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INTERNATIONAL STANDARD

Cable networks for television signals, sound signals and interactive services – Part 6: Optical equipment

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 6: Optical equipment

FOREWORD

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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 third edition cancels and replaces the second edition published in 2003 of which it constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition.

- The normative references were updated.
- The methods of measurement for optical power and return loss were substituted by references to other standards.
- The method of measurement for polarization dependent loss was deleted.

- A method of measurement for carrier-to-crosstalk ratio (CCR) was added.
- The methods of measurement for CSO and CTB of optical amplifiers were substituted by a method of measurement for microscopic gain tilt of optical amplifiers. This parameter can be used for calculating the second order distortion of optical amplifiers according to the method described in the new Annex B.
- New classes for optical transmitters and receivers have been defined.

The text of this standard is based on the following documents:

CDV	Report on voting
100/1654/CDV	100/1789/RVC

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.

The list of all the parts of the IEC 60728 series, under the general title *Cable networks for television signals, sound signals and interactive services,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Standards of the IEC 60728 series deal with cable networks including equipment and associated methods of measurement for headend reception, processing and distribution of television signals, sound signals and their associated data signals and for processing, interfacing and transmitting all kinds of signals for interactive services using all applicable transmission media.

- This covers 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.

NOTE CATV encompasses the Hybrid Fibre Coaxial (HFC) networks used nowadays to provide telecommunications services, voice, data and audio and video both broadcast and narrowcast.

The extent of this standardisation work is from the antennas and/or special signal source inputs to the headend or other interface points to the network up to the terminal input.

The standardisation of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals, etc.) as well as of any coaxial, balanced and optical cables and accessories thereof is excluded.

The reception of television signals inside a building requires an outdoor antenna and a distribution network to convey the signal to the TV receivers.

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.
- 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 60068-1:1988, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12+ 12 h cycle)*

IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-40, *Environmental testing – Part 2-40: Tests – Test Z/AM: Combined cold/low air pressure tests*

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, *Graphical symbols for use on equipment*

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

IEC 60617, *Graphical symbols for diagrams*

IEC 60728-1, *Cable networks for television signals, sound signals and interactive services – Part 1: System performance of forward paths*

IEC 60728-2, *Cable networks for television signals, sound signals and interactive services – Part 2: Electromagnetic compatibility for equipment*

IEC 60728-3:2010, *Cable networks for television signals, sound signals and interactive services – Part 3: Active wideband equipment for coaxial cable networks*

IEC 60728-11, *Cable networks for television signals, sound signals and interactive services – Part 11: Safety*

IEC 60728-13:2010, *Cable networks for television signals, sound signals and interactive services – Part 13: Optical systems for broadcast signal transmissions*

IEC 60793-2-50:2008, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 61280-1-1, *Fibre optic communication subsystem basic test procedures – Part 1-1: Test procedures for general communication subsystems – Transmitter output optical power measurement for single-mode optical fibre cable*

IEC 61280-1-3, *Fibre optic communication subsystem basic test procedures – Part 1-3: General communication subsystems – Central wavelength and spectral width measurement*

IEC 61282-4, *Fibre optic communication system design guides – Part 4: Accomodation and utilization of non-linear effects*

IEC 61290-1 (all parts), *Optical amplifiers – Test methods – Part 1: Power and gain parameters*

IEC 61290-1-3, *Optical amplifiers – Test methods – Part 1-3: Power and gain parameters – Optical power meter method*

IEC 61290-3-2:2003, *Optical amplifiers – Part 3-2: Test methods for noise figure parameters – Electrical spectrum analyzer method*

IEC 61290-5 (all parts), *Optical amplifiers – Test methods – Part 5: Reflectance parameters*

IEC 61290-6 (all parts), *Optical fibre amplifiers – Basic specification – Part 6: Test methods for pump leakage parameters*

IEC 61290-11 (all parts), *Optical amplifiers – Test methods – Part 11: Polarization mode dispersion parameter*

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

IEC 61291-5-2, *Optical amplifiers – Part 5-2: Qualification specifications – Reliability qualification for optical fibre amplifiers*

IEC 61300-3-6, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*

IEC 61754-4, *Fibre optic connector interfaces – Part 4: Type SC connector family*

IEC/TR 61931:1998, *Fibre optic – Terminology*

IEC 80416 (all parts), *Basic principles for graphical symbols for use on equipment*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

3.1.1
optical transmitting unit
optical transmitter
TX
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

[IEC/TR 61931:1998, definition 2.9.6]

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

3.1.2
optical receiving unit
optical receiver
Rx
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)

[IEC/TR 61931:1998, definition 2.9.7]

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

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

[IEC/TR 61931:1998, 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/TR 61931:1998, 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

[IEC 60050-731:1991, 731-05-05, modified] and [IEC/TR 61931:1998, 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/TR 61931:1998, 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/TR 61931:1998, 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

[IEC/TR 61931:1998, 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 the following equation:

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

where

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

$P_{\mathrm{opt,RX}}$ 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

$$m = \frac{\phi_{\mathrm{h}} - \phi_{\mathrm{l}}}{\phi_{\mathrm{h}} + \phi_{\mathrm{l}}} \qquad (2)$$

where ϕ_{h} is the highest and ϕ_{l} is the lowest instantaneous optical power of the intensity modulated optical signal

NOTE 1 This term is mainly used for analogue systems.

NOTE 2 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/TR 61931 are 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 (OA), expressed in dB

[IEC 61291-1:2006, definition 3.2.38]

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

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

NOTE 1 The RIN is usually expressed in dB(Hz^{-1}) resulting in negative values.

NOTE 2 The value for the RIN can be calculated from the results of a carrier-to-noise measurement for the system (see 4.16).

3.1.13
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:

$$I_r = \sqrt{\frac{C}{Z\,10^{\frac{1}{10}C/N}}} \tag{3}$$

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 is expressed in units of A/√Hz.

3.1.14
responsivity
ratio of an optical detector's electrical output to its optical input at a given wavelength

[IEC 60050-731:1991, 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/TR 61931:1998, definition 2.7.56]

3.1.15
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/TR 61931:1998, definition 2.4.54]

3.1.16
wavelength
distance covered in a period by the wavefront of a harmonic plane wave

[IEC/TR 61931:1998, definition 2.2.9]

NOTE 1 The wavelength λ of light in vacuum is given by

$$\lambda = \frac{c}{f} \tag{4}$$

where

c is the speed of light in vacuum ($c \approx 2{,}997\ 92 \times 10^8$ m/s);

f is the optical frequency.

NOTE 2 Although the wavelength in dielectric material such as fibres is shorter than in vacuum, only the wavelength of light in vacuum is used.

3.1.17
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/TR 61931:1998, definition 2.7.44]

3.1.18
polarization
orientation of the electric field vector of the electromagnetic radiation

[IEC/TR 61931:1998, definition 2.1.44]

3.1.19
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

3.1.20
coherence time
time over which a propagating light may be considered to be coherent radiation

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 60050-731:1991, 731-01-18] and [IEC/TR 61931:1998, definition 2.1.68]

3.1.21
amplified spontaneous emission
ASE
optical power associated to spontaneously emitted photons amplified by an active medium in an optical amplifier

[IEC/TR 61931:1998, definition 2.7.87]

3.1.22
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/TR 61931:1998, definition 2.6.50]

3.1.23
centre wavelength
average of those wavelengths at which the amplitude of a light source reaches or last falls to half of the maximum amplitude

3.1.24
spectral width
measure of the wavelength range of a spectrum or spectral characteristic

[IEC 60050-731:1991, 731-06-24 modified] and [IEC/TR 61931:1998, definition 2.7.42]

3.1.25
(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/TR 61931:1998, definition 2.1.88]

3.1.26
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 should be stated.

