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

Transmission media and optical systems characteristics –
Characteristics of optical components and subsystems

Transmission characteristics of optical components and subsystems

Recommendation ITU-T G.671



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ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
General	G.600–G.609
Symmetric cable pairs	G.610–G.619
Land coaxial cable pairs	G.620–G.629
Submarine cables	G.630–G.639
Free space optical systems	G.640–G.649
Optical fibre cables	G.650–G.659
Characteristics of optical components and subsystems	G.660–G.679
Characteristics of optical systems	G.680–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

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Recommendation ITU-T G.671

Transmission characteristics of optical components and subsystems

Summary

Recommendation ITU-T G.671 covers the transmission-related aspects of all types of optical components used in long-haul networks and access networks. A broad range of types of optical components is included in this Recommendation. This Recommendation also includes transmission characteristics of optical components under the full range of operating conditions, but does not specify the operating service conditions, installation aspects or other aspects of components not affecting the optical transmission path. This Recommendation also draws upon the relevant IEC definitions and test methods where applicable.

History

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

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Table of Contents

		Page
1	Scope	1
2	References.....	2
3	Terms and definitions	4
3.1	Terms defined elsewhere	4
3.2	Terms defined in this Recommendation.....	4
4	Abbreviations and acronyms	22
5	Parameter test methods and values	23
5.1	Optical add/drop multiplexer (OADM) subsystems (for WDM)	24
5.2	Asymmetric branching component (wavelength non-selective)	25
5.3	Optical attenuator	26
5.4	Optical branching component (wavelength non-selective)	26
5.5	Optical branching component (wavelength non-selective) for PONs	27
5.6	Optical connector.....	30
5.7	Delay line interferometer.....	30
5.8	Dynamic channel equalizer (DCE).....	31
5.9	Optical filter.....	31
5.10	Optical isolator	32
5.11	Passive (chromatic) dispersion compensator.....	32
5.12	Single optical channel passive (chromatic) dispersion compensator	33
5.13	Optical splice	33
5.14	Optical switch.....	34
5.15	Optical termination	35
5.16	Tuneable (chromatic) dispersion compensator.....	35
5.17	Tuneable filter	35
5.18	Optical wavelength MUX/DMUX	36

Recommendation ITU-T G.671

Transmission characteristics of optical components and subsystems

1 Scope

The object of this Recommendation is to identify the transmission-related parameters for each of the components listed below and define the values of such parameters specifiable for each of the most relevant system applications. Where applicable, IEC definitions will be used. Applicable systems are anticipated to be covered by the following ITU-T Recommendations:

- Long-haul terrestrial networks: networks using equipment with interfaces according to [ITU-T G.957], and Recommendations of optical interfaces for single channel and multichannel systems with optical amplifiers including [ITU-T G.691], [ITU-T G.692] and [ITU-T G.959.1].
- Access networks: networks using equipment according to [ITU-T G.982] and the ITU-T Recommendation of optical access networks to support services greater than the ISDN primary bit-rate (when published).

This Recommendation covers optical components used in the optical networks described in the Recommendations above. Where possible, common parameter values will be defined across all applications but, where necessary, specific values to each of the application groups may be given.

This Recommendation covers the transmission characteristics in the various operating conditions of the following optical components (listed in alphabetical order):

- optical add/drop multiplexer (OADM) subsystem;
- asymmetric branching component;
- optical attenuator;
- optical branching component (wavelength non-selective);
- optical connector;
- delay line interferometer;
- dynamic channel equalizer (DCE);
- optical filter;
- optical isolator;
- passive (chromatic) dispersion compensator;
- single optical channel passive (chromatic) dispersion compensator;
- optical splice;
- optical switch;
- optical termination;
- tuneable (chromatic) dispersion compensator;
- tuneable filter;
- optical wavelength multiplexer (MUX)/demultiplexer (DMUX);
 - coarse WDM device;
 - dense WDM device;
 - wide WDM device.

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This Recommendation does not cover:

- Installation aspects, service conditions and environmental and mechanical characteristics not affecting the optical transmission path of the various optical components.
- Specific details of test methods. According to an agreement with IEC TC 86 and its subcommittees, the guidelines to be followed for the measurement of most of the parameters defined in clause 5 are given in the IEC 61300-3 series of transmission and geometric test methods. The tables in clause 5 indicate the recommended test methods, collecting the test parameters into homogeneous groups and quoting for each group the relevant IEC basic specification number(s).

