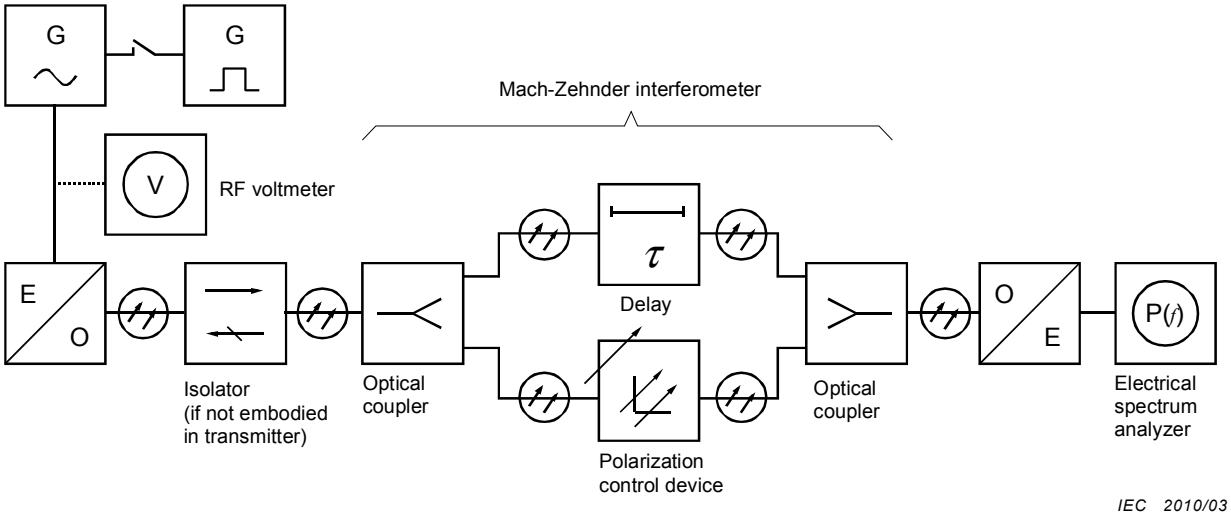


Figure 7 – Measurement of the chirping and the linewidth of transmitters

b) For measuring the linewidth, turn off the signal generator.

c) For measuring chirping, the generator shall be gated on and off as described in 4.8.2. For adjusting the output level of the signal generator, switch it into continuous mode. Replace the transmitter by the RF voltmeter and choose an output level resulting in an optical modulation index of the transmitter in the range of m = 0,5 to 0,7. Note the reading U of the RF voltmeter. Reconnect the optical transmitter and turn on the gating signal.

d) Adjust the polarization controller to maximize the amplitude displayed by the spectrum analyzer.

e) Locate the –3 dB roll-off of the electrical power starting at the lowest frequency of the spectrum shown by the spectrum analyzer.

NOTE If the –3 dB roll-off exceeds the range of the spectrum analyzer, a smaller optical modulation index may be used. Care must be taken to ensure stable operation of the laser.

f) If the signal generator is turned off, the frequency reading at this point represents the linewidth of the transmitter. If the inverse of this linewidth is not lower than the delay time τ, the measurement shall be repeated with a higher delay time.

g) With the signal generator turned on, the spectrum is broadened. The change in frequency reading Δf at the –3 dB point is the total chirping in MHz.

h) The chirping is calculated from

$$f_{\mathrm{C}} = \Delta f \frac{Z}{U} \tag{11}$$

where

f_{C} is the chirping;

Δf is the change in frequency reading (total chirping);

Z is the input impedance of the optical transmitter;

U is the output level of the signal generator.

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4.8.5 Potential sources of error

- This linewidth measurement technique is strictly correct only for transmitters with a Lorentzian lineshape.
- Asymmetric spectra will lead to wrong results.
- Additionally the following features of the equipment can impair the accuracy of the measurement:
  – the inaccuracy of the spectrum analyzer;
  – instability of the transmitter.

4.9 Optical modulation index

4.9.1 Purpose

The purpose of this test method is to measure the individual optical power modulation index (modulation index per channel) of a transmitter under specified conditions. This method is not suitable for measuring the total modulation index of a transmitter modulated by a multi-channel signal.

4.9.2 Equipment required

a) A **selective voltmeter** or spectrum analyzer with a defined input impedance.

b) A **PIN-photodiode** with 1 dB-bandwidth much larger than that of the transmitter to be tested.

c) A **DC power supply** which provides a voltage less than the breakdown voltage of the PIN-diode.

d) A DC current meter.

e) An **RF choke** suitable for the frequencies at which the tests are to be carried out.

f) A terminating **resistor** (50 Ω or 75 Ω), suitable for the frequencies at which the tests are to be carried out, for use when the selective voltmeter or spectrum analyzer has a high input impedance.

g) A low-loss **capacitor** with an impedance much lower than that of the selective voltmeter (spectrum analyzer) at the frequencies at which the tests are to be carried out.

h) A length of **fibre** for connecting the transmitter to the PIN-diode.

NOTE A calibrated receiver may be used instead of the PIN-diode, the RF choke, the resistor and the capacitor if the DC of the detector can be measured.

4.9.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Apply the specified input signal. Connect the equipment as shown in Figure 8.

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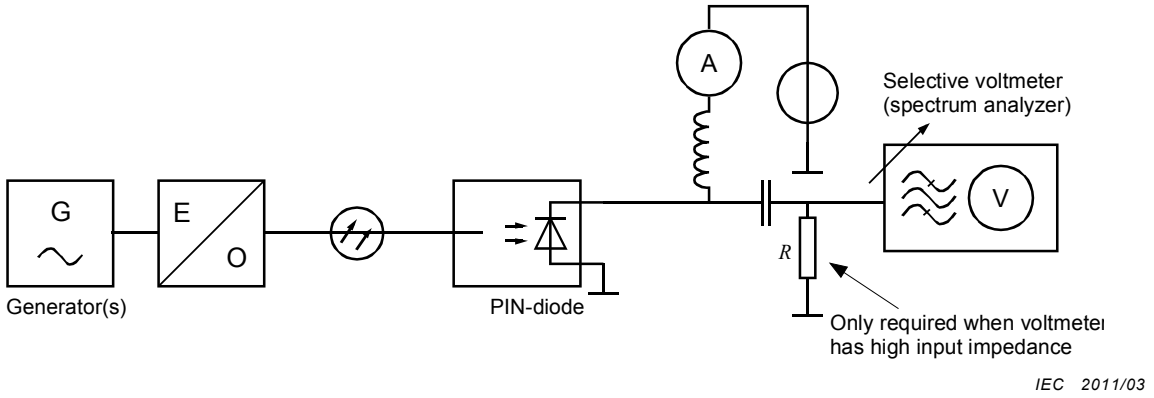


Figure 8 – Measurement of the optical modulation index

c) Tune the selective voltmeter (spectrum analyzer) to the frequency of the channel at which the individual optical modulation index is to be measured.

d) Record the readings of the DC meter and the selective voltmeter (spectrum analyzer). The optical modulation index is calculated from:

$$m = \frac{\sqrt{2}U}{RI} \tag{12}$$

where

I is the reading of the DC meter;

U is the reading of the selective voltmeter (spectrum analyzer);

R is the resistance of the resistor or the input impedance of the selective voltmeter or spectrum analyzer.

4.9.4 Potential sources of error

The following features of the equipment can impair the accuracy of the measurement. A method with higher accuracy is given in 4.19.

- The inaccuracy of the DC meter.
- The inaccuracy of the selective voltmeter (spectrum analyzer).
- The frequency response of the PIN-diode.
- Differences between the static responsivity and the dynamic responsivity of the PIN-diode. A correction factor shall be used for calculating the modulation index in this case.

4.10 Reference output level of an optical receiver

4.10.1 Purpose

The purpose of this test method is to measure the reference output level of a receiver under specified conditions. The reference output level shall be expressed in dB(μV).

4.10.2 Equipment required

a) A suitable **RF generator**.

b) A **transmitter** with known differential efficiency and optical output power compatible with the range of optical input power of the receiver under test.

c) A length of **fibre** for connecting the transmitter to the receiver.

d) A **cladding mode stripper**, if the fibre has no cladding mode stripping coating.

e) An RF voltmeter.

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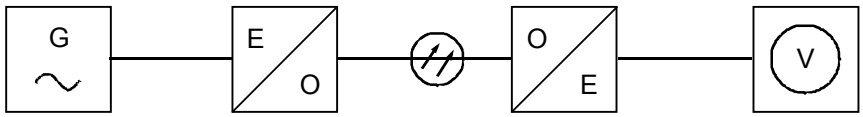
4.10.3 General measurement requirements

- Care shall be taken to ensure that all the optical output power is coupled to the receiver.
- The automatic gain control (AGC) (if any) for the receiver shall be disabled. The gain shall be set to maximum.

4.10.4 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 9.



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Figure 9 – Measurement of the reference output level of an optical receiver

c) Adjust the amplitude of the generator to obtain the optical modulation index required.

d) Measure the RF voltage at the frequencies of interest.

e) The reference output level is calculated from:

$$x = U - 2P_{\text{opt,RX}} - 10\lg\frac{m}{0{,}05} \qquad (13)$$

where

x is the reference output level in dB(μV);

U is the electrical output level in dB(μV);

$P_{\text{opt,RX}}$ is the optical input level in dB(mW);

m is the optical modulation index used for the measurement.

4.10.5 Potential sources of error

Such sources of error are the following:

- the inaccuracy of the voltmeter;
- the attenuation of the fibre and the optical connectors;
- the inaccuracy of the output level of the generator;
- the uncertainty of the characteristic of the transmitter;
- the saturation of the optical receiver when the AGC is disabled.

4.11 Slope and flatness

4.11.1 Purpose

The purpose of this test method is to measure the slope and the flatness of optical transmitters and receivers within a given frequency range under specified conditions. The slope and the flatness shall be expressed in dB.