[IEC 61291-1:1998, definition 3.2.33]

3.1.27
optical return loss
return loss
ORL
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:

$$-10\lg\frac{P_r}{P_i} \qquad (5)$$

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/TR 61931:1998, 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.

3.1.28
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

[IEC 60050-731:1991, 731-03-60] and [IEC/TR 61931:1998, definition 2.4.10]

3.1.29
slope
gain or attenuation difference at two defined frequencies between any two ports of a device or system

NOTE 1 In this document the term slope relates only to the electrical gain or attenuation of equipment.

NOTE 2 In equipment for cable networks a line of best fit of the amplitude frequency response is considered at the band limits (see 4.10).

3.1.30
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

3.1.31
small-signal gain
SSG
for an optical fibre amplifier, the gain of the OFA, when operated in the linear regime, where it is quite independent of the input signal optical power, at a given signal wavelength and pump optical power level

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

[IEC 61281-1:1999, definition 3.83]

3.1.32
centroidal wavelength
the mean or average wavelength of an optical spectrum

NOTE Other spectral wavelengths are centre wavelengths, half-power wavelengths, and peak wavelengths.

[IEC 61281-1:1999, definition 3.10]

3.1.33
microscopic gain tilt
slope due to ripples in sub-nanometre intervalls in the gain-versus-wavelength characteristic in the specified wavelength range of optical amplifiers (see Figure 1).

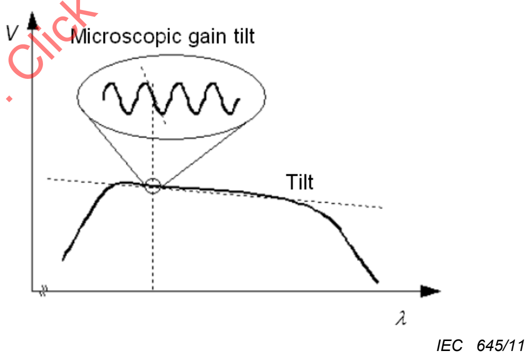


Figure 1 – Tilt and microscopic gain tilt of optical amplifiers

3.1.34
carrier-to-crosstalk ratio
CCR
level difference of CATV broadcast carrier level and worst case of other services single frequency crosstalk signal measured at RF output port of optical receiver for CATV broadcast service, as given by the following equation:

$$CCR = D_{\text{CATV}} - U_{\text{OtherService}} \quad (6)$$

where

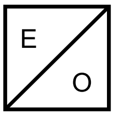
D_{CATV} is the nominal level of CATV broadcast signal in dB(μV) at RF output port of optical CATV broadcast receiver;

$U_{\text{OtherService}}$ is the worst case level of another service’s single frequency crosstalk in dB(μV) at RF output port of optical CATV broadcast receiver.

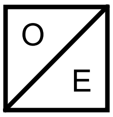
CCR is expressed in dB.

3.2 Symbols

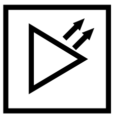
The following graphical symbols are used in the figures of this standard. These symbols are either listed in IEC 60617 or based on symbols defined in IEC 60617.



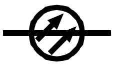
Optical transmitter
based on
[IEC 60617-S00213
(2001-07)]



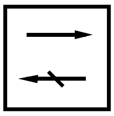
Optical receiver
based on
[IEC 60617-S00213
(2001-07)]



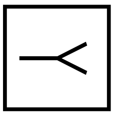
Optical amplifier
based on
[IEC 60617-S00127
(2001-07) and
IEC 60617-S01239
(2001-07)]



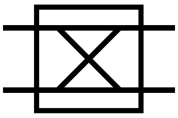
Optical fibre
[IEC 60617-S01318
(2001-07)]



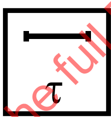
Isolator
[IEC 60617-S01175
(2001-07)]



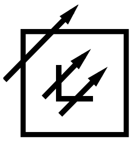
Coupler
based on
[IEC 60617-S00059,
(2001-07) and
IEC 60617-S01188
(2001-07)]



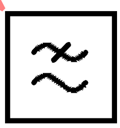
Directional coupler
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S01193
(2001-07)]



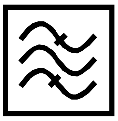
Delay line
based on
[IEC 60617-S00608
(2001-07)]



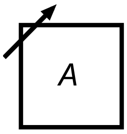
Polarisation control device
[IEC 60617-S001430
(under consideration)]



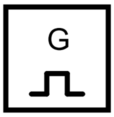
Low-pass filter
[IEC 60617-S01248
(2001-07, modified)]



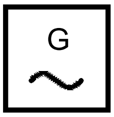
Bandpass filter
[IEC 60617-S01249
(2001-07)]



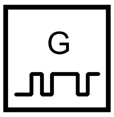
Variable attenuator
[IEC 60617-S01245
(2001-07)]



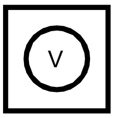
Pulse generator
[IEC 60617-S01228
(2001-07)]



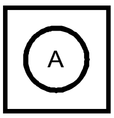
Sine-wave generator
based on
[IEC 60617-S00899,
(2001-07) and
IEC 60617-S01403
(2001-09)]



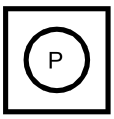
Bit pattern generator



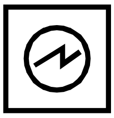
Voltmeter
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S00913
(2001-07)]



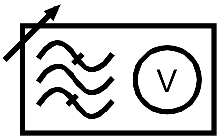
Ammeter
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S00910
(2001-07)]



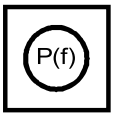
Power meter
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S00910
(2001-07)]



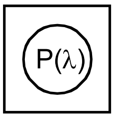
Oscilloscope
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S00922
(2001-07)]



Selective voltmeter
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S00081
(2001-07) and
IEC 60617-S00913
(2001-07) and
IEC 60617-S01249
(2001-07)]



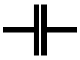
Electrical spectrum analyzer
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S00910
(2001-07)]



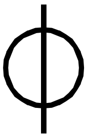
Optical spectrum analyzer
based on
[IEC 60617-S00059
(2001-07) and
IEC 60617-S00910
(2001-07)]

RF choke
[IEC 60617-S00583
(2001-07)]

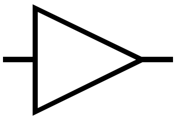
Resistor
[IEC 60617-S00555
(2001-07)]



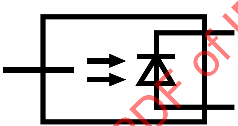
Capacitor
[IEC 60617-S00567
(2001-07)]



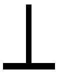
DC power supply
[IEC 60617-S00206
(2001-07)]



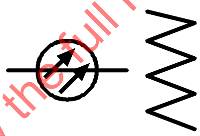
Amplifier
[IEC 60617-S01239
(2001-07, modified)]



