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

Transmission media characteristics – Characteristics of  
optical components and subsystems

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## **Transmission characteristics of optical components and subsystems**

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# **ITU-T Recommendation G.671**

## **Transmission characteristics of optical components and subsystems**

### **Summary**

This Recommendation 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.

## CONTENTS

### Page

1	Scope .....	3
2	References.....	4
3	Terms and definitions .....	5
3.1	Component definitions .....	5
3.2	Parameter definitions.....	8
3.3	Definition of terms .....	20
4	Abbreviations and acronyms .....	24
5	Parameter test methods and values .....	24
5.1	Optical add/drop multiplexer (OADM) subsystems (for WDM) .....	26
5.2	Asymmetric branching component (wavelength non-selective) .....	26
5.3	Optical attenuator .....	27
5.4	Optical branching component (wavelength non-selective) .....	28
5.5	Optical connector.....	29
5.6	Dynamic channel equalizer (DCE).....	30
5.7	Optical filter.....	31
5.8	Optical isolator .....	31
5.9	Passive (chromatic) dispersion compensator.....	32
5.10	Optical splice .....	34
5.11	Optical switch.....	34
5.12	Optical termination.....	35
5.13	Tuneable filter .....	36
5.14	Optical wavelength MUX/DMUX .....	37
5.14.1	Coarse WDM (CWDM) device.....	37
5.14.2	Dense WDM (DWDM) device $1 \times X$ .....	38
5.14.3	Wide WDM (WWDM) device $1 \times X$ .....	39

# ITU-T Recommendation 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 Rec. G.957, and Recommendations of optical interfaces for single channel and multichannel systems with optical amplifiers including ITU-T Recs G.691, G.692 and G.959.1.
- Access networks: Networks using equipment according to ITU-T Rec. G.982, and the 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;
- Dynamic channel equalizer (DCE);
- Optical filter;
- Optical isolator;
- Passive dispersion compensator;
- Optical splice;
- Optical switch;
- Optical termination;
- 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 TC86 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 Geometrical 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.

- [1] ITU-T Recommendation G.650.1 (2002), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable.*
- [2] ITU-T Recommendation G.650.2 (2002), *Definitions and test methods for statistical and non-linear attributes of single-mode fibre and cable.*
- [3] ITU-T Recommendation G.652 (2000), *Characteristics of a single-mode optical fibre cable.*
- [4] ITU-T Recommendation G.653 (2000), *Characteristics of dispersion-shifted single-mode optical fibre cable.*
- [5] ITU-T Recommendation G.654 (2002), *Characteristics of cut-off single-mode optical fibre and cable.*
- [6] ITU-T Recommendation G.655 (2000), *Characteristics of a non-zero dispersion shifted single-mode optical fibre cable.*
- [7] ITU-T Recommendation G.661 (1998), *Definition and test methods for the relevant generic parameters of optical amplifier devices and subsystems.*
- [8] ITU-T Recommendation G.662 (1998), *Generic characteristics of optical amplifier devices and subsystems.*
- [9] ITU-T Recommendation G.691 (2000), *Optical interfaces for single-channel STM-64, STM-256 and other SDH systems with optical amplifiers.*
- [10] ITU-T Recommendation G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers.*
- [11] ITU-T Recommendation G.693 (2001), *Optical interfaces for intra-office systems.*
- [12] ITU-T Recommendation G.694.1 (2002), *Spectral grids for WDM applications: DWDM frequency grid.*
- [13] ITU-T Recommendation G.694.2 (2002), *Spectral grids for WDM applications: CWDM wavelength grid.*
- [14] ITU-T Recommendation G.957 (1999), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*

- [15] ITU-T Recommendation G.959.1 (2001), *Optical transport network physical layer interfaces*.
- [16] ITU-T Recommendation G.982 (1996), *Optical access network to support services up to the ISDN primary rate or equivalent bit rates*.
- [17] IEC-61300-3 series of *Transmission and geometrical parameters*.
- [18] IEC 61300-3-2:1999, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-2: Examinations and measurements – Polarization dependence of attenuation in a single-mode fibre optic device*.
- [19] IEC 61300-3-4:2001, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation*.
- [20] IEC 61300-3-6:1997, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*.
- [21] IEC 61300-3-7:2000, *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*.
- [22] IEC 61300-3-12:1997, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-12: Examinations and measurements – Polarization dependence of attenuation of a single-mode fibre-optic component: Matrix calculation method*.
- [23] 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*.

### 3 Terms and definitions

Most of the definitions of parameters specified in this Recommendation, for each of the abovementioned passive components, are given in the corresponding IEC generic specification and summarized below:

IEC 60869-1 (1999), Generic specification for fibre-optic attenuators.

IEC 60875-1 (2000), Generic specification for fibre-optic branching devices.

IEC 60876-1 (2001), Generic specification for fibre-optic switches.

IEC 61202-1 (2000), Generic specification for fibre-optic isolators.

IEC 61931-1, Fibre-optic terminology.

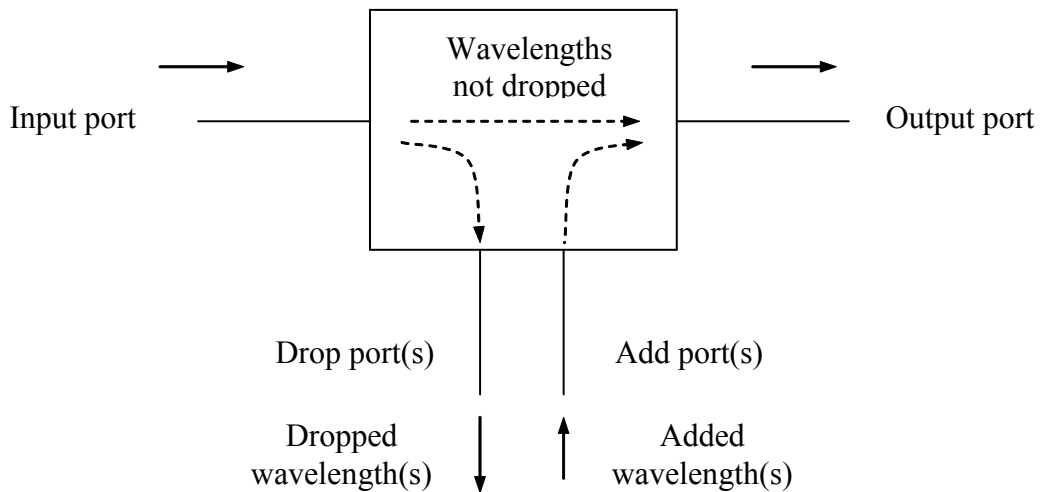
Where IEC definitions are used, they are noted as such. Additional parameters under study or not defined in IEC documents are also given in this clause.

#### 3.1 Component definitions

##### 3.1.1 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/G.671 – Optical add/drop multiplexer (OADM) subsystem**

**3.1.2 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 (1.1/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 in percent 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 (1.3.19/IEC 60875-1).

**3.1.3 optical attenuator:** A passive component that produces a controlled signal attenuation in an optical fibre transmission line (1.3.1/IEC 60869-1).

**3.1.4 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 (1.1/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 (1.3.2/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 (1.3.18/IEC 60875-1).

**3.1.5 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 (6.01/IEC 61931-1).

**3.1.6 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.

**3.1.7 optical filter:** A passive component used to modify the optical radiation passing through it, generally by altering the spectral distribution (6.35/IEC 61931-1). 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.

**3.1.8 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 (1.3.1/IEC 61202-1).

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

**3.1.10 optical splice:** A permanent or semi-permanent joint whose purpose is to couple optical power between two optical fibres (6.08/IEC 61931-1).

Fusion splice: a splice in which the fibre ends are joined in a permanent manner by means of fusion (6.09/IEC 61931-1).

Mechanical splice: a splice in which the fibre ends are joined in a permanent or separable manner by means other than fusion (6.10/IEC 61931-1).

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

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

**3.1.13 tuneable filter:** See 3.1.7.

**3.1.14 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 (6.51/IEC 61931-1).

Both wavelength multiplexers (MUX) and wavelength demultiplexers (DMUX) 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 (6.52/IEC 61931-1).

