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

Transmission media characteristics – Characteristics of optical components and subsystems

Transmission characteristics of optical components and subsystems

ITU-T Recommendation G.671

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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 fibre-optic 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.

Source

ITU-T Recommendation G.671 was revised by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 9 February 2001.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. 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.

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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, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

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 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 Recommendation of optical access networks to support services greater than the ISDN primary bit-rate.

This Recommendation covers fibre-optic components[1] 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:

- Wideband WDM device;
- Narrowband WDM device;
- (Fibre-optic) branching component (wavelength non-selective);
- (Fibre-optic) attenuator;
- (Fibre-optic) filter;
- (Fibre-optic) isolator;
- (Fibre-optic) termination;
- (Fibre-optic) switch;
- Passive dispersion compensator;
- (Fibre-optic) connector;
- (Fibre-optic) splice;
- Tunable Filters;
- OADM Subsystems (For WDM).

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.

[1] The term fibre-optic device is intended to refer to all implementations of technologies for the devices specified, and not limited to just the ones implemented in optical fibre.

- Specific details of test methods. According to an agreement with IEC TC86, 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.

– ITU-T G.650 (2000), *Definition and test methods for the relevant parameters of single-mode fibres.*

– ITU-T G.652 (2000), *Characteristics of a single-mode optical fibre cable.*

– ITU-T G.653 (2000), *Characteristics of dispersion-shifted single-mode optical fibre cable.*

– ITU-T G.654 (2000), *Characteristics of a cut-off-shifted single-mode optical fibre cable.*

– ITU-T G.655 (2000), *Characteristics of a non-zero dispersion shifted single-mode optical fibre cable.*

– ITU-T G.661 (1998), *Definition and test methods for the relevant generic parameters of optical amplifier devices and subsystems.*

– ITU-T G.662 (1998), *Generic characteristics of optical amplifier devices and subsystems.*

– ITU-T G.691 (2000), *Optical interfaces for single-channel STM-64, STM-256 systems and other SDH systems with optical amplifiers.*

– ITU-T G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers.*

– ITU-T G.957 (1999), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*

– ITU-T G.959.1 (2001), *Optical transport network physical layer interfaces.*

– ITU-T G.982 (1996), *Optical access networks to support services up to the ISDN primary rate or equivalent bit rates.*

3 Terms and definitions

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 and summarized in the clause below:

– IEC 60869-1 (1994), *Fibre-optic attenuators – Part 1: Generic specification.*

– IEC 60874-1 (1993), *Connectors for optical fibres and cables – Part 1: Generic specification.*

– IEC 60875-1 (1996), *Non-wavelength-selective-fibre optic branching devices – Part 1: Generic specifications.*

– IEC 60876-1 (1994), *Fibre-optic spatial switches – Part 1: Generic specification.*

– IEC 61073-1 (1994), *Mechanical splices and fusion splice protectors for optical fibres and cables – Part 1: Generic Specification*.

– IEC 61202-1 (1994), *Fibre-optic isolators – Part 1: Generic specification*.

– IEC 61931-1/TR3 (1998), *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 Wavelength multiplexer and demultiplexer (including WDM device)

3.1.1.1 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 (IEC 61931-1)

Both wavelength multiplexers and wavelength demultiplexers are generally called "WDM Devices" since often the same device can be used to multiplex and demultiplex channels.

3.1.1.2 wavelength multiplexer: 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. (IEC 61931-1)

3.1.1.3 wavelength demultiplexer: 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. (IEC 61931-1)

3.1.2 wideband WDM device: A class of WDM devices having a channel wavelength spacing greater than or equal to 50 nm. This device class separates a channel in one conventional transmission window (e.g. 1310 nm) from another (e.g. 1550 nm).

3.1.3 WDM device: A class of WDM devices having a channel spacing less than that of a Wideband WDM device.

3.1.4 (fibre-optic) 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. (IEC 60875-1)

3.1.5 coupler (Splitter-Combiner): A term which 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. (IEC 60875-1)

3.1.6 symmetric branching component: A device whose transfer matrix is diagonally symmetric, i.e. where for all i and o, t_{io} and t_{oi} are nominally equal. (IEC 60875-1)

3.1.7 asymmetric branching component: A device whose transfer matrix is diagonally asymmetric, i.e. where for all i and o, t_{io} and t_{oi} are nominally unequal. (IEC 60875-1)

3.1.8 (fibre-optic) attenuator: A passive component which produces a controlled signal attenuation in an optical fibre transmission line. (IEC 60869-1)

3.1.9 (fibre-optic) filter: A passive component used to modify the optical radiation passing through it, generally by altering the spectral distribution (IEC 61931-1). Alternative: In particular, (Fibre-optic) 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.

3.1.10 (fibre-optic) 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. (IEC 61202-1)

3.1.11 (fibre-optic) termination: A component used to terminate a fibre (connectorized or not) in order to suppress reflections.

3.1.12 (fibre-optic) switch: A passive component possessing one or more ports which selectively transmits, redirects, or blocks optical power in an optical fibre transmission line. (IEC 60876-1)

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

3.1.14 (fibre-optic) 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. (IEC 61931-1)

3.1.15 (fibre-optic) splice: A permanent or semi-permanent joint whose purpose is to couple optical power between two optical fibres. (IEC 61931-1)

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

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

3.1.16 optical Add/Drop Multiplexer (OADM) subsystem

For further study.