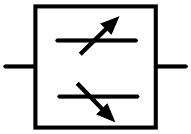
Photodiode with fibre pigtail
[IEC 60617-S01327
(2001-07)]



Ground
[IEC 60617-S01410
(2001-11)]



Optical terminator
based on
[IEC 60617-S01389
(obsolete) and
IEC 60617-S01318
(2001-07)]



Cladding mode stripper
[IEC 60617-S01333
(2001-07)]

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
CCR	carrier-to-crosstalk ratio
CSO	composite second order
CTB	composite triple beat
CW	continuous wave
DC	direct current

EMC	electromagnetic compatibility
FTTH	fibre to the home
HFC	hybrid fibre coaxial
IF	intermediate frequency
MATV	master antenna television (network)
MIB	management information base
MTBF	mean time between failure
NF	noise figure
OA	optical amplifier
ORL	optical return loss
PMD	polarization mode dispersion
PRBS	pseudo random bit sequence
RF	radio frequency
RIN	relative intensity noise
Rx	(optical) receiver
SBS	stimulated Brillouin scattering
SMATV	satellite master antenna television (network)
SNMP	simple network management protocol
SSG	small-signal gain
Tx	(optical) transmitter
WDM	wavelength division multiplexing
XM	composite crossmodulation

4 Methods of measurement

4.1 Measurement requirements

4.1.1 General

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

4.1.2 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.

4.1.3 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

For measuring the total average optical power emanating from the end of a test fibre, the method described in IEC 61280-1-1 shall be used. The test fibre and the coupling means shall be as specified by the manufacturer. The optical power shall be expressed in dB(mW).

4.3 Loss, isolation, directivity and coupling ratio

4.3.1 General

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 61290-1-3.

4.3.2 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.

4.3.3 Principle of measurement

For the measurement proceed as follows.

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.

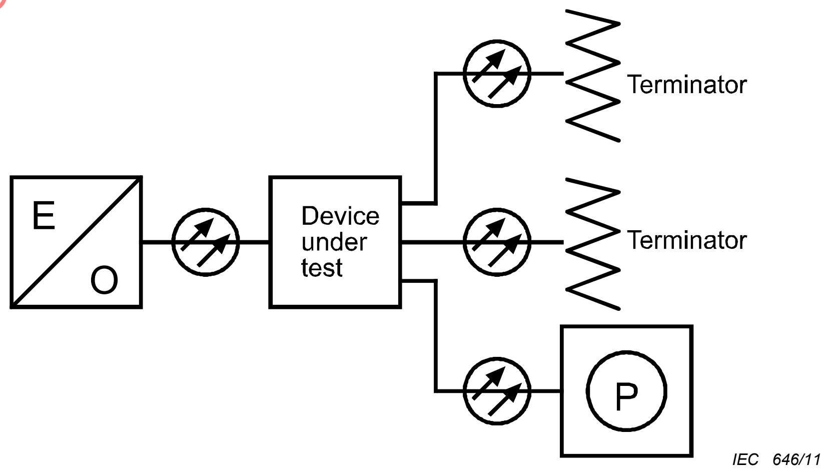


Figure 2 – Measurement of optical loss, directivity and isolation

c) The loss, directivity or isolation is calculated by

$$a = 10 \cdot \lg \frac{P_1}{P_2} \tag{7}$$

4.4 Return loss

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. Any measurement for return loss of optical equipment shall be carried out as specified in IEC 61300-3-6. 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.

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 3. 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)).

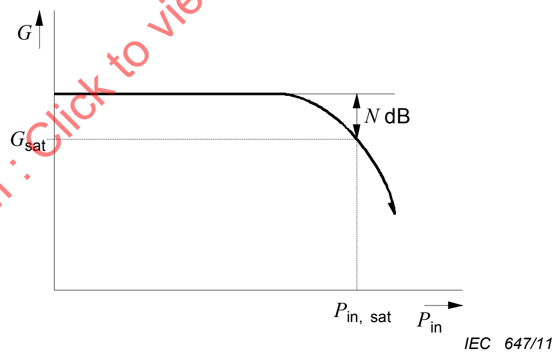


Figure 3 – Optical saturation output power

4.6 Centroidal wavelength and spectral width under modulation

For measuring the centroidal wavelength λ_0 of the spectrum and the spectral width $\Delta\lambda$ of a transmitter under modulation, the method decribed in IEC 61280-1-3 shall be used. The centroidal wavelength and the spectral width shall be expressed in nanometres. That method is not suitable for light sources and transmitters with very narrow spectral width (single mode laser) or for measuring the chirping of transmitters (see 4.7).

4.7 Linewidth and chirping of transmitters with single mode lasers

4.7.1 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.

4.7.2 Equipment required

For this test method the following pieces of equipment are needed.

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.

4.7.3 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 µs to 50 µs.

4.7.4 Procedure

For the measurement proceed as follows.

a) Connect the equipment as shown in Figure 4.

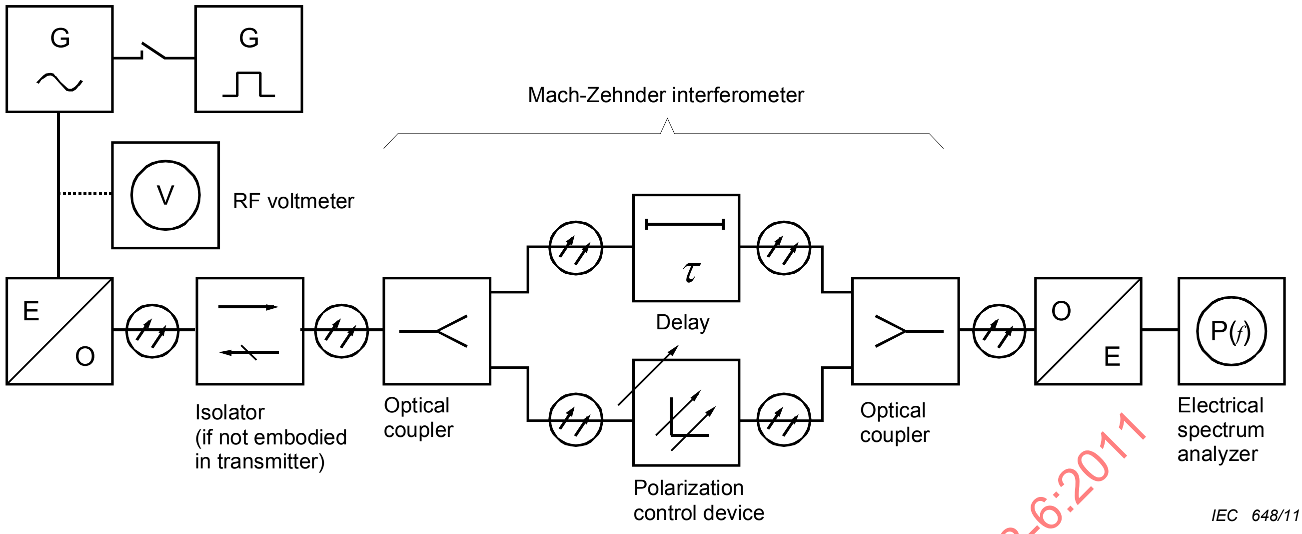


Figure 4 – Measurement of the chirping and the linewidth of transmitters

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

c) For measuring chirping, the sine wave generator shall be gated on and off as described in 4.7.2. For adjusting the output level of the sine wave generator, switch it into continuous mode. Connect the RF voltmeter at the output of the sine wave generator 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 sine wave generator to the optical transmitter and turn on the gating signal of the pulse generator.