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 (6.53/IEC 61931-1).

**3.1.14.1 coarse WDM (CWDM) device:** A class of WDM devices having a channel wavelength spacing less than 50 nm but greater than 1000 GHz (about 8 nm at 1550 nm and 5.7 nm at 1310 nm). Devices within this class can cover several spectral bands.

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

**3.1.14.3 wide WDM (WWDM) device:** A class of WDM devices having 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. 1310 nm) from another (e.g. 1550 nm).

**3.1.15 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.

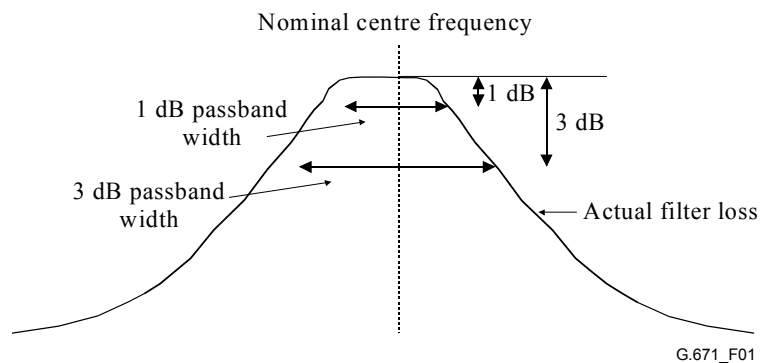
**3.1.16 Tuneable (chromatic) dispersion compensator:** A component used to compensate the chromatic dispersion of an optical path where the magnitude of dispersion compensation can be adjusted within a defined range.

**3.2 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 will be found in clause 5.

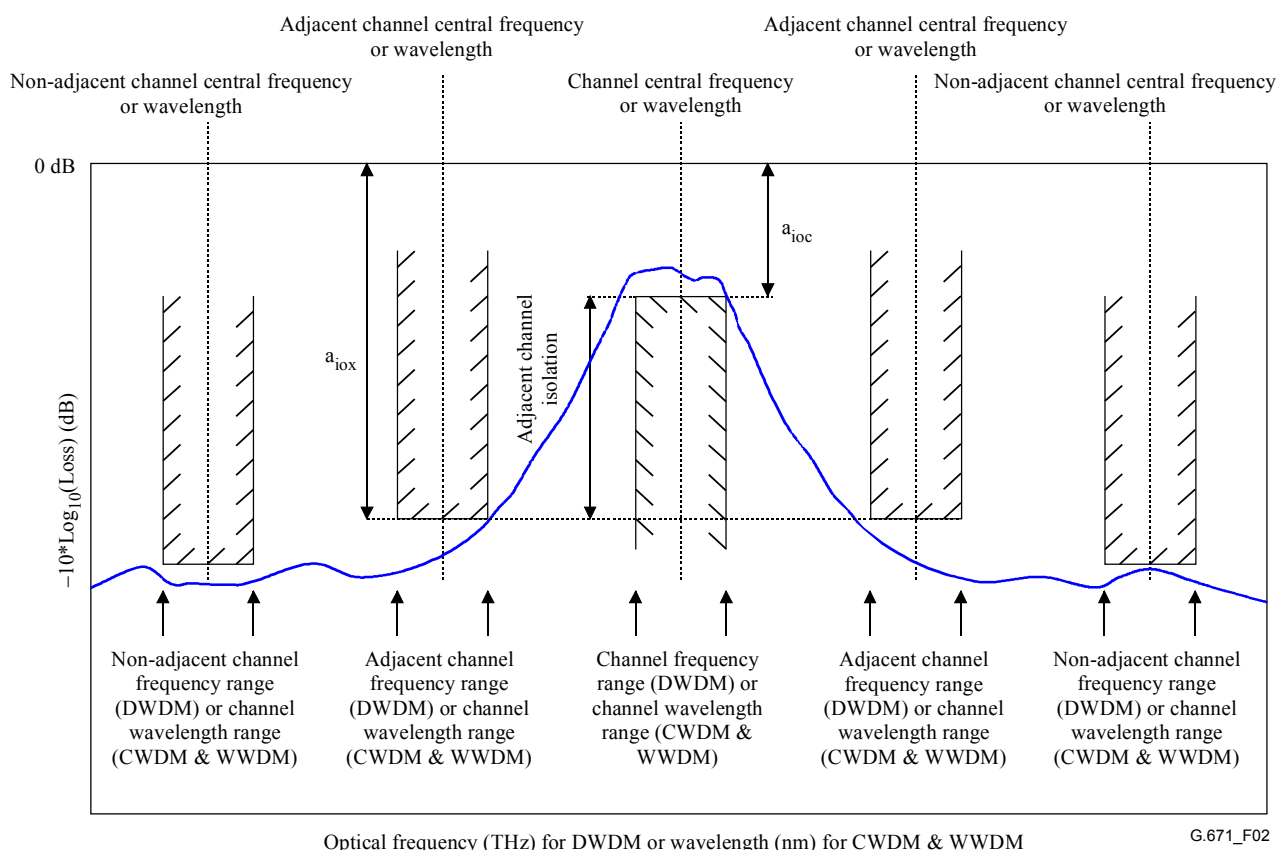
**3.2.1 1 dB and 3 dB passband width:** The 1 dB passband width  $D_1$  of an optical filter is the total frequency range over which the filter is required to have less than 1 dB of loss with respect to the minimum loss within that range. The 1 dB passband width is symmetrical with respect to the nominal 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/G.671 – Illustration of 1 dB and 3 dB passband width**

**3.2.2 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/G.671 – Illustration of adjacent channel isolation for a WDM device**

**3.2.3 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.

**3.2.4 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 (1.3.10/IEC 61202-1).

**3.2.5 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:

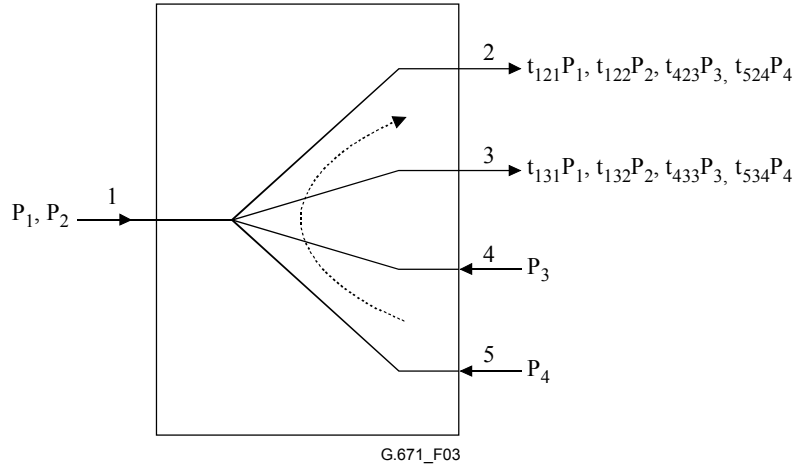
$$BCA = a_{mox}$$

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  $m$ .

**3.2.6 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/G.671 – Example of bidirectional (near-end) isolation**

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

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

$a_{max}$  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  $m$ .