3.2 Functional 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 clauses 5 and 6.

3.2.1 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 a (Fibre-optic) 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. (IEC 60875-1)

NOTE 2 – For a (Fibre-optic) 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. (IEC 60876-1)

NOTE 3 – For a (Fibre-optic) filter, it shall be specified as a maximum value and a minimum value over each operating wavelength range.

3.2.2 channel insertion loss (WDM devices): It is the reduction in optical power between an input and output port of a WDM device 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 – 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 wideband WDM devices, it shall be specified as a maximum value and a minimum value at each operating wavelength range. For narrowband WDM devices, it shall be specified as a maximum value and a minimum value within the channel frequency range.

3.2.3 return loss: It is the fraction of input power that is returned from the input port of a passive component. It is defined as:

$$RL = -10 \log\left(\frac{P_r}{P_i}\right)$$

where P_i is optical power launched into the input port and P_r the optical power received back from the same input port.

NOTE 1 – For a (Fibre-optic) branching component, it is an element a_{ii} (where i is the input port number), of the logarithmic transfer matrix. (IEC 60875-1)

NOTE 2 – 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 wideband WDM devices, it shall be specified as a maximum value at each operating wavelength range. For narrowband WDM devices, it shall be specified as a maximum value within the channel frequency range.

NOTE 3 – For a (Fibre-optic) 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. (IEC 60876-1)

NOTE 4 – For a (Fibre-optic) filter, it shall be specified in each operating wavelength range.

NOTE 5 – For clarity, return loss values for fibre-optic devices do not include the return loss contributions of connectors. Return loss contributions from connectors will be considered separately.

3.2.4 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:

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

NOTE – When referring to reflected power from an individual component, reflectance is the term preferred to return loss (IEC 61931-1). For clarity, reflectance values for fibre-optic devices do not include the reflectance contributions of connectors. Reflectance contributions from connectors will be considered separately.

3.2.5 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. (IEC 60875-1)

NOTE 1 – For a (Fibre-optic) branching component with more than one operating wavelength, the corresponding wavelength ranges are not necessarily equal. (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.

3.2.6 polarization Dependent Loss (PDL): Maximum variation of insertion loss due to a variation of the state of polarization over all states of polarization.

3.2.7 polarization dependent reflectance: Maximum variation of reflectance due to a variation of the state of polarization over all states of polarization.

3.2.8 differential Group Delay (DGD): The Differential Group Delay (DGD) is the time difference in the group delays of the two principal states of polarization.

In the case of optical components having non-deterministic DGD, the relationship between maximum DGD and mean DGD can be defined only probabilistically. This Recommendation defines the maximum DGD that the component can have with a defined probability.

The probability of the instantaneous DGD exceeding any given value can be inferred from its probability density function. In the case of Maxwellian statistics the equivalent mean DGD can be derived by dividing the maximum by *S* which is the ratio of maximum to mean that corresponds to an acceptable probability. Some example ratios are given below in Table 1. A more complete treatment of this topic can be found in IEC 61282-3.

Table 1/G.671 – DGD means and probabilities

Ratio of maximum to mean (S)	Probability of exceeding maximum
3.0	4.2E-05
3.5	7.7E-07
4.0	7.4E-09

For components in this Recommendation a value of $S = 3.0$ corresponding to a probability of 4.2E-05 is used. It should be noted that maximum DGD values for other probabilities are calculated from the specified value assuming that the distribution is approximately Maxwellian.

3.2.9 Wavelength dependent attenuation

For further study.

3.2.10 backward loss [Isolation] (for a fibre-optic isolator): A measure of the decrease in optical power (decibels) 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:

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

where:

P_{ob} is the optical power measured at the input port of the isolator when P_{ib} is launched into the operating port. In operating conditions, P_{ib} is the optical power reflected at the far end optical circuit devices in the backward direction into the output port of the isolator being measured. (IEC 61202-1)

3.2.11 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:

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

a_{iox} and a_{ioc} are elements of the logarithmic transfer matrix (see 3.4.3), 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 λ_c and k–1 isolation wavelengths λ_x.

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

As an example using the transfer matrix defined in 3.4.1, if powers P_1, P_2, P_3, … P_k were launched into a WDM demultiplexer device at wavelengths 1, 2, 3, … k respectively, then the signals emerging from port x would be:

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

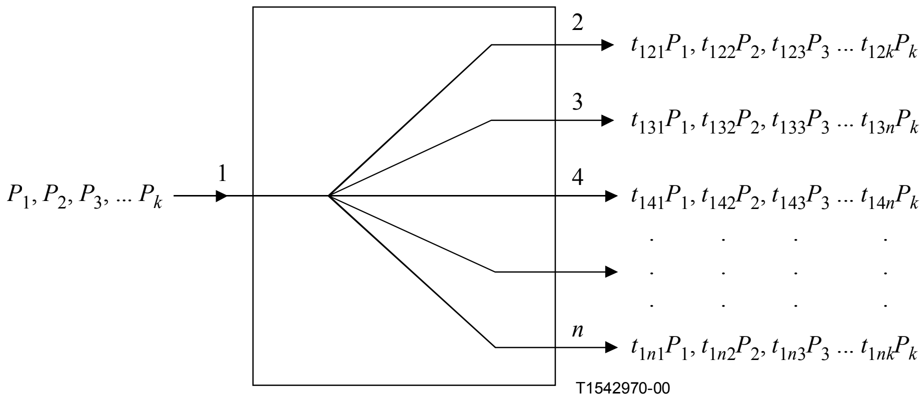

Figure 1/G.671 – Example of WDM demultiplexer device

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

3.2.12 unidirectional (far-end) crosstalk attenuation (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) 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:

$$UCA = a_{iox}$$

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.