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 should 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 of the sine wave 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

$$f_{\mathrm{c}} = \Delta f \frac{Z}{U} \qquad (8)$$

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.

4.7.5 Potential sources of error

Such sources of error are the following:

- 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.

4.8 Optical modulation index

4.8.1 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.

4.8.2 Equipment required

For this test method the following pieces of equipment are needed.

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.

4.8.3 Procedure

For the measurement proceed as follows.

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 5.

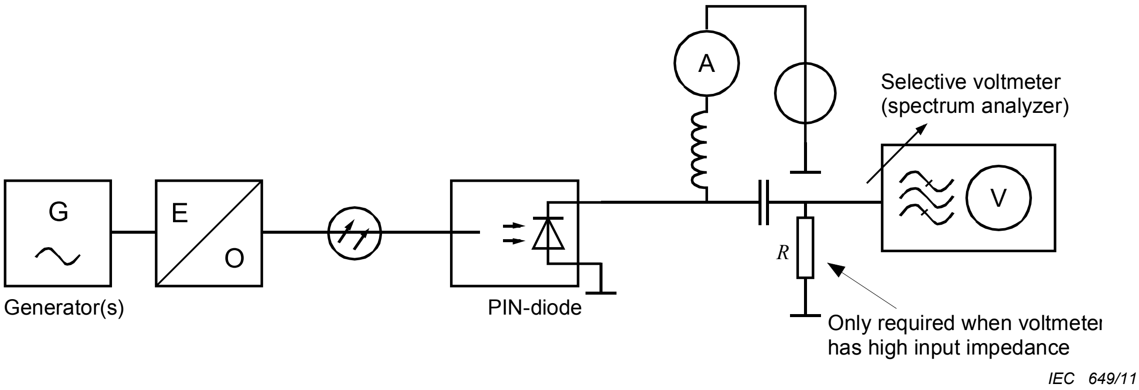


Figure 5 – Measurement of the optical modulation index

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 current meter and the selective voltmeter (spectrum analyzer). The optical modulation index is calculated from:

$$m = \frac{\sqrt{2}U}{RI} \tag{9}$$

where

I is the reading of the DC current 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.

4.8.4 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 4.17.

- The inaccuracy of the DC current 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.

4.9 Reference output level of an optical receiver

4.9.1 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).

4.9.2 Equipment required

For this test method the following pieces of equipment are needed.

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.

4.9.3 General measurement requirements

The following measurement requirements shall be met.

- 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.

4.9.4 Procedure

For the measurement proceed as follows.

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 6.

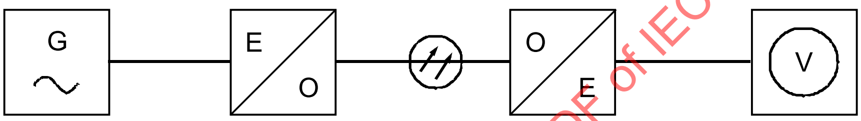


Figure 6 – Measurement of the reference output level of an optical receiver

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:

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

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.

4.9.5 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.

4.10 Slope and flatness

4.10.1 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 versus frequency response falls to –3 dB of the peak value.

4.10.2 Equipment required

For this test method the following pieces of equipment are needed.

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 versus 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.

4.10.3 Procedure

For the measurement proceed as follows.

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 7.

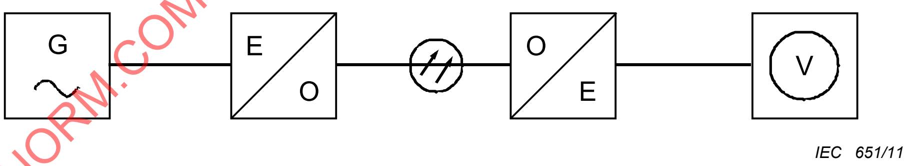


Figure 7 – Measurement of the slope and flatness

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 8). The difference $A_1 - A_2$ shall be stated as the slope of the device.

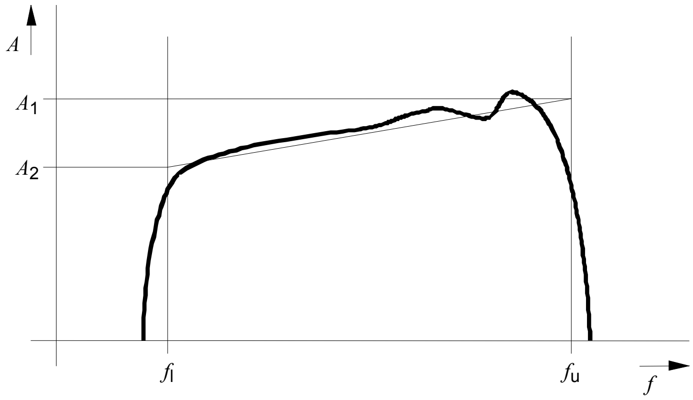


Figure 8 – Evaluation of the slope

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 9). 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.

Figure 9 – Evaluating the flatness

4.10.4 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 4.10.2.

4.11 Composite second order distortion (CSO) of optical transmitters

4.11.1 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.

4.11.2 Equipment required

For this test method the following pieces of equipment are needed.

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 4.14).

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.

4.11.3 Procedure

For the measurement proceed as follows.

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.

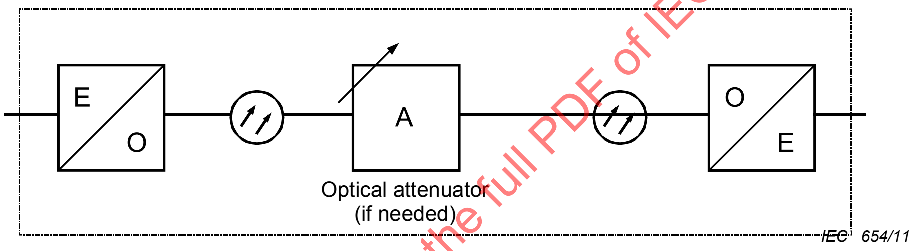


Figure 10 – Device under test for measuring CSO of optical transmitters

c) The device under test shown in Figure 10 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.

4.11.4 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.

4.12 Composite triple beats (CTB) of optical transmitters

4.12.1 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.

4.12.2 Equipment required

For this test method the following pieces of equipment are needed.

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 4.14).
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

For the measurement proceed as follows.

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 11.

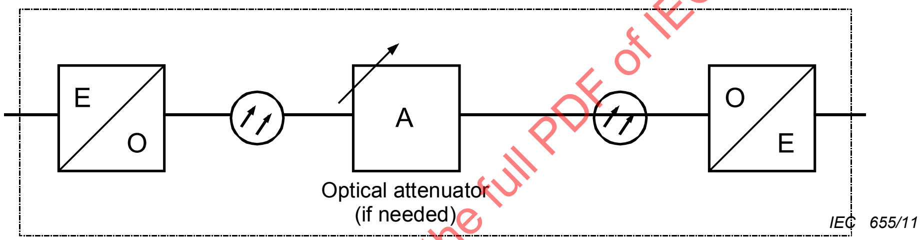


Figure 11 – Device under test for measuring CTB of optical transmitters

c) The test configuration shown in Figure 11 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.