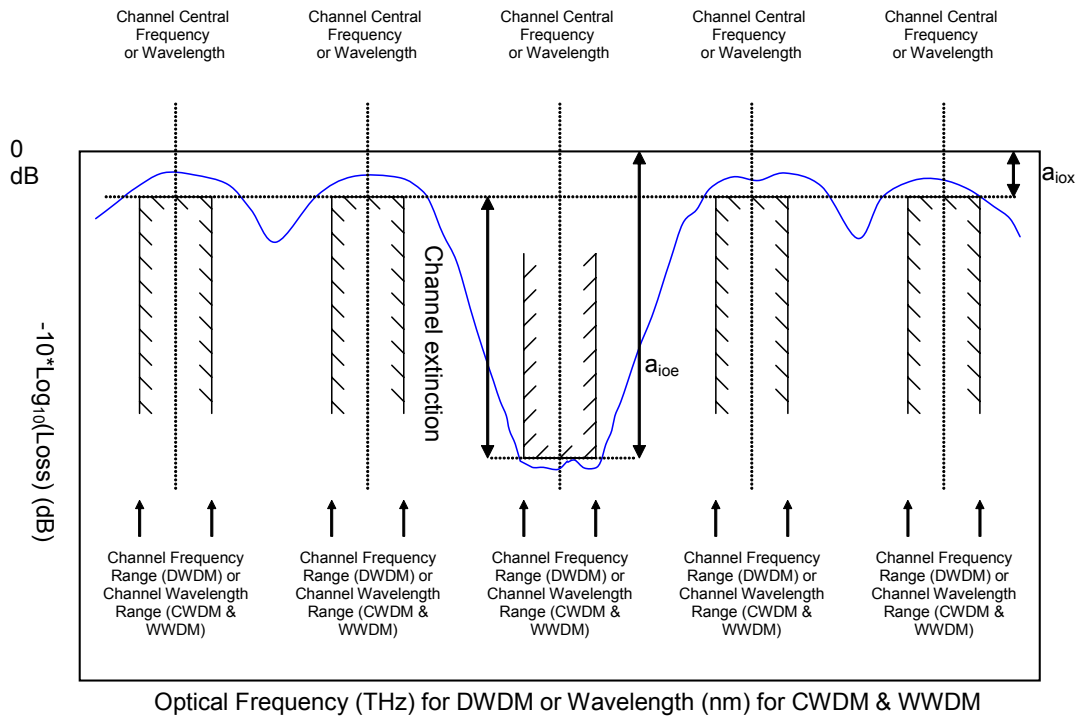
For the example given above, the bidirectional isolation of port 2 to wavelength 3 is  $a_{423} - a_{121}$ .

**3.2.7 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 3.3), 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/G.671 – 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.

**3.2.8 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  $\Delta f_{max}$  is the maximum channel central frequency deviation. Nominal channel central frequency and maximum channel central frequency deviation are defined in ITU-T Rec. G.692.

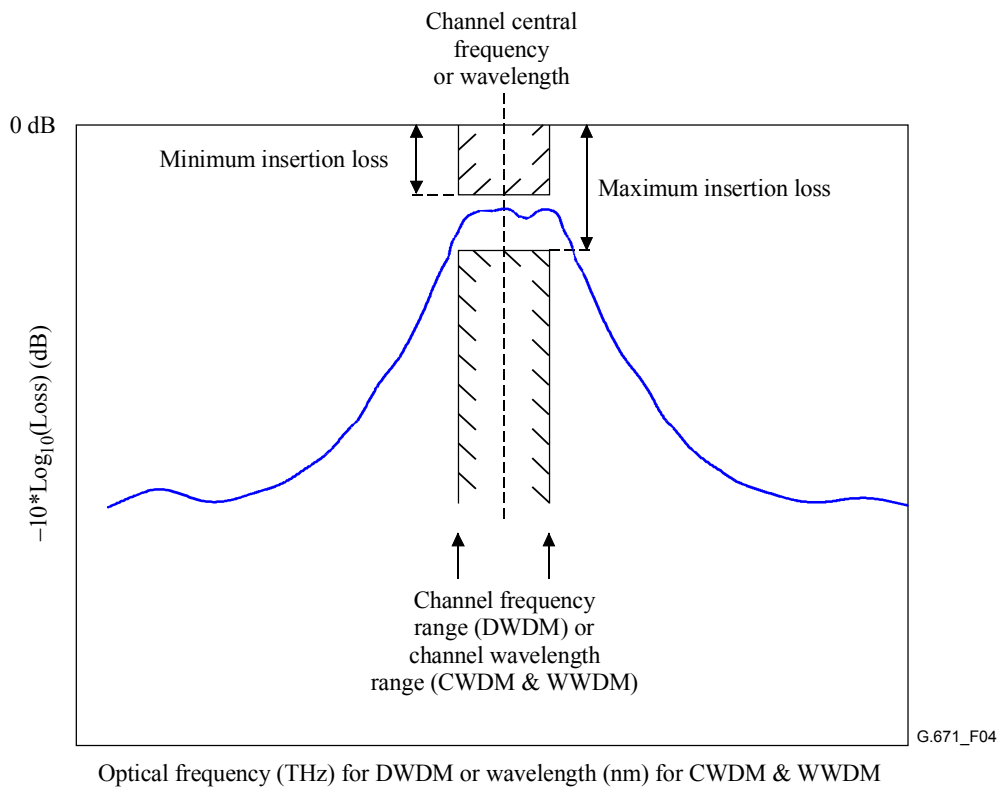
**3.2.9 channel insertion loss (WDM devices):** It is the reduction in optical power between an input and output port of a WDM device in decibels (dB). It is defined as:

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

where:

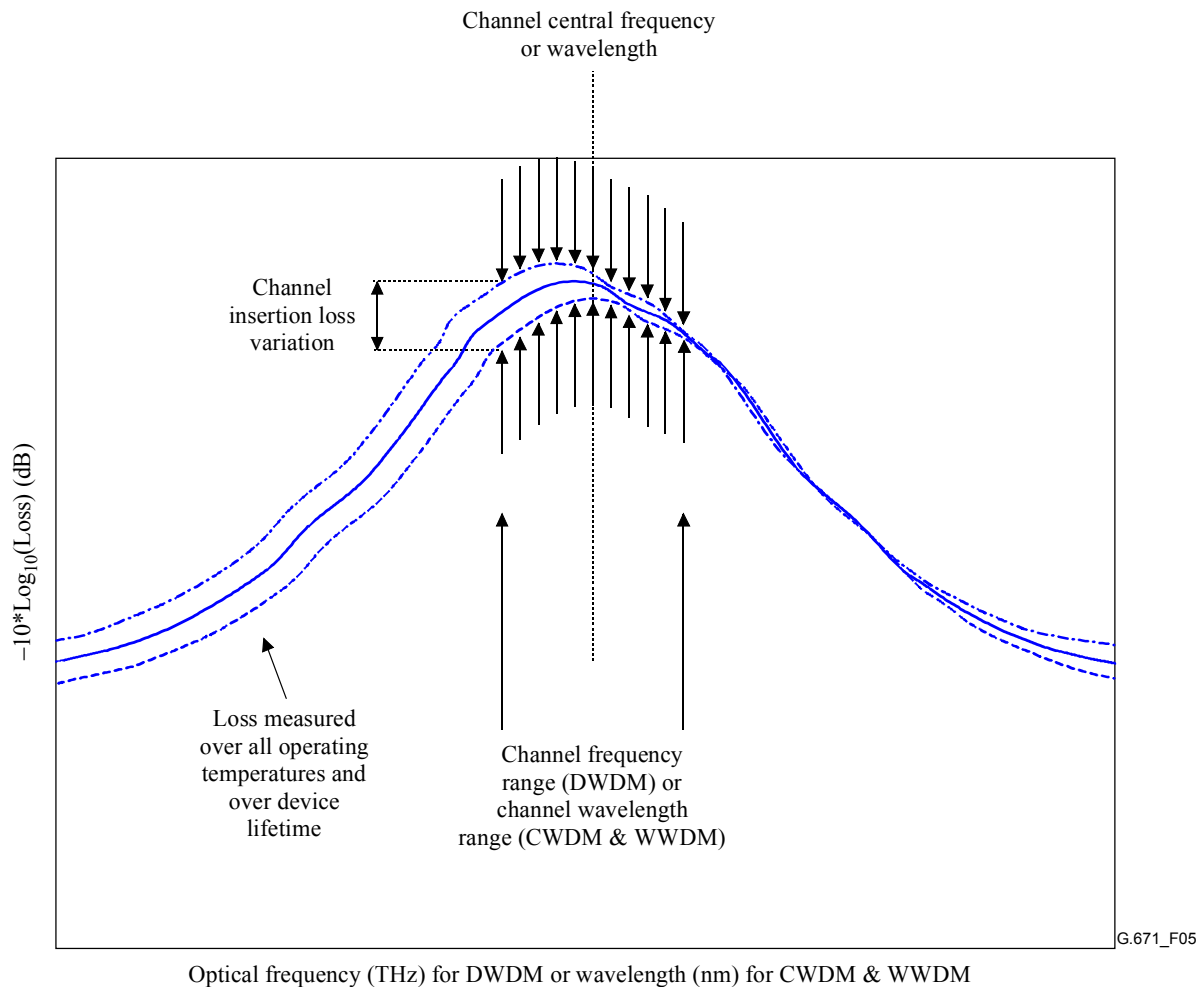
$P_{in}$  is the optical power launched into the input port and  $P_{out}$  the optical power received from the output port.

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/G.671 – Illustration of maximum and minimum insertion loss of a WDM device**

**3.2.10 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/G.671 – Illustration of channel insertion loss variation of a WDM device**

**3.2.11 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.

**3.2.12 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.

**3.2.13 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 Rec. G.694.1. CWDM channel spacings are based on the grid found in ITU-T Rec. G.694.2.

**3.2.14 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,  $\lambda_{nomi}$ , 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.

**3.2.15 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 (1.3.11/IEC 60875-1).

**3.2.16 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 (1.3.6/IEC 60869-1).

**3.2.17 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  $P_{out}$  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 (1.3.7/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 (1.3.9/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.

**3.2.18 insertion loss tolerance (optical attenuators only):** The difference between nominal and actual insertion loss of the attenuator.

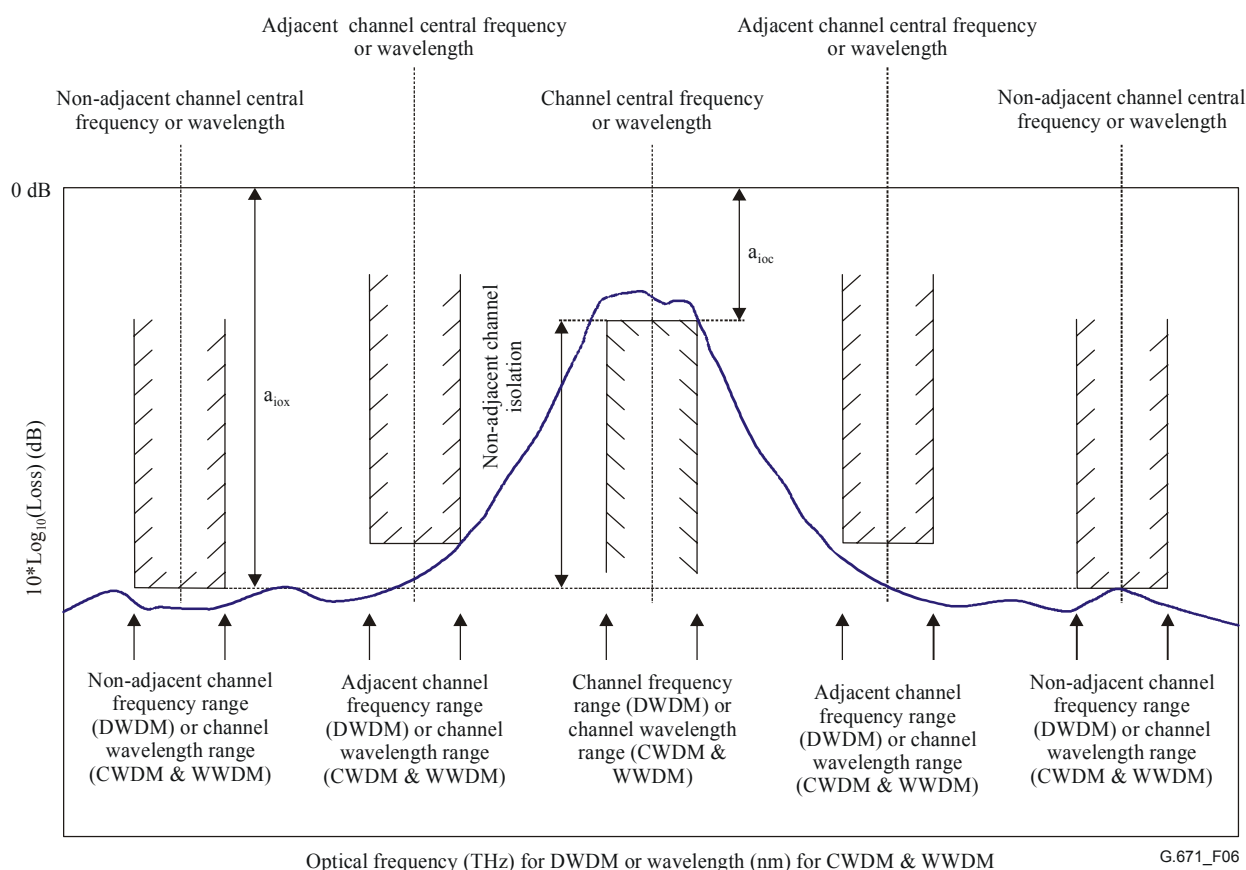
**3.2.19 isolation of an optical switch:** The isolation of an optical switch is the minimum value of the ratio of the transfer coefficient of the switch in its on state to the transfer coefficient in its off state, over the operating wavelength range. It is defined as:

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

Where  $t_{io}$  is the transfer coefficient (as defined in 3.3) from port  $i$  to port  $o$  with path  $io$  switched on and  $t_{io}^o$  is the transfer coefficient from port  $i$  to port  $o$  with path  $io$  switched off.

**3.2.20 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.





G.671\_F06

Figure 8/G.671 – Illustration of non-adjacent channel isolation for a WDM device

**3.2.21 operating wavelength range:** The specified range of wavelengths from  $\lambda_{imin}$  to  $\lambda_{imax}$  about a nominal operating wavelength  $\lambda_i$ , within which a passive component is designed to operate with a specified performance (1.3.21/IEC 60875-1).

NOTE 1 – For an optical branching component with more than one operating wavelength, the corresponding wavelength ranges are not necessarily equal (1.3.21/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.

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

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

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

**3.2.25 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.

$$DGDmax_{link} = \left[ DGDmax_F^2 + S^2 \sum_i PMD_{Ci}^2 \right]^{1/2}$$

where:

- $DGDmax_{link}$ : maximum link DGD (ps);  
 $DGDmax_F$ : 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  $DGDmax_{link}$  being controlled by the value of the Maxwell adjustment factor taken from Table 1.

**Table 1/G.671 – 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	$4.2 \times 10^{-5}$	4	$7.4 \times 10^{-9}$
3.2	$9.2 \times 10^{-6}$	4.2	$9.6 \times 10^{-10}$
3.4	$1.8 \times 10^{-6}$	4.4	$1.1 \times 10^{-10}$
3.6	$3.2 \times 10^{-7}$	4.6	$1.2 \times 10^{-11}$
3.8	$5.1 \times 10^{-8}$		

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  $DGDmax_{link}$  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 vs. wavelength is such that the Maxwell distribution does not underestimate the maximum DGD for probabilities less than  $4.2 \times 10^{-5}$ , 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.

**3.2.26 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:

$$R = 10 \log \left( \frac{P_r}{P_i} \right) \quad (1.34/\text{IEC 61931-1})$$

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 (1.3.8/IEC 60875-1).
- For a WDM device, it is an element  $a_{iww}$  (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 (1.3.10/IEC 60876-1).
- For an optical filter, it shall be specified in each operating wavelength range.

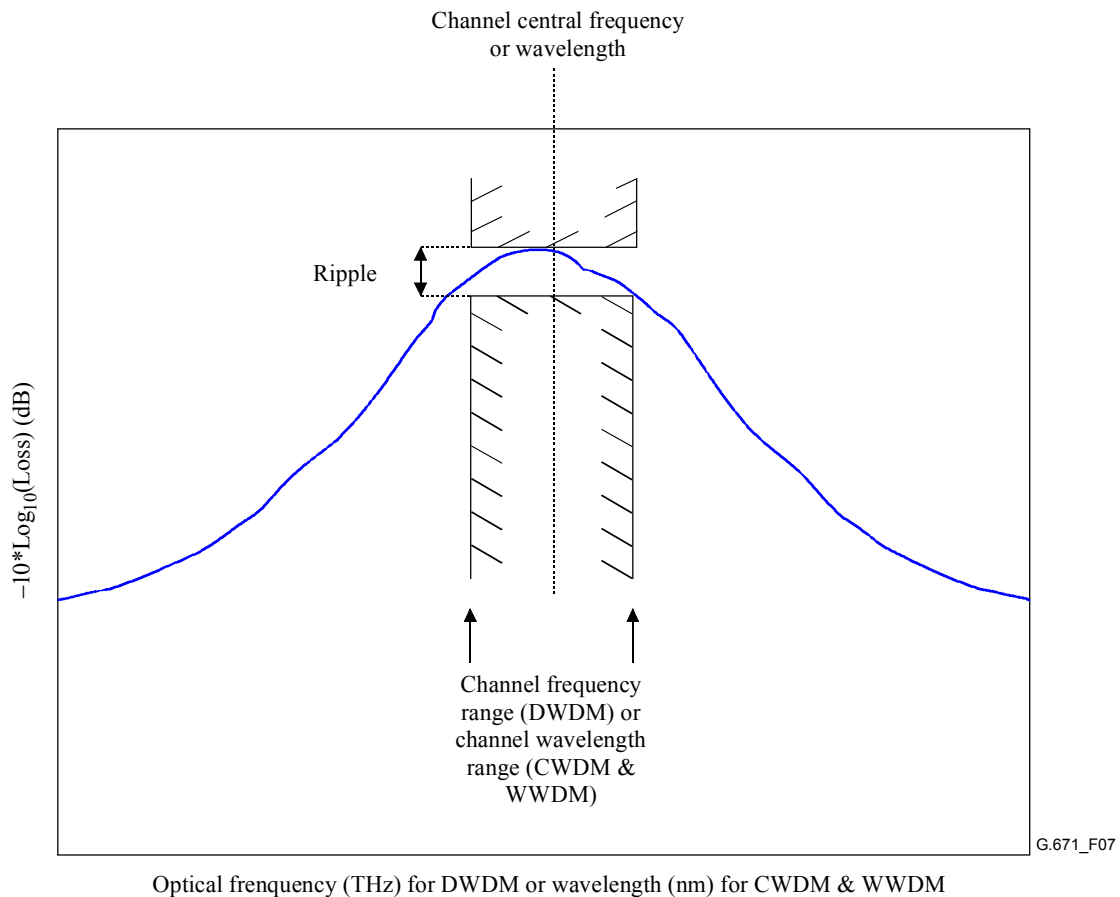
NOTE 2 – For clarity, reflectance values for optical devices do not include the reflectance contributions of connectors or unterminated optical ports. Reflectance contributions from connectors will be considered separately.

NOTE 3 – Generally, within the 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.

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

**3.2.28 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.

**3.2.29 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/G.671 – Illustration of ripple for a WDM device**

**3.2.30 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 (1.3.19/IEC 60876-1).

**3.2.31 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  $\pm$  half of the 3 dB passband width.

NOTE – 0.1 dB has been proposed.

**3.2.32 unidirectional (far-end) crosstalk attenuation (for a WDM device):** In a WDM device able to separate  $k$  wavelengths ( $\lambda_1, \lambda_2, \dots, \lambda_k$ ) 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:

$$UCA = a_{iox}$$

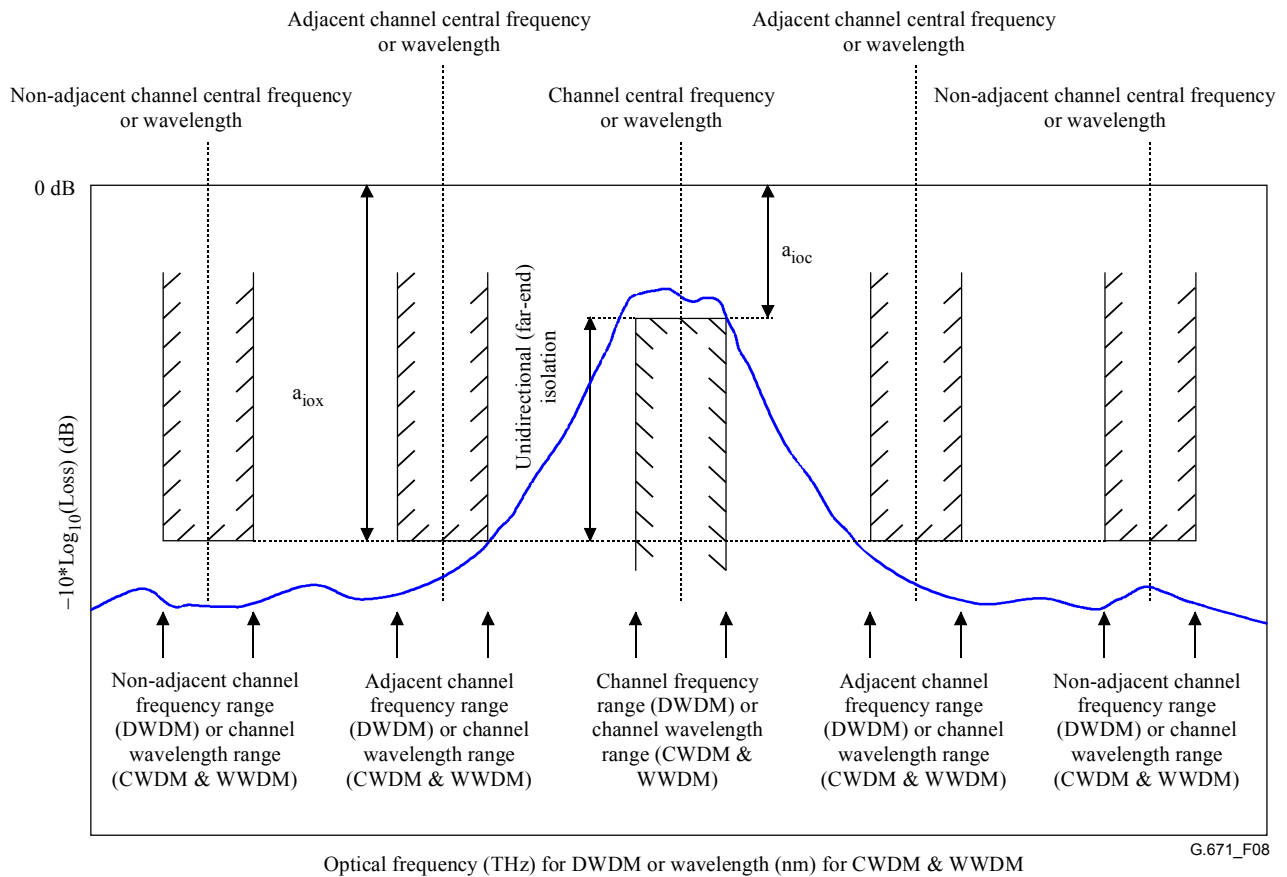
The term  $a_{iox}$  is an element of the logarithmic transfer matrix where  $i$  is the input port number,  $o$  is the output port number and  $x$  is the isolation wavelength number, where  $x$  is any wavelength number not equal to the (channel) wavelength number associated with port  $o$ . In each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

**3.2.33 Unidirectional (far-end) isolation (for a WDM device):** In a WDM device able to separate  $k$  wavelengths ( $\lambda_1, \lambda_2, \dots, \lambda_k$ ) radiation coming from one input port into  $k$  output ports, each one nominally passing radiation at one specific wavelength only. The unidirectional (far-end) 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 3.3), 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  $\lambda_c$  and  $k-1$  isolation wavelengths  $\lambda_x$ . This is illustrated in Figure 10.

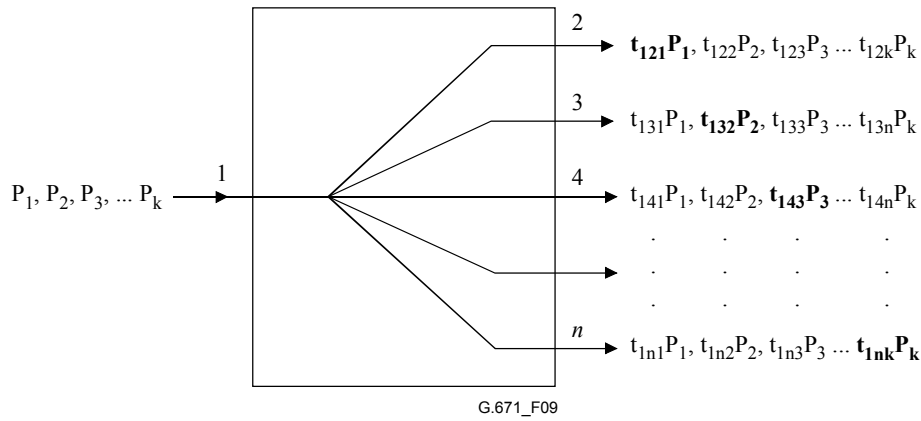
NOTE –  $\lambda_c$  is used in this Recommendation to denote channel wavelength and not fibre cut-off wavelength.



**Figure 10/G.671 – Illustration of unidirectional (far-end) isolation of a WDM device**

Figure 11 illustrates an example using the transfer matrix defined in 3.3, if powers  $P_1, P_2, P_3, \dots, P_k$  were launched into a WDM DMUX device at wavelengths 1, 2, 3, ...  $k$  respectively, then the signals emerging from port  $x$  would be:

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



**Figure 11/G.671 – Example of WDM demultiplexer device**

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

**3.2.34 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 (1.3.16/IEC 60875-1).

**3.2.35 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.

**3.2.36 Group delay ripple:**

The group delay ripple of an optical device is the maximum peak-to-peak variation of the group delay through the device within the channel frequency range (DWDM devices) or channel wavelength range (CWDM and WWDM devices).

In a group of waves that have slightly different individual frequencies, the group delay is the time required for any defined point on the envelope (i.e., the envelope determined by the additive resultant of the group of waves) to travel through the device.

The relationship between the group delay ripple and the optical penalty it causes is dependent on factors such as how rapidly the group delay varies with optical frequency (wavelength), the signal bit rate, modulation format etc. This means that the value of this parameter must be determined from the application in the relevant transmission system Recommendation

**3.2.37 Dynamic channel attenuation range (dynamic channel equaliser only):** For a dynamic channel equaliser, 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.

**3.2.38 Channel attenuation resolution (dynamic channel equaliser 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 equaliser (in dB).

**3.3 Definition of terms**

The following terms are used in the parameter definitions in 3.2.

**3.3.1 conducting port:** Two ports  $i$  and  $o$  between which  $t_{io}$  is nominally greater than zero (1.3.12/IEC 60875-1).

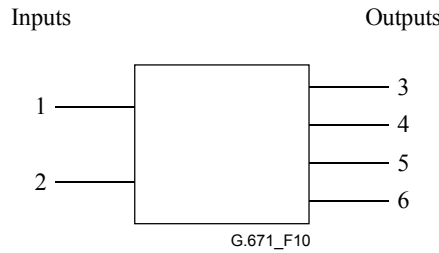
**3.3.2 coupling ratio:** For a given input port  $i$ , this is the ratio of light at a given output port  $o$  to the total light from all output ports. It is defined as:

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

where  $n$  are the operational output ports (1.3.17/IEC 60875-1).

**3.3.3 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/G.671 – 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  $6 \times 6 \times 4$  matrix: loss at  $\lambda_1$  from port 1 to port 6 would use  $a_{161}$ . Reflectance of port 2 at  $\lambda_4$  would use  $a_{224}$ . Loss from port 5 to port 2 at  $\lambda_3$  would use  $a_{523}$ .

**3.3.4 isolated port:** Two ports  $i$  and  $o$  between which  $t_{io}$  is nominally zero and  $a_{io}$  is nominally infinite (1.3.13/IEC 60875-1).

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

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

**Figure 13/G.671 – 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,  $a_{io}^o = -10 \log (t_{io}^o)$ . This matrix is intended for definition purposes only (1.3.8/IEC 60876-1).

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

$$A = \begin{matrix} & \begin{matrix} \text{Return port number} \\ 1 & 2 & \cdot & n \end{matrix} \\ \begin{matrix} \text{Wavelengths} \\ 1 & 2 & \cdot & k \end{matrix} & \begin{pmatrix} a_{11k} & a_{12k} & \cdot & a_{1nk} \\ a_{21k} & a_{22k} & \cdot & a_{2nk} \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1k} & a_{n2k} & \cdot & a_{nnk} \end{pmatrix} \end{matrix} \begin{matrix} 1 \\ 2 \\ \cdot \\ n \end{matrix} \left. \vphantom{\begin{matrix} a_{11k} \\ a_{21k} \\ \cdot \\ a_{n1k} \end{matrix}} \right\} \begin{matrix} \text{Send port number} \\ 1 \\ 2 \\ \cdot \\ n \end{matrix}$$

$$A = \begin{pmatrix} a_{111} & a_{121} & \cdot & a_{1n1} \\ a_{211} & a_{221} & \cdot & a_{2n1} \\ \cdot & \cdot & \cdot & \cdot \\ a_{n11} & a_{n21} & \cdot & a_{nn1} \end{pmatrix}$$

G.671\_F12

**Figure 14/G.671 – 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  $\lambda_w$ ). This matrix is intended for definition purposes only (1.3.9/IEC 60875-1).

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

**3.3.7 operating wavelength:** A nominal wavelength  $\lambda$ , at which a passive component is designed to operate with the specified performance (1.3.20/IEC 60875-1).

**3.3.8 port:** An optical fibre or an optical fibre connector attached to an optical component for the entry and/or exit of the optical power (1.3.1/IEC 60875-1).

**3.3.9 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.

**3.3.10 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 (1.3.20/IEC 60876-1).

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

**Figure 15/G.671 – Switching time matrix for an optical switch**

**3.3.11 transfer coefficient (for optical branching and WDM devices):** An element  $t_{io}$  of the transfer matrix (1.3.8/IEC 60875-1).



**3.3.12 transfer coefficient (for an optical switch):** An element  $t_{io}$  or  $t_{io}^o$  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  $t_{io}^o$  is the worst case (maximum) fraction of power transferred from port  $i$  to port  $o$  for any state with path  $io$  switched off (1.3.7/IEC 60876-1).

**3.3.13 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.

$$T = \begin{matrix} & \begin{matrix} \text{Return port number} \\ 1 & 2 & \dots & n \end{matrix} \\ \begin{matrix} \text{Send port number} \\ 1 & 2 & \dots & n \end{matrix} & \begin{matrix} \text{Wavelengths} \\ 1 & 2 & \dots & k \end{matrix} \\ \left( \begin{matrix} t_{111} & t_{121} & \dots & t_{1n1} \\ t_{211} & t_{221} & \dots & t_{2n1} \\ \vdots & \vdots & \ddots & \vdots \\ t_{n11} & t_{n21} & \dots & t_{nn1} \end{matrix} \right) & \dots & \left( \begin{matrix} t_{11k} & t_{12k} & \dots & t_{1nk} \\ t_{21k} & t_{22k} & \dots & t_{2nk} \\ \vdots & \vdots & \ddots & \vdots \\ t_{n1k} & t_{n2k} & \dots & t_{nnk} \end{matrix} \right) \end{matrix}$$

G.671\_F14

**Figure 16/G.671 – 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  $\lambda_w$ ). 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  $t_{sr}$ .

**3.3.14 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 (1.3.6/IEC 60876-1).

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

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

**Figure 17/G.671 – Transfer matrix for an optical switch**

#### **4 Abbreviations and acronyms**

This Recommendation uses the following abbreviations:

CWDM	Coarse Wavelength Division Multiplexing
DCE	Dynamic Channel Equalizer
DGD	Differential Group Delay
DWDM	Dense Wavelength Division Multiplexing
ffs	for further study
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 Basic Standard on

tests and measurement procedures for interconnecting devices and passive components are referenced to the functional parameters.

Values for 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.

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 like 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 Rec. G.650 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.

NOTE 6 – Values derived from assumptions of compensating a specific length of G.652 type fibre, using the equation found in I.2/G.652, although other lengths and assumptions are under study. Values for compensators of lengths of G.653 and 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 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.

## 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
5.1.6	Polarization dependent loss (PDL) (dB)	ffs	na	
5.1.8	Number of add/drop/through channels	sba	sba	
5.1.10	Channel wavelength range (nm) (CWDM and WWDM devices)	sba	sba	
5.1.12	1 dB passband width (nm)	sba	sba	
5.1.14	Ripple (dB)	ffs	na	
5.1.15	Input to drop	na	sba	
	Channel extinction (dB)			
5.1.18	Allowable input power (dBm)	ffs (Note 2)	na	

## 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, IEC 61300-3-12
5.2.7	Polarization dependent loss (PDL)– tap port (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
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	G.650 (Note 3)
5.2.11	Directivity (dB)	na	ffs	ffs

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, IEC 61300-3-12

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	G.650 (Note 3)
5.3.9	Insertion loss tolerance (dB)	$\pm 15\%$	$\pm 15\%$	ffs
5.3.10	Attenuation range (variable attenuator) (dB)	sba	sba	ffs
5.3.11	Incremental attenuation (variable attenuator) (dB)	sba	sba	ffs

#### 5.4 Optical branching component (wavelength non-selective)

$1 \times X$  and  $2 \times X$  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, IEC 61300-3-12
5.4.6	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.4.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.4.8	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
5.4.9	Directivity (dB)	na	50	ffs
5.4.10	Uniformity (dB)	$1.0 \log_2 X$	na	ffs

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

X	$1 \times X$		$2 \times X$	
	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 connector

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB)			
5.5.1	for single fibre (Note 7)	0.5	na	IEC 61300-3-4, IEC 61300-3-7
5.5.2	for multifibre (Note 7)	1.0	na	IEC 61300-3-4, IEC 61300-3-7
5.5.3	Reflectance (dB)	−35 (Notes 7 and 8)	na	IEC 61300-3-6
	Operating wavelength range (nm) (Note 1)			
5.5.4	1310 nm window	1360	1260	IEC 61300-3-7
5.5.5	1550 nm window	1580	1480	IEC 61300-3-7
5.5.6	Polarization dependent loss (PDL) (dB)	0.1	na	IEC 61300-3-2, IEC 61300-3-12
5.5.7	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.5.8	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.5.9	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
NOTE – Insertion loss and reflectance values also include effects of mating durability.				

## 5.6 Dynamic channel equalizer (DCE)

Clause	Parameter	Max	Min	Test method
5.6.1	Insertion loss (dB)	6	ffs	IEC 61300-3-4, IEC 61300-3-7
5.6.2	Reflectance (dB)	na	−45	IEC 61300-3-6
5.6.3	Operating wavelength range (nm)	sba	sba	IEC 61300-3-7
	Polarization dependent loss (PDL) (dB)			
5.6.4	Over full dynamic channel attenuation range	0.4	na	IEC 61300-3-2, IEC 61300-3-12
5.6.5	Over reduced dynamic channel attenuation range of 10 dB	0.2	na	IEC 61300-3-2, IEC 61300-3-12
5.6.6	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.6.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.6.8	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
5.6.9	Channel extinction (dB)	na	40	
5.6.10	Out-of-band attenuation (dB)	na	40	
5.6.11	Channel attenuation resolution (dB)	0.2	na	
5.6.12	Dynamic channel attenuation range (dB)	na	20	
5.6.13	Ripple (dB)	0.2	na	
5.6.14	Channel response time (ms)	30	na	
5.6.15	Channel spacing (nm)	sba	sba	
5.6.16	Number of channels	sba	sba	



## 5.7 Optical filter

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB)			
5.7.1	Pass band	sba	sba	IEC 61300-3-4, IEC 61300-3-7
5.7.2	Stop band	na	sba	
5.7.3	Reflectance (dB)	−40	na	IEC 61300-3-6
5.7.4	Operating wavelength range (nm)	sba	sba	IEC 61300-3-7
5.7.5	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.7.6	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.7.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.7.8	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
5.7.9	Ripple (dB)	ffs	na	ffs

## 5.8 Optical isolator

Clause	Parameter	Max	Min	Test method
5.8.1	Insertion loss (dB)	ffs	na	
5.8.2	Backward loss (isolation)	na	sba	IEC 61300-3-4, IEC 61300-3-7
5.8.3	Reflectance (dB)	−40	na	IEC 61300-3-6
	Operating wavelength range (nm) (Note 1)			
5.8.4	1310 nm window	1360	1260	IEC 61300-3-7
5.8.5	1550 nm window	1580	1480	IEC 61300-3-7
5.8.6	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.8.7	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.8.8	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.8.9	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)

## 5.9 Passive (chromatic) dispersion compensator

Clause	Parameter (km of G.652 equivalent compensation)	Max	Min	Test method
	Insertion loss (dB)			IEC 61300-3-4, IEC 61300-3-7
5.9.1	2.5	ffs	na	
5.9.2	5	ffs	na	
5.9.3	7.5	ffs	na	
5.9.4	10	ffs	na	
5.9.5	20	3.6	ffs	
5.9.6	30	ffs	ffs	
5.9.7	40	5.5	ffs	
5.9.8	50	ffs	ffs	
5.9.9	60	7.5	ffs	
5.9.10	70	ffs	ffs	
5.9.11	80	9.5	ffs	
5.9.12	90	ffs	ffs	
5.9.13	100	11.5	ffs	
5.9.14	110	ffs	ffs	
5.9.15	120	13.5	ffs	
5.9.16	Reflectance (dB)	−27	na	IEC 61300-3-6
5.9.17	Operating wavelength range (nm) (Note 5)	1565	1525	IEC 61300-3-7
5.9.18	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.9.19	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.9.20	Allowable input power (dBm)	ffs (Note 2)	na	ffs
	Dispersion over operating wavelength range (Note 6) (ps/nm)			ffs
5.9.21	2.5	ffs	ffs	
5.9.22	5	ffs	ffs	

Clause	Parameter (km of G.652 equivalent compensation)	Max	Min	Test method
5.9.23	7.5	ffs	ffs	
5.9.24	10	ffs	ffs	
5.9.25	20	−310	−360	
5.9.26	30	ffs	ffs	
5.9.27	40	−620	−710	
5.9.28	50	ffs	ffs	
5.9.29	60	−930	−1070	
5.9.30	70	ffs	ffs	
5.9.31	80	−1240	−1420	
5.9.32	90	ffs	ffs	
5.9.33	100	−1550	−1780	
5.9.34	110	ffs	ffs	
5.9.35	120	−1860	−2140	
	Polarization mode dispersion (PMD) (Note 7) (ps)			G.650 (Note 3)
5.9.36	2.5	ffs	na	
5.9.37	5	ffs	na	
5.9.38	7.5	ffs	na	
5.9.39	10	ffs	na	
5.9.40	20	ffs	na	
5.9.41	40	ffs	na	
5.9.42	60	ffs	na	
5.9.43	80	ffs	na	
5.9.44	100	ffs	na	
5.9.45	120	ffs	na	

## 5.10 Optical splice

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB) (Note 9)			IEC 61300-3-4, IEC 61300-3-7
5.10.1	Mechanical splice	0.50	na	
5.10.2	Fusion Splice (Active Alignment)	0.30	na	
5.10.3	Fusion Splice (Passive Alignment)	0.50	na	
	Reflectance (dB)			IEC 61300-3-6
5.10.4	Mechanical splice	−40	na	
5.10.5	Fusion splice	−70	na	
	Operating wavelength range (nm) (Note 1)			
5.10.6	1310 nm window	1360	1260	IEC 61300-3-7
5.10.7	1550 nm window	1580	1480	IEC 61300-3-7
5.10.8	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.10.9	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.10.10	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.10.11	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)

## 5.11 Optical switch

Clause	Parameter	1 × X switches		2 × 2 switches		Test method
		Max	Min	Max	Std	
5.11.1	Insertion loss (dB)	$2.5 \mid \log_2 X$ (Note 4)	na	ffs	na	IEC 61300-3-4, IEC 61300-3-7
5.11.2	Reflectance (dB)	−40	na	−40	na	IEC 61300-3-6
5.11.3	Operating wavelength range (nm)	ffs	ffs	ffs	ffs	IEC 61300-3-7

Clause	Parameter	1 × X switches		2 × 2 switches		Test method
		Max	Min	Max	Std	
5.11.4	Polarization dependent loss (PDL) (dB)	ffs   0.1 (1 + log <sub>2</sub> X) (Note 4)	na	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.11.5	Polarization dependent reflectance (dB)	ffs	na	ffs	na	IEC 61300-3-19
5.11.6	Allowable input power (dBm)	ffs (Note 2)	na	ffs (Note 2)	na	ffs
5.11.7	Polarization mode dispersion (PMD) (ps)	ffs	na	ffs	na	G.650 (Note 3)
5.11.8	Switching time	10 s   20 ms (Note 4)	na	ffs	na	ffs
5.11.9	Repeatability (dB)	0.25	na	ffs	na	ffs
5.11.10	Uniformity (dB)	ffs   0.4 log <sub>2</sub> X (Note 4)	na	ffs	na	ffs
5.11.11	Isolation (dB)	sba	na	sba	na	ffs
5.11.12	Directivity (dB)	na	50	na	ffs	ffs
NOTE – 2 × X switches are for future study.						

## 5.12 Optical termination

Clause	Parameter	Max	Min	Test method
5.12.1	Reflectance (dB)	–50	na	IEC 61300-3-6
	Operating wavelength range (nm) (Note 1)			
5.12.2	1310 nm window	1360	1260	IEC 61300-3-7
5.12.3	1550 nm window	1580	1480	IEC 61300-3-7
5.12.4	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.12.5	Allowable input power (dBm)	ffs (Note 2)	na	ffs

### 5.13 Tuneable filter

Clause	Parameter	Max	Min	Test method
	Insertion loss (dB)			IEC 61300-3-4, IEC 61300-3-7
5.13.1	Pass band	sba	sba	
5.13.2	Stop band	na	sba	
5.13.3	Reflectance (dB)	ffs	na	IEC 61300-3-6
5.13.4	Operating wavelength range (nm)	sba	sba	IEC 61300-3-7
5.13.5	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.13.6	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.13.7	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.13.8	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
5.13.9	1 dB passband width (nm)	sba	sba	ffs
5.13.10	3 dB passband width (nm)	sba	sba	ffs
5.13.11	Ripple (dB)	ffs	na	ffs
5.13.12	Reproducibility of passband setting (nm)	ffs	na	ffs
5.13.13	Tuning (settling) time (s)	sba	sba	ffs
5.13.14	Channel insertion loss deviation (dB)	ffs	ffs	ffs

## 5.14 Optical wavelength MUX/DMUX

### 5.14.1 Coarse WDM (CWDM) device

Clause	Parameter	Max	Min	Test method
5.14.1.1	Channel insertion loss (dB)	ffs	ffs	IEC 61300-3-4, IEC 61300-3-7
5.14.1.2	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.14.1.3	Reflectance (dB)	ffs	na	IEC 61300-3-6
5.14.1.4	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.14.1.5	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.14.1.6	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.14.1.7	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
5.14.1.8	Channel wavelength range (nm)	sba	sba	
5.14.1.9	Ripple (dB)	ffs	ffs	
5.14.1.10	Adjacent channel isolation (dB)	na	sba	
5.14.1.11	Non-adjacent channel isolation (dB)	na	sba	
5.14.1.12	Bidirectional (near-end) isolation (dB)	na	sba	
5.14.1.13	Unidirectional (far-end) crosstalk attenuation (dB)	na	sba	
5.14.1.14	Bidirectional (near-end) crosstalk attenuation (dB)	na	sba	

### 5.14.2 Dense WDM (DWDM) device 1 × X

Clause	Parameter	Max	Min	Test method
5.14.2.1	Channel insertion loss (dB)	sba	sba	IEC 61300-3-4, IEC 61300-3-7
5.14.2.2	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.14.2.3	Reflectance (dB)	ffs	na	IEC 61300-3-6
5.14.2.4	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.14.2.5	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.14.2.6	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.14.2.7	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
5.14.2.8	Channel frequency range (GHz)	sba	sba	ffs
5.14.2.9	Ripple (dB)	ffs	na	ffs
5.14.2.10	Adjacent channel isolation (dB)	na	sba	
5.14.2.11	Non-adjacent channel isolation (dB)	na	sba	ffs
5.14.2.12	Bidirectional (near-end) isolation (dB)	na	sba	ffs
5.14.2.13	Unidirectional (far-end) crosstalk attenuation (dB)	na	sba	ffs
5.14.2.14	Bidirectional (near-end) crosstalk attenuation (dB)	na	sba	ffs



### 5.14.3 Wide WDM (WWDM) device 1 × X

Clause	Parameter	Max	Min	Test method
5.14.3.1	Channel insertion loss (dB)	$1.5 \log_2 X$	ffs	IEC 61300-3-4, IEC 61300-3-7
5.14.3.2	Channel insertion loss deviation (dB)	ffs	ffs	ffs
5.14.3.3	Reflectance (dB)	−40	na	IEC 61300-3-6
	Operating wavelength range (nm) (Note 1)			
5.14.3.4	1310 nm window	1360	1260	IEC 61300-3-7
5.14.3.5	1550 nm window	1580	1480	IEC 61300-3-7
5.14.3.6	Polarization dependent loss (PDL) (dB)	$0.1 (1 + \log_2 X)$	na	IEC 61300-3-2, IEC 61300-3-12
5.14.3.7	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.14.3.8	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.14.3.9	Polarization mode dispersion (PMD) (ps)	ffs	na	G.650 (Note 3)
5.14.3.10	Unidirectional (far-end) isolation (dB)	na	sba	ffs
5.14.3.11	Bidirectional (near-end) isolation (dB)	na	sba	ffs
5.14.3.12	Unidirectional (far-end) crosstalk attenuation (dB)	na	sba	ffs
5.14.3.13	Bidirectional (near-end) crosstalk attenuation (dB)	na	sba	ffs

### 5.15 Single optical channel passive (chromatic) dispersion compensator

	Parameter (km of G.652 equivalent compensation)	Max	Min	Test method
	Dispersion over the channel frequency range (ps/nm)			ffs

	Parameter (km of G.652 equivalent compensation)	Max	Min	Test method
5.15.1	10	-168	-178	
5.15.2	20	-337	-356	
5.15.3	30	-506	-533	
5.15.4	40	-675	-711	
5.15.5	50	-844	-888	
5.15.6	60	-1013	-1066	
5.15.7	70	-1182	-1244	
5.15.8	80	-1351	-1421	
5.15.9	Insertion loss	ffs	ffs	IEC 61300-3-4, IEC 61300-3-7
5.15.10	Reflectance (dB)	-27	na	IEC 61300-3-6
5.15.11	Channel frequency range (THz)	192.14	192.06	
5.15.11	Polarization dependent loss (PDL) (dB)	ffs	na	IEC 61300-3-2, IEC 61300-3-12
5.15.12	Polarization dependent reflectance (dB)	ffs	na	IEC 61300-3-19
5.15.13	Allowable input power (dBm)	ffs (Note 2)	na	ffs
5.15.14	Polarization mode dispersion (PMD) (Note 7) (ps)	ffs	na	G.650 (Note 3)

## 5.16 Tuneable (chromatic) dispersion compensator

Clause	Parameter	Max	Min	Test method
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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, IEC 61300-3-12
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	G.650 (Note 3)
5.16.9	Group delay ripple	Sba	na	Ffs