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T G.650.1] Recommendation ITU-T G.650.1 (2004), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable.*
- [ITU-T G.650.2] Recommendation ITU-T G.650.2 (2007), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable.*
- [ITU-T G.652] Recommendation ITU-T G.652 (in force), *Characteristics of a single-mode optical fibre and cable.*
- [ITU-T G.653] Recommendation ITU-T G.653 (in force), *Characteristics of a dispersion-shifted single-mode optical fibre and cable.*
- [ITU-T G.654] Recommendation ITU-T G.654 (2006), *Characteristics of a cut-off shifted single-mode optical fibre and cable.*
- [ITU-T G.655] Recommendation ITU-T G.655 (in force), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable.*
- [ITU-T G.661] Recommendation ITU-T G.661 (2007), *Definition and test methods for the relevant generic parameters of optical amplifier devices and subsystems.*
- [ITU-T G.662] Recommendation ITU-T G.662 (2005), *Generic characteristics of optical amplifier devices and subsystems.*
- [ITU-T G.691] Recommendation ITU-T G.691 (in force), *Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers.*
- [ITU-T G.692] Recommendation ITU-T G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers.*
- [ITU-T G.693] Recommendation ITU-T G.693 (2006), *Optical interfaces for intra-office systems.*
- [ITU-T G.694.1] Recommendation ITU-T G.694.1 (2002), *Spectral grids for WDM applications: DWDM frequency grid.*
- [ITU-T G.694.2] Recommendation ITU-T G.694.2 (2003), *Spectral grids for WDM applications: CWDM wavelength grid.*

- [ITU-T G.698.1] Recommendation ITU-T G.698.1 (2006), *Multichannel DWDM applications with single-channel optical interfaces*.
- [ITU-T G.957] Recommendation ITU-T G.957 (2006), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.
- [ITU-T G.959.1] Recommendation ITU-T G.959.1 (in force), *Optical transport network physical layer interfaces*.
- [ITU-T G.982] Recommendation ITU-T G.982 (1996), *Optical access networks to support services up to the ISDN primary rate or equivalent bit rates*.
- [ITU-T G.983.1] Recommendation ITU-T G.983.1 (2005), *Broadband optical access systems based on Passive Optical Networks (PON)*.
- [ITU-T G.983.3] Recommendation ITU-T G.983.3 (2001), *A broadband optical access system with increased service capability by wavelength allocation*.
- [ITU-T G.984.2] Recommendation ITU-T G.984.2 (2003), *Gigabit-capable Passive Optical Networks (GPON): Physical Media Dependent (PMD) layer specification*.
- [IEC 60869-1] IEC 60869-1 (1999), *Fibre optic attenuators – Part 1: Generic specification*.
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- [IEC 60875-1] IEC 60875-1 ed. 5.0 (2010), *Fibre optic interconnecting devices and passive components – Non-wavelength-selective fibre optic branching devices – Part 1: Generic specification*.
<<http://webstore.iec.ch/webstore/webstore.nsf/mysearchajax?Openform&key=IEC%2060875-1&sorting=&start=1&onglet=1>>
- [IEC 60876-1] IEC 60876-1 ed.4 (2012), *Fibre optic interconnecting devices and passive components – Fibre optic spatial switches – Part 1: Generic specification*.
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- [IEC 61202-1] IEC 61202-1 ed. 3.0 (2009), *Fibre optic interconnecting devices and passive components – Fibre optic isolators – Part 1: Generic specification*.
<<http://webstore.iec.ch/webstore/webstore.nsf/mysearchajax?Openform&key=IEC%2061202-1&sorting=&start=1&onglet=1>>
- [IEC 61300-3-2] IEC 61300-3-2 (1999), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-2: Examination and measurements – Polarization dependent loss in a single-mode fibre optic device*.
<<http://webstore.iec.ch/webstore/webstore.nsf/mysearchajax?Openform&key=IEC%2061300-3-2&sorting=&start=1&onglet=1>>
- [IEC 61300-3-2a] IEC 61300-3-2 ed. 3.0 (2009), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-2: Examination and measurements – Polarization dependent loss in a single-mode fibre optic device*.
<<http://webstore.iec.ch/webstore/webstore.nsf/mysearchajax?Openform&key=IEC%2061300-3-2&sorting=&start=1&onglet=1>>
- [IEC 61300-3-4] IEC 61300-3-4 (2001), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation*.
<<http://webstore.iec.ch/webstore/webstore.nsf/artnum/026685>>