4.12.4 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.

4.13 Composite crossmodulation of optical transmitters

4.13.1 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.

4.13.2 Equipment required

For this test method the following pieces of equipment are needed.

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.

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.

4.13.3 Procedure

For the measurement proceed as follows.

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 12.

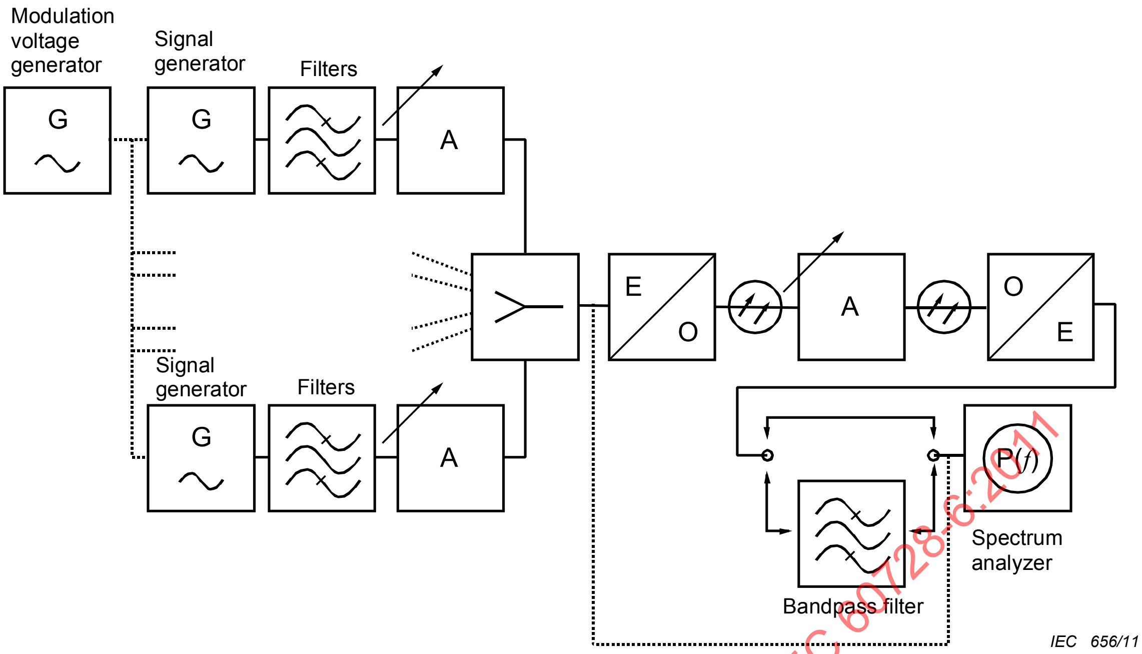


Figure 12 – Arrangement for measuring composite crossmodulation of optical transmitters

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

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:

$$XM = 20\lg\left(10^{\frac{XM_1}{20}} + 10^{\frac{XM_2}{20}}\right) \quad (11)$$

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.

4.13.4 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.

4.14 Receiver intermodulation

4.14.1 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.

4.14.2 Equipment required

For this test method the following pieces of equipment are needed.

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.

4.14.3 General measurement requirements

The following measurement requirements shall be met.

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.

4.14.4 Procedure

For the measurement proceed as follows.

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.

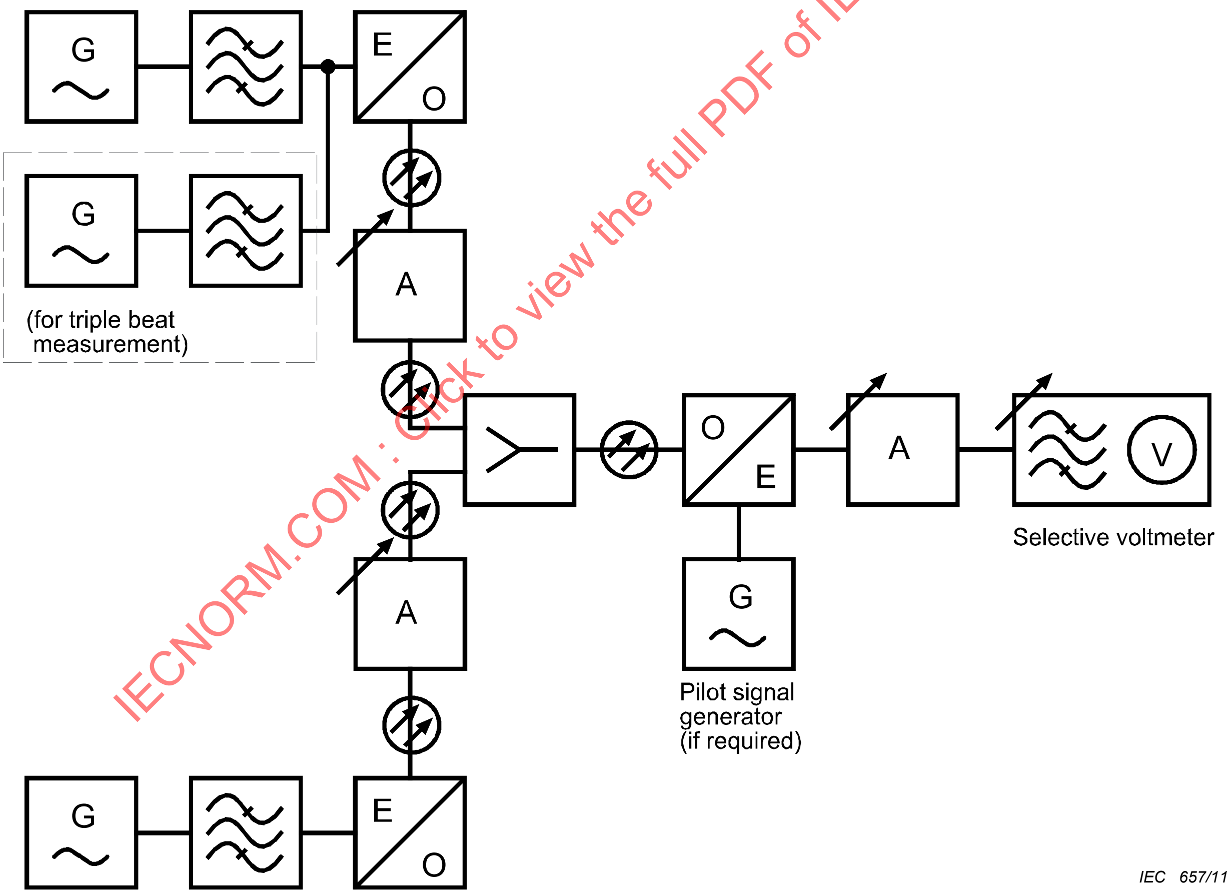


Figure 13 – Arrangement of test equipment for measuring receiver intermodulation

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 Annex 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.

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

$$S/I = a_1 - a_2 \qquad (12)$$

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.

4.14.5 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.