3.2.13 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.

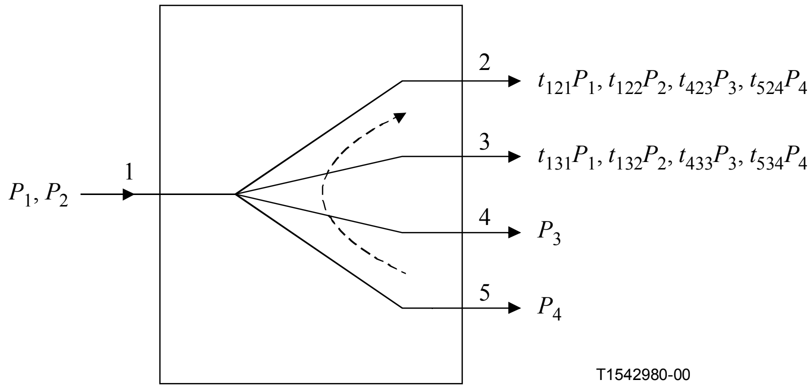

Figure 2/G.671 – Example for bidirectional (near-end) isolation

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

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

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*.

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

3.2.14 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:

$$BCA = a_{mox}$$

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*.

3.2.15 directivity: For a (Fibre-optic) branching component, the value a_{sr}, of the logarithmic transfer matrix, where *s* and *r* are the port numbers of two nominally isolated ports. (IEC 60875-1)

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

3.2.17 attenuation range (variable attenuators only)

For further study.

3.2.18 incremental attenuation (variable attenuators only): A term applicable only to variable attenuators. It refers to the difference between the attenuation of the component at a given setting and the minimum attenuation. (IEC 60869-1)

3.2.19 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. (IEC 60876-1)

3.2.20 insertion loss tolerance (for (Fibre-optic) attenuators only): The difference between nominal and actual insertion loss of the attenuator.

3.2.21 directivity of a (fibre-optic) switch

For further study.

3.2.22 (Far-end) crosstalk of a (fibre-optic) switch

For further study.

3.2.23 repeatability of a (fibre-optic) switch

For further study.

3.2.24 channel frequency range: The frequency range within which a narrowband WDM 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. Nominal channel central frequency and maximum channel central frequency deviation are defined in ITU-T G.692.

3.3 Definitions of component characteristics

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 clauses 5 and 6.

3.3.1 port: An optical fibre or an optical fibre connector attached to a (Fibre-optic) component for the entry and/or exit of the optical power. (IEC 60875-1)

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

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

3.4 Definitions of functional parameter characteristics

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 clauses 4 and 5. Figure 3 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.

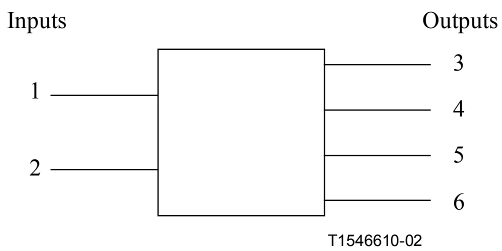

Figure 3/G.671 – An example of the port assignments for the transfer matrix

For the example shown, if there are four operating wavelengths, then the resulting transfer matrix would be 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}.

3.4.1 transfer matrix (for (Fibre-optic) branching device and WDM device): The optical properties of a fibre-optic 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 4.

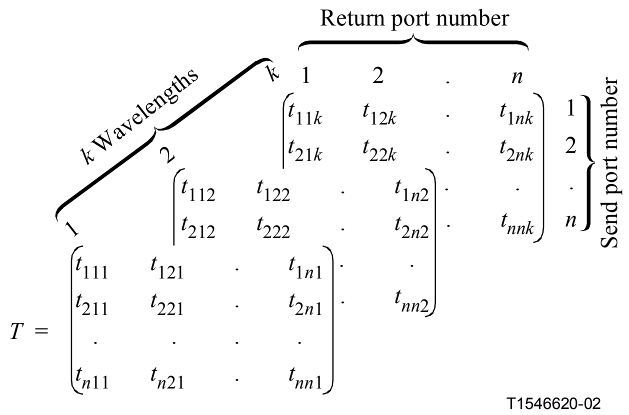

Figure 4/G.671 – Transfer matrix

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 **s**ent to the device for measurement, the second index always denotes the port number used to measure the **r**eturn 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}.

3.4.2 transfer coefficient (for (Fibre-optic) branching device and WDM device): An element t_{io} of the transfer matrix. (IEC 60875-1)

3.4.3 logarithmic transfer matrix coefficient (for (Fibre-optic) branching and WDM device): In general, the logarithmic transfer matrix is shown in Figure 5.

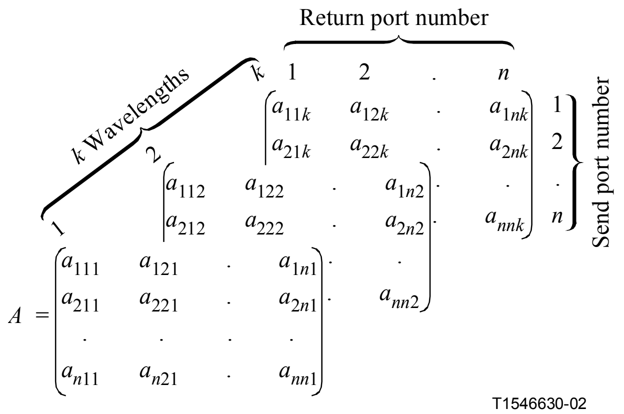

Figure 5/G.671 – Logarithmic transfer matrix

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 **s**ent 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. (IEC 60875-1)

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

3.4.4 transfer matrix (for (Fibre-optic) switch): The optical properties of a fibre-optic 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 6. This matrix is intended for definition purposes only. (IEC 60876-1)

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

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

Figure 6/G.671 – Transfer matrix for (fibre-optic) switch

3.4.5 transfer coefficient (for (fibre-optic) 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. (IEC 60876-1)

3.4.6 logarithmic transfer matrix (for (Fibre-optic) switch): In general a logarithmic transfer matrix is shown in Figure 7.