NOTE The frequency range is usually lower than the 3 dB-bandwidth. The 3 dB-bandwidth is the difference of the lower frequency and the higher frequency where the amplitude vs. frequency response falls to –3 dB of the peak value.

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4.11.2 Equipment required

a) A signal generator with a frequency range greater than the expected range of the device to be tested.

b) An RF voltmeter for the amplitude vs. frequency response.

c) If the device to be tested is a transmitter, an optical receiver with known frequency response (calibrated receiver) is needed. If the device to be tested is a receiver, an optical transmitter with known frequency response (calibrated transmitter) is needed.

d) A length of fibre for connecting the transmitter and the receiver.

NOTE A network analyzer may be used instead of the signal generator and the voltmeter. A spectrum analyzer with tracking generator may also be used. A swept generator with broadband diode detector may be used if all measurements are taken at the same detected signal level by re-adjustment of the generator level to maintain this condition.

4.11.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 10.

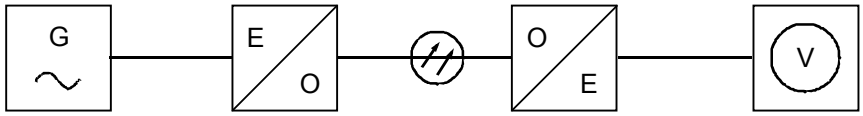


Figure 10 – Measurement of the frequency range and flatness

c) Measure the signal output voltage at a sufficient number of frequencies covering the specified frequency range. The readings shall be corrected by the known frequency response of the respective calibrated device. If the device to be tested is a receiver, the optical input power used during the measurement shall be stated, because the results may vary with the input power.

d) If the device under test is supposed to have a slope, lay a straight line through the measured points using the least square method. Determine the amplitudes A_1 and A_2 at the intersections between this line and the frequency range limits f_l and f_u (see Figure 11). The difference $A_1 - A_2$ shall be stated as the slope of the device.

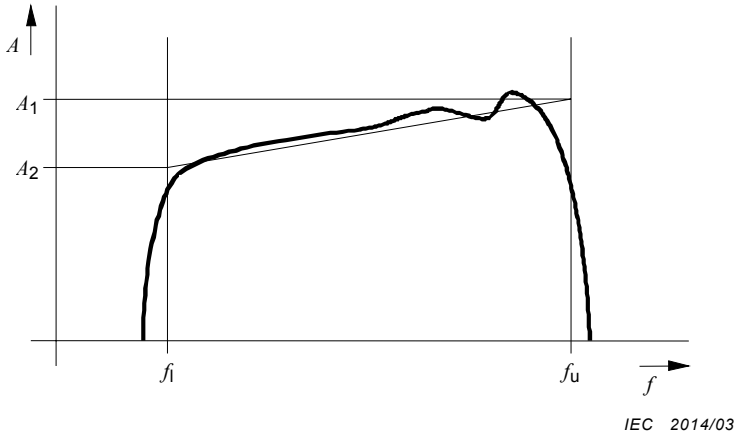


Figure 11 – Evaluation of the slope

e) If the device under test is supposed to have a slope, the amplitudes shall be corrected by the amount of slope at the individual frequencies.

f) Note the peak value A_{max} and the minimum value A_{min} of the resulting frequency response within the frequency range (see Figure 12). The flatness is the difference of A_{max} and A_{min}.

NOTE A_{max} and A_{min} may be the amplitudes at the limits of frequency range.

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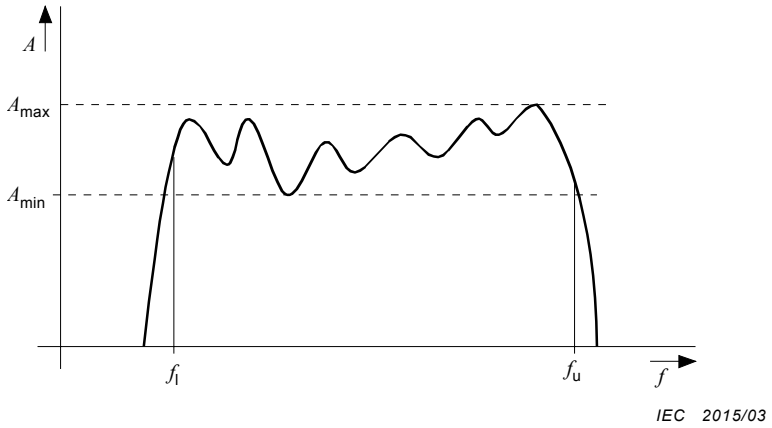


Figure 12 – Evaluating the flatness

4.11.4 Potential sources of error

Such sources of error are the following:

- the inaccuracy of the frequency and the amplitude of the test generator;
- the inaccuracy of the voltmeter;
- the inaccuracy of the calibrated receiver (transmitter);
- the inaccuracy of the measuring equipment mentioned in the note of 4.11.2.

4.12 Composite second order distortion (CSO) of optical transmitters

4.12.1 Purpose

The purpose of this test method is to measure the CSO of optical transmitters modulated by multiple carriers. The definition of CSO is primarily valid for electrical amplifiers but also applies to devices with an optical output. In this case, it is related to the electrical signals which modulate the light. The CSO shall be expressed in dB.

4.12.2 Equipment required

a) All equipment required for measuring CSO of electrical amplifiers (see IEC 60728-3).

b) An **optical receiver** with CSO at least 10 dB better than the CSO expected of the transmitter to be tested. The CSO of optical receivers can be estimated from the results of a receiver intermodulation measurement (see 4.15).

c) A length of **fibre** for connecting the transmitter to the receiver.

d) If the optical output power of the transmitter is higher than the specified input power of the receiver, an **optical attenuator** shall be used to reduce the power.

4.12.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 13.

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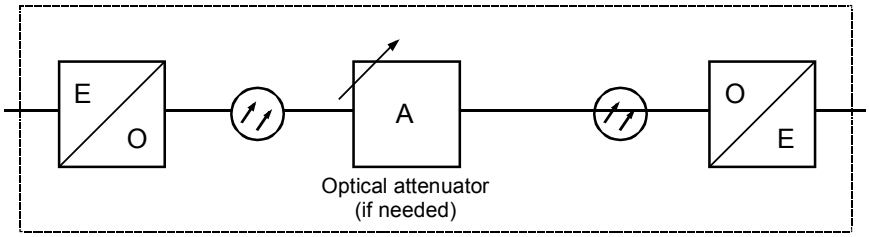


Figure 13 – Device under test for measuring CSO of optical transmitters

c) The device under test shown in Figure 13 provides an electrical input and an electrical output. Therefore, it can be treated as an electrical amplifier. The procedure for measuring CSO (see IEC 60728-3) can be used for this arrangement. The result is the figure which shall be given as the CSO of the optical transmitter.

d) To make sure that the distortion of the receiver can be neglected, a second measurement shall be carried out with a different attenuation between the optical transmitter and the optical receiver. If the result changes, it indicates that the receiver distortion is too high.

4.12.4 Potential sources of error

The figure measured is the CSO of the whole optical system. The influence of the optical receiver can be neglected only if its CSO is much better than that of the transmitter, but there is no direct way of measuring the CSO of an optical receiver. It can only be estimated from the results of an intermodulation measurement. This estimate is not very accurate, because the laws of addition of the beats are frequency-dependent and not well-known.

4.13 Composite triple beats (CTB) of optical transmitters

4.13.1 Purpose

The purpose of this test method is to measure the CTB of optical transmitters modulated with multiple carriers. The definition of CTB is primarily valid for electrical amplifiers but also applies to devices with an optical output. In this case, it is related to the electrical signals which modulate the light. The CTB shall be expressed in dB.

4.13.2 Equipment required

a) All equipment required for measuring CTB of electrical amplifiers (see IEC 60728-3).

b) An **optical receiver** with CTB at least 15 dB better than the CTB expected for the transmitter to be tested. The CTB of optical receivers can be estimated from the results of a receiver intermodulation measurement (see 4.15).

c) A length of **fibre** for connecting the transmitter to the receiver.

d) If the optical output power of the transmitter is higher than the specified input power of the receiver, an **optical attenuator** shall be used to reduce the power.

4.13.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 14.

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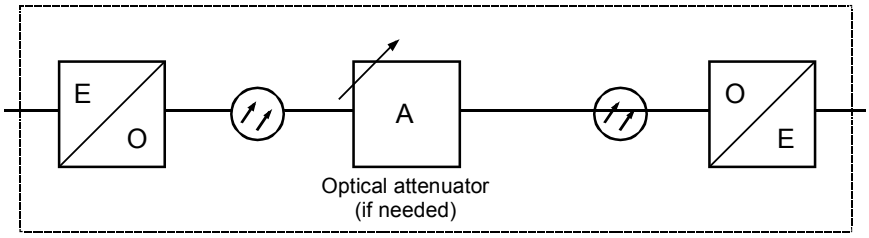


Figure 14 – Device under test for measuring CTB of optical transmitters

c) The test configuration shown in Figure 14 provides an electrical input and an electrical output; it can therefore be treated as an electrical amplifier. The procedure for measuring CTB (see IEC 60728-3) can be used for this arrangement. The result is the figure which shall be given as the CTB of the optical transmitter.

d) To make sure that the distortion of the receiver can be neglected, a second measurement shall be carried out with a different attenuation between the optical transmitter and the optical receiver. If the result changes, it indicates that the receiver distortion is too high.

4.13.4 Potential sources of error

The figure measured is the CTB of the whole optical system. The influence of the optical receiver can be neglected only if its CTB is much better than that of the transmitter, but there is no direct way of measuring the CTB of an optical receiver. It can only be estimated from the results of an intermodulation measurement. This estimate is not very accurate, because the laws of addition of the beats are frequency-dependent and not well-known.

4.14 Composite crossmodulation of optical transmitters

4.14.1 Purpose

The purpose of this test method is to measure the composite crossmodulation of optical transmitters modulated with multiple carriers. The definition of composite crossmodulation is primarily valid for electrical amplifiers but also applies to devices with an optical output. In this case, it is related to the electrical signals which modulate the light. The crossmodulation shall be expressed in dB.

NOTE The method described in IEC 60728-3 for active coaxial equipment is not applicable to optical equipment.

4.14.2 Equipment required

a) **Signal generators** covering the appropriate vision carrier frequencies as listed in Annex C of IEC 60728-3, all having the required modulation facilities, and linearity at the depth of modulation to be used.

NOTE It is recommended that the modulation frequency approximate the line scan frequency of the TV signals in order to include effects which may be caused by the low frequency circuits (e.g. decoupling) in the equipment to be tested. The modulation frequency should not be a multiple of the power supply frequency. Any symmetrical modulation waveform (excluding pulse modulation) may be used providing the same signal generator is used for both calibration and measurement, and the modulation depth and waveform remain the same.

b) A modulating voltage **generator** of sufficient output to provide common modulation of the signal generators in item a).

c) A **combiner, matching device, attenuators, filters**, etc. to obtain the correct signal levels, matching and reduction of spurious signals.

d) A **spectrum analyzer** with 1 kHz IF bandwidth and 10 Hz video bandwidth capability.

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e) A **bandpass filter** for each channel to be tested or a tuneable bandpass filter. This filter shall attenuate the other channels present on the system to be tested sufficiently to ensure that the products generated by non-linearity in the spectrum analyzer itself do not contribute significantly to the crossmodulation products to be measured. The passband of this filter shall be flat at least to within 1 dB over the frequency range of interest, and shall be well-matched over the complete frequency band. If necessary, a fixed attenuator shall be connected to the input of the filter.

f) An **optical receiver** with high linearity.

g) A length of **fibre** for connecting the transmitter to the receiver.

h) If the optical output power of the transmitter is higher than the specified input power of the receiver, an **optical attenuator** shall be used to reduce the power.

4.14.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 15.

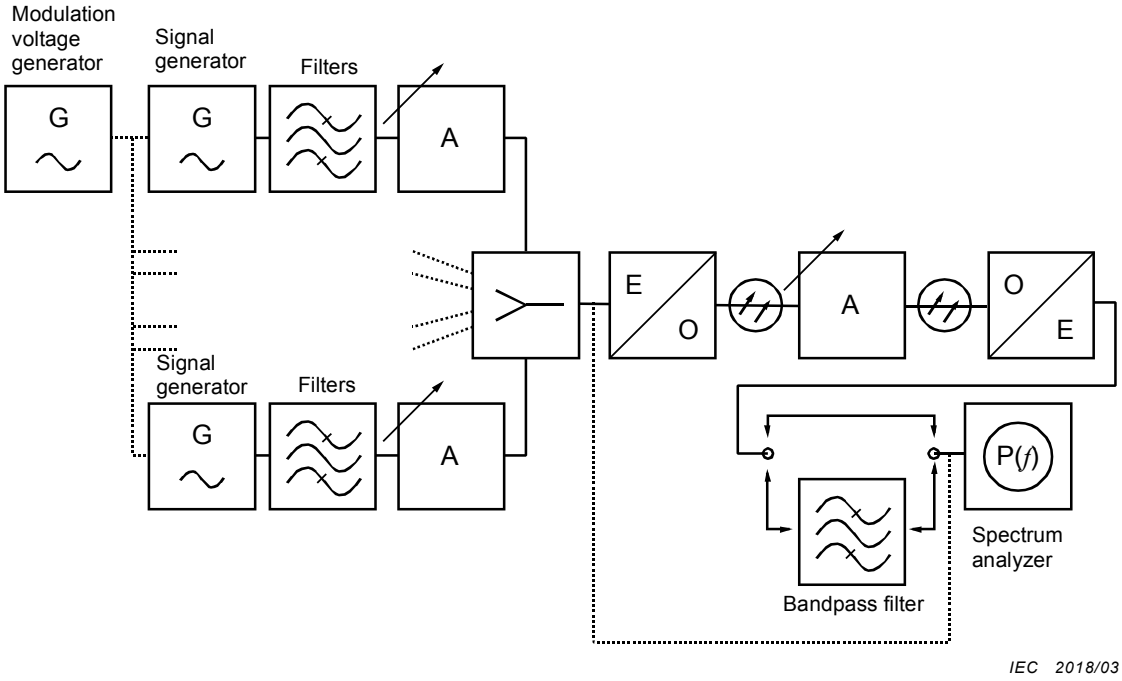


Figure 15 – Arrangement for measuring composite crossmodulation of optical transmitters

c) Connect the output of the RF combiner to the input of the spectrum analyzer.

d) Select each signal generator in turn, set the modulation depth and adjust the output to give the RF peak level needed to obtain the specified input level for the optical transmitter to be tested.

e) Connect the output of the optical receiver to the spectrum analyzer.

f) Adjust the spectrum analyzer as follows:

IF bandwidth	1	kHz
Video bandwidth	10	Hz
Horizontal scale	5	kHz/div
Vertical scale	10	dB/div
Scan time	5	s/div

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g) Tune the spectrum analyzer to the channel on which the measurement is to be made so as to display the vision carrier and a frequency range of 25 kHz on either side of the carrier.

h) Switch off all other channels and switch on the modulation of the channel to be measured.

i) Insert the bandpass filter corresponding to the channel to be measured and adjust the input attenuator to correct for the attenuation of the filter.

NOTE When using a spectrum analyzer with minimum video filtering capabilities greater than 10 Hz, the composite crossmodulation may be noisy and should be read at the middle of the trace.

j) Adjust the sensitivity of the spectrum analyzer together with its internal and/or external input attenuators in such a way that the responses to the first sidebands, approximately 15 kHz on either side of the vision carrier, correspond to a full scale reference. At the same time, the noise level shall be at least 10 dB lower than the distortion level expected.

k) Switch off the modulation of the wanted carrier and switch on all the other carriers.

l) Switch on the modulation of every second one of the other carriers.

m) Measure the amplitude of the sidebands on either side of the wanted carrier caused by the total composite crossmodulation transfer. The difference in dB between the full scale reference and the largest of the sidebands, corrected as in Table 2 of IEC 60728-3 to obtain the ratio referred to 100 % modulation, shall be noted.

n) Repeat the previous step with the modulation of the previously modulated carriers turned off and the modulation of the other half of the unwanted carriers turned on.

o) The composite total crossmodulation can be calculated from:

$$XM = 20 \lg \left(10^{\frac{XM_1}{20}} + 10^{\frac{XM_2}{20}} \right) \qquad (14)$$

where

XM_1 is the first measured value, in dB;

XM_2 is the second measured value, in dB.

p) Repeat steps g) to o) of this procedure, each time selecting a different wanted signal, until all channels used in this test have been selected.

q) To make sure that the distortion of the receiver can be neglected, a second measurement shall be carried out with a different attenuation between the optical transmitter and the optical receiver. If the result changes, it indicates that the receiver distortion is too high.

r) The worst case maximum output level giving the required signal to composite total crossmodulation ratio shall be noted for publication.

4.14.4 Potential sources of error

The figure measured is the composite crossmodulation of the whole optical system. The influence of the optical receiver can be neglected only if its crossmodulation is much better than that of the transmitter, but there is no direct way of measuring the crossmodulation of an optical receiver. The only way to make sure that the receiver has no influence on the result is to repeat the measurement several times with different optical levels at the receiver's input.

4.15 Receiver intermodulation

4.15.1 Purpose

This method is applicable to the measurement of the carrier to second and third-order intermodulation products and triple beats produced in optical receivers with high linearity. The method described is not applicable to coherent receivers. The intermodulation shall be expressed in dB.

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4.15.2 Equipment required

a) Two **signal generators** for second and third-order intermodulation and three signal generators for triple beats covering the frequencies at which the tests are to be carried out.

b) Two **transmitters** with similar optical output power but slightly different wavelengths. The difference of the frequencies of the emitted light shall be greater than the bandwidth of the receiver to be tested.

c) An **optical coupler** with similar loss in both paths.

d) Two **variable optical attenuators** with a range great enough to cover the range of the optical input power of the receiver to be tested.

e) A **variable electrical attenuator** with a range greater than the signal-to-intermodulation ratio expected.

f) A **selective voltmeter** covering the frequency range of the receiver to be tested.

g) Lengths of **fibre** for connecting the transmitters to the coupler and the coupler to the receiver.

4.15.3 General measurement requirements

a) Unless otherwise required, the reference levels used in the measurements shall be the normal operating levels specified for the receiver. If the specified levels are not constant over the frequency range then the levels of all the test signals shall be quoted in the results.

b) Where the receiver to be measured includes automatic level control (ALC) pilot signals of the correct type, frequency and level shall be maintained throughout the tests.

4.15.4 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 16.