4.15 Microscopic gain tilt of optical amplifiers

4.15.1 Purpose

The purpose of this method is to measure small changes in the gain-versus-wavelength curve of optical amplifiers, called microscopic gain tilt. Microsocopic gain tilt is the main source of distortion caused by optical amplifiers (see Annex B). It shall be expressed in dB/nm.

4.15.2 Equipment required

For this method of measurement the following pieces of equipment are needed.

a) An **optical light source** generating a locked inversion signal with the same wavelength and the same optical power as used for analogue transmission.

b) An **optical light source** generating a probe signal with variable wavelength covering the range close to the wavelength of the locked inversion signal. The output power of this probe signal shall be at least 20 dB lower than the locked inversion signal.

c) An **optical coupler** used as a combiner for the locked inversion signal and the probe signal.

d) A **variable optical attenuator** with a range suitable to adjust the output power of the optical coupler to the input power range of the device under test.

e) An **optical spectrum analyser** suitable for the output signal of the device under test and able to show a wavelength range of several nanometres around the locked inversion signal.

4.15.3 Procedure

For the measurement proceed as follows.

a) Connect the equipment as shown in Figure 14.

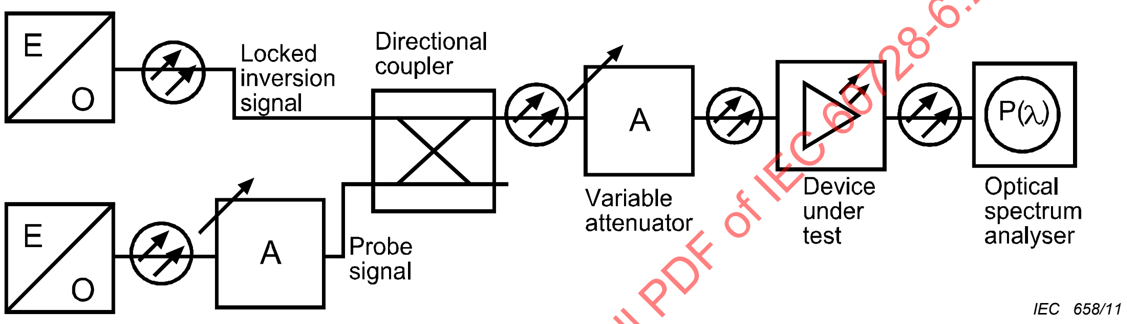


Figure 14 – Arrangement of test equipment for measuring microscopic gain tilt

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

c) Select the wavelength of the locked inversion signal to be the same as the optical signal used for the transmission of frequency multiplexed RF carriers.

d) Set the optical power of the locked inversion signal to achieve the specified input power of the optical amplifier to be tested.

e) Adjust the optical power of the probe signal to be at least 20 dB lower than the locked inversion signal but at least 10 dB higher than the noise floor of the optical spectrum amplifier.

f) Sweep the wavelength of the probe signal by 3 nm above and below of the wavelength of the locked inversion signal.

g) Determine the power of the probe signal $P_{\text{in, prb}}(\lambda)$ at the input of the optical amplifier to be tested, the power of the amplified probe signal $P_{\text{out, prb}}(\lambda)$ and the amplified spontaneous emission (ASE) $P_{\text{ASE, prb}}(\lambda)$ at various wavelengths λ.

h) Derive the locked inversion gain $LI_{\text{Gain}}(\lambda)$ at various wavelengths λ by

$$LI_{\text{Gain}}(\lambda) = 10\lg \frac{P_{\text{out,prb}}(\lambda) - P_{\text{ASE,prb}}(\lambda)}{P_{\text{in,prb}}(\lambda)} \qquad (13)$$

i) Plot the result using the probe signal wavelength for the horizontal axis and the measured $LI_{\text{Gain}}(\lambda)$ of the probe signal for the vertical axis.

j) Derive an empirical formula using a second-order approximation of the plotted graph.

k) The first order differentiation of the second-order approximated plot yields the microsocopic gain tilt in dB/nm.

4.15.4 Potential sources of error

One potential source of such an error may be the inaccuracy of the optical spectrum analyser.

4.16 Noise parameters of optical transmitters and optical receivers

4.16.1 Purpose

The purpose of this test method is to measure the relative intensity noise (RIN) of optical transmitters and the equivalent input noise current density (I_r) of optical receivers. The relative intensity noise shall be given in dB/Hz and the equivalent noise current density in pA/√Hz.

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 noise contribution of 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.

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 15).

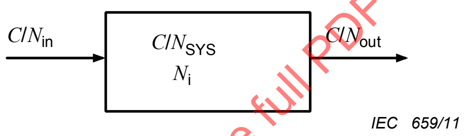


Figure 15 – System with internal noise sources

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.

$$C/N_{sys} = -10\lg\left(10^{-\frac{1}{10}C/N_{out}} - 10^{-\frac{1}{10}C/N_{in}}\right) \qquad (14)$$

4.16.2 Equipment required

4.16.2.1 General

For this test method the following pieces of equipment are needed.

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 16) for testing an optical transmitter or a reference transmitter for testing an optical receiver.

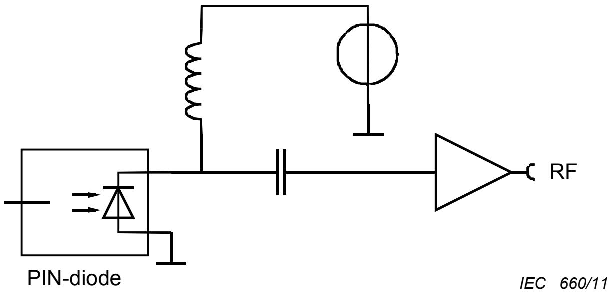


Figure 16 – PIN diode receiver

4.16.2.2 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:

$$C/N_{\mathrm{TX}} = 10\lg\frac{m^2}{2B} - RIN \qquad (15)$$

where

m is the optical modulation index;

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

B is the bandwidth in Hz.

4.16.2.3 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:

$$C/N_{\mathrm{RX}} = 10\lg\left(\frac{m^2 P_0^2 r^2}{2B(2erP_0 + I_{\mathrm{r}}^2)}\right) \qquad (16)$$

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;

B is the bandwidth in Hz;

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

I_{r} is the equivalent input 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).

4.16.3 General measurement requirements

The following measurement requirements shall be met.

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.

4.16.4 Procedure

For the measurement proceed as follows.

a) The method for measuring the carrier-to-noise ratio of analogue optical transmission systems is nearly the same as for cable networks (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 17).

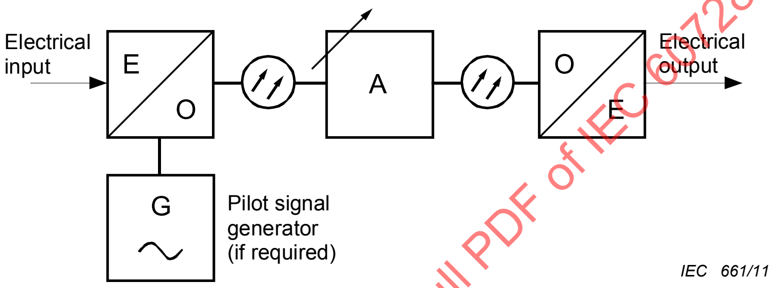


Figure 17 – Optical transmission system under test

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 18.