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \cdots & a_{ij} & \cdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix}$$

Figure 7/G.671 – Logarithmic transfer matrix for (fibre-optic) 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. (IEC 60876-1)

3.4.7 excess loss (for (fibre-optic) branching device): The total power lost in a branching device when an optical signal is launched into port i. It is defined as:

$$EL_i = 10 \log \sum_o t_{io}$$

where the summation is performed only over those values of o for which i and o are conducting ports. For a branching device with N input ports, there will be an array of N values of excess loss, one for each input port i. (IEC 60875-1)

3.4.8 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. (IEC 60875-1)

3.4.9 Operating wavelength

A nominal wavelength λ, at which a passive component is designed to operate with the specified performance. (IEC 60875-1)

3.4.10 switching time matrix (for (Fibre-optic) 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 8. This matrix is intended for definition purposes only. (IEC 60876-1)

$$S = \begin{pmatrix} s_{11} & \cdots & s_{1n} \\ \cdots & s_{io} & \cdots \\ s_{n1} & \cdots & s_{nn} \end{pmatrix}$$

Figure 8/G.671 – Switching time matrix for (fibre-optic) switch

3.4.11 ripple: For a narrowband WDM devices and tuneable filters, the peak-to-peak difference in insertion loss within a channel frequency range. Future work on possible additional specifications is needed on the use and application of this parameter for cascading of multiple devices.

3.4.12 adjacent channel isolation: For two signals λ_w and λ_x that are adjacent in frequency,

$$ISOL_{wx} = IL_{min}(\lambda_w) - IL_{max}(\lambda_x)$$

where $IL_{max}(\lambda_x)$ is the maximum insertion loss of λ_x's signal within λ_x's channel frequency range and $IL_{min}(\lambda_w)$ is the minimum insertion loss of λ_w's signal within λ_x's channel frequency range.

3.4.13 non-adjacent channel isolation

For further study.

3.4.14 channel spacing: The centre-to-centre difference in frequency (or wavelength) between adjacent channels in a WDM device. Narrowband channel spacings compliant to ITU-T G.692 are 50 GHz, 100 GHz, 200 GHz, 400 GHz, 500 GHz, 600 GHz, and 1000 GHz.

3.4.15 reproduceability of passband setting: The variance of the difference between the demanded centre frequency and the centre of the tuneable filter 3 dB passband when setup is repeated many times.

3.4.16 dynamic characteristics: Tuning (settling) time. The tuning (settling) time 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.

3.4.17 Long term stability

For further study.

3.4.18 1 dB and 3 dB passband width: 1 dB passband width: The 1 dB passband width D_1 of an optical filter is defined to be 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 $f_c + D_{1/2}$.

3 dB passband width: The 3 dB passband width D_3 of an optical filter is defined to be 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 $f_c + D_{3/2}$.

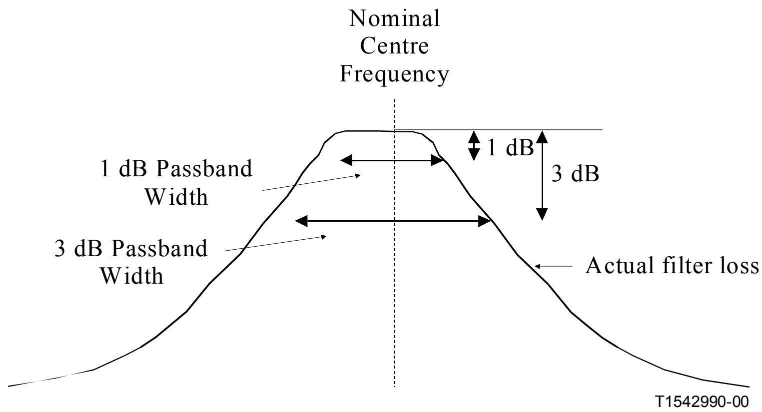

Figure 9/G.671 – Illustration of 1 dB and 3 dB passband width

4 Abbreviations

This Recommendation uses the following acronyms:

DGD	Differential Group Delay
ffs	for further study
MUX/DMUX	Multiplexer/Demultiplexer
NA	Not Applicable
OADM	Optical Add Drop Multiplexer
PDL	Polarization Dependent Loss
PMD	Polarization Mode Dispersion
WDM	Wavelength Division Multiplexing.

5 Test methods

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 of this Recommendation and in the IEC 61300 Basic Standard on tests and measurement procedures for interconnecting devices and passive components are referenced to the functional parameters.

The following minimum list of functional parameters for the specification of the optical passive components cited in clause 1 are applicable over the optical passbands of 1260 nm to 1360 nm and 1480 nm to 1580 nm unless differently specified.

5.1 Parameters common to all components

These parameters are applicable to all component types cited in clause 1 with the exceptions noted below.