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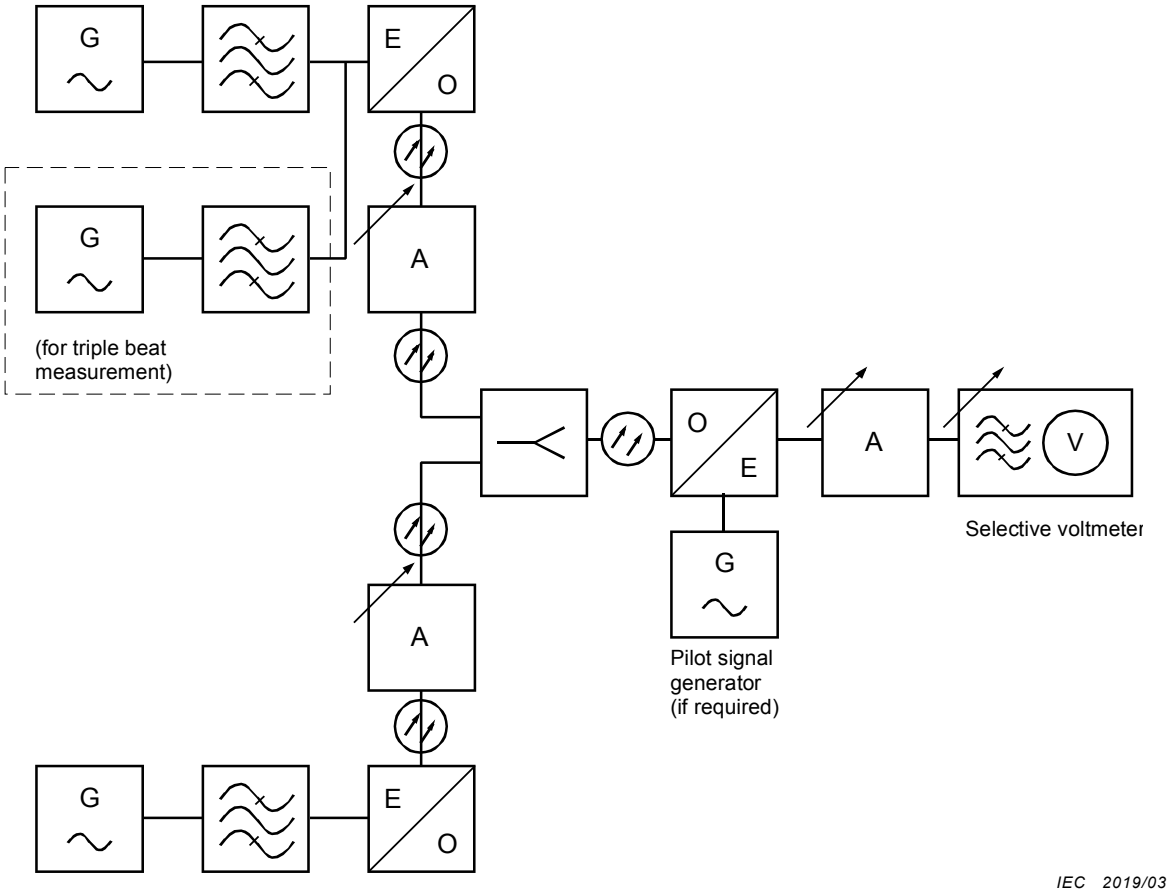


Figure 16 – Arrangement of test equipment for measuring receiver intermodulation

c) Carry out measurements with the test signals widely and closely spaced over each band of interest at frequencies capable of producing significant products within the overall frequency range.

d) Carry out measurements over the full specified range of optical input power of the receiver.

e) Adjust the optical attenuators to obtain the same optical level at the output of the optical coupler for both transmitters.

f) A check should be made to determine if harmonics and other spurious signals at the outputs of the signal generators are likely to affect materially the results of the measurements.

g) Set the signal generators to the frequencies of the test signals and adjust their outputs to obtain a modulation index of m = 0,4 per carrier for both transmitters. With three generators for triple beat measurements a modulation index of m = 0,3 per carrier shall be used.

h) Connect the variable attenuator and selective voltmeter to the point of measurement. Tune the meter to each test signal and note the attenuator value a_1 required to obtain a convenient meter reading R for the reference signal. The attenuator value a_1 should be slightly greater than the signal to intermodulation product ratio expected at the point of measurement.

i) Tune the meter to the intermodulation product to be measured and reduce the attenuator setting to the value a_2 required to obtain the same meter reading R.

j) When using three carriers, care shall be taken that the intermodulation products of the transmitter with two carriers do not coincide with the intermodulation products to be measured.

k) When measuring levels of intermodulation products, it may be necessary to insert a filter at the input to the meter (see Appendix B of IEC 60728-3). In such instances the insertion loss (in dB) of the filter at the frequency of the products shall be added to the attenuator value a_2.

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l) The signal to intermodulation product ratio, in dB, is given by

$$S/I = a_1 - a_2 \quad (15)$$

where

a_1 is the attenuator value for the test signal used as a reference, in dB;

a_2 is the attenuator value for the intermodulation product, in dB.

4.15.5 Potential sources of error

Such sources of error are the following:

- the inaccuracy of the selective voltmeter;
- the inaccuracy of the filter attenuation;
- the inaccuracy of the variable attenuator;
- the inaccuracy of the modulation index.

4.16 CSO of optical amplifiers

Under consideration.

4.17 CTB of optical amplifiers

Under consideration.

4.18 Carrier-to-noise ratio

4.18.1 Purpose

The purpose of this test method is to measure the carrier-to-noise ratio of optical transmitters and receivers.

In passing through an analogue transmission system the carrier-to-noise ratio of a given input signal C/N_{in} is deteriorated by internal noise sources N_i (see Figure 17).

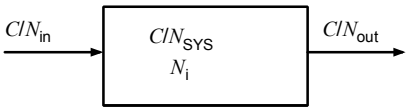


Figure 17 – System with internal noise sources

The magnitude of this noise can also be expressed as a carrier-to-noise ratio C/N_{SYS}. C/N_{SYS} is equivalent to the carrier-to-noise ratio of the output signal with a noise-free input signal. It can be calculated from measured carrier-to-noise ratios at the input and the output of the system.

$$C/N_{SYS} = -10 \lg \left(10^{-\frac{1}{10} C/N_{in}} - 10^{-\frac{1}{10} C/N_{out}} \right) \quad (16)$$

In optical transmission systems both the transmitter and the receiver contribute to the noise of the system. Because of the different kind of signals, there is no direct way of measuring the carrier-to-noise ratio for the transmitter or the receiver independently. Therefore, the individual figures have to be calculated from system measurements using a receiver with known noise behaviour for obtaining the transmitter noise, and vice versa. The carrier-to-noise ratio shall be given in dB at a system bandwidth of B = 4,75 MHz.

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4.18.2 Equipment required

a) A **spectrum analyzer** with a known noise bandwidth less than that of the channel to be measured.

b) A **CW signal generator** covering the frequencies at which the tests are to be carried out. The amplitude of the generator shall be adjustable to obtain an optical modulation index of m = 0,2.

c) A **variable attenuator** with a range greater than the carrier-to-noise ratio expected.

d) An **optical attenuator** with a range great enough to accomplish the following tasks: testing the transmitter, the optical attenuator is used to adjust the received optical power to the specified range of the receiver. Testing the receiver, the optical attenuator is used to measure the carrier-to-noise ratio as a function of the optical input power.

e) A **reference receiver** (Figure 18) for testing an optical transmitter or a reference transmitter for testing an optical receiver.

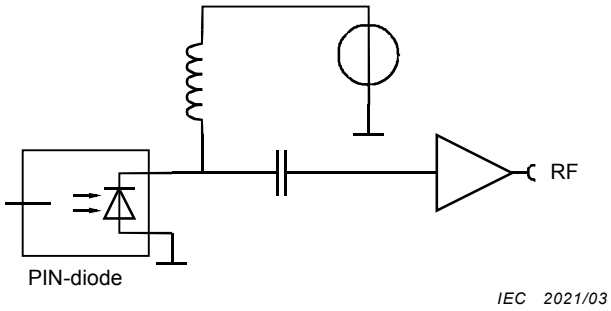


Figure 18 – PIN diode receiver

4.18.2.1 Reference transmitter

Using a laser for the transmitter, the noise is caused by fluctuations of the light output power. It depends on the modulation frequency and can be described by the relative intensity noise (RIN). It can be easily converted to a carrier-to-noise ratio:

$$C / N_{\mathrm{TX}} = 10 \lg \frac{m^2}{2B} - RIN \qquad (17)$$

where

m is the optical modulation index;

RIN is the relative intensity noise in dB(Hz^{-1});

B is the bandwidth in Hz.

4.18.2.2 Reference receiver

Since the noise behavior of a PIN-diode receiver is well-known, it can be used as a reference receiver. One part of the receiver noise is the photodiode shot noise. The other part of the receiver noise is the available thermal noise of the following amplifier. The carrier-to-noise ratio of a PIN-diode receiver can be calculated:

$$C / N_{\mathrm{RX}} = 10 \lg \left(\frac{m^2 P_0^2 r^2}{2B(2erP_0 + I_{\mathrm{r}}^2)} \right) \qquad (18)$$

where

m is the optical modulation index;

P_0 is the optical power incident on the photodiode in W;

r is the responsivity of the photodiode in A/W;

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B is the bandwidth in Hz;

e is $1{,}6 \times 10^{-19}$ As (charge of an electron);

I_r is the effective spectral noise current density of the amplifier in A/√Hz.

NOTE Additional items may be necessary, for example, to ensure correct calibration and operation of the test equipment (see IEC 60728-1).

4.18.3 General measurement requirements

a) The test set-up shall be well-matched (electrically and optically) and the sensitivity of the measuring equipment (see IEC 60728-1) shall be well-known over the frequency range of the channel to be measured. The optical return loss shall be better than that allowed by the specification of the transmitter.

b) Where the system to be measured includes automatic level control (ALC), pilot signals of the correct type and frequency and level shall be maintained throughout the tests.

c) The spectrum analyzer shall be calibrated and checked for satisfactory operation.

4.18.4 Procedure

a) The method for measuring the carrier-to-noise ratio of analogue optical transmission systems is nearly the same as for cabled distribution systems (see IEC 60728-1). In this case, the system under test consists of an optical receiver connected to an optical transmitter via an optical attenuator (see Figure 19).

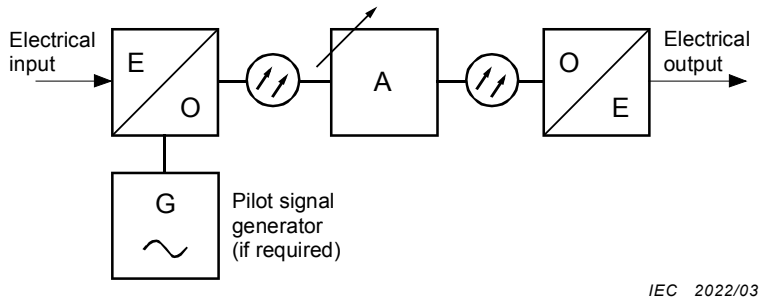


Figure 19 – Optical transmission system under test

b) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

c) Connect the equipment as shown in Figure 20.

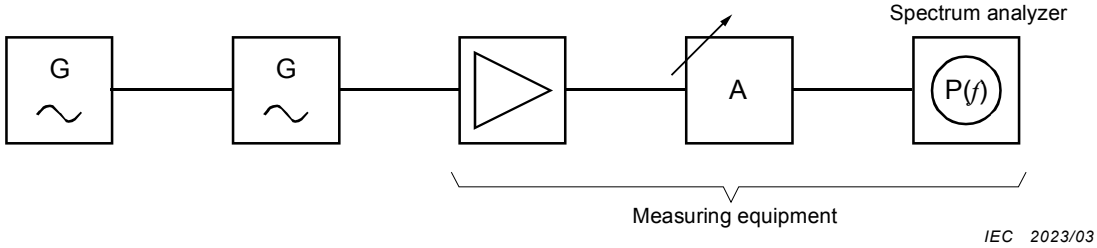


Figure 20 – Arrangement of test equipment for carrier-to-noise measurement

d) Set the signal generator to the carrier frequency of the channel to be tested. The amplitude of the signal generator shall be set to obtain a modulation index of m = 0,2. The result of this measurement might be extrapolated to other modulation indices using Equation 19.

e) Connect the output of the system under test to the variable attenuator and the spectrum analyzer.

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f) Adjust the spectrum analyzer as follows:

IF bandwidth (3 dB)	10	kHz
Video bandwidth	30	Hz
Horizontal scale	200	kHz/div
Vertical scale	10	dB/div
Scan time	2	s/div
Set 'low noise' measurement (if this option is available)		

The carrier-to-noise ratio of the system in dB is given by

$$C/N_{SYS} = m_{delta} - C_b + C_a - C_n \quad (19)$$

where

m_{delta} is the delta marker level;

C_a is the analyzer correction factor;

C_b is the bandwidth correction factor;

C_n is the noise correction factor.

The bandwidth correction factor C_b for the system is given by

$$C_b = 10 \lg[(BW)_{IF} / (BW)_{SYS}] \quad (20)$$

where

$(BW)_{IF}$ is the bandwidth of the spectrum analyzer in MHz;

$(BW)_{SYS}$ is the bandwidth of the system assumed to be 4,75 MHz.

The analyzer correction factor C_a is typically 2,5 dB (it accounts for the correction of 1,05 dB due to the narrowband envelope detection and the 1,45 dB due to the logarithmic amplifier).

If the spectrum analyzer offers the option to measure phase noise (marker noise), the C/N ratio can be read directly in dB(Hz^{-1}). This value has still to be referred to the system bandwidth.

$$C/N_{SYS} = C/N_{meas} - C_n \quad (21)$$

NOTE In most cases, this measurement option of the spectrum analyzer includes the correction factor C_a, so it does not have to be considered any further.

When making the noise level contribution of the measuring equipment, noise can be taken into account reducing the measured noise level by an amount given by the noise correction factor C_n indicated in Table 1 that depends on the difference D between the measure noise level N_m measured when the measuring equipment is connected to the system under test and the noise level N_{eq} measured when the input of the measurement equipment is terminated on its characteristic impedance.

Firstly calculate the difference D:

$$D = N_m - N_{eq} \quad (22)$$

Then read the noise correction factor C_n from Table 1. If the level difference D is lower than 4 dB the reliability of the measurements becomes very low due to the high value of the correction factor C_n.

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Table 1 – Noise correction factors C_n for different noise level differences D

D in dB	4,0	5,0	6,0	7,0	8,0	9,0	10,0
C_n in dB	2,20	1,65	1,26	0,97	0,75	0,58	0,46

According to equation 16, the carrier-to-noise ratios of the transmitter and the receiver can be calculated from the measured carrier-to-noise ratio of the whole system:

a) for the receiver

$$C/N_{RX} = -10 \lg\left(10^{-\frac{1}{10}C/N_{SYS}} - 10^{-\frac{1}{10}C/N_{TX}}\right) \quad (23)$$

b) for the transmitter

$$C/N_{TX} = -10 \lg\left(10^{-\frac{1}{10}C/N_{SYS}} - 10^{-\frac{1}{10}C/N_{RX}}\right) \quad (24)$$

where

C/N_{SYS} is the measured C/N of the system;

C/N_{TX} is the C/N of the transmitter;

C/N_{RX} is the C/N of the receiver.

4.18.5 Potential sources of error

Such sources of error are the following:

- the inaccuracy and the calibration of the selective voltmeter;
- the inaccuracy of the variable attenuator;
- the method actually determines carrier (plus noise)-to-noise ratio; however, the difference between this and the carrier-to-noise ratio is very small if the value exceeds 15 dB. The method assumes that the random noise is evenly distributed within the channel.

4.19 Method for combined measurement of relative intensity noise (RIN), optical modulation index and equivalent input noise current

4.19.1 Purpose

With this method the relative intensity noise and the optical modulation index of the transmitter as well as the equivalent input noise current of the receiver can be calculated from the noise measurement of the complete optical system.

The noise of an optical system consisting of a transmitter and a PIN-diode receiver is determined by the following noise sources:

- the relative intensity noise of the transmitter;
- the shot noise of the PIN-diode of the receiver;
- the effective spectral input noise current of the optical receiver, which includes all receiver-related noise sources excluding shot noise.

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Knowing the appropriate quantities, the carrier-to-noise ratio for the whole system can be calculated from

$$C/N = 20\lg m - 10\lg 2B - 10\lg\left(10^{-\frac{1}{10}RIN} + \left(\frac{2e}{rP_{\text{opt}}} + \frac{I_{\text{r}}^2}{r^2 P_{\text{opt}}^2}\right)\right) \quad (25)$$

where

RIN is the relative intensity noise in dB(Hz^{-1});

m is the optical modulation index;

P_{opt} is the optical power incident on the photodiode in W

r is the responsivity of the photodiode in A/W

B is the bandwidth in Hz

e is $1{,}6 \times 10^{-19}$ As (charge of an electron)

I_{r} is the effective spectral noise current density in A/√Hz

With known responsivity r, the values of RIN, m and I_{r} can be extracted from a sufficiently large set of measurements of C/N vs. P_{opt} using methods of curve fitting.

4.19.2 Equipment required

a) A **DC meter** with a range suitable for the currents of the photodiode of the receiver.

b) A **selective voltmeter** with a known noise bandwidth less than that of the channel to be measured.

c) A **CW signal generator** or a multi-carrier signal generator covering the frequencies at which the tests are to be carried out. The amplitude of the generator(s) shall be adjustable so that the sum of the individual modulation indices exceeds 0,2.

d) A **variable attenuator** with a range greater than the carrier-to-noise ratio expected.

e) An **optical attenuator** with a range great enough to adjust the received optical power to the specified range of the receiver.

f) An **optical power meter** with a range suitable for the expected power. The detector system of the power meter shall have a sufficiently large area to collect all the radiation from the fibre and a spectral sensitivity compatible with the transmitter. A minimum accuracy of ±10 % is recommended.

g) Two lengths of **fibre** for connecting the equipment.

4.19.3 General measurement conditions

For this measurement, a total optical modulation index of at least m = 0,2 shall be used to avoid instability of the transmitter.

4.19.4 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 21.

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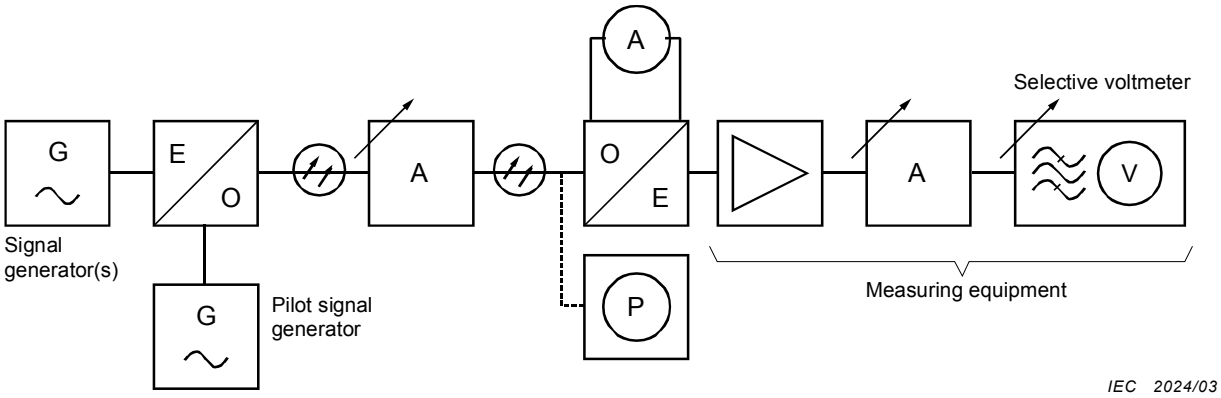


Figure 21 – Measurement set-up for determination of the noise parameters and the optical modulation index

c) Adjust the optical attenuator to an output level suitable for the optical receiver.

d) Record the reading P_1 of the optical power meter.

e) After replacing the optical power meter by the optical receiver, measure the current I_1 of the photodiode.

f) Reconnect the optical power meter and adjust the optical attenuator to a different optical power P_2.

g) Replace the optical power meter by the optical receiver and measure the current I_2 of the photodiode.

h) The responsivity of the photodiode can be calculated by

$$r = \frac{I_2 - I_1}{P_2 - P_1} \tag{26}$$

i) Connect the variable attenuator and selective voltmeter (and other items if required – see IEC 60728-1) to the output of the receiver.

j) As described in 4.18 a set of (5 to 15) C/N-measurements shall be carried out over the range of the optical input power of the receiver.

k) The values for RIN, m and I_r can be extracted from the measurements by methods of curve fitting to equation 25.

4.19.5 Potential sources of error

The following features of the test equipment can impair the accuracy of the measurement:

- the inaccuracy and the calibration of the selective voltmeter;
- the inaccuracy of the variable attenuator;
- the inaccuracy of the power meter;
- the attenuation of the fibre and the optical connectors.

NOTE Statistical errors will be averaged depending on the number of measurements carried out.

4.20 Noise figure of optical amplifiers

For measuring the noise figure of optical amplifiers, the method described in IEC 61290-3-2 shall be used, because for modulated RF carrier systems, the total noise figure must be measured. For measuring the linewidth of the source (see 5.1 of IEC 61290-3-2) the method of 4.8 of this standard can be used.

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4.21 Influence of fibre

4.21.1 Purpose

Fibres influence the system performance of optical transmission systems through dispersion and other effects. This can result in a decrease of bandwidth and carrier-to-noise ratio and under certain circumstances leads to poor linearity of the systems. The purpose of this test method is to measure the influence of fibre on the performance of optical transmission systems.

4.21.2 Equipment required

a) A length of **test fibre** corresponding in length and type to the specification of the transmitter. If no fibre type is specified by the manufacturer, standard G.652 fibre shall be used.

b) All equipment necessary to carry out measurements of C/N (see 4.18) and CSO (see 4.12)

4.21.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the fibre to the transmitter.

c) Repeat the measurements for C/N (see 4.18) and CSO (see 4.12) substituting the fibre at the output of the transmitter by this test fibre.

4.21.4 Potential sources of error

The following features of the test equipment can impair the accuracy of the measurement (see 4.18 and 4.12).

4.22 SBS threshold

4.22.1 Purpose

Stimulated Brillouin scattering limits the maximum optical power which can be launched into the fibre. The threshold at which the SBS effect starts to influence the carrier-to-noise ratio of the optical transmission system depends on the spectrum of the transmitter and the fibre properties. The purpose of this test method is to measure this threshold under specified conditions. The SBS threshold shall be expressed in dB(mW). Guidelines to accommodate and utilize non-linear effects in single mode fibre optic systems is published as IEC 61282-4.

4.22.2 Equipment required

a) All equipment necessary to carry out C/N measurements for optical transmitters (see 4.18).

b) A length of **test fibre** corresponding in length and type to the specification of the transmitter. If no fibre type is specified by the manufacturer, standard G.652 fibre shall be used.

c) An **optical amplifier** suitable for the transmitter to be tested. The output power of this amplifier shall be higher than the expected SBS threshold plus the minimum attenuation of the second variable attenuator and the attenuation of the optical filter (see below).

d) An **optical filter** suited for the wavelength of the transmitter suppressing the ASE of the optical amplifier in order to prevent spontaneous-spontaneous beat noise at the receiver.

e) A second **variable optical attenuator** able to attenuate the output power of the optical amplifier below P = 3 dB(mW).

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4.22.3 Procedure

a) Set the supply voltage(s) and any control input signal(s) to the specified value(s).

b) Connect the equipment as shown in Figure 22.

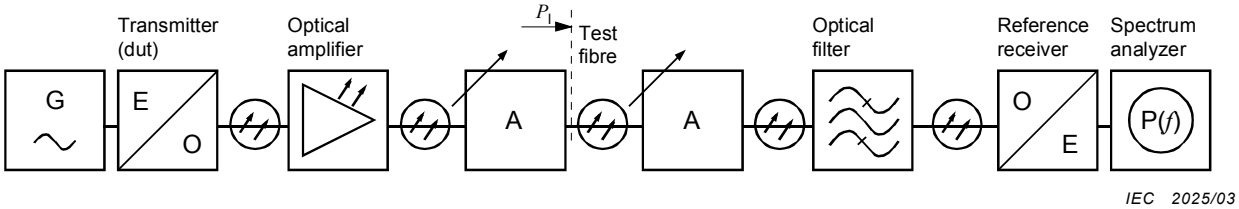


Figure 22 – Arrangement for measuring the SBS threshold

c) Adjust the optical power launched into the fibre to below P_I = 3 dB(mW) using the left variable attenuator. The other variable attenuator shall be adjusted to an output power level suitable for the optical receiver. This level should be close to the upper limit of the input power range of the receiver to obtain a high carrier-to-noise ratio.

d) Carry out a C/N measurement (see 4.18).

e) Increase the launched power P_I in a suitable step (e.g. +1 dB) using the left attenuator. Increase the attenuation of the right attenuator by the same amount of which the left attenuation was reduced to make sure that the optical receiver gets the same optical input power again.

f) Repeat steps d) and e) until the carrier-to-noise ratio measured dropped by more than 0,5 dB. The optical power launched into the fibre at this point is the SBS threshold.

4.22.4 Potential sources of error

The following features of the test equipment can impair the accuracy of the measurement:

- see 4.18.5;
- the inaccuracy of the variable attenuators;
- any instability of the optical amplifier.

5 Universal performance requirements and recommendations

5.1 Safety

The relevant safety requirements of all equipment shall conform to IEC 60728-11, where applicable.

5.2 Electromagnetic compatibility (EMC)

The limits of radiation and susceptibility to interference for all equipment covered by this standard are laid down in IEC 60728-2.

5.3 Environmental

Manufacturers shall publish relevant environmental information on their products in accordance with the requirements of IEC 60068-2:

5.3.1 Storage

Storage (simulated effects of) IEC 60068-2-48

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5.3.2 Transportation

Air freight (combined cold and low pressure)	IEC 60068-2-40
Road transport (bump test)	IEC 60068-2-29
Road transport (shock test)	IEC 60068-2-27

5.3.3 Installation or maintenance

Topple or drop test	IEC 60068-2-31
Free fall test	IEC 60068-2-32

5.3.4 Operation

IP Class. Protection provided by enclosures	IEC 60529
Climatic category of component or equipment for storage and operation as defined in	Appendix A of IEC 60068-1
Cold	IEC 60068-2-1
Dry heat	IEC 60068-2-2
Damp heat	IEC 60068-2-30
Change of temperature (test Nb)	IEC 60068-2-14
Vibration (sinusoidal)	Appendix B of IEC 60068-2-6

This will enable users to judge the product's suitability with regard to four main requirements: storage, transportation, installation and operation.

5.4 Marking

Each equipment shall be legibly and durably marked with the manufacturer's name and type number.

It is recommended that symbols in accordance with IEC 80416 and IEC 60417 are used when marking ports.

6 Active equipment

6.1 Optical downlink transmitters

Optical downlink transmitters used in the forward path (from the headend to the subscriber) are classified into 6 performance classes to take different applications into account. These classes are numbered AD to FD.

6.1.1 Data publication requirement

Manufacturers shall at least publish information on the following parameters. Given figures are recommended values.

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Table 2 – Data publication requirements for optical downlink transmitters

Parameter	Classes AD to DD	Classes ED and FD
Type of light source	For example Fabry-Perot- or DFB laser diode, cooled or not cooled	
Output power in dB(mW) and its tolerance – without optical amplifier – with optical amplifier	 >3 dB(mW) -	 >5 dB(mW) >13 dB(mW)
RF input level	Maximum level at which the performance requirements according to 6.1.3 can be met	
Fibre connection	Connector/splice type and type of fibre	
Power consumption	-	

6.1.2 Recommendations

The manufacturer shall at least publish information on parameters deviating from the following recommendations.

Table 3 – Recommendations for optical downlink transmitters

Parameter	Classes AD to FD
Frequency range	47 to 862 MHz
RF input level to obtain a modulation index of m = 0,05	87 dB(μV)
Supply voltage	One of the following: DC 48 V / 120 V or AC 65 V / 230 V
Alarms and indicators	Optical output level failure and divergence from nominal temperature range
Mechanical dimensions	For operation in buildings: 19" rack mountable

6.1.3 Performance requirements

Optical downlink transmitters according to this standard shall fulfil the requirements of one of the following classes given below in Table 4.

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Table 4 – Requirements for optical downlink transmitters

Parameter	Class AD	Class BD	Class CD	Class DD	Class ED	Class FD
C/N						
– without optical amplifier	>55 dB	>55 dB	>53 dB	>51 dB	>60 dB	>59 dB
– with optical amplifier	-	-	-	-	>57,5 dB	>56,5 dB
CSO	>63 dB	>60 dB	>60 dB	>60 dB	>63 dB	>65 dB
CTB	>68 dB	>65 dB	>65 dB	>65 dB	>63 dB	>65 dB
Influence of fibre:						
C/N degradation	-	-	-	-	<2,5 dB	
CSO degradation	-	-	-	-	<2 dB	
SBS threshold	-	-	-	-	>13 dB(mW)	
At a fibre length of	-	-	-	-	65 km	
Wavelength	1310 nm ± 10 nm				1555 nm ± 5 nm or ITU G.692-grid	
Electrical input port	Impedance: 75 Ω Connector: IEC 60169-2 female or IEC 60169-24 Return loss: according to category B defined in IEC 60728-3					
Optical output port	Any high return loss connector (return loss > 50 dB)					
Flatness	<1 dB					
Minimum optical return loss of the system to be tolerated (discrete reflections only)	45 dB				55 dB	
Test point output for checking the actual modulation index	It shall be specified which voltage is needed at this test point to achieve a modulation index of m = 20%					
Indicators	A laser “on” indicator, indicating when light is emitted Laser operating out of range (current and/or temperature)					
Alarms	Output power failure Out of temperature range (for cooled lasers only)					
Mean operating time between failure (MTBF)	Under consideration					

NOTE 1 C/N, CSO and CTB are specified at the same optical index and with the operating carriers. The modulation index should be published (see 6.1.1). The minimum modulation index accepted for this specification should be m = 0,04.

NOTE 2 C/N may be calculated from the RIN by equation 17 in 4.18.2.1.

6.2 Optical uplink transmitters

Optical uplink transmitters used in the return path (from the subscriber to the headend) are classified according to Figure 23. These classes are numbered AR to GR.

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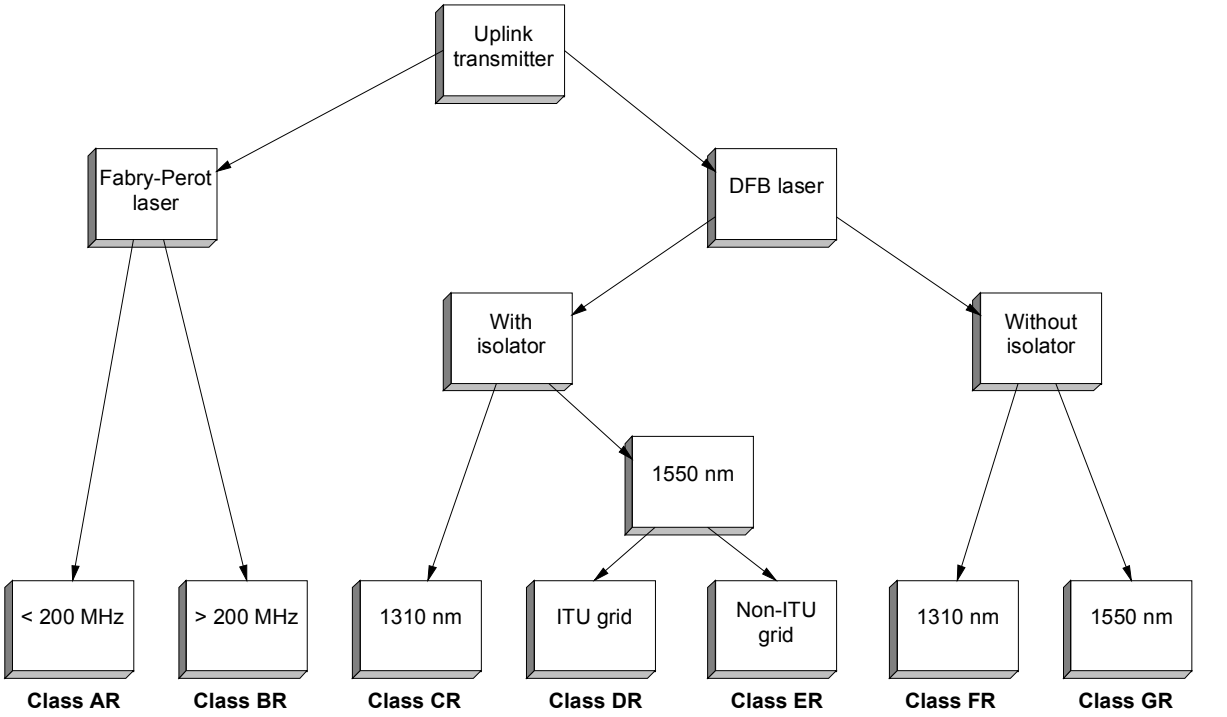


Figure 23 – Classification of uplink transmitters

6.2.1 Data publication requirement

The manufacturer shall at least publish information on the following parameters. Given figures are recommended values.

Table 5 – Data publication requirements for optical uplink transmitters

Parameter	Class AR	Class BR	Classes CR and DR	Classes ER to GR
Output power in dB(mW) and its tolerance	> –7 dB(mW)	> –3 dB(mW)	> 0 dB(mW)	> –3 dB(mW)
Fibre connection	Connector/splice type and type of fibre			
Power consumption	-			

6.2.2 Recommendations

Manufacturers shall at least publish information on parameters deviating from the following recommendations.

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Table 6 – Recommendations for optical uplink transmitters

Parameter	Class AR	Class BR	Class CR	Class DR	Classes ER to GR
Frequency range	5 to 200 MHz	5 to >200 MHz	5 to 200 MHz		
RIN	< –130 dB(Hz^{-1})		< –140 dB(Hz^{-1})	< –145 dB(Hz^{-1})	< –140 dB(Hz^{-1})
RF input level for obtaining m = 0,35	75 dB(μV)				
Flatness	<2 dB				
Supply voltage	One of the following: DC 48 V / 120 V or AC 65 V / 230 V (if used as stand-alone equipment)				
Mechanical dimensions	-				

6.2.3 Performance requirements

Optical uplink transmitters according to this standard shall fulfil the requirements of one of the following classes.

Table 7 – Requirements for optical uplink transmitters

Parameter	Classes AR, BR	Class CR	Class DR	Class ER	Class FR	Class GR
Wavelength	1310 nm ± 30 nm	1310 nm ± 20 nm	1550 nm ± 10 nm		1310 nm ± 30 nm	1550 nm ± 20 nm
Intermodulation	Under consideration					
Electrical input port (for stand-alone equipment only)	Impedance: 75 Ω Connector: IEC 60169-2 female or IEC 60169-24 Return loss: according to category B defined in IEC 60728-3					
Optical output port	Any high return loss connector (return loss > 50 dB)					
Minimum optical return loss of the system to be tolerated (discrete reflections only)	45 dB				55 dB	
Environmental conditions	According to ETS 300 019-1-3 class 3.3					
Indicators	Laser “on” indicator, indicating when light is emitted Laser operating out of range (current and/or temperature)					
Alarms	Output power failure Out of temperature range (for cooled lasers only)					
Mean operating time between failure (MTBF)	Under consideration					

6.3 Optical receivers

Optical receivers are classified according to Table 8 for taking into account different applications.

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Table 8 – Classification of optical receivers

Class	Characteristic
A	High electrical output level
B	Low electrical output level
C	High optical input power
D	Fibre to the building (FTTB)
E	Return path

6.3.1 Data publication requirements

The manufacturer shall at least publish information on the following parameters. The given figures are recommended values.

Table 9 – Data publication requirements for optical receivers

Parameter	Class A	Class B	Class C	Class D	Class E
Equivalent noise current density	<8 pA/√Hz	<9 pA/√Hz	<12 pA/√Hz	<7 pA/√Hz	<10 pA/√Hz
Reference output level	-				
Receiver intermodulation					
– second order	>60 dB				>40 dB
– triple beat	>70 dB				>50 dB
Fibre connection	Connector/splice type and type of fibre				
Power consumption	-				

6.3.2 Recommendations

Manufacturers shall at least publish information on parameters deviating from the following recommendations.

Table 10 – Recommendations for optical receivers

Parameter	Class A	Class B	Class C	Class D	Class E
Wavelength range	1250 to nm				
Optical input power	–7 to 0 dB(mW)	–4 to 3 dB(mW)	0 ... 6 dB(mW)	–10 to –1 dB(mW)	–20 to dB(mW)
Output level adjustment range	>10 dB				>18 dB
Output level AGC range	≥± 3 dB			No AGC	>± 5 dB
Slope (adjustable or with plug)	0 to 12 dB	0 to 6 dB	0 to 3 dB	0	0
Flatness	<3 dB	<2 dB	<1,5 dB	<4 dB	<1,5 dB
Frequency range	47 to 862 MHz				5 to 200 MHz
Supply voltage	One of the following: DC 48 V / 120 V or AC 65 V / 230 V (class F: only for stand-alone equipment)				
DC monitor output for optical input power	10 V/mW	1 V/mW		10 V/mW	
Mechanical dimensions	For operation in buildings: 19“ rack mountable				

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6.3.3 Performance requirements

Optical receivers according to this standard shall fulfil the requirements of one of the following classes.

Table 11 – Performance requirements for optical receivers

Parameter	Classes A and B	Class C	Classes E and F
Responsivity of the internal photo diode	≥0,8 A/W for the whole wavelength range		
Electrical output port	Impedance: 75 Ω Connector: IEC 60169-2 female or IEC 60169-24 Return loss: according to category B defined in IEC 60728-3		
Optical return loss	>45 dB	>50 dB	>40 dB
Fibre connection	Connector/splice type and type of fibre		
Indicators	Optical input level failure		
Alarms	Optical input level failure Out of AGC range (if AGC available)		
Mean operating time between failure (MTBF)	Under consideration		

6.4 Optical amplifiers

6.4.1 Data publication requirements

The manufacturer shall at least publish information as specified in Annex B and, additionally on the following parameters :

- saturation output power in dB(mW) versus input wavelength. If a compression factor N different than N = 3 is used, this factor has to be stated;
- input reflectance. It is recommended that this value should be lower than –45 dB at any wavelength within the range of the amplifier;
- fibre connection:
  - connector/splice type,
  - type of fibre;
- supply voltages and currents. In case of stand-alone equipment it is recommended that one of the following supply voltages is used: DC 48 V / 120 V or AC 65 V / 230 V;
- mean operating time between failure (MTBF)
  - under consideration.

6.4.2 Performance requirements

- Indicator
  - An output power “on” indicator, indicating when light is emitted, shall be provided.

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7 Passive equipment

7.1 Connectors and splices

7.1.1 Data publication requirements

Manufacturers shall publish information on the following parameters:

- type of connector or splice;
- type of fibre;
- insertion loss in dB:
  - maximum value,
  - mean value,
  - for connectors: repeatability;
- minimum return loss in dB: it is recommended that this value should exceed 50 dB
- operating wavelength range in nm;
- mean operating time between failure (MTBF): under consideration.

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Annex A
(informative)

A simplified method of measurement for return loss

A.1 Purpose

This method of measurement is an alternative to the method described in 4.4, when no reference reflector is available and a lower precision can be tolerated. Specifications based on the use of this method have to be marked accordingly by a footnote.

A.2 Equipment required

A.2.1 **A fused fibre coupler with a directivity higher than the return loss to be measured.**

A.2.2 A continuous **light source.**

A.2.3 An **optical power meter** with a dynamic range higher than the return loss to be measured.

A.2.4 **Lengths of fibre** for connecting the optical equipment.

A.2.5 Two **optical terminators** with reflection ideally 20 dB better than the return loss to be measured.

A.3 Procedure

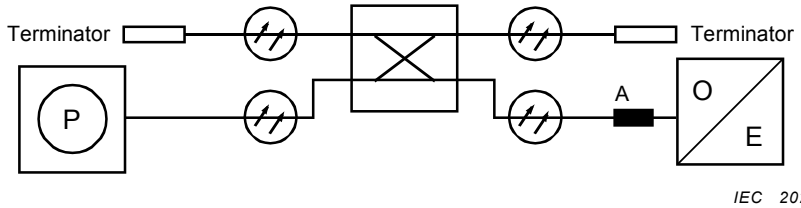
The procedure consists of two independent measurements:

A.3.1 Calibration

If return loss measurements have to be carried out on a series of devices, calibration can be made once for the whole series.

A.3.1.1 Set the supply voltage(s) and any control input signal(s) to the specified value(s).

A.3.1.2 Connect the optical transmitter to the connector that terminates the port A of the coupler as shown in Figure A.1 and note the reading P'_0 of the optical power meter.



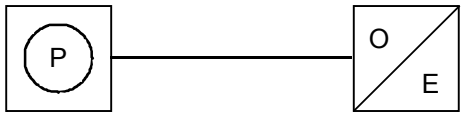
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Figure A.1 – Test set-up for calibration

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A.3.1.3 Connect the optical power meter directly to the light source as shown in Figure A.2 and note the reading P_0 of the optical power meter.

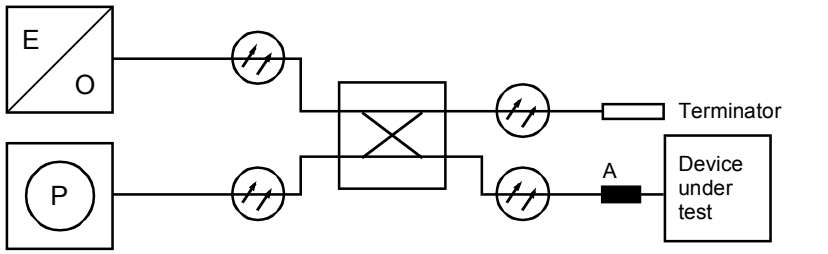


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Figure A.2 – Measurement of the optical power of the light source

A.3.2 Measurement of the device under test

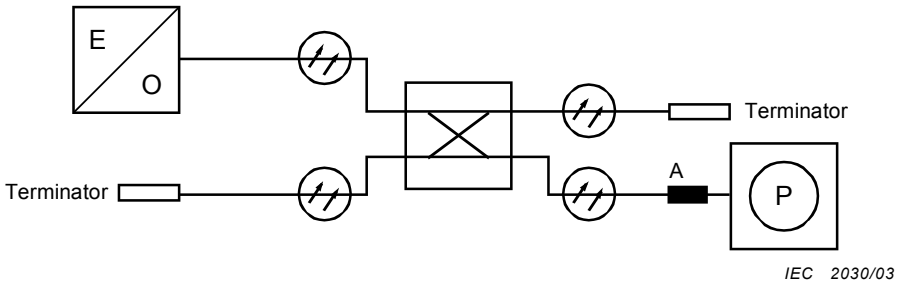
A.3.2.1 Connect the equipment as shown in Figure A.3 and note the reading P_1 of the optical power meter.



IEC 2029/03

Figure A.3 – Test set-up for device under test

A.3.2.2 Connect the optical power meter to port A as shown in Figure A.4 and note the reading P_2 of the optical power meter.



IEC 2030/03

Figure A.4 – Measurement of the optical power at port A

A.3.2.3 The return loss a_r of the device under test shall be calculated from:

$$a_r = 10\lg\frac{P_1}{P_2} - 10\lg\frac{P_0'}{P_0} \qquad (27)$$

A.4 Potential sources of error

The potential sources of error are the same as listed in 4.4.5.

Additionally the variation of the insertion loss of the connector terminating port A of the coupler reduces the accuracy of the measurement.

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Annex B
(informative)

Product specification worksheets for optical amplifiers

B.1 General

The object of these performance specification templates is to provide a frame for the preparation of detail specifications on the performances of optical fibre amplifier devices and sub-systems to be used in analogue applications.

B.2 Product specification worksheet for power amplifiers

The following worksheet contains a minimum list of specification parameters to be included in detail specifications of optical fibre amplifier devices to be used as power amplifiers in analogue applications, together with their specification criterion (that is in terms of maximum value, minimum value or both) and the indication of the corresponding standard test method.

Table B.1 – Minimum list of relevant parameters of power amplifiers to be specified for analogue applications

	Parameters		Unit	Minimum value	Maximum value	Test method
Transmission characteristics	Wavelength band		nm			IEC 61290-2 series
	Input power range		dB(mW)			IEC 61290-2 series
	Output power range		dB(mW)			IEC 61290-2 series
	Maximum total output power		dB(mW)	na		IEC 61290-2 series
	Noise figure		dB	na		IEC 61290-3 series
	Gain slope		dB/nm			IEC 61291-4 series
	Input reflectance		dB	na		IEC 61290-5 series
	Maximum reflectance tolerable at input		dB	na		IEC 61290-5 series
	Output reflectance		dB	na		IEC 61290-5 series
	Maximum reflectance tolerable at output		dB	na		IEC 61290-5 series
	Pump leakage to input		dB(mW)	na		IEC 61290-6 series
	Polarization mode dispersion (PMD)		ps	na		To be considered
Environmental parameters	Operating temperature		°C			IEC 61290-8 series
	Maximum operating relative humidity		%	na		IEC 61290-8 series
	Maximum operating vibration severity	Range of frequencies	Hz			IEC 61290-8 series
		Amplitude	mm p-p	na		IEC 61290-8 series
	Storage temperature		°C			IEC 61290-8 series
	Maximum storage relative humidity		%	na		IEC 61290-8 series
	Maximum transport shock severity	Peak acceleration	g	na		IEC 61290-8 series
		Duration	ms	na		IEC 61290-8 series
Safety parameters	Safety laser classification			na	na	IEC 60825-1

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B.3 Product specification worksheet for line amplifiers

The following worksheet contains a minimum list of specification parameters to be included in detail specifications of optical fibre amplifier devices to be used as line amplifiers in analogue applications, together with their specification criterion (that is in terms of maximum value, minimum value or both) and the indication of the corresponding standard test method.

Table B.2 – Minimum list of relevant parameters of line amplifiers to be specified for analogue applications

	Parameters		Unit	Minimum value	Maximum value	Test method
Transmission characteristics	Wavelength band		nm			IEC 61290-2 series
	Input power range		dB(mW)			IEC 61290-2 series
	Output power range		dB(mW)			IEC 61290-2 series
	Maximum total output power		dB(mW)	na		IEC 61290-2 series
	Noise figure		dB	na		IEC 61290-3 series
	Gain slope		dB/nm			IEC 61291-4 series
	Input reflectance		dB	na		IEC 61290-5 series
	Maximum reflectance tolerable at input		dB	na		IEC 61290-5 series
	Output reflectance		dB	na		IEC 61290-5 series
	Maximum reflectance tolerable at output		dB	na		IEC 61290-5 series
	Polarization mode dispersion (PMD)		ps	na		To be considered
Environmental parameters	Operating temperature		°C			IEC 61290-8 series
	Maximum operating relative humidity		%	na		IEC 61290-8 series
	Maximum operating vibration severity	Range of frequencies	Hz			IEC 61290-8 series
		Amplitude	mm p-p	na		IEC 61290-8 series
	Storage temperature		°C			IEC 61290-8 series
	Maximum storage relative humidity		%	na		IEC 61290-8 series
	Maximum transport shock severity	Peak acceleration	g	na		IEC 61290-8 series
		Duration	ms	na		IEC 61290-8 series
Safety parameters	Safety laser classification			na	na	IEC 60825-1

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B.4 Product specification worksheet for optically amplified transmitters (OAT)

The following worksheet contains a minimum list of specification parameters to be included in detail specifications of optical fibre amplifier sub-systems to be used as optically amplified transmitters in analogue applications, together with their specification criterion (that is in terms of maximum value, minimum value or both) and the indication of the corresponding standard test method.

Table B.3 – Minimum list of relevant parameters of optically amplified transmitters (OAT) to be specified for analogue applications

	Parameters		Unit	Minimum value	Maximum value	Test method
Transmission characteristics	**Operating signal wavelength range**		nm			IEC 61280-1-3
	Signal linewidth		nm	na		IEC 61280-1-3
	Side mode suppression		dB		na	IEC 61280 series
	Maximum output signal power		dB(mW)		na	IEC 61290-2 series
	Nominal output signal power		dB(mW)			IEC 61290-2 series
	Maximum return optical power		dBm	na		IEC 61290-2 series
	Large signal output stability		dB	na		IEC 61290-2 series
	Composite second order distortion (CSO)		dBc	na		IEC 61280-3-3
	Composite triple-beat distortion (CTB)		dBc	na		IEC 61280-3-4
	Carrier to noise ratio (CNR)		dB	na		IEC 61280-3-2
	Output reflectance		dB	na		IEC 61290-5 series
	Maximum reflectance tolerable at output		dB	na		IEC 61290-5 series
	Pump leakage to output		dB(mW)	na		IEC 61290-6 series
Environmental parameters	**Operating temperature**		°C			IEC 61290-8 series
	Maximum operating relative humidity		%	na		IEC 61290-8 series
	Maximum operating vibration severity	**Range of frequencies**	Hz			IEC 61290-8 series
		Amplitude	mm p-p	na		IEC 61290-8 series
	Storage temperature		°C			IEC 61290-8 series
	Maximum storage relative humidity		%	na		IEC 61290-8 series
	Maximum transport shock severity	**Peak acceleration**	g	na		IEC 61290-8 series
		Duration	ms	na		IEC 61290-8 series
Safety parameters	**Safety laser classification**			na	na	IEC 60825-1

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