International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.671
(08/2019)

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

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.

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

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.671	1996-11-11	15	11.1002/1000/3814
2.0	ITU-T G.671	2001-02-09	15	11.1002/1000/5349
3.0	ITU-T G.671	2002-06-29	15	11.1002/1000/6075
4.0	ITU-T G.671	2005-01-13	15	11.1002/1000/7470
4.1	ITU-T G.671 (2005) Amd. 1	2006-03-29	15	11.1002/1000/8754
4.2	ITU-T G.671 (2005) Amd. 2	2006-12-14	15	11.1002/1000/8978
4.3	ITU-T G.671 (2005) Amd. 3	2008-03-29	15	11.1002/1000/9368
5.0	ITU-T G.671	2009-01-13	15	11.1002/1000/9645
6.0	ITU-T G.671	2012-02-13	15	11.1002/1000/11481
7.0	ITU-T G.671	2019-08-29	15	11.1002/1000/13994

Keywords

Optical components, optical subsystems.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization 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.

INTELLECTUAL PROPERTY RIGHTS

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

As of the date of approval of this Recommendation, 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/.

Table of Contents

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.

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 60869-1:2018, *Fibre optic interconnecting devices and passive components – Fibre optic passive power control devices – Part 1: Generic specification*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/60884>

[IEC 60875-1] IEC 60875-1:2015, *Fibre optic interconnecting devices and passive components – Non-wavelength-selective fibre optic branching devices – Part 1: Generic specification*.
<https://webstore.iec.ch/publication/22396>

[IEC 60876-1] IEC 60876-1:2014, *Fibre optic interconnecting devices and passive components – Fibre optic spatial switches – Part 1: Generic specification*.
<https://webstore.iec.ch/publication/3790>

[IEC 61202-1] IEC 61202-1:2016, *Fibre optic interconnecting devices and passive components – Fibre optic isolators – Part 1: Generic specification*.
<https://webstore.iec.ch/publication/32707>

[IEC 61300-3-2] IEC 61300-3-2:2009, *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*.
<https://webstore.iec.ch/publication/5212>

[IEC 61300-3-4] IEC 61300-3-4:2008, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation*.
<https://webstore.iec.ch/publication/5233>

[IEC 61300-3-6] IEC 61300-3-6:2008, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*.
<https://webstore.iec.ch/publication/5247>

[IEC 61300-3-7] IEC 61300-3-7:2009, *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*.
<https://webstore.iec.ch/publication/5248>

[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*.
<https://webstore.iec.ch/publication/5211>

[IEC 61300-3-38] IEC 61300-3-38:2012, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-38: Examinations and measurements – Group delay, chromatic dispersion and phase ripple.*
<https://webstore.iec.ch/publication/5231>

[IEC/TR 61931] IEC/TR 61931:1998, *Fibre optic – Terminology*.
<https://webstore.iec.ch/publication/6111>

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.

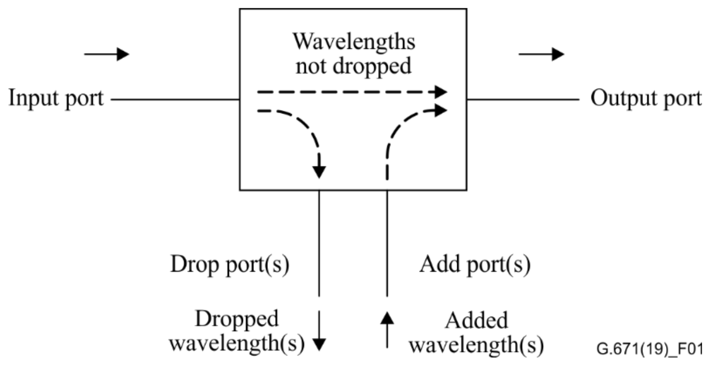

Figure 1 – Optical add/drop multiplexer (OADM) subsystem

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 clause 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.

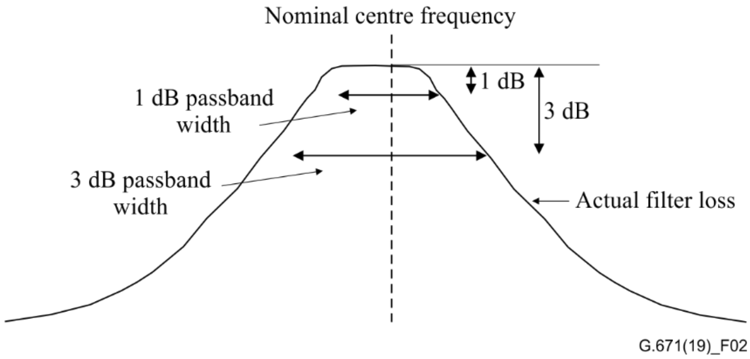

Figure 2 – Illustration of 1 dB and 3 dB passband width

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.

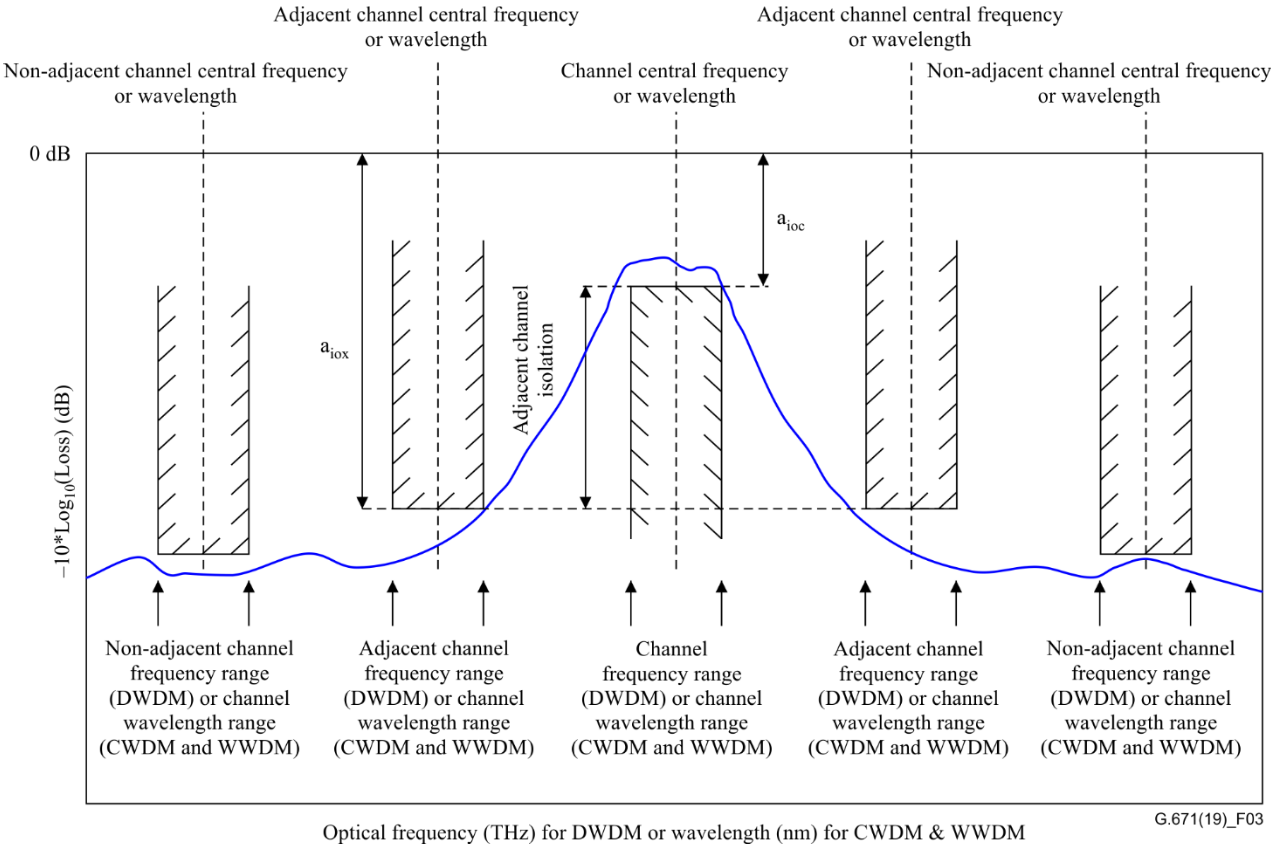

Figure 3 – Illustration of adjacent channel isolation for a WDM device

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.

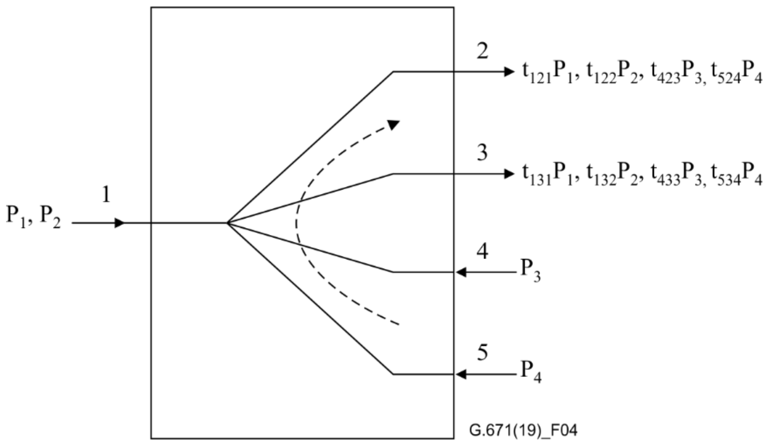

Figure 4 – Example of bidirectional (near-end) isolation

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

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

a_{mox} and a_{doc} are elements of the logarithmic transfer matrix where *d* is the DMUX input port number, *o* is the DMUX output port number, *c* is the (channel) wavelength number associated with port *o*, *m* is the MUX input port number and *x* is the wavelength number associated with port *m*.

3.2.2.8 channel attenuation resolution (dynamic channel equalizer only): The channel attenuation resolution is the maximum difference between the insertion losses within a channel frequency (or wavelength) range of any two adjacent attenuation settings within the dynamic attenuation range of a dynamic channel equalizer (in dB).

For the example given above, the bidirectional isolation of port 2 to wavelength 3 is $a_{423} - a_{121}$.

3.2.2.9 channel extinction: Within the operating wavelength range, the difference (in dB) between the maximum insertion loss for the non-extinguished (non-blocked) channels and the minimum insertion loss for the extinguished (blocked) channels.

It is given by the following formula:

$$CE = a_{ioe} - a_{iox}$$

The terms a_{ioe} and a_{iox} are elements of the logarithmic transfer matrix (defined in clause 3.2.3.5), where *i* is the input port number, *o* is the output port number, *e* is the (channel) wavelength number of the extinguished channel and *x* is the wavelength number of the non-extinguished channel with highest loss. This is illustrated in Figure 5.

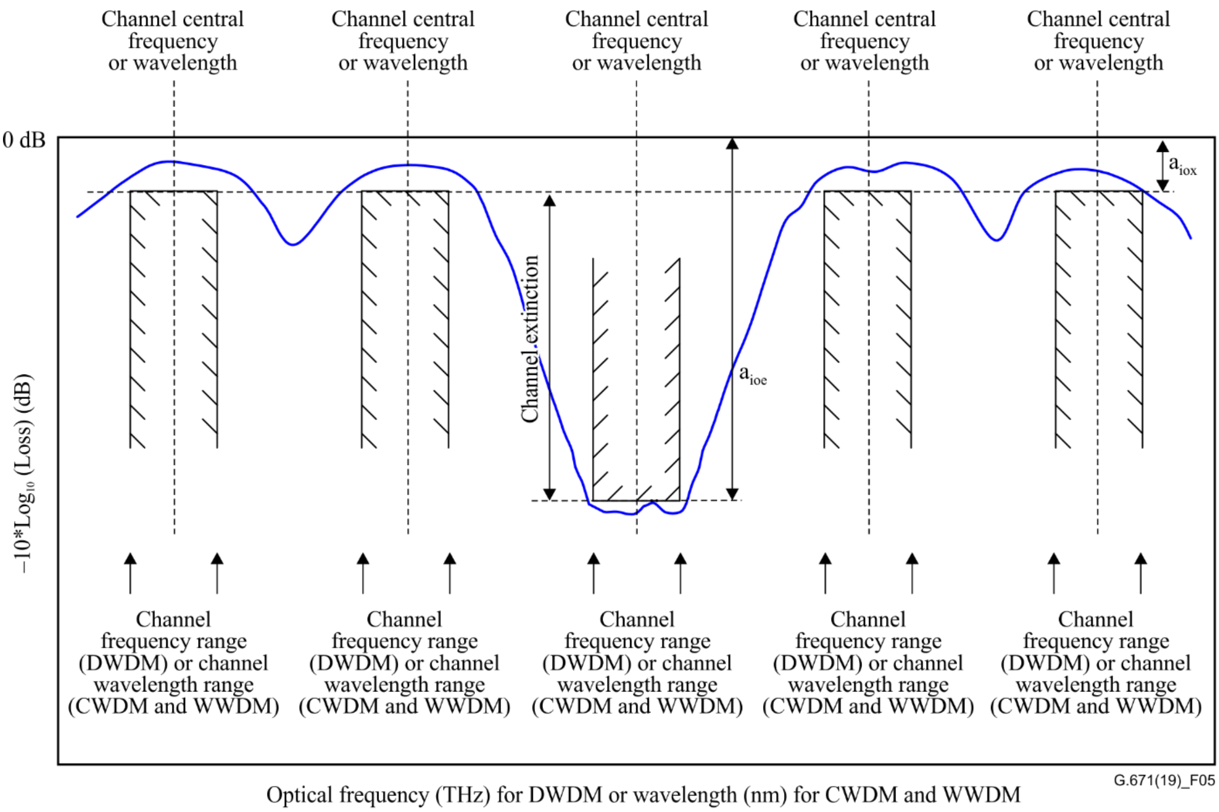

Figure 5 – Illustration of channel extinction of a WDM device

NOTE – A definition of channel extinction that is different from the above is sometimes used, which is the difference between the insertion loss for the channel when not extinguished (not blocked) and the minimum insertion loss for the same channel when extinguished (blocked). Channel extinction evaluated by this method may have a higher value, but under some circumstances the interferometric crosstalk predicted using this channel extinction may not be the worst-case value.

3.2.2.10 channel frequency range: The frequency range within which a DWDM device is required to operate with a specified performance. For a particular nominal channel central frequency, f_{nomi}, this frequency range is from $f_{imin} = (f_{nomi} - \Delta f_{max})$ to $f_{imax} = (f_{nomi} + \Delta f_{max})$, where Δf_{max} is the maximum channel central frequency deviation or the spectral excursion. Nominal channel central frequency and maximum channel central frequency deviation are defined in [ITU-T G.692] and spectral excursion is defined in [ITU-T G.698.1].

3.2.2.11 channel insertion loss (WDM devices): It is the reduction in optical power between an input and output port of a WDM device in decibels (dB). It is defined as:

$$IL = -10 \log\left(\frac{P_{out}}{P_{in}}\right)$$

where:

P_{in} is the optical power launched into the input port and

P_{out} is the optical power received from the output port.

NOTE – For a WDM device, it is an element a_{iow} of the $n \times n \times k$ element logarithmic transfer matrix. Here i is the input port number, o is the output port number and w is the wavelength number associated with port i or o, n is the total number of input + output ports and k is the total number of wavelengths of the logarithmic transfer matrix. For WWDM devices, it shall be specified as a maximum value and a minimum value at each operating wavelength range. For DWDM and CWDM devices, it shall be specified as a maximum value and a minimum value within the channel frequency (or wavelength) range as illustrated in Figure 6.

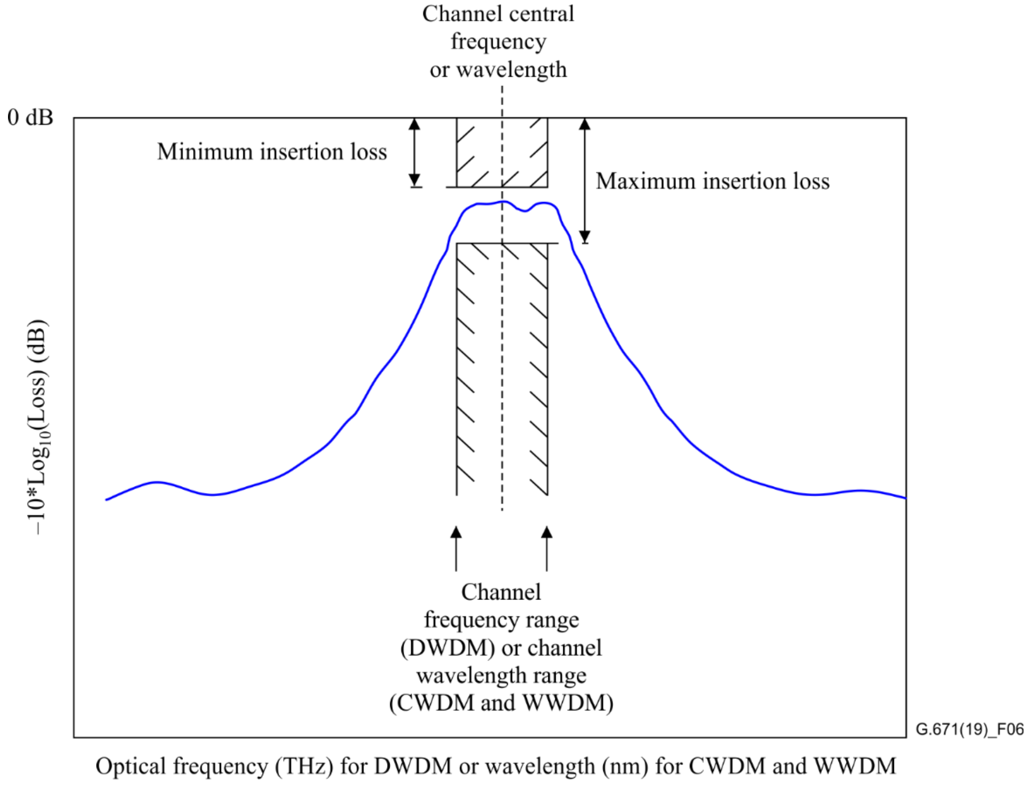

Figure 6 – Illustration of maximum and minimum insertion loss of a WDM device

3.2.2.12 channel insertion loss deviation (WDM devices): This is the maximum variation of insertion loss at any frequency within the channel frequency range (DWDM devices) or channel wavelength range (CWDM and WWDM devices). This is illustrated in Figure 7.

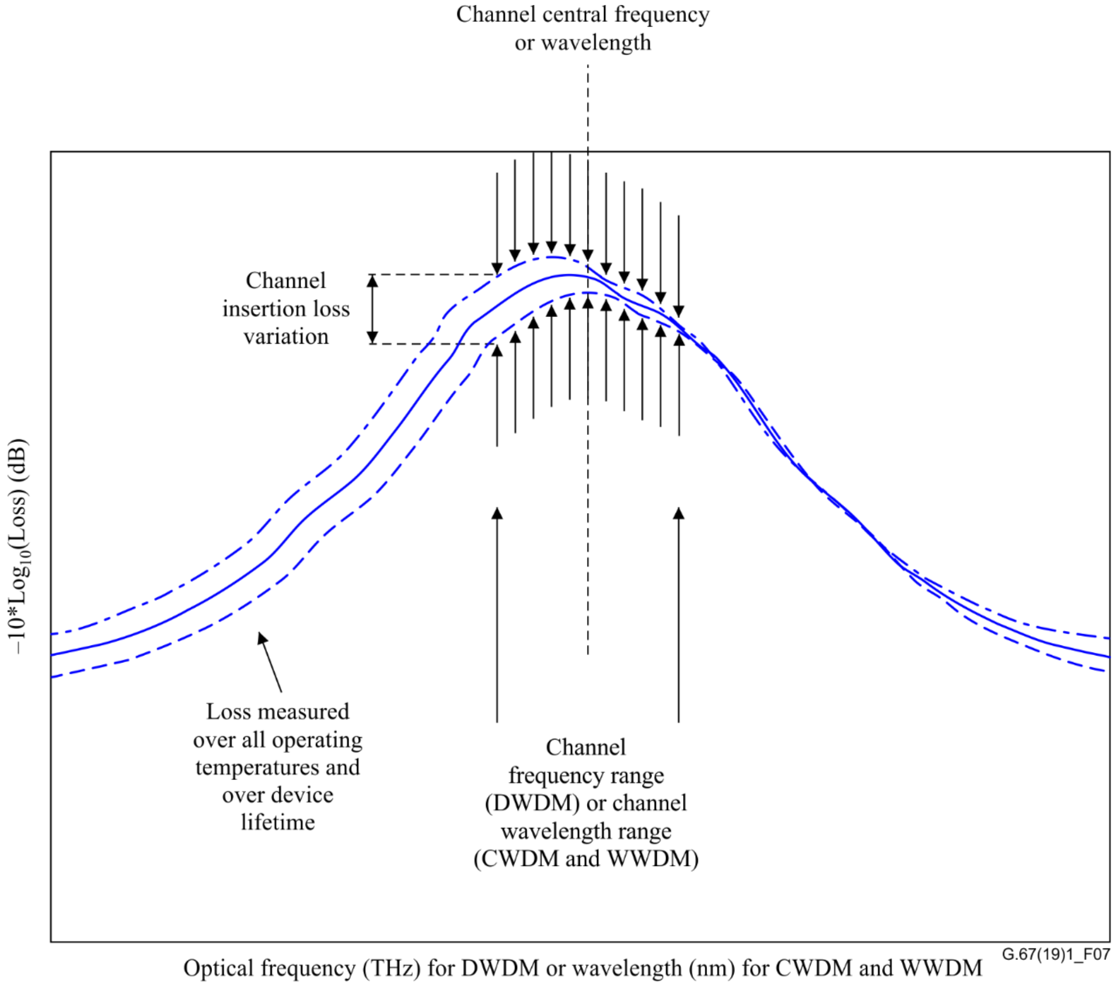

Figure 7 – Illustration of channel insertion loss variation of a WDM device

3.2.2.13 channel non-uniformity: The difference (in dB) between the powers of the channel with the most power (in dBm) and the channel with the least power (in dBm). This applies to a multichannel signal across the operating wavelength range.

3.2.2.14 channel polarization dependent loss (PDL) (for OADM type subsystems): Maximum variation of insertion loss due to a variation of the state of polarization (SOP) over all SOPs within the channel frequency range (DWDM devices) or channel wavelength range (CWDM and WWDM devices).

3.2.2.15 channel polarization mode dispersion (PMD) (for OADM type subsystems): The polarization mode dispersion as defined in clause 3.2.2.36 within the channel frequency range (DWDM devices) or channel wavelength range (CWDM and WWDM devices).

3.2.2.16 channel response time: The elapsed time it takes a device to transform a channel from a specified initial power level to a specified final power level desired state, when the resulting output channel non-uniformity tolerance is met, measured from the time the actuation energy is applied or removed.

3.2.2.17 channel spacing: The centre-to-centre difference in frequency or wavelength between adjacent channels in a WDM device. DWDM channel spacings are based on the grid found in [ITU-T G.694.1]. CWDM channel spacings are based on the grid found in [ITU-T G.694.2].

3.2.2.18 channel wavelength range: The wavelength range within which a CWDM or WWDM device is required to operate with a specified performance. For a particular nominal channel central wavelength, λ_{nomi}, this wavelength range is from $\lambda_{imin} = (\lambda_{nomi} - \Delta\lambda_{max})$ to $\lambda_{imax} = (\lambda_{nomi} + \Delta\lambda_{max})$, where $\Delta\lambda_{max}$ is the maximum channel wavelength deviation.

3.2.2.19 delay between balanced ports (delay line interferometer only): The optical delay (ps) between the two output signals obtained at the output ports of a delay line interferometer.

NOTE – This optical delay is different from the delay between the interferometer arms described in clause 3.2.1.6.

3.2.2.20 demodulation extinction ratio (delay line interferometer only): The intensity difference (dB) between the transmitted optical intensity maximum and the transmitted optical minimum when the device is tuned through the FSR.

NOTE – The parameter "demodulation extinction ratio" is measured with CW input light and is sometimes also referred to as the "isolation" or "extinction ratio" of a delay line interferometer. This is, however, a different parameter from the "demodulated extinction ratio" which is a characteristic of the result of passing a phase modulated signal through a delay line interferometer to convert the phase modulation into amplitude modulation.

3.2.2.21 directivity: For an optical branching component or an optical switch, the value a_{sr} of the logarithmic transfer matrix, where s and r are the port numbers of two nominally isolated ports (clause 1.3.11 in [IEC 60875-1]).

3.2.2.22 dispersion compensation tuning range (for tuneable dispersion compensator): The difference between maximum and minimum dispersion (in ps/nm) that can be achieved by the tuneable dispersion compensator over the channel frequency range.

3.2.2.23 dynamic channel attenuation range (dynamic channel equalizer only): For a dynamic channel equalizer, this is the difference (in dB) between the insertion loss and the largest value of channel attenuation for which the other parameter specifications are met.

3.2.2.24 free-spectral range (delay line interferometer only): The spacing (difference) in optical frequency (GHz) between two successive transmitted optical intensity maxima or minima of a delay line interferometer.

3.2.2.25 group delay: This is the time required for a signal to propagate through a device (clause 3 in [IEC 61300-3-38]) between the connector end face of the input port and the connector end face of the output port. If no connectors are provided at the input or output port, a reference plane must be defined in the optical path of the optical signal. For some devices, the group delay can depend on the signal wavelength. For multiple input or output ports, the group delay can depend on the input / output port combination.

The asymmetric group delay of an optical link can be derived from the minimum and maximum group delay of the devices in the link and the measured group delay of the optical fibre connecting the devices. The minimum group delay for one direction is obtained by adding the minimum group delay values for the individual components within the optical path for this direction together with the measured fibre propagation delay for this direction. A similar calculation is performed by adding the maximum instead of the minimum group delay values for the individual components to obtain the maximum group delay for this direction. The minimum and maximum group delays for the opposite direction are calculated in the same way.

The maximum expected link asymmetry is then obtained by subtracting the minimum delay value for one direction from the maximum delay value for the opposite direction and vice versa, and then taking the larger value of the two calculated differences.

3.2.2.26 incremental attenuation (variable attenuators only): A term applicable only to variable attenuators. It refers to the difference between the nominal attenuation of the component at a given setting and the minimum nominal attenuation (clause 1.3.6 in [IEC 60869-1]).

3.2.2.27 insertion loss (delay line interferometer only): It is the reduction in optical power (dB) between the input and the output ports of a delay line interferometer. It is defined as:

$$IL = -10\log\left(\frac{Min\left[P_{out1}, P_{out2}\right]}{P_{in}}\right)$$

where:

P_{in} is the optical power launched into the input port;

P_{out1} is the lowest optical power received from output port 1 when tuned for any maximum within the operating wavelength range; and

P_{out2} is the lowest optical power received from output port 2 when tuned for any maximum within the operating wavelength range.

3.2.2.28 insertion loss (non-WDM devices): It is the reduction in optical power between an input and output port of a passive component in decibels. It is defined as:

$$IL = -10\log\left(\frac{P_{out}}{P_{in}}\right)$$

where:

P_{in} is the optical power launched into the input port and

P_{out} is the optical power received from the output port.

NOTE 1 – For an optical branching component, it is an element a_{io} (where i is the input port number and o is the output port number) of the logarithmic transfer matrix (clause 1.3.7 in [IEC 60875-1]).

NOTE 2 – For an optical switch, it is an element a_{io} (where i is the input port number and o is the output port number) of the logarithmic transfer matrix. It depends on the state of the switch (clause 1.3.9 in [IEC 60876-1]).

NOTE 3 – For an optical filter, it shall be specified as a maximum value and a minimum value over each operating wavelength range.

3.2.2.29 isolation of an optical switch: The isolation of an optical switch is the minimum value of the ratio of the transfer coefficient of the switch in its on state to the transfer coefficient in its off state over the operating wavelength range. It is defined as:

$$IOS = 10\ \log\left(\frac{t_{io}}{t^{o}{}_{io}}\right)$$

Where t_{io} is the transfer coefficient (as defined in clause 3.2.3.12) from port i to port o with path io switched on and $t^{o}{}_{io}$ is the transfer coefficient from port i to port o with path io switched off.

3.2.2.30 non-adjacent channel isolation: The non-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 each of the channels **not** immediately adjacent to the (channel) wavelength number associated with port o. This is illustrated in Figure 8.

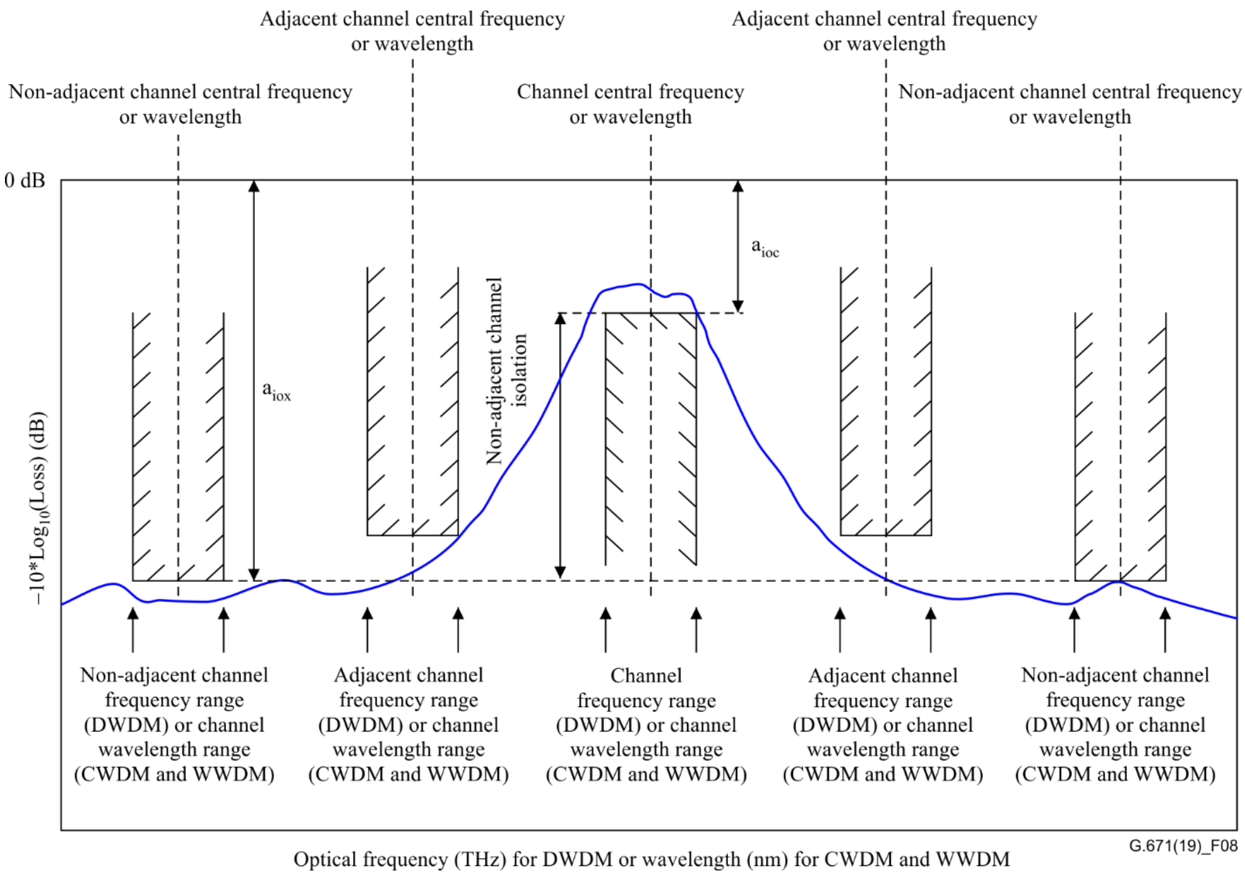

Figure 8 – Illustration of non-adjacent channel isolation for a WDM device

3.2.2.31 operating wavelength range: The specified range of wavelengths from λ_{imin} to λ_{imax} about a nominal operating wavelength λ_i, within which a passive component is designed to operate with a specified performance (clause 1.3.21 in [IEC 60875-1]).

NOTE 1 – For an optical branching component with more than one operating wavelength, the corresponding wavelength ranges are not necessarily equal (clause 1.3.21 in [IEC 60875-1]).

NOTE 2 – The components, including attenuators, terminations, connectors and splices may operate with a specified performance or acceptable performance even outside the specified range of wavelengths.

3.2.2.32 out-of-band attenuation: The minimum attenuation (in dB) of channels that fall outside of the operating wavelength range.

3.2.2.33 phase ripple: The phase ripple of an optical device is the maximum peak-to-peak variation of the phase through the device with respect to a quadratic approximation of the phase characteristic within the channel frequency range (DWDM devices) or channel wavelength range (CWDM and WWDM devices).

Some optical devices exhibit chromatic dispersion within the channel frequency range. This means that the optical phase varies (approximately) in a quadratic manner with frequency. The phase ripple is therefore defined as the peak-to-peak variation in phase with respect to a quadratic change in phase with frequency.

The relationship between the phase ripple and the optical penalty it causes is dependent on factors such as the signal bit rate, modulation format, width of the optical spectrum, position of the signal within the channel frequency range, etc. This means that the value of this parameter must be determined from the application in the relevant transmission system Recommendation.

3.2.2.34 polarization dependent frequency shift (delay line interferometer only): The maximum frequency shift (GHz) of the transmitted optical intensity maxima or minima of a delay line interferometer among all polarization states.

3.2.2.35 polarization dependent loss (PDL): Maximum variation of insertion loss due to a variation of the state of polarization (SOP) over all SOPs.

3.2.2.36 polarization dependent reflectance: Maximum variation of reflectance due to a variation of the state of polarization (SOP) over all SOPs.

3.2.2.37 polarization mode dispersion (PMD): Polarization mode dispersion (PMD) is usually described in terms of a differential group delay (DGD), which is the time difference between the principal states of polarization (SOPs) of an optical signal at a particular wavelength and time.

The goal of the PMD specifications in this Recommendation is to be able to define a single parameter for each component that can be substituted in the equation below, which calculates the maximum DGD of a link (containing one or more of the components in question) with a defined probability of being exceeded.

$$DGD\max_{link} = \left[DGD\max_F^2 + S^2 \sum_i PMD_{Ci}^2 \right]^{1/2}$$

where:

$DGD\max_{link}$: maximum link DGD (ps)

$DGD\max_F$: maximum concatenated optical fibre cable DGD (ps)

S: Maxwell adjustment factor (see Table 1)

PMD_{Ci}: PMD value of the i-th component (ps)

This equation assumes that the statistics of the instantaneous DGD are approximated by a Maxwell distribution, with the probability of the instantaneous DGD exceeding $DGD\max_{link}$ being controlled by the value of the Maxwell adjustment factor taken from Table 1.

Table 1 – S values and probabilities

Ratio of max. to mean (S)	Probability of exceeding max.	Ratio of max. to mean (S)	Probability of exceeding max.
3	4.2×10^{-5}	4	7.4×10^{-9}
3.2	9.2×10^{-6}	4.2	9.6×10^{-10}
3.4	1.8×10^{-6}	4.4	1.1×10^{-10}
3.6	3.2×10^{-7}	4.6	1.2×10^{-11}
3.8	5.1×10^{-8}		

Within this Recommendation, the PMD value of an optical component is defined as the maximum DGD over the operating wavelength range unless it can be shown that the component characteristics are such that the alternative definition of PMD used does not lead to the value of $DGD\max_{link}$ predicted by the above equation being an underestimate for any of the operating wavelengths.

Where it can be established that, for a particular component, the distribution of DGD with time is approximately Maxwell then the PMD value can be defined to be the value of the time-averaged DGD at the worst wavelength. If it can also be shown that the distribution of DGD with wavelength is Maxwell with a mean value approximately the same as for the distribution of DGD with time, then the PMD value can be defined to be the value of the wavelength-averaged DGD. This condition would be expected to be true for fibre-based components such as dispersion compensating fibre.

Alternatively, for components where the DGD may vary with wavelength, but not appreciably with time, and the distribution of DGD versus wavelength is such that the Maxwell distribution does not underestimate the maximum DGD for probabilities less than 4.2×10^{-5}, the PMD may also be defined to be the value of the wavelength-averaged DGD. This, however, also requires that there is negligible correlation between the DGD of one device and that of another at the same wavelength.

Some optical components consist of multiple optical paths. Examples include WDM MUX/DMUX and hybrid C-band/L-band amplifiers or compensators. When these multi-path components are specified with a single value, then the PMD of each distinct optical path should be found separately and the resulting component PMD defined to be the maximum of these values.

3.2.2.38 **reflectance**: The ratio of reflected power P_r to incident power P_i at a given port of a passive component, for given conditions of spectral composition, polarization and geometrical distribution. Generally expressed in dB as:

$$R = 10 \log\left(\frac{P_r}{P_i}\right)$$ (clause 1.34 in [IEC/TR 61931])

NOTE 1 –

- For an optical branching component, it is an element a_{ii} (where i is the input port number), of the logarithmic transfer matrix (clause 1.3.8 in [IEC 60875-1]).
- For a WDM device, it is an element a_{iiw} (where i is the input port number, w is the wavelength number), of the logarithmic transfer matrix. For WWDM devices, it shall be specified as a maximum value at each operating wavelength range. For CWDM devices, it shall be specified as a maximum value within the channel wavelength range. For DWDM devices, it shall be specified as a maximum value within the channel frequency range.
- For an optical switch, it is an element a_{ii} (where i is the input port number), of the logarithmic transfer matrix. It depends on the state of the switch (clause 1.3.10 in [IEC 60876-1]).
- For an optical filter, it shall be specified in each operating wavelength range.

NOTE 2 – For clarity, reflectance values for optical devices do not include the reflectance contributions of connectors or unterminated optical ports. Reflectance contributions from connectors will be considered separately.

NOTE 3 – Where the total reflection from the component is made up of reflections from multiple points, the component reflectance must include all such contributions.

NOTE 4 – Generally, within ITU-T, components are specified in terms of their reflectance (a negative value in dB) while systems are specified using the term return loss (a positive value in dB). In some IEC documents, components (which may have multiple interfaces) are normally specified in terms of return loss.

3.2.2.39 **repeatability of an optical switch**: For further study.

3.2.2.40 **reproducibility of passband setting**: The variance of the difference between the demanded centre frequency and the centre of the tuneable filter 3 dB passband when set-up is repeated many times.

3.2.2.41 **response time (variable attenuators only)**: The response time (of a variable attenuator) is defined as the time-duration from starting to change its attenuator insertion loss to the time when the variable attenuator insertion loss converges to within (ffs) dB of its final value.

3.2.2.42 **ripple**: For WDM devices and tuneable filters, the peak-to-peak difference in insertion loss within a channel frequency (or wavelength) range. Future work on possible additional specifications is needed on the use and application of this parameter for cascading of multiple devices. This is illustrated in Figure 9.

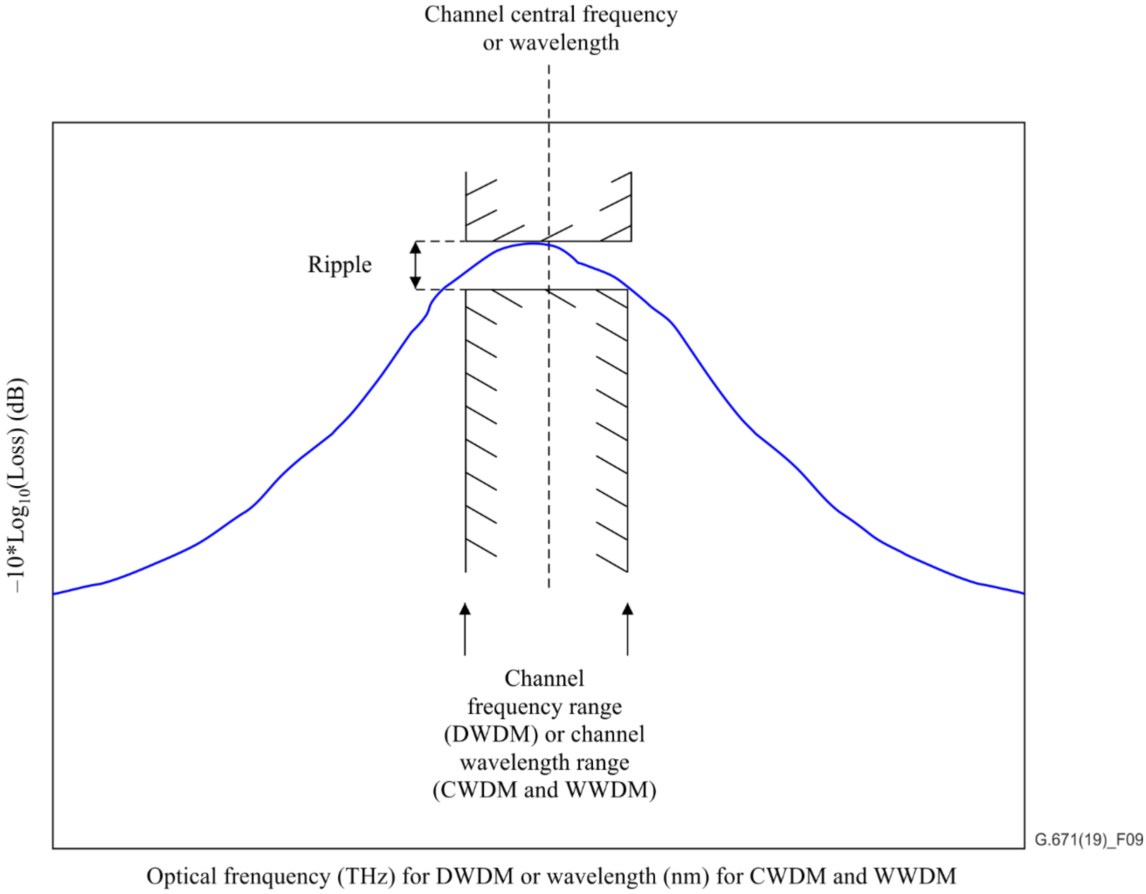

Figure 9 – Illustration of ripple for a WDM device

3.2.2.43 switching time: The elapsed time it takes the switch to turn path *io* on or off from a particular initial state, measured from the time the actuation energy is applied or removed (clause 1.3.19 in [IEC 60876-1]).

3.2.2.44 tuning range (delay line interferometer only): The maximum variation (as a multiple of the device FSR) of the transmitted optical intensity maxima or minima obtained by tuning the delay line interferometer.

3.2.2.45 tuning (settling) time: The tuning (settling) time of a tuneable filter is defined as the time-duration from the start of frequency tuning to the time when the tuneable filter loss converges to within (ffs) dB of its final value at the demanded filter centre frequency ± half of the 3 dB passband width.

NOTE – 0.1 dB has been proposed.

3.2.2.46 unidirectional (far-end) crosstalk attenuation (for a WDM device): In a WDM device able to separate k wavelengths ($\lambda_1, \lambda_2, ..., \lambda_k$) radiation coming from one input port into k output ports, each one nominally passing radiation at one specific wavelength only. The unidirectional (far-end) crosstalk attenuation is a measure of the part of the optical power at each wavelength exiting from the port at wavelengths different from the nominal wavelength. It is given by the following formula:

$$UCA = a_{iox}$$

The term a_{iox} is an element of the logarithmic transfer matrix where i is the input port number, o is the output port number and x is the isolation wavelength number, where x is any wavelength number not equal to the (channel) wavelength number associated with port o. In each output port o, there are $k - 1$ isolation wavelengths λ_x.

3.2.2.47 unidirectional (far-end) isolation (for a WDM device): In a WDM device able to separate k wavelengths (λ_1, λ_2, ..., λ_k) radiation coming from one input port into k output ports, each one nominally passing radiation at one specific wavelength only. The unidirectional (far-end) isolation is a measure of the part of the optical power at each wavelength exiting from the port at wavelengths different from the nominal wavelength relative to the power at the nominal wavelength. It is given by the following formula:

$$I_U = a_{iox} - a_{ioc}$$

The terms a_{iox} and a_{ioc} are elements of the logarithmic transfer matrix (defined in clause 3.2.3.5), where i is the input port number, o is the output port number, c is the (channel) wavelength number associated with port o and x is the isolation wavelength number, where x is any wavelength number not equal to c. In each output port o, there is one channel wavelength λ_c and k – 1 isolation wavelengths λ_x. This is illustrated in Figure 10.

NOTE – λ_c is used in this Recommendation to denote channel wavelength and not fibre cut-off wavelength.

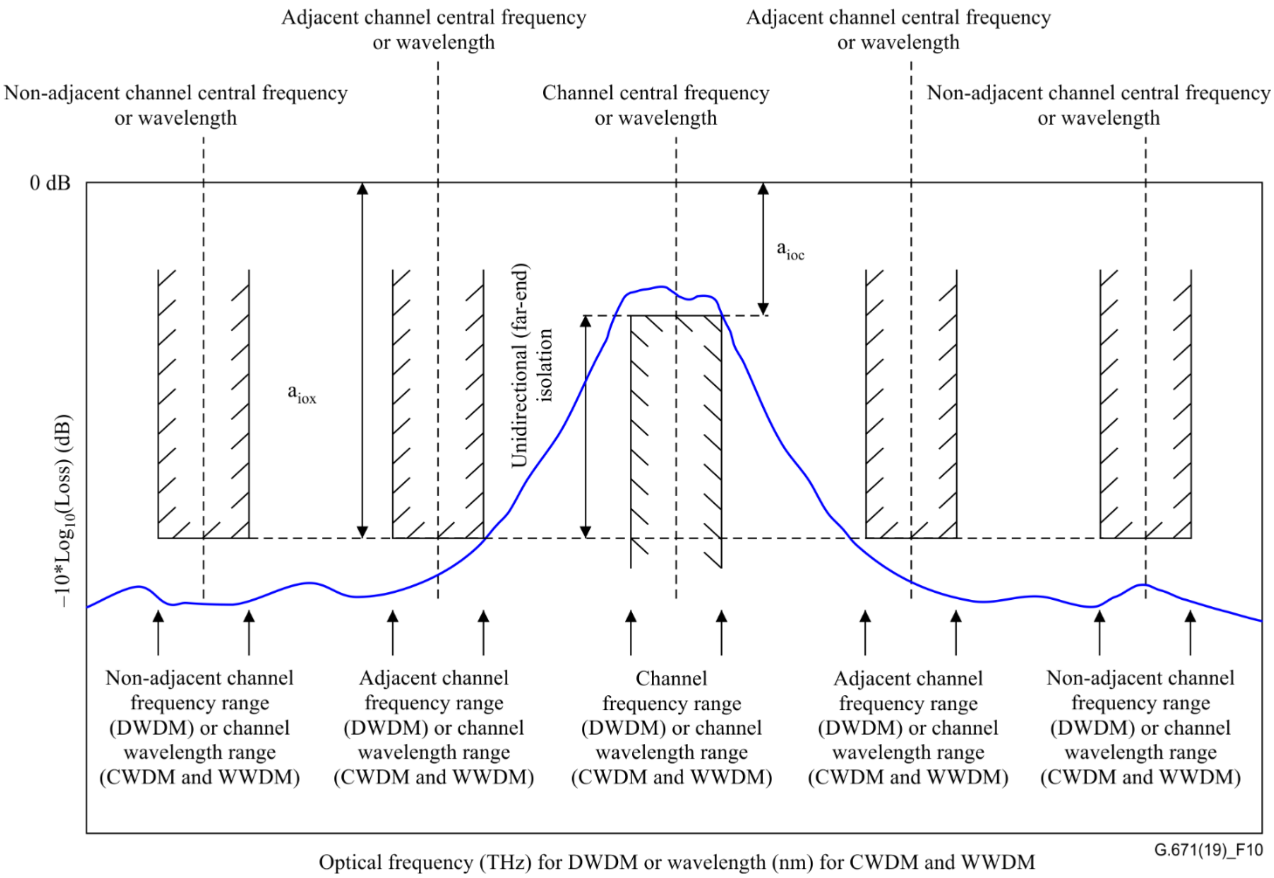

Figure 10 – Illustration of unidirectional (far-end) isolation of a WDM device

Figure 11 illustrates an example using the transfer matrix defined in clause 3.2.3.13, if powers P_1, P_2, P_3, ..., P_k were launched into a WDM DMUX device at wavelengths 1, 2, 3, ..., k, respectively, then the signals emerging from port x would be:

$$t_{1x1}P_1, t_{1x2}P_2, t_{1x3}P_3, ..., t_{1xk}P_k$$

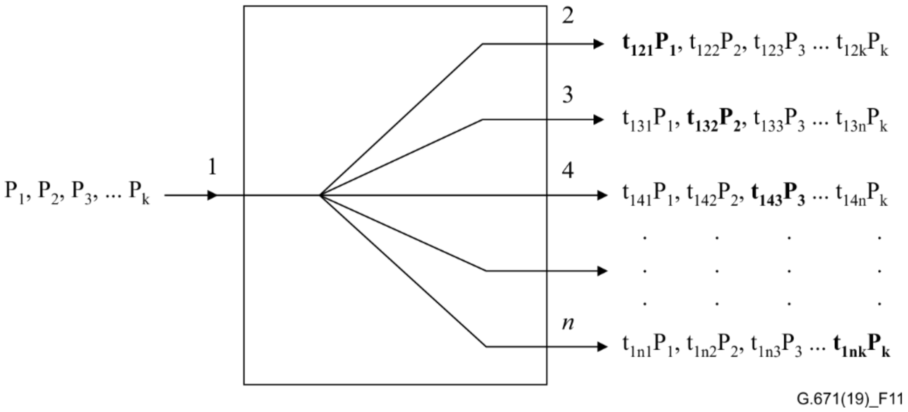

Figure 11 – Example of WDM demultiplexer device

So the isolation of port 2 to wavelength 3 would be $a_{123} – a_{121}$.

3.2.2.48 uniformity: The logarithmic transfer matrix of a component may contain a specified set of coefficients that are nominally finite and equal. In this case, the range of these coefficients a_{io}, expressed in decibels, is termed the uniformity of the component (clause 1.3.16 in [IEC 60875-1]).

3.2.2.49 uniformity (delay line interferometer only): The uniformity of the delay line interferometer is the difference between the insertion loss from input to one output at a transmission peak wavelength and the insertion loss from input to the other output at its transmission peak wavelength closest to the first output's transmission peak wavelength.

3.2.3 Definition of terms used in the parameter definitions

The following terms are used in the parameter definitions in clause 3.2.2.

3.2.3.1 conducting port: Two ports i and o between which t_{io} is nominally greater than zero (clause 1.3.12 in [IEC 60875-1]).

3.2.3.2 coupling ratio: For a given input port i, this is the ratio of light at a given output port o to the total light from all output ports. It is defined as:

$$CR_{io} = \frac{t_{io}}{\Sigma_n t_{in}}$$

where n are the operational output ports (clause 1.3.17 in [IEC 60875-1]).

3.2.3.3 input/output port pair: Conducting ports i and o (t_{io} nominally greater than zero) that are isolated from any other ports j (a_{ij} nominally infinite).

Figure 12 shows an example of a six-port device, with two input ports and four output ports. The ports are numbered sequentially, so that the transfer matrix is developed to show all ports and all possible combinations. The port numbering is arbitrary.

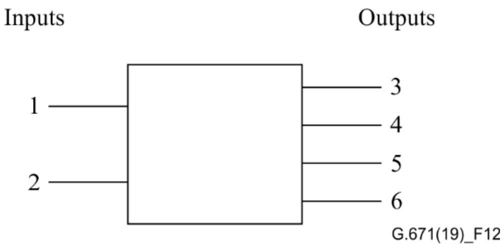

Figure 12 – An example of the port assignments for the transfer matrix

For the example shown, if there are four operating wavelengths, then the resulting transfer matrix becomes a 6 × 6 × 4 matrix: loss at λ_1 from port 1 to port 6 would use a_{161}. Reflectance of port 2 at λ_4 would use a_{224}. Loss from port 5 to port 2 at λ_3 would use a_{523}.

3.2.3.4 **isolated port**: Two ports *i* and *o* between which t_{io} is nominally zero and a_{io} is nominally infinite (clause 1.3.13 in [IEC 60875-1]).

3.2.3.5 **logarithmic transfer matrix (for an optical switch)**: A general logarithmic transfer matrix is shown in Figure 13.

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdot & a_{1n} \\ a_{21} & a_{22} & \cdot & a_{2n} \\ \cdot & \cdot & a_{io} & \cdot_{n} \\ a_{n1} & a_{n2} & \cdot & a_{nn} \end{pmatrix}$$

G.671(19)_F13

Figure 13 – Logarithmic transfer matrix for an optical switch

where a_{io} is the optical power reduction in decibels out of port *o* with unit power into port *i*, i.e.,:

$$a_{io} = -10 \log (t_{io})$$

where t_{io} is the transfer matrix coefficient.

Similarly, for the off state, $a_{io} = -10 \log (t_{io})$. This matrix is intended for definition purposes only (clause 1.3.8 in [IEC 60876-1]).

3.2.3.6 **logarithmic transfer matrix coefficient (for optical branching and WDM devices)**: In general, the logarithmic transfer matrix is shown in Figure 14.

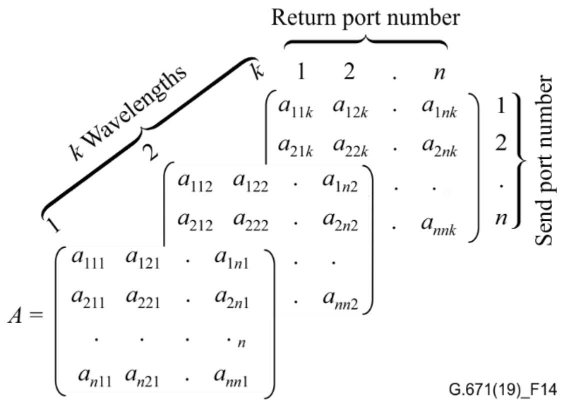

Figure 14 – Logarithmic transfer matrix

where a_{srw} is the optical power reduction in decibels out of port number *r* with unit power into port number *s*, at wavelength number *w*, i.e.,:

$$a_{srw} = -10 \log t_{srw}$$

where t_{srw} is the transfer matrix coefficient, *s* is the port number into which optical power is sent to the device for measurement, *r* is the port number used to measure the return and *w* the wavelength number of the measurement (i.e., the measurement is performed at wavelength λ_w). This matrix is intended for definition purposes only (clause 1.3.9 in [IEC 60875-1]).

NOTE – If the device is wavelength insensitive, then *A* becomes an $n \times n$ matrix with elements a_{sr}.

3.2.3.7 **operating wavelength**: A nominal wavelength λ, at which a passive component is designed to operate with the specified performance (clause 1.3.20 in [IEC 60875-1]).

3.2.3.8 port: An optical fibre or an optical fibre connector attached to an optical component for the entry and/or exit of the optical power (clause 1.3.1 in [IEC 60875-1]).

3.2.3.9 specified by application (sba): In the tables of parameter values in clause 5, some parameters are given as "sba". This means that the value of this parameter for this component must be determined from the application in the relevant transmission system Recommendation rather than being specified here.

3.2.3.10 switching time matrix (for an optical switch): A matrix of coefficients in which each coefficient s_{io} is the longest switching time to turn path *io* on or off from any initial state, as shown in Figure 15. This matrix is intended for definition purposes only (clause 1.3.20 in [IEC 60876-1]).

$$S = \begin{pmatrix} s_{11} & s_{12} & \cdot & s_{1n} \\ s_{21} & s_{22} & \cdot & s_{2n} \\ \cdot & \cdot & s_{io} & \cdot \\ s_{n1} & s_{n2} & \cdot & s_{nn} \end{pmatrix}$$

G.671(19)_F15

Figure 15 – Switching time matrix for an optical switch

3.2.3.11 transfer coefficient (for optical branching and WDM devices): An element t_{io} of the transfer matrix (clause 1.3.8 in [IEC 60875-1]).

3.2.3.12 transfer coefficient (for an optical switch): An element t_{io} or t^o_{io} of the transfer matrix. Each coefficient t_{io} is the worst case (minimum) fraction of power transferred from port *i* to port *o* for any state with path *io* switched on. Each coefficient t^o_{io} is the worst case (maximum) fraction of power transferred from port *i* to port *o* for any state with path *io* switched off (clause 1.3.7 in [IEC 60876-1]).

3.2.3.13 transfer matrix (for optical branching and WDM devices): The optical properties of an optical branching device can be defined in terms of an $n \times n \times k$ matrix of coefficients, where *n* is the total number of (input and output) ports and *k* is the number of wavelengths. The coefficients represent the fractional optical power transferred between designated ports. In general, the transfer matrix *T* is shown in Figure 16.

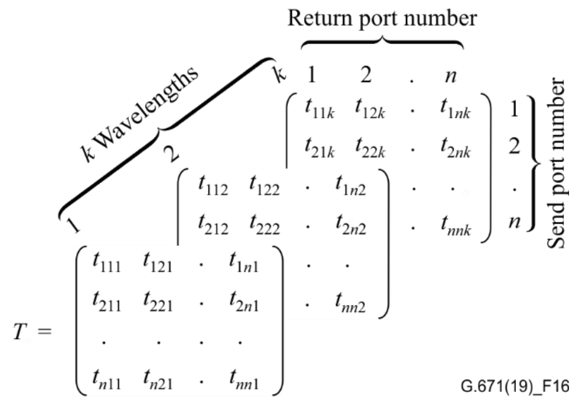

Figure 16 – Transfer matrix

where t_{srw} is the ratio of optical power P_{out} transferred out of port number *r* with respect to input power P_{in} into port number *s* at wavelength number *w*, i.e.,:

$$t_{srw} = P_{out}/P_{in} \text{ at wavelength number } w$$

The first index of the term t_{srw} is always used to denote the port into which optical power is sent to the device for measurement, the second index always denotes the port number used to measure the return and the third index is always the wavelength number of the measurement (i.e., the measurement is performed at wavelength λ_w). This matrix is intended for definition purposes only.

NOTE – If the device is wavelength insensitive, then T becomes an $n \times n$ matrix with elements t_{sr}.

3.2.3.14 transfer matrix (for an optical switch): The optical properties of an optical switch can be defined in an $n \times n$ matrix of coefficients (n is the total number of ports). The T matrix represents the on-state paths (worst-case transmission), and the T^o matrix represents the off-state paths (worst-case isolation). In general, the transfer matrices are shown in Figure 17. This matrix is intended for definition purposes only (clause 1.3.6 in [IEC 60876-1]).

$$T = \begin{pmatrix} t_{11} & t_{12} & \cdots & t_{io} \\ t_{21} & t_{22} & \cdots & t_{nn} \\ \cdots & \cdots & t_{io} & \cdots \\ t_{n1} & t_{n2} & \cdots & t_{nn} \end{pmatrix}$$

$$T^o = \begin{pmatrix} t^o_{11} & t^o_{12} & \cdots & t^o_{1n} \\ t^o_{21} & t^o_{22} & \cdots & t^o_{2n} \\ \cdots & \cdots & t^o_{io} & \cdots \\ t^o_{n1} & t^o_{n2} & \cdots & t^o_{nm} \end{pmatrix}$$

G.671(19)_F17

Figure 17 – Transfer matrix for an optical switch

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CW	Continuous Wave
CWDM	Coarse Wavelength Division Multiplexing
DCE	Dynamic Channel Equalizer
DGD	Differential Group Delay
DWDM	Dense Wavelength Division Multiplexing
ffs	for further study
FSR	Free Spectral Range
IL	Insertion Loss
ISDN	Integrated Services Digital Network
MUX/DMUX	Multiplexer/Demultiplexer
na	not applicable
OADM	Optical Add/Drop Multiplexer
PDL	Polarization Dependent Loss
PMD	Polarization Mode Dispersion
sba	specified by application
SOP	State of Polarization
WDM	Wavelength Division Multiplexing
WWDM	Wide Wavelength Division Multiplexing

5 Parameter test methods and values

Generally, in this Recommendation, the test methods for relevant parameters will not be developed. However, full reference to existing IEC basic specifications are made according to the lists provided in the following tables. The measurement and environmental test procedures that are reported in the IEC generic specifications cited in clause 3 and in the IEC 61300 series on tests and measurement procedures for interconnecting devices and passive components are referenced to the functional parameters.

Values for a statistical approach are ffs and will eventually be considered in an appendix.

All table values represent worst-case end-of-life values over all specified temperature, humidity and perturbations. Unless the context requires otherwise, numerical limits in this standard are to be taken as exact, irrespective of the number of significant digits or trailing zeros.

For particular applications, tighter reflectance values than those indicated in these tables could be required.

Inclusion of polarization-dependent reflectance is under study.

For some components (e.g., branching components, fibre optic filters, passive dispersion compensators, optical connectors and tuneable filters), the values for the maximum insertion loss reflect the current technological status. Further reduction of the maximum insertion loss is subject to technological progress and joint engineering.

In the tables below, X = the number of wavelength-specific ports.

The following notes apply in the tables below:

NOTE 1 – Assumes operation at either or both passbands, but if a restricted wavelength range exists over a passband, then parameter values such as loss apply only over that restricted band as well.

NOTE 2 – The maximum value of allowable input power is under discussion. A value of +20 dBm is considered a starting point. When high input power is launched into optical components, care must be taken to eliminate contamination such as dust or particles from the connector end faces.

NOTE 3 – The measurement methods outlined in [ITU-T G.650.2] can be used only where it can be shown that the use of the wavelength averaged DGD does not lead to an underestimate of the total link DGD.

NOTE 4 – Dual values (a | b) indicate values for "slow" and "fast" switches, respectively.

NOTE 5 – For some passive dispersion compensators, the operating wavelength range can be narrower, but covering the wavelength range of the used optical source.

For example, there are some passive dispersion compensators that are optimized for the C-band and others that accommodate the C+L bands.

NOTE 6 – Values of maximum and minimum dispersion at any wavelength λ (in nm) within the operating wavelength range can be found by substituting the value of λ into the given function and multiplying by the value of ITU-T G.652 equivalent compensation of the dispersion compensator in km.

For example, for a dispersion compensator with 40 km of ITU-T G.652 equivalent compensation, the limits in clause 5.10.21 result in the requirements:

$$40\left[-15.8-0.058(\lambda-1550)\right]\geq D(\lambda)\geq 40\left[-17.6-0.058(\lambda-1550)\right]$$

Where D(λ) is the dispersion in ps/nm and λ is the wavelength in nm.

Values for compensators of lengths of ITU-T G.653 and ITU-T G.655 fibre are under study.

NOTE 7 – When used over an extended operating temperature range, these values may be exceeded and are under study.

NOTE 8 – For networks other than those covered by [ITU-T G.982], including other access networks, a value of –27 dB is allowed; however, care should be taken to ensure system functionality in systems implemented with several optical components with reflectance values at, or near, this limit. In consideration of future network evolutions, a value of –40 dB is under study.

NOTE 9 – These values assume the joining of fibre types covered by the same Recommendation. These values are worst-case over all environments and for a large sample size. Typical values of insertion loss for mechanical splices are 0.15 dB, actively – aligned fusion splices 0.08 dB and passively – aligned fusion splices 0.15 dB.

NOTE 10 – These values are derived from calculating the minimum loss of one of the ports if all of the other ports show identical loss while assuming no excess loss and meeting the maximum values of uniformity requirement. If this is done the minimum loss is:

$$Min\_loss = -10 Log\left(\frac{U}{U + X - 1}\right)$$

where:

U is the linear uniformity, i.e., $U = 10^{\frac{uniformity}{10}}$

X is the number of ways of the branching component (2, 4, 8, 16, 32 or 64)

NOTE 11 – While this component has a maximum operating wavelength in range WR2 of 1660 nm, the operation of optical fibres such as [ITU-T G.652] at wavelengths beyond 1625 nm may not be ensured.

5.1 Optical add/drop multiplexer (OADM) subsystems (for WDM)

Clause	Parameter	Max	Min	Test method
	Channel insertion loss (dB)			
5.1.1	Input to output	sba	sba	
5.1.2	Input to drop	sba	sba	
5.1.3	Add to output	sba	sba	
5.1.4	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.1.5	Reflectance (dB)	ffs	na	
	Channel polarization dependent loss (PDL) (dB)			
5.1.6	Input to output	ffs	na	
5.1.7	Input to drop	ffs	na	
5.1.8	Add to output	ffs	na	
5.1.9	Type of OADM subsystem	sba	sba	
5.1.10	Number of add/drop/through channels	sba	sba	
5.1.11	Type of passband profile (flat-top or Gaussian)	ffs	ffs	
5.1.12	Channel wavelength range (nm) (CWDM and WWDM devices)	sba	sba	
5.1.13	Channel frequency range (GHz) (DWDM devices)	sba	sba	
5.1.14	1 dB passband width (nm)	sba	sba	
5.1.15	3 dB passband width (nm)	sba	sba	
5.1.16	Ripple (dB)	ffs	na	
	Adjacent channel isolation (dB)			
5.1.17	Input to drop	na	sba	
	Non-adjacent channel isolation (dB)			
5.1.18	Input to drop	na	sba	
	Channel extinction (dB)			
5.1.19	Input to output	na	sba	

Clause	Parameter	Max	Min	Test method
5.1.20	Allowable input power (dBm)	ffs (Note 2)	na	
	Channel polarization mode dispersion (PMD) (ps)			[ITU-T G.650.2] (Note 3)
5.1.21	Input to output	ffs	na	
5.1.22	Input to drop	ffs	na	
5.1.23	Add to output	ffs	na	
	Group delay (ps)			[IEC 61300-3-38]
5.1.24	Input to output	sba	sba	
5.1.25	Input to drop	sba	sba	
5.1.26	Add to output	sba	sba	

5.2 Asymmetric branching component (wavelength non-selective)

Tap couplers with coupling factors F = 20%, 10%, 5%, 2% and 1%.

Clause	Parameter	Max	Min	Test method
5.2.1	Insertion loss – main port (dB)	See table below	See table below	[IEC 61300-3-4], [IEC 61300-3-7]
5.2.2	Insertion loss – tap port (dB)	See table below	See table below	[IEC 61300-3-4], [IEC 61300-3-7]
5.2.3	Reflectance (dB)	ffs	na	[IEC 61300-3-6]
	Operating wavelength range (nm) (Note 1)			
5.2.4	1310 nm window	1360	1260	[IEC 61300-3-7]
5.2.5	1550 nm window	1580	1480	[IEC 61300-3-7]
5.2.6	Polarization dependent loss (PDL) – main port (dB)	ffs	na	[IEC 61300-3-2]
5.2.7	Polarization dependent loss (PDL) – tap port (dB)	ffs	na	[IEC 61300-3-2],
5.2.8	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.2.9	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.2.10	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.2.11	Directivity (dB)	na	ffs	ffs
5.2.12	Group delay (ps)	sba	sba	[IEC 61300-3-38]

F	Main port		Tap port	
	Min. IL (dB)	Max. IL (dB)	Min. IL (dB)	Max. IL (dB)
80/20	ffs	ffs	ffs	ffs
90/10	ffs	ffs	ffs	ffs
95/5	ffs	ffs	ffs	ffs
98/2	ffs	ffs	ffs	ffs
99/1	ffs	ffs	ffs	ffs

5.3 Optical attenuator

Clause	Parameter	Max	Min	Test method
5.3.1	Insertion loss (dB) (fixed attenuator)	sba	sba	[IEC 61300-3-4], [IEC 61300-3-7]
5.3.2	Reflectance (dB)	–40	na	[IEC 61300-3-6]
	Operating wavelength range (nm) (Note 1)			
5.3.3	1310 nm window	1360	1260	[IEC 61300-3-7]
5.3.4	1550 nm window	1580	1480	[IEC 61300-3-7]
5.3.5	Polarization dependent loss (PDL) (dB)	0.3	na	[IEC 61300-3-2]
5.3.6	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.3.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.3.8	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.3.9	Attenuation accuracy (dB)	sba	na	ffs
5.3.10	Attenuation range (variable attenuator) (dB)	sba	sba	ffs
5.3.11	Incremental attenuation (variable attenuator) (dB)	sba	sba	ffs
5.3.12	Response time (variable attenuator) (ms)	sba	sba	
5.3.13	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.4 Optical branching component (wavelength non-selective)

1 × X and 2 × X ports where X = 2, 3, 4, 6, 8, 12, 16, 24 and 32.

Clause	Parameter	Max	Min	Test method
5.4.1	Insertion loss (dB)	See table below	See table below	[IEC 61300-3-4], [IEC 61300-3-7]
5.4.2	Reflectance (dB)	–40	na	[IEC 61300-3-6]
	Operating wavelength range (nm) (Note 1)			
5.4.3	1310 nm window	1360	1260	[IEC 61300-3-7]
5.4.4	1550 nm window	1580	1480	[IEC 61300-3-7]
5.4.5	Polarization dependent loss (PDL) (dB)	$0.1 (1 + \log_2 X)$	na	[IEC 61300-3-2]
5.4.6	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]

Clause	Parameter	Max	Min	Test method
5.4.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.4.8	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.4.9	Directivity (dB)	na	50	ffs
5.4.10	Uniformity (dB)	1.0 $\log_2 X$	na	ffs
5.4.11	Group delay (ps)	sba	sba	[IEC 61300-3-38]

This table assumes symmetrical power distribution between the output ports of the branching device.

X	1 × X		2 × X	
	Min. IL (dB)	**Max. IL (dB)**	**Min. IL (dB)**	**Max. IL (dB)**
2	2.6	4.2	2.5	4.5
3	4.1	6.3	4.0	6.6
4	5.4	7.8	5.3	8.1
6	6.8	9.9	6.7	10.2
8	8.1	11.4	8.0	11.7
12	9.5	13.5	9.4	13.8
16	10.8	15.0	10.7	15.3
24	12.0	17.1	11.95	17.4
32	13.1	18.6	13.1	18.9

5.5 Optical branching component (wavelength non-selective) for PONs

N × X where the number of input ports N = 1 or 2 and the number of output ports X = 2, 4, 8, 16, 32 or 64.

Clause	Parameter		Max	Min	Test method
5.5.1	Insertion loss (dB)		See loss table below	See loss table below	[IEC 61300-3-4], [IEC 61300-3-7]
5.5.2	Reflectance (dB)		–55	na	ffs
	Operating wavelength range (nm) (Note 1)				
5.5.3	WR1	1310 nm window	1360	1260	[IEC 61300-3-7]
		1550 nm window	1625	1480	
5.5.4	WR2	1310 nm window	1360	1260	[IEC 61300-3-7]
		1550 nm window	1660 (Note 11)	1480	
5.5.5	Polarization-dependent loss (PDL)		See PDL table below	na	[IEC 61300-3-2]
5.5.6	Polarization dependent reflectance (dB)		ffs	na	ffs
5.5.7	Allowable input power (dBm)		ffs (Note 2)	na	ffs

Clause	Parameter	Max	Min	Test method
5.5.8	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.5.9	Directivity (dB)	na	55	ffs
5.5.10	Uniformity (dB)	See uniformity table below	na	ffs
5.5.11	Group delay (ps)	sba	sba	[IEC 61300-3-38]
NOTE – The WR2 covers both a wavelength range intended for data signals as well as a wavelength range intended for maintenance.				

Insertion loss requirements

N	X	For normal reach				For extended reach			
		WR1		WR2		WR1		WR2	
		Min. IL (dB) (Note 10)	Max. IL (dB)	Min. IL (dB) (Note 10)	Max. IL (dB)	Min. IL (dB) (Note 10)	Max. IL (dB)	Min. IL (dB) (Note 10)	Max. IL (dB)
1	2	2.8	3.9	2.7	4.0	2.8	3.8	2.8	3.9
1	4	5.4	7.4	5.3	7.6	5.6	7.1	5.4	7.3
1	8	8.2	10.6	7.9	10.9	8.2	10.5	7.9	10.8
1	16	10.8	14.1	10.5	14.5	10.8	13.7	10.5	14.1
1	32	13.3	17.5	12.8	18.1	13.6	17.1	13.0	17.7
1	64	16.1	20.9	15.5	21.5	16.2	20.3	15.6	20.9
2	2	2.6	4.2	2.5	4.3	2.6	4.1	2.6	4.2
2	4	5.1	7.7	4.9	7.9	5.2	7.5	5.0	7.7
2	8	7.6	11.2	7.3	11.5	7.7	10.9	7.4	11.2
2	16	10.1	14.7	9.7	15.1	10.2	14.3	9.8	14.7
2	32	12.7	18.2	12.2	18.7	12.8	17.7	12.3	18.2
2	64	15.2	21.7	14.6	22.3	15.3	21.1	14.7	21.7

Branching component should comply with the insertion loss requirements for both WR1 and WR2.

Polarization-dependent loss requirements

N	X	Maximum values (dB)
1	2	0.2
1	4	0.2
1	8	0.25
1	16	0.3
1	32	0.4
1	64	0.4
2	2	0.3
2	4	0.3
2	8	0.4
2	16	0.4
2	32	0.5
2	64	0.5

Uniformity requirements

N	X	Maximum values (dB)			
		For normal reach		For extended reach	
		WR1	WR2	WR1	WR2
1	2	0.5	0.6	0.4	0.5
1	4	0.8	1.0	0.6	0.8
1	8	1.0	1.3	1.0	1.3
1	16	1.3	1.7	1.3	1.7
1	32	1.8	2.4	1.5	2.1
1	64	2.0	2.6	1.9	2.5
2	2	0.9	1.0	0.8	0.9
2	4	1.3	1.5	1.2	1.4
2	8	1.7	2.0	1.6	1.9
2	16	2.1	2.5	2.0	2.4
2	32	2.5	3.0	2.4	2.9
2	64	2.9	3.5	2.8	3.4

Branching component should comply with uniformity requirements for both WR1 and WR2.

5.6 Optical connector

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB)			
5.6.1	for single fibre (Note 7)	0.5	na	[IEC 61300-3-4], [IEC 61300-3-7]
5.6.2	for multifibre (Note 7)	1.0	na	[IEC 61300-3-4], [IEC 61300-3-7]
5.6.3	Reflectance (dB)	–35 (Notes 7 and 8)	na	[IEC 61300-3-6]
	Operating wavelength range (nm) (Note 1)			
5.6.4	1310 nm window	1360	1260	[IEC 61300-3-7]
5.6.5	1550 nm window	1580	1480	[IEC 61300-3-7]
5.6.6	Polarization dependent loss (PDL) (dB)	0.1	na	[IEC 61300-3-2]
5.6.7	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.6.8	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.6.9	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
NOTE – Insertion loss and reflectance values also include effects of mating durability.				

5.7 Delay line interferometer

Clause	Parameter	Max	Min	Test method
5.7.1	Operating wavelength range (nm)	sba	sba	
5.7.2	Free spectral range (GHz)	sba	sba	
5.7.3	Insertion loss (dB)	sba	na	
5.7.4	Uniformity (dB)	sba	na	
5.7.5	Demodulation extinction ratio (dB)	na	sba	
5.7.6	Polarization dependent loss (PDL) (dB)	sba	na	[IEC 61300-3-2]
5.7.7	Polarization mode dispersion (PMD) (Note 7) (ps)	sba	na	ffs
5.7.8	Reflectance (dB)	-35	na	[IEC 61300-3-6]
5.7.9	Polarization dependent frequency shift (% of FSR)	sba	na	
5.7.10	Delay between balanced ports (ps)	sba	na	
5.7.11	Tuning range (times FSR)	sba	sba	
5.7.12	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.8 Dynamic channel equalizer (DCE)

Clause	Parameter	Max	Min	Test method
5.8.1	Insertion loss (dB)	6	ffs	[IEC 61300-3-4], [IEC 61300-3-7]
5.8.2	Reflectance (dB)	na	–45	[IEC 61300-3-6]
5.8.3	Operating wavelength range (nm)	sba	sba	[IEC 61300-3-7]
	Polarization dependent loss (PDL) (dB)			
5.8.4	Over full dynamic channel attenuation range	0.4	na	[IEC 61300-3-2]
5.8.5	Over reduced dynamic channel attenuation range of 10 dB	0.2	na	[IEC 61300-3-2]
5.8.6	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.8.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.8.8	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.8.9	Channel extinction (dB)	na	40	
5.8.10	Out-of-band attenuation (dB)	na	40	
5.8.11	Channel attenuation resolution (dB)	0.2	na	
5.8.12	Dynamic channel attenuation range (dB)	na	20	
5.8.13	Ripple (dB)	0.2	na	
5.8.14	Channel response time (ms)	30	na	
5.8.15	Channel spacing (nm)	sba	sba	
5.8.16	Number of channels	sba	sba	
5.8.17	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.9 Optical filter

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB)			
5.9.1	Pass band	sba	sba	[IEC 61300-3-4], [IEC 61300-3-7]
5.9.2	Stop band	na	sba	
5.9.3	Reflectance (dB)	–40	na	[IEC 61300-3-6]
5.9.4	Operating wavelength range (nm)	sba	sba	[IEC 61300-3-7]
5.9.5	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.9.6	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.9.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.9.8	Polarization mode dispersion (PMD) (ps)	ffs	na	ffs
5.9.9	Ripple (dB)	ffs	na	ffs
5.9.10	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.10 Optical isolator

Clause	Parameter	Max	Min	Test method
5.10.1	Insertion loss (dB)	ffs	na	
5.10.2	Backward loss (isolation)	na	sba	[IEC 61300-3-4], [IEC 61300-3-7]
5.10.3	Reflectance (dB)	–40	na	[IEC 61300-3-6]
	Operating wavelength range (nm) (Note 1)			
5.10.4	1310 nm window	1360	1260	[IEC 61300-3-7]
5.10.5	1550 nm window	1580	1480	[IEC 61300-3-7]
5.10.6	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.10.7	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.10.8	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.10.9	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.10.10	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.11 Passive (chromatic) dispersion compensator

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB) for ITU-T G.652 equivalent compensation length of:			[IEC 61300-3-4], [IEC 61300-3-7]
5.11.1	2.5 km	ffs	na	
5.11.2	5 km	ffs	na	
5.11.3	7.5 km	ffs	na	
5.11.4	10 km	ffs	na	
5.11.5	20 km	3.6	ffs	
5.11.6	30 km	ffs	ffs	
5.11.7	40 km	5.5	ffs	
5.11.8	50 km	ffs	ffs	
5.11.9	60 km	7.5	ffs	
5.11.10	70 km	ffs	ffs	
5.11.11	80 km	9.5	ffs	
5.11.12	90 km	ffs	ffs	
5.11.13	100 km	11.5	ffs	
5.11.14	110 km	ffs	ffs	
5.11.15	120 km	13.5	ffs	
5.11.16	Reflectance (dB)	–27	na	[IEC 61300-3-6]
5.11.17	Operating wavelength range (nm) (Note 5)	1616	1525	[IEC 61300-3-7]
5.11.18	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.11.19	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.11.20	Allowable input power (dBm)	ffs (Note 2)	na	ffs

Clause	Parameter	Max	Min	Test method
5.11.21	Dispersion coefficient (ps/nm/km) at wavelength λ (nm) of ITU-T G.652 equivalent compensation (Note 6)	–15.8 –0.058*(λ –1550)	–17.6 –0.058*(λ –1550)	ffs
5.11.22	Polarization mode dispersion (PMD) (ps) (Note 7)	ffs	ffs	[ITU-T G.650.2] (Note 3)
5.11.23	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.12 Single optical channel passive (chromatic) dispersion compensator

Clause	Parameter	Max	Min	Test method
	Dispersion over the channel frequency range (ps/nm) for ITU-T G.652 equivalent compensation length of			ffs
5.12.1	10 km	–168	–178	
5.12.2	20 km	–337	–356	
5.12.3	30 km	–506	–533	
5.12.4	40 km	–675	–711	
5.12.5	50 km	–844	–888	
5.12.6	60 km	–1013	–1066	
5.12.7	70 km	–1182	–1244	
5.12.8	80 km	–1351	–1421	
5.12.9	Insertion loss	ffs	ffs	[IEC 61300-3-4], [IEC 61300-3-7]
5.12.10	Reflectance (dB)	–27	na	[IEC 61300-3-6]
5.12.11	Channel frequency range (THz)	192.14	192.06	
5.12.12	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.12.13	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.12.14	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.12.15	Polarization mode dispersion (PMD) (Note 7) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.12.16	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.13 Optical splice

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB) (Note 9)			[IEC 61300-3-4], [IEC 61300-3-7]
5.13.1	Mechanical splice	0.50	na	
5.13.2	Fusion splice (active alignment)	0.30	na	
5.13.3	Fusion splice (passive alignment)	0.50	na	
	Reflectance (dB)			[IEC 61300-3-6]
5.13.4	Mechanical splice	–40	na	

Clause	Parameter	Max	Min	Test method
5.13.5	Fusion splice	–70	na	
	Operating wavelength range (nm) (Note 1)			
5.13.6	1310 nm window	1360	1260	[IEC 61300-3-7]
5.13.7	1550 nm window	1580	1480	[IEC 61300-3-7]
5.13.8	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.13.9	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.13.10	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.13.11	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)

5.14 Optical switch

Clause	Parameter	1 × X switches		2 × 2 switches		Test method
		Max	Min	Max	Std	
5.14.1	Insertion loss (dB)	2.5 | $\log_2 X$ (Note 4)	na	ffs	na	[IEC 61300-3-4], [IEC 61300-3-7]
5.14.2	Reflectance (dB)	–40	na	–40	na	[IEC 61300-3-6]
5.14.3	Operating wavelength range (nm)	ffs	ffs	ffs	ffs	[IEC 61300-3-7]
5.14.4	Polarization dependent loss (PDL) (dB)	ffs | 0.1 $(1 + \log_2 X)$ (Note 4)	na	ffs	na	[IEC 61300-3-2]
5.14.5	Polarization dependent reflectance (dB)	ffs	na	ffs	na	[IEC 61300-3-19]
5.14.6	Allowable input power (dBm)	ffs (Note 2)	na	ffs (Note 2)	na	ffs
5.14.7	Polarization mode dispersion (PMD) (ps)	ffs	na	ffs	na	[ITU-T G.650.2] (Note 3)
5.14.8	Switching time	10 s | 20 ms (Note 4)	na	ffs	na	ffs
5.14.9	Repeatability (dB)	0.25	na	ffs	na	ffs
5.14.10	Uniformity (dB)	ffs | 0.4 $\log_2 X$ (Note 4)	na	ffs	na	ffs
5.14.11	Isolation (dB)	sba	na	sba	na	ffs
5.14.12	Directivity (dB)	na	50	na	ffs	ffs
5.14.13	Group delay (ps)	sba	sba	sba	sba	[IEC 61300-3-38]
NOTE – 2 × X switches are for future study.						

5.15 Optical termination

Clause	Parameter	Max	Min	Test method
5.15.1	Reflectance (dB)	–50	na	[IEC 61300-3-6]
	Operating wavelength range (nm) (Note 1)			
5.15.2	1310 nm window	1360	1260	[IEC 61300-3-7]
5.15.3	1550 nm window	1580	1480	[IEC 61300-3-7]
5.15.4	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.15.5	Allowable input power (dBm)	ffs (Note 2)	na	ffs

5.16 Tuneable (chromatic) dispersion compensator

Clause	Parameter	Max	Min	Test method
5.16.1	Dispersion compensation tuning range (ps/nm)	na	400	ffs
5.16.2	Channel frequency range (THz)	sba	sba	
5.16.3	Insertion loss	ffs	ffs	[IEC 61300-3-4], [IEC 61300-3-7]
5.16.4	Reflectance (dB)	–27	na	[IEC 61300-3-6]
5.16.5	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.16.6	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.16.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.16.8	Polarization mode dispersion (PMD) (Note 7) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.16.9	Phase ripple	sba	na	ffs
5.16.10	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.17 Tuneable filter

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB)			[IEC 61300-3-4], [IEC 61300-3-7]
5.17.1	Pass band	sba	sba	
5.17.2	Stop band	na	sba	
5.17.3	Reflectance (dB)	ffs	na	[IEC 61300-3-6]
5.17.4	Operating wavelength range (nm)	sba	sba	[IEC 61300-3-7]
5.17.5	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.17.6	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.17.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.17.8	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.17.9	1 dB passband width (nm)	sba	sba	ffs
5.17.10	3 dB passband width (nm)	sba	sba	ffs
5.17.11	Ripple (dB)	ffs	na	ffs

Clause	Parameter	Max	Min	Test method
5.17.12	Reproducibility of passband setting (nm)	ffs	na	ffs
5.17.13	Tuning (settling) time (s)	sba	sba	ffs
5.17.14	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.17.15	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.18 Optical wavelength MUX/DMUX

5.18.1 Coarse WDM (CWDM) device

Clause	Parameter	Max	Min	Test method
5.18.1.1	Channel insertion loss (dB)	ffs	ffs	[IEC 61300-3-4], [IEC 61300-3-7]
5.18.1.2	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.18.1.3	Reflectance (dB)	ffs	na	[IEC 61300-3-6]
5.18.1.4	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.18.1.5	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.18.1.6	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.18.1.7	Polarization mode dispersion (PMD) (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.18.1.8	Channel wavelength range (nm)	sba	sba	
5.18.1.9	Ripple (dB)	ffs	ffs	
5.18.1.10	Adjacent channel isolation (dB)	na	sba	
5.18.1.11	Non-adjacent channel isolation (dB)	na	sba	
5.18.1.12	Bidirectional (near-end) isolation (dB)	na	sba	
5.18.1.13	Unidirectional (far-end) crosstalk attenuation (dB)	na	sba	
5.18.1.14	Bidirectional (near-end) crosstalk attenuation (dB)	na	sba	
5.18.1.15	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.18.2 Dense WDM (DWDM) device 1 × X

Clause	Parameter	Max	Min	Test method
5.18.2.1	Channel insertion loss (dB)	sba	sba	[IEC 61300-3-4], [IEC 61300-3-7]
5.18.2.2	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.18.2.3	Reflectance (dB)	ffs	na	[IEC 61300-3-6]
5.18.2.4	Polarization dependent loss (PDL) (dB)	ffs	na	[IEC 61300-3-2]
5.18.2.5	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.18.2.6	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.18.2.7	Polarization mode dispersion (PMD) (ps)	ffs	na	ffs
5.18.2.8	Channel frequency range (GHz)	sba	sba	ffs
5.18.2.9	Ripple (dB)	ffs	na	ffs
5.18.2.10	Adjacent channel isolation (dB)	na	sba	

Clause	Parameter	Max	Min	Test method
5.18.2.11	Non-adjacent channel isolation (dB)	na	sba	ffs
5.18.2.12	Bidirectional (near-end) isolation (dB)	na	sba	ffs
5.18.2.13	Unidirectional (far-end) crosstalk attenuation (dB)	na	sba	ffs
5.18.2.14	Bidirectional (near-end) crosstalk attenuation (dB)	na	sba	ffs
5.18.2.15	Group delay (ps)	sba	sba	[IEC 61300-3-38]

5.18.3 Wide WDM (WWDM) device 1 × X

Clause	Parameter	Max	Min	Test method
5.18.3.1	Channel insertion loss (dB)	1.5 $\log_2 X$	ffs	[IEC 61300-3-4], [IEC 61300-3-7]
5.18.3.2	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.18.3.3	Reflectance (dB)	–40	na	[IEC 61300-3-6]
	Operating wavelength range (nm) (Note 1)			
5.18.3.4	1310 nm window	1360	1260	[IEC 61300-3-7]
5.18.3.5	1550 nm window	1580	1480	[IEC 61300-3-7]
5.18.3.6	Polarization dependent loss (PDL) (dB)	0.1 $(1 + \log_2 X)$	na	[IEC 61300-3-2]
5.18.3.7	Polarization dependent reflectance (dB)	ffs	na	[IEC 61300-3-19]
5.18.3.8	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.18.3.9	Polarization mode dispersion (PMD (ps)	ffs	na	[ITU-T G.650.2] (Note 3)
5.18.3.10	Unidirectional (far-end) isolation (dB)	na	sba	ffs
5.18.3.11	Bidirectional (near-end) isolation (dB)	na	sba	ffs
5.18.3.12	Unidirectional (far-end) crosstalk attenuation (dB)	na	sba	ffs
5.18.3.13	Bidirectional (near-end) crosstalk attenuation (dB)	na	sba	ffs
5.18.3.14	Group delay (ps)	sba	sba	[IEC 61300-3-38]

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	**Transmission systems and media, digital systems and networks**
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2019