Clause	Parameter	Test Method
5.1.1	Insertion Loss (Notes 1 and 2) (Per Channel for WDM Devices)	IEC 61300-3-4, IEC 61300-3-7
5.1.2	Reflectance	IEC 61300-3-6
5.1.3	Operating Wavelength Range	IEC 61300-3-7
5.1.4	Polarization Dependent Loss (Note 1)	IEC 61300-3-2, IEC 61300-3-12
5.1.5	Polarization Dependent Reflectance	IEC 61300-3-19
5.1.6	Maximum Allowable Input Power	ffs (Note 3)
5.1.7	Differential Group Delay (ps)	ITU-T G.650 (Note 4)

NOTE 1 – Not applicable for (Fibre-optic) optical terminations.

NOTE 2 – Insertion loss for filters, both fixed or tuneable, may include the insertion loss of pass band and stop band.

NOTE 3 – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.

NOTE 4 – IEC 61282-3 could be useful to help understand the relationship between polarization mode dispersion (PMD) and differential group delay (DGD).

5.2 Parameters unique to specific components

The parameters cited in this clause are unique to the specific type of components listed below.

5.2.1 Wideband WDM device (wavelength multiplexer or demultiplexer)

Clause	Parameter	Test Method
5.2.1.1	Wavelength dependent attenuation	ffs
5.2.1.2	Unidirectional (far-end) Isolation	ffs
5.2.1.3	Bidirectional (near-end) Isolation	ffs
5.2.1.4	Unidirectional (far-end) crosstalk attenuation	ffs
5.2.1.5	Bidirectional (near-end) crosstalk attenuation	ffs

5.2.2 Narrowband WDM device (wavelength multiplexer or demultiplexer)

Clause	Parameter	Test Method
5.2.2.1	Channel Frequency Range	ffs
5.2.2.2	Ripple	ffs
5.2.2.3	Adjacent channel isolation	ffs
5.2.2.4	Unidirectional (far-end) Isolation	ffs
5.2.2.5	Bidirectional (near-end) Isolation	ffs
5.2.2.6	Unidirectional (far-end) crosstalk attenuation	ffs
5.2.2.7	Bidirectional (near-end) crosstalk attenuation	ffs

5.2.3 (Fibre-optic) branching component (wavelength non-selective)

Clause	Parameter	Test Method
5.2.3.1	Directivity	ffs
5.2.3.2	Uniformity	ffs

5.2.4 (Fibre-optic) attenuator

Clause	Parameter	Test Method
5.2.4.1	Insertion loss tolerance	ffs
5.2.4.2	Attenuation range (Variable attenuator)	ffs
5.2.4.3	Incremental attenuation (Variable attenuator)	ffs

5.2.5 (Fibre-optic) filter

Clause	Parameter	Test Method
5.2.5.1	Ripple	ffs

5.2.6 (Fibre-optic) isolator

Clause	Parameter	Test Method
5.2.6.1	Backward Loss	ffs

5.2.7 (Fibre-optic) termination

No additional parameters specified.

5.2.8 (Fibre-optic) switch

Clause	Parameter	Test Method
5.2.8.1	Switching time matrix	ffs
5.2.8.2	Repeatability	ffs
5.2.8.3	Uniformity	ffs
5.2.8.4	Crosstalk	ffs
5.2.8.5	Directivity	ffs
5.2.8.6	Transfer Matrix	ffs

5.2.9 Passive dispersion compensator

Clause	Parameter	Test Method
5.2.9.1	Dispersion over operating wavelength range	ffs

5.2.10 (Fibre-optic) connector

No additional parameters specified.

5.2.11 (Fibre-optic) splice

No additional parameters specified.

5.2.12 Tuneable Filters

Clause	Parameter	Test Method
5.2.12.1	Optical Frequency Tuning Range (nm)	ffs
5.2.12.2	1 dB Passband Width	ffs
5.2.12.3	3 dB Passband Width	ffs
5.2.12.4	Passband Ripple	ffs
5.2.12.5	Reproduceability of Passband Setting	ffs
5.2.12.6	Temperature Dependance of Passband Setting	ffs
5.2.12.7	Dynamic Characteristics (Tuning Time ...)	ffs
5.2.12.8	Long Term Stability	ffs

5.2.13 OADM Subsystems (For WDM)

For further study.

6 Values of functional transmission parameters

This clause cites the recommended values of functional transmission parameters by (Fibre-optic) component type.

NOTE 1 – Values for statistical approach are for further study and will eventually be considered in an appendix.

NOTE 2 – All table values represent worst case end of life values over all temperature, humidity, and pertubations.

NOTE 3 – Insertion Loss and reflectance values for (Fibre-optic) connectors shall include the effects of mating durability.

NOTE 4 – For particular applications, tighter reflectance values than those indicated in these tables could be required.

NOTE 5 – Inclusion of polarization dependent reflectance is under study.

NOTE 6 – For some components, (e.g. branching components, fibre optic filters, passive dispersion compensators, fibre optic 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.

6.1 Wideband WDM device (wavelength multiplexer or demultiplexer) 1 × *X*

where X = number of wavelength specific ports.

Clause	Parameter	All Networks	
		Max	**Min**
6.1.1	Channel Insertion Loss (dB)	$1.5 \log_2 X$	ffs
6.1.2	Optical Reflectance (dB)	–40	NA
6.1.3	Operating Wavelength Range(Note 1) (nm)	<u>1580</u> 1360	<u>1480</u> 1260
6.1.4	Polarization Dependent Loss (Δ dB)	$0.1 (1 + \log_2 X)$	NA
6.1.5	Wavelength dependent attenuation	ffs	NA
6.1.6	Unidirectional (far-end) Isolation (dB)	ffs	NA
6.1.7	Bidirectional (near-end) Isolation (dB)	NA	ffs
6.1.8	Unidirectional (far-end) crosstalk attenuation (dB)	ffs	NA
6.1.9	Bidirectional (near-end) crosstalk attenuation (dB)	NA	ffs
6.1.10	Maximum Allowable Input Power	NA	ffs (Note 2)
6.1.11	Differential Group Delay (ps)	ffs	ffs
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 value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.			