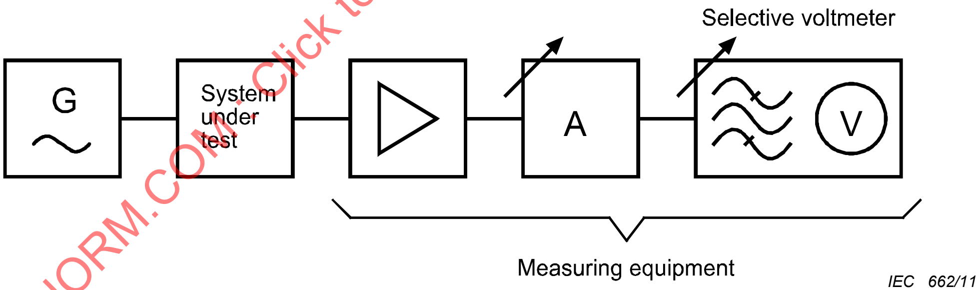


Figure 18 – Arrangement of test equipment for carrier-to-noise measurement

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 (17).

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

f) Adjust the spectrum analyzer as follows:

resolution bandwidth (RSBW) (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

$$C/N_{SYS} = m_{delta} - C_b + C_a - C_n \tag{17}$$

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

$$C_b = 10\lg\left[(BW)_{RSBW}/(BW)_{SYS}\right] \tag{18}$$

where

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

$(BW)_{SYS}$ is the bandwidth of the channel (e.g. for analogue television systems B and G it is assumed to be 4,75 MHz).

The analyzer correction factor C_a is typically 1,7 dB (it accounts for a –0,8 dB term that takes into account that the equivalent noise bandwidth of the IF filter of the spectrum analyser is greater than the resolution bandwidth RSBW (indicated on the spectrum analyser) by a factor of 1,2, 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.

$$C/N_{SYS} = C/N_{meas} - C_n \tag{19}$$

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 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:

$$D = N_m - N_{eq} \tag{20}$$

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.

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 (14), 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:

g) for the receiver

$$C/N_{RX} = -10\lg\left(10^{-\frac{1}{10}C/N_{SYS}} - 10^{-\frac{1}{10}C/N_{TX}}\right) \quad (21)$$

h) for the transmitter

$$C/N_{TX} = -10\lg\left(10^{-\frac{1}{10}C/N_{SYS}} - 10^{-\frac{1}{10}C/N_{RX}}\right) \quad (22)$$

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.

4.16.5 Relative intensity noise

Transforming Equation (15), a measured transmitter's carrier-to-noise ratio can be converted to its relative intensity noise (RIN):

$$RIN = 10\lg\frac{m^2}{2B} - C/N_{TX} \quad (23)$$

where

m is the optical modulation index;

C/N_{TX} is the transmitters carrier-to-noise ratio in dB;

B is the bandwidth in Hz.

4.16.6 Equivalent input noise current density

Transforming Equation (16), a measured receivers carrier-to-noise ratio can be converted to its equivalent noise current density:

$$I_r = \sqrt{\frac{m^2 P_0^2 r^2}{2B\cdot 10^{\frac{C/N_{RX}}{10}}} - 2erP_0} \quad (24)$$

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;

B is the bandwidth in Hz;

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

C/N_{RX} is the carrier-to-noise ratio of the receiver in dB.

4.16.7 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.

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

4.17.1 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.

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

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

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 versus P_{opt} using methods of curve fitting.

4.17.2 Equipment required

For this test method the following pieces of equipment are needed.

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.

4.17.3 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.

4.17.4 Procedure

For the measurement proceed as follows.

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 19.

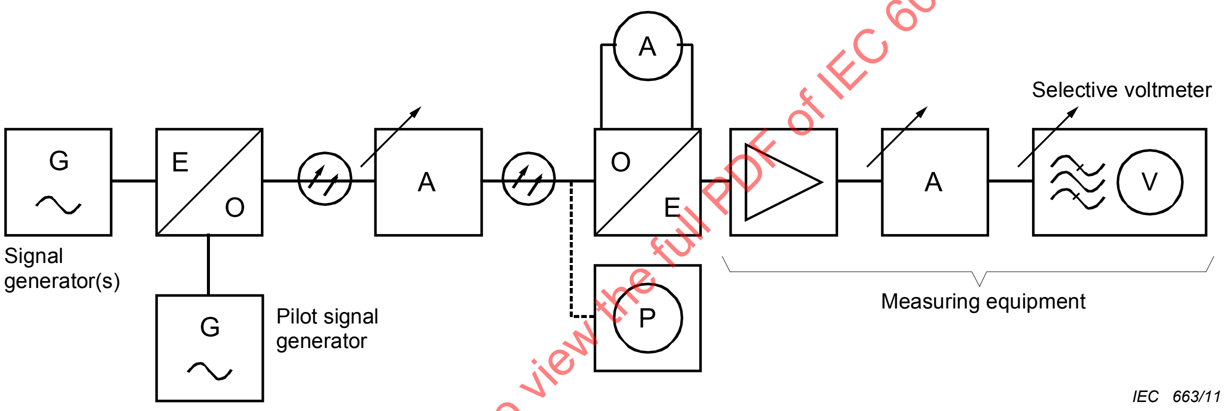


Figure 19 – Measurement set-up for determination of the noise parameters and the optical modulation index

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 in mW.

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 in mW.

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

$$r = \frac{I_2 - I_1}{P_2 - P_1} \qquad (26)$$

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 4.16 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).

4.17.5 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.

4.18 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 4.7 of this standard can be used.

4.19 Influence of fibre

4.19.1 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.

4.19.2 Equipment required

For this test method the following pieces of equipment are needed.

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, class B1.3 fibre according to IEC 60793-2-50 shall be used.
b) All equipment necessary to carry out measurements of C/N (see 4.16) and CSO (see 4.11)

4.19.3 Procedure

For the measurement proceed as follows.

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 CSO (see 4.11) substituting the fibre at the output of the transmitter by this test fibre.

4.19.4 Potential sources of error

The following features of the test equipment can impair the accuracy of the measurement (see 4.16 and 4.11).

4.20 SBS threshold

4.20.1 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 are published as IEC 61282-4.

4.20.2 Equipment required

For this test method the following pieces of equipment are needed.

a) All equipment necessary to carry out C/N measurements for optical transmitters (see 4.16).

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, class B1.3 fibre according to IEC 60793-2-50 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).

4.20.3 Procedure

For the measurement proceed as follows.

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 20.

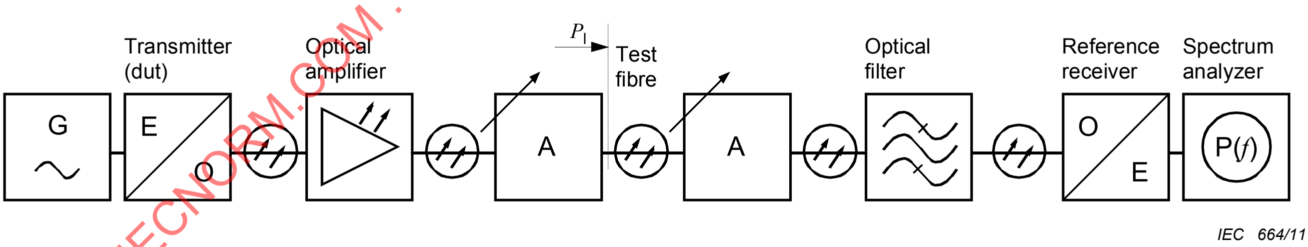


Figure 20 – Arrangement for measuring the SBS threshold

c) Adjust the optical power launched into the fibre to below P_l = 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 4.16).

e) Increase the launched power P_l 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.

4.20.4 Potential sources of error

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

- see 4.17.5;
- the inaccuracy of the variable attenuators;
- any instability of the optical amplifier.

4.21 Carrier-to-crosstalk ratio (CCR)

4.21.1 Purpose

This method of measurement is applicable when other services (i.e. digital communication signals like GPON, GEPON or Ethernet-Point-to-Point) besides CATV broadcast transmission (i.e. AM-VSB and 64/256QAM broadcast signals) are transmitted in the optical network. Other services may produce crosstalk effects in optical receiver devices with high linearity. The method of measurement for system CCR is laid down in 6.6 of IEC 60728-13.

Crosstalk effects may arise, when other services are transmitted by using wavelength division multiplexing (WDM) on the same fibre, and when there is either insufficient optical wavelength filtering or relevant presence of non-linear fibre optical effects, or both. Insufficient optical wavelength filtering may be due to low triplexer quality. Important non-linear fibre optical effects may be Stimulated Raman Scattering (SRS), Self-Phase Modulation (SPM) and Cross Phase Modulation (XPM). Among these causes SRS induced crosstalk is typically dominant, when analogue CATV broadcasting is transmitted on 1 550 nm wavelength and digital service signals use the 1 490 nm wavelength due to the fixed wavelength spacing.

4.21.2 Equipment required

For this test method the following pieces of equipment are needed.

a) Running System with implemented CATV broadcast service and other service(s).

b) A **selective voltmeter** (or spectrum analyser) covering the frequency range of CATV broadcast service.

4.21.3 Procedure

For the measurement proceed as follows.

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.

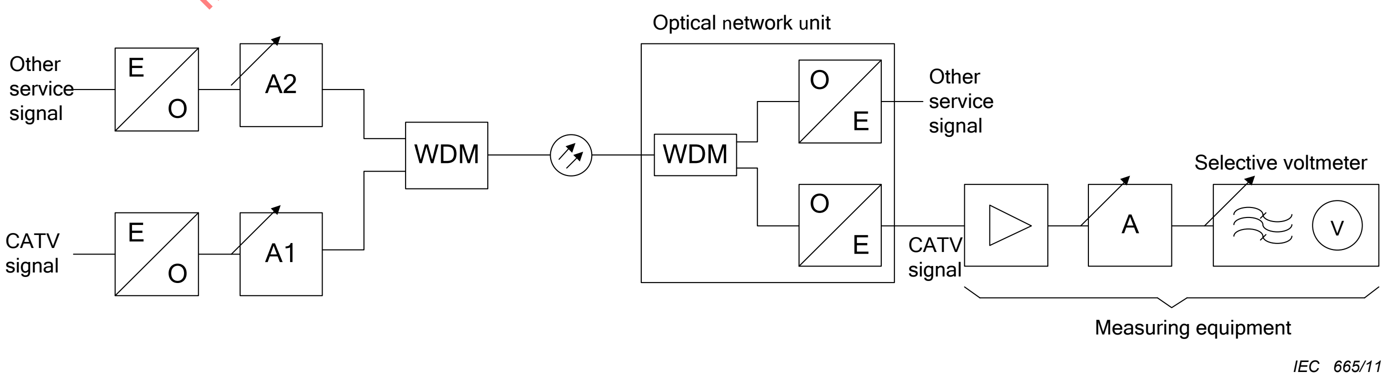


Figure 21 – Arrangement for measuring the CCR

c) Carry out measurements with the service signals widely and closely spaced over each band of interest.

d) Carry out measurements over the full specified range of both, optical power of CATV signal and optical power of other service signal at optical fibre input by adjusting optical attenuators A1 and A2.

e) Carry out measurements with various other services' communication signal patterns. E.g. measurement should be performed with and without digital idle signals (with and without payload), because signal pattern characteristics will influence crosstalk intensity.

f) Connect the variable RF attenuator A and selective voltmeter to the RF output port of optical receiver for CATV broadcast service. Tune the meter to each CATV carrier and note the attenuator A 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 other services crosstalk CCR expected at the point of measurement.

g) Tune the meter to the other services crosstalk product to be measured and reduce the RF attenuator A setting to the value a_2 required to obtain the same meter reading R.

NOTE It may be necessary to temporarily switch off one CATV carrier occupying frequency band of local interest during measurement of other services crosstalk single frequency level in order to obtain an accurate value a_2.

h) The other services crosstalk, in dB, is given by

$$CCR = a_1 - a_2 \tag{27}$$

where

a_1 is the RF attenuator A value when measuring the test signal used as a reference, in dB;

a_2 is the RF attenuator A value when measuring the crosstalk product, in dB.

4.21.4 Potential sources of error

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

- the inaccuracy of the selective voltmeter;
- the inaccuracy of the variable attenuators.

5 Universal performance requirements and recommendations

5.1 Safety

The relevant safety requirements of all equipment shall conform to IEC 60728-11, where applicable. Concerning laser safety, optical transmitters and optical amplifiers shall additionally fulfill the requirements of IEC 60825-1.

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

5.3.1 Requirements

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

5.3.2 Storage

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

5.3.3 Transportation

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

5.3.4 Installation or maintenance

Rough handling test	IEC 60068-2-31

5.3.5 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)	Annex 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 forward path transmitters

6.1.1 Classification

Optical 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 F1 to F6 (see Table 2).

Table 2 – Classes of optical forward path transmitters

Class	Application
F1	high performance TX (long haul, HFC, externally modulated laser)
F2	high performance TX (long haul, HFC, directlly modulated laser)
F3	medium performance TX (short haul, HFC, directly modulated laser)
F4	low performance TX (very short haul, narrow-cast)
F5	FTTH, multi-channel
F6	FTTH, re-transmission

6.1.2 Data publication requirement

Manufacturers shall at least publish information on the parameters as specified in Table 3.

Table 3 – Data publication requirements for optical forward path transmitters

Parameter	Classes F1 and F2	Classes F3 and F4	Class F5	Class F6
Type of light source	For example Fabry-Perot- or DFB laser diode, cooled or not cooled, directly or externally modulated			
Output power in dB(mW) and its tolerance – without optical amplifier – with optical amplifier	>5 dB(mW) >13 dB(mW)	>3 dB(mW) –	>5 dB(mW)	>3 dB(mW)
RF input level	Maximum level at which the performance requirements according to 6.1.3 can be met			
Wavelength in nm	-		1 555 nm ± 5 nm	1 540 nm to 1 560 nm or 1 560 nm to 1 580 nm
Fibre connection	Connector/splice type and type of fibre		according to IEC 61754-4 (SC type)	according to IEC 61754-4 (SC type)
Power consumption	–			
NOTE The output power values for classes F1 to F4 are recommended values. The values for classes F5 and F6 are requirements (see 6.1.4).				

6.1.3 Recommendations

The manufacturer shall at least publish information on parameters deviating from the recommendations as specified in Table 4.