- [IEC 61300-3-6] IEC 61300-3-6 (2005), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*.
- [IEC 61300-3-7] IEC 61300-3-7 (2004), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-7: Examinations and measurements – Wavelength dependence of attenuation and return loss*.
- [IEC 61300-3-19] IEC 61300-3-19 (1997), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-19: Examinations and measurements – Polarization dependence of return loss of a single-mode fibre optic component*.
<<http://webstore.iec.ch/webstore/webstore.nsf/artnum/021976>>
- [IEC/TR 61931] IEC/TR 61931 (1998), *Fibre optic – Terminology*.
<<http://webstore.iec.ch/webstore/webstore.nsf/artnum/023183>>

3 Terms and definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

Most of the definitions of parameters specified in this Recommendation, for each of the above-mentioned passive components, are given in the corresponding IEC generic specification.

Where IEC definitions are used, they are noted as such. Additional parameters under study or not defined in IEC documents are also given in this clause.

This Recommendation defines the following terms:

3.2.1 Component definitions

3.2.1.1 optical add/drop multiplexer (OADM) subsystem: A wavelength selective branching device (used in WDM transmission systems) having a wavelength "drop" function in which one or more optical signals can be transferred from an input port to either an output port or drop port(s) depending on the wavelength of the signal and also having a wavelength "add" function in which optical signals presented to the add port(s) are also transferred to the output port as shown in Figure 1.

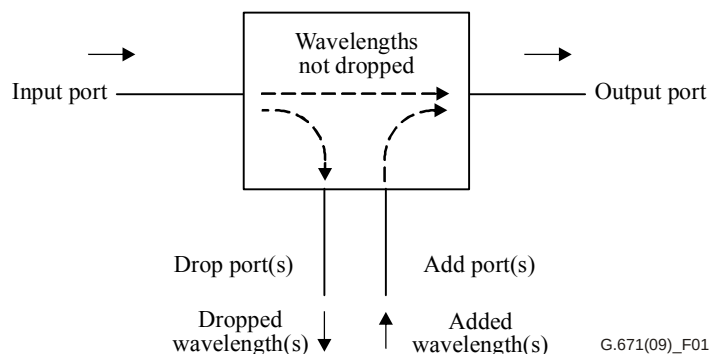


Figure 1 – Optical add/drop multiplexer (OADM) subsystem

3.2.1.2 asymmetric branching component: A passive component (wavelength non-selective) possessing three or more ports which shares optical power among its ports in a predetermined fashion, without any amplification, switching or other active modulation (clause 1.1 in [IEC 60875-1]). A tap coupler is used as a synonym for an asymmetric branching device.

The majority of the optical power is normally transferred to the main port of a tap coupler while a small fraction (1% to 20%) is transferred to the tap port. The ratio of the optical power in the main port to the tap port as a percentage is called the coupling fraction F .

Optical branching devices can be divided into categories of symmetric and asymmetric. A device whose transfer matrix is diagonally asymmetric, i.e., where for all i and o , t_{io} and t_{oi} are nominally unequal (clause 1.3.19 in [IEC 60875-1]).

3.2.1.3 optical attenuator: A passive component that produces a controlled signal attenuation in an optical fibre transmission line (clause 1.3.1 in [IEC 60869-1]).

3.2.1.4 optical branching component (wavelength non-selective): A passive component (wavelength non-selective) possessing three or more ports which shares optical power among its ports in a predetermined fashion, without any amplification, switching or other active modulation (clause 1.1 in [IEC 60875-1]). The term coupler (splitter-combiner) is used as a synonym for a branching device. The term is also used to define a structure for transferring optical power between two fibres or between an active device and a fibre (clause 1.3.2 in [IEC 60875-1]).

Optical branching devices can be divided into categories of symmetric and asymmetric. A symmetric branching component is a device whose transfer matrix is diagonally symmetric, i.e., where for all i and o , t_{io} and t_{oi} are nominally equal (clause 1.3.18 in [IEC 60875-1]).

3.2.1.5 optical connector: A component normally attached to an optical cable or piece of apparatus for the purpose of providing frequent optical interconnection/disconnection of optical fibres or cables (clause 6.01 in [IEC/TR 61931]).

3.2.1.6 delay line interferometer: A component used to demodulate a phase-modulated optical signal by converting the phase modulation into an amplitude modulation. The device has a single input and two output ports. The optical input signal is split into two beams with nominally equal power. The beams traverse the arms of a Mach-Zehnder or Michelson interferometer. One beam is delayed compared to the other (by an amount τ which depends on the particular application) before the beams are re-combined and interfere with each other constructively for one output and destructively for the other. The resultant two output signals are amplitude modulated signals, where the phase to amplitude conversion at one output is the inverse of that for the other.

3.2.1.7 dynamic channel equalizer (DCE): A device that is capable of transforming, by internal or external automatic control, a multichannel input signal with time-varying averaged powers into an output signal in which all working channel powers are nominally equal or are set for a required level of pre-emphasis.

NOTE – This device may also provide the extinction of one or more of the input channels.

3.2.1.8 optical filter: A passive component used to modify the optical radiation passing through it, generally by altering the spectral distribution (clause 2.6.35 of [IEC/TR 61931]). Alternative: In particular, optical filters are usually employed to reject or absorb optical radiation in particular ranges of wavelength, while transmitting optical radiation in other ranges of wavelength.

NOTE – A tuneable optical filter has the ability to track the signal wavelength variation over its operating wavelength range. A non-tuneable optical filter has a fixed value over the operating wavelength range.

3.2.1.9 optical isolator: A non-reciprocal optical device intended to suppress backward reflections along an optical fibre transmission line while having minimum insertion loss in the forward direction (clause 1.3.1 in [IEC 61202-1]).

3.2.1.10 passive (chromatic) dispersion compensator: A passive component used to compensate the chromatic dispersion of an optical path.

3.2.1.11 single optical channel passive (chromatic) dispersion compensator: A passive component used to compensate the chromatic dispersion of an optical path where the parameters are only required to be met within the frequency range of a single optical channel.

3.2.1.12 optical splice: A permanent or semi-permanent joint whose purpose is to couple optical power between two optical fibres (clause 6.08 in [IEC/TR 61931]).

Fusion splice: A splice in which the fibre ends are joined in a permanent manner by means of fusion (clause 6.09 in [IEC/TR 61931]).

Mechanical splice: A splice in which the fibre ends are joined in a permanent or separable manner by means other than fusion (clause 6.10 in [IEC/TR 61931]).

3.2.1.13 optical switch: A passive component possessing two or more ports which selectively transmits, redirects or blocks optical power in an optical fibre transmission line (clause 1.3.1 in [IEC 60876-1]).

3.2.1.14 optical termination: A component used to terminate a fibre (connectorized or not) in order to suppress reflections.

3.2.1.15 tuneable (chromatic) dispersion compensator: A component used to compensate the chromatic dispersion of an optical path where the magnitude of dispersion compensation can be adjusted within a defined range.

3.2.1.16 tuneable filter: See 3.2.1.8.

3.2.1.17 optical wavelength multiplexer (MUX)/demultiplexer (DMUX): WDM device: A 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 (clause 6.51 in [IEC/TR 61931]).

Both wavelength multiplexers (MUXs) and wavelength demultiplexers (DMUXs) are generally called 'WDM devices' since often the same device can be used to multiplex and demultiplex channels.

Wavelength MUX: A branching device with two or more input ports and one output port where the light in each input port is restricted to a preselected wavelength range and the output is the combination of the light from the input ports (clause 6.52 in [IEC/TR 61931]).

Wavelength DMUX: A device which performs the inverse operation of a wavelength multiplexer, where the input is an optical signal comprising two or more wavelength ranges and the output of each port is a different preselected wavelength range (clause 6.53 in [IEC/TR 61931]).

3.2.1.17.1 coarse WDM (CWDM) device: A class of WDM devices that have a channel wavelength spacing less than 50 nm but greater than 1000 GHz (about 8 nm at 1 550 nm and 5.7 nm at 1 310 nm). Devices within this class can cover several spectral bands.

3.2.1.17.2 dense WDM (DWDM) device: A class of WDM devices that have a channel spacing less than or equal to 1000 GHz. Devices within this class can cover one or more spectral bands.

3.2.1.17.3 wide WDM (WWDM) device: A class of WDM devices that have a channel wavelength spacing greater than or equal to 50 nm. This device class typically separates a channel in one conventional transmission window (e.g., 1 310 nm) from another (e.g., 1 550 nm).

3.2.2 Parameter definitions

NOTE – Not all of the definitions cited in this clause apply to all devices. The relevance of a particular definition to a specific type of device can be found in clause 5.

3.2.2.1 1 dB and 3 dB passband width: The 1 dB passband width D_1 of an optical filter is the total frequency range over which the filter is required to have less than 1 dB of loss with respect to the minimum loss within that range. The 1 dB passband width is symmetrical with respect to the nominal centre frequency f_c of the filter, i.e., the loss is required to be within 1 dB of the minimum at all frequencies between $f_c - D_1/2$ and $f_c + D_1/2$. This is illustrated in Figure 2.

The 3 dB passband width D_3 of an optical filter is the total frequency range over which the filter is required to have less than 3 dB of loss with respect to the minimum loss within that range. The 3 dB passband width is symmetrical with respect to the nominal centre frequency f_c of the filter, i.e., the loss is required to be within 3 dB of the minimum at all frequencies between $f_c - D_3/2$ and $f_c + D_3/2$. This is illustrated in Figure 2.

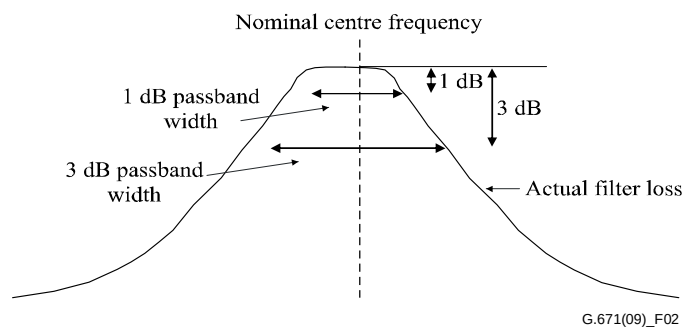


Figure 2 – Illustration of 1 dB and 3 dB passband width

3.2.2.2 adjacent channel isolation: The adjacent channel isolation (of a WDM device) is defined to be equal to the unidirectional (far-end) isolation of that device with the restriction that x , the isolation wavelength number, is restricted to the channels immediately adjacent to the (channel) wavelength number associated with port o . This is illustrated in Figure 3.

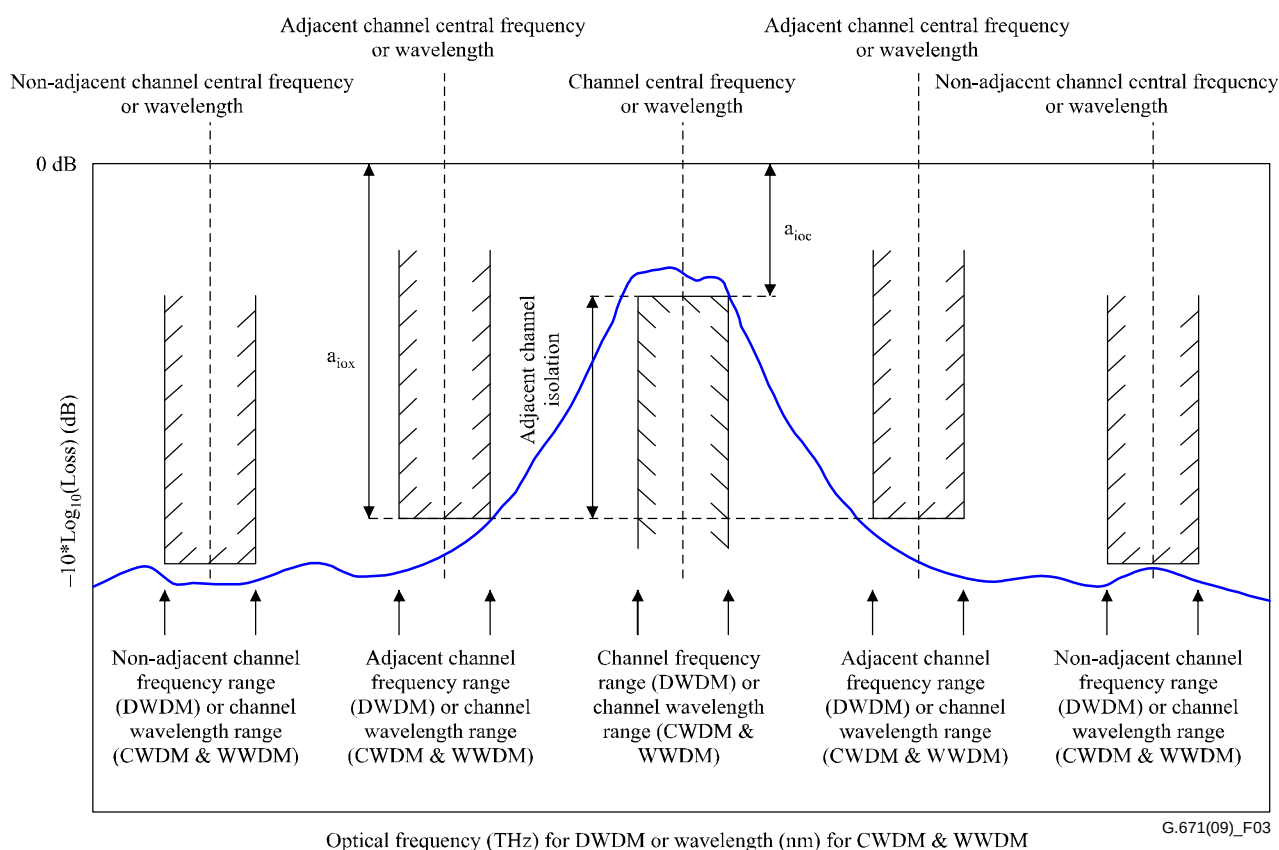


Figure 3 – Illustration of adjacent channel isolation for a WDM device

3.2.2.3 attenuation accuracy (optical attenuators only): The difference between nominal and actual insertion loss of the attenuator.

3.2.2.4 attenuation range (variable attenuators only): The attenuation range (of a variable attenuator) is the difference (in dB) between the maximum and minimum nominal loss settings.

3.2.2.5 backward loss (isolation) (for an optical isolator): A measure of the decrease in optical power (dB) resulting from the insertion of an isolator in its backward direction. The launching port is the output port and the receiving port is the input port of the isolator. It is given by the following formula:

$$BL = -10 \log \left(\frac{P_{ob}}{P_{ib}} \right)$$

where:

P_{ob} is the optical power emerging from the input port of the isolator when P_{ib} is launched into the output port. In operating conditions, P_{ib} is the optical power reflected in the backward direction into the output port of the isolator being measured (clause 1.3.10 of [IEC 61202-1]).

3.2.2.6 bidirectional (near-end) crosstalk attenuation (for a WDM device): In a bidirectional WDM-MUX/DMUX device, the bidirectional (near-end) crosstalk attenuation is defined to be:

$$BCA = a_{mox}$$

where:

a_{mox} is an element of the logarithmic transfer matrix where m is the MUX input port number, o is the DMUX output port number and x is the wavelength number associated with port m .

3.2.2.7 bidirectional (near-end) isolation (for a WDM device): Because bidirectional WDM-MUX/DMUX devices have both input channels and output channels at the same side of the device, input light for one direction can appear on the output port for the other direction.

In the example given below of a four-wavelength bidirectional system, wavelengths 1 and 2 travel from left to right and wavelengths 3 and 4 from right to left.

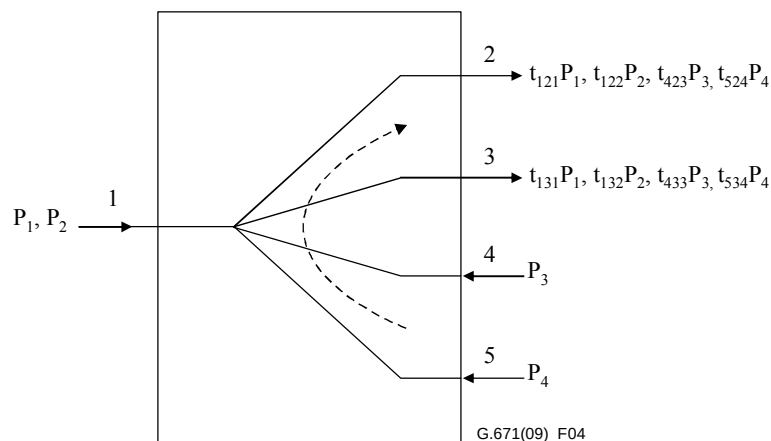


Figure 4 – Example of bidirectional (near-end) isolation

The bidirectional (near-end) isolation is therefore defined to be:

$$I_B = a_{mox} - a_{doc}$$