6.2 Narrowband WDM device (wavelength multiplexer or demultiplexer) $1 \times X$

Clause	Parameter	All Networks	
		Max	Min
6.2.1	Channel Insertion Loss (dB)	ffs	ffs
6.2.2	Optical Reflectance (dB)	ffs	NA
6.2.3	Channel Frequency range (GHz)	ffs	ffs
6.2.4	Polarization Dependent Loss (Δ dB)	ffs	NA
6.2.5	Ripple (dB)	ffs	ffs
6.2.6	Wavelength dependent attenuation	ffs	NA
6.2.7	Unidirectional (far-end) Isolation (dB)	ffs	NA
6.2.8	Bidirectional (near-end) Isolation (dB)	NA	ffs
6.2.9	Unidirectional (far-end) crosstalk attenuation (dB)	ffs	NA
6.2.10	Bidirectional (near-end) crosstalk attenuation (dB)	NA	ffs
6.2.11	Maximum Allowable Input Power	NA	ffs
6.2.12	Differential Group Delay (ps)	ffs	ffs
NOTE – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.			

6.3 (Fibre-optic) branching component (Wavelength non-selective)

Clause	Parameter				
6.3.1	Insertion Loss for 1 × X and 2 × X ports (fibre optic) branching components (wavelength non-selective), where X = 2, 3, 4, 6, 8, 12, 16, 24 and 32				
	X	**1 × *X***		**2 × *X***	
		Min. Insertion Loss (dB)	**Max. Insertion Loss (dB)**	**Min. Insertion Loss (dB)**	**Max. Insertion Loss (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
NOTE – This table assumes symmetrical power distribution between the output ports of the branching device					

Clause	Parameter	All Networks	
		Max	**Min**
6.3.2	Optical Reflectance (dB)	–40	NA
6.3.3	Operating Wavelength Range (Note 1) (nm)	1580 1360	1480 1260
6.3.4	Polarization Dependent Loss (Δ dB)	$0.1\ (1 + \log_2 X)$	NA
6.3.5	Directivity (dB)	NA	50
6.3.6	Uniformity (dB)	$1.0 \log_2 X$	NA
6.3.7	Maximum Allowable Input Power	NA	ffs (Note 2)
6.3.8	Differential Group Delay (ps)	ffs	ffs
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 value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.			

6.4 (Fibre-optic) attenuator

Clause	Parameter	All Networks		All Networks
		Max	Min	Nominal
6.4.1	Insertion Loss Tolerance	± 15%	± 15%	NA
6.4.2	Insertion Loss (dB) (Fixed Attenuators)	NA	NA	3, 5, 10, 15, 20, 25, 30
6.4.3	Optical Reflectance (dB)	–40	NA	NA
6.4.4	Operating Wavelength Range (Note 1) (nm)	1580 1360	1480 1260	1310 1550
6.4.5	Polarization Dependent Loss (Δ dB)	0.3	NA	NA
6.4.6	Attenuation range (Variable attenuator) (Δ dB)	ffs	ffs	NA
6.4.7	Incremental attenuation (Variable attenuator) (dB)	ffs	ffs	NA
6.4.8	Maximum Allowable Input Power	NA	ffs (Note 2)	NA
6.4.9	Differential Group Delay (ps)	ffs	ffs	ffs

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 value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.

6.5 (Fibre-optic) filter

Clause	Parameter	All Networks	
		Max	Min
6.5.1	Insertion Loss (Pass Band) (dB)	1.5	NA
6.5.2	Insertion Loss (Stop Band) (dB)	NA	40
6.5.3	Optical Reflectance (dB)	–40	NA
6.5.4	Operating Wavelength Range (nm)	(Note 3)	
6.5.5	Polarization Dependent Loss (Δ dB)	ffs	NA
6.5.6	Maximum Allowable Input Power	NA	ffs (Note 2)
6.5.7	Differential Group Delay (ps)	ffs	ffs
6.5.8	Ripple	ffs	NA

NOTE 1 – The filters described in this clause are intended to be used in the optical path. The device described in clause 6.11 is intended to be used for applications in multichannel systems using optical amplifiers.

NOTE 2 – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.

NOTE 3 – Operating wavelength pass band and stop band as defined in relevant specifications.

6.6 (Fibre-optic) isolator

Clause	Parameter	All Networks	
		Max	Min
6.6.1	(Isolation) Backward Insertion Loss (dB)	NA	ffs
6.6.2	Forward Insertion Loss (dB)	ffs	NA
6.6.3	Optical Reflectance (dB)	–40	NA
6.6.4	Operating Wavelength Range (Note 1) (nm)	1580 1360	1480 1260
6.6.5	Polarization Dependent Loss (Δ dB)	ffs	NA
6.6.6	Differential Group Delay (ps)	ffs	ffs
6.6.7	Maximum Allowable Input Power	NA	ffs (Note 2)
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 value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.			

6.7 (Fibre-optic) termination

Clause	Parameter	All Networks	
		Max	Min
6.7.1	Optical Reflectance (dB)	–50	NA
6.7.2	Operating Wavelength Range (Note 1) (nm)	1580 1360	1480 1260
6.7.3	Maximum Allowable Input Power	NA	ffs (Note 2)
6.7.4	Differential Group Delay (ps)	ffs	ffs
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 value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.			

6.8 (Fibre-optic) switch

NOTE – $2 \times X$ switches for future study.

Clause	Parameter	$1 \times X$ Switches		2×2 Switches	
		Max	**Min**	**Mean**	**Std**
6.8.1	Insertion Loss (dB)	2.5 | $\log_2 X$	NA	ffs	NA
6.8.2	Optical Reflectance (dB)	–40	NA	–40	NA
6.8.3	Operating Wavelength Range (nm)	ffs	ffs	ffs	ffs
6.8.4	Polarization Dependent Loss (Δ dB)	ffs | 0.1 $(1 + \log_2 X)$	NA	ffs	NA
6.8.5	Switching time	10s | 20ms	NA	ffs	NA
6.8.6	Repeatability (dB)	0.25	NA	ffs	NA
6.8.7	Uniformity (dB)	ffs | 0.4 $\log_2 X$	NA	ffs	NA
6.8.8	Crosstalk (dB)	NA	ffs (Note 3)	ffs	NA
6.8.9	Directivity (dB)	NA	50	ffs	NA
6.8.10	Maximum Allowable Input Power	NA	ffs (Note 2)	NA	ffs (Note 2)
6.8.11	Differential Group Delay (ps)	ffs	ffs	ffs	ffs

NOTE 1 – Dual values (a | b) indicate values for "slow" and "fast" switches respectively.

NOTE 2 – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.

NOTE 3 – A value of 25 dB is under consideration, pending an agreed definition of crosstalk.

6.9 Passive dispersion compensator

Clause	Parameter (in km of G.652 equivalent compensation)	All Networks	
		Max	**Min**
6.9.1	Insertion Loss (dB)		
	2.5 km	ffs	NA
	5 km	ffs	NA
	7.5 km	ffs	NA
	10 km	ffs	NA
	20 km	3.6	NA
	30 km	ffs	NA
	40 km	5.5	NA
	50 km	ffs	NA
	60 km	7.5	NA
	70 km	ffs	NA
	80 km	9.5	NA
	90 km	ffs	NA
	100 km	11.5	NA
	110 km	ffs	NA
	120 km	13.5	NA
6.9.2	Optical Reflectance (dB)	–27	NA
6.9.3	Operating Wavelength Range (Note 1) (nm)	1565	1525
6.9.4	Polarization Dependent Loss (Δ dB)	ffs	ffs
6.9.5	Dispersion over operating wavelength range (Note 2) (ps/nm)	Max	Min
	2.5 km	ffs	ffs
	5 km	ffs	ffs
	7.5 km	ffs	ffs
	10 km	ffs	ffs
	20 km	–310	–360
	30 km	ffs	ffs
	40 km	–620	–710
	50 km	ffs	ffs
	60 km	–930	–1070
	70 km	ffs	ffs

Clause	Parameter (in km of G.652 equivalent compensation)	All Networks	
		Max	**Min**
	80 km	–1240	–1420
	90 km	ffs	ffs
	100 km	–1550	–1780
	110 km	ffs	ffs
	120 km	–1860	–2140
6.9.6	Maximum Allowable Input Power	NA	ffs (Note 3)
6.9.7	Differential Group Delay (ps)		
	2.5 km	ffs	NA
	5 km	ffs	NA
	7.5 km	ffs	NA
	10 km	ffs	NA
	20 km	ffs	NA
	40 km	ffs	NA
	60 km	ffs	NA
	80 km	ffs	NA
	100 km	ffs	NA
	120 km	ffs	NA

NOTE 1 – For some passive dispersion compensators, the operating wavelength range can be narrower, but covering the wavelength range of the used optical source.

NOTE 2 – Values derived from assumptions of compensating a specific length of G.652 type fibre, using the equation found in 2.2/G.652, although other lengths and assumptions are under study.

NOTE 3 – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.

NOTE 4 – Values for compensators of lengths of G.653 and G.655 fibre are under study.

NOTE 5 – For 40 Gbit/s transmission, the maximum DGD value of the dispersion compensators may have to be reduced in the future to allow effective transmission of high rates over long distances.

6.10 (Fibre-optic) Connector

Clause	Parameter	All Networks	
		Max	Min
6.10.1	Insertion Loss (dB)	0.5 for single fibre (Note 2) 1.0 for multifibre (Note 2)	NA
6.10.2	Optical Reflectance (dB)	–35 (Notes 2 and 3)	NA
6.10.3	Operating Wavelength Range (Note 4) (nm)	1580 1360	1480 1260
6.10.4	Polarization Dependent Loss (Δ dB)	0.1	NA
6.10.5	Maximum Allowable Input Power (Note 5)	NA	ffs (Note 6)
6.10.6	Differential Group Delay (ps)	ffs	ffs

NOTE 1 – Insertion loss and reflectance values also include effects of mating durability.

NOTE 2 – When used over an extended operating temperature range, these values may be exceeded and are under study.

NOTE 3 – 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 4 – 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 5 – 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 6 – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.

6.11 (Fibre-optic) splice

Clause	Parameter	All Networks	
		Max	Min
6.11.1	Insertion Loss (Notes 1 and 2) (dB)		
	Mechanical splice	0.50	NA
	Fusion Splice (Active Alignment)	0.30	NA
	Fusion Splice (Passive Alignment)	0.50	NA
6.11.2	Optical Reflectance (dB)		
	Mechanical splice	–40	NA
	Fusion splice	–70	NA
6.11.3	Operating Wavelength Range (Note 3) (nm)	<u>1580</u> 1360	<u>1480</u> 1260
6.11.4	Polarization Dependent Loss (Δ dB)	ffs	NA
6.11.5	Polarization Dependent Reflectance (Δ dB)	ffs	NA
6.11.6	Maximum Allowable Input Power	NA	ffs (Note 4)
6.11.7	Differential Group Delay (ps)	ffs	ffs

NOTE 1 – These values assume the joining of fibre types covered by the same Recommendation.

NOTE 2 – 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 3 – 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 4 – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.

6.12 Tuneable Filters

Clause	Parameter	All Networks	
		Max	Min
6.12.1	Insertion Loss (Pass Band) (dB)	ffs	ffs
6.12.2	Insertion Loss (Stop Band) (dB)	ffs	ffs
6.12.3	Optical Reflectance (dB)	ffs	ffs
6.12.4	Optical Frequency Tuning Range (nm)	ffs	ffs
6.12.5	Polarization Dependent Loss (Δ dB)	ffs	ffs
6.12.6	1 db Passband Width	ffs	ffs
6.12.7	3 dB Passband Width	ffs	ffs
6.12.8	Passband Ripple	ffs	ffs
6.12.9	Reproduceability of Passband Setting	ffs	ffs
6.12.10	Temperature Dependance of Passband Setting	ffs	ffs
6.12.11	Dynamic Characteristics (Tuning Time…)	ffs	ffs
6.12.12	Long Term Stability	ffs	ffs
6.12.13	Maximum Allowable Input Power	NA	ffs (Note)
6.12.14	Differential Group Delay (ps)	ffs	ffs
NOTE – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.			

6.13 OADM Subsystems

Clause	Parameter	All Networks	
		Max	Min
6.13.1	Insertion Loss (dB)	ffs	ffs
6.13.2	Optical Reflectance (dB)	ffs	ffs
6.13.3	Polarization Dependent Loss (Δ dB)	ffs	ffs
6.13.4	Type of OADM Subsystem	ffs	ffs
6.13.5	Number of Add/Drop/Through Channels	ffs	ffs
6.13.6	Type of Passband Profile (Flat-top or Gaussian)	ffs	ffs
6.13.7	Nominal Central Frequency	ffs	ffs
6.13.8	1 dB Passband Width	ffs	ffs
6.13.9	3 dB Passband Width	ffs	ffs
6.13.10	Passband Ripple	ffs	ffs
6.13.11	Reproduceability of Passband Setting	ffs	ffs
6.13.12	Adjacent Channel Isolation	ffs	ffs
6.13.13	Non-Adjacent Channel Isolation	ffs	ffs
6.13.14	Maximum Allowable Input Power	NA	ffs (Note 1)
6.13.15	Differential Group Delay (ps)	ffs	ffs
NOTE – The value of Maximum Allowable Input Power is under discussion. A minimum value of +20 dBm is considered a starting point.			

ANNEX A

Reference list of IEC test methods

The following IEC documents are referred to for measurement purposes:

IEC-61300-3 Series Transmission and Geometrical Parameters

IEC 61300-3-1 Visual Examination

IEC 61300-3-2 Polarization Dependence

IEC 61300-3-3 Monitoring Attenuation and Return Loss (Multiple Path)

IEC 61300-3-4 Attenuation

IEC 61300-3-5 Monitoring Attenuation

IEC 61300-3-6 Return Loss

IEC 61300-3-7 Spectral Loss

IEC 61300-3-8 Ambient Light Coupling

IEC 61300-3-9	Crosstalk
IEC 61300-3-10	Gage Retention
IEC 61300-3-11	Engagement and Separation
IEC 61300-3-12	Polarization Dependence of Attenuation of a Single-Mode Fibre-optic Component: Matrix Calculation
IEC 61300-3-13	Control Stability of a Fibre-optic Switch
IEC 61300-3-14	Accuracy and Repeatability of the Attenuation Settings of a Variable Attenuator
IEC 61300-3-15	Eccentricity of a Convex Polished Ferrule Endface
IEC 61300-3-16	Endface Radius of Convex Polished Ferrules
IEC 61300-3-17	Endface Angle of Angle-Polished Connectors
IEC 61300-3-18	Keying Accuracy of an Angled Endface Connector
IEC 61300-3-19	Polarization Dependence of Return Loss of a Single-Mode Component
IEC 61300-3-20	Monitoring of Attenuation and Return Loss (Single Path)
IEC 61300-3-21	Switch and Bounce Time
IEC 61300-3-22	Ferrule Compression Force

APPENDIX I

Two-dimensional Logarithmic Transfer Matrices of WDM Devices

I.1 Introduction

This appendix defines two-dimensional logarithmic transfer matrices for several specific WDM devices. The definitions apply to WDM devices for which the number of wavelength specific ports equals the number of wavelengths. Unidirectional MUX (*M*), unidirectional DMUX (*D*) and bidirectional MUX/DMUX (*B*) devices are considered.

The three-dimensional matrices described in this Recommendation are usable for all possible configurations of WDM Devices. The two-dimensional matrices presented in this appendix are valid only for $k \times 1$ MUX devices and $1 \times k$ DMUX devices having one wavelength per port.

The port numbering of the two-dimensional matrices is fixed, while the port numbering of the three-dimensional matrices contained in this Recommendation is allowed to be arbitrary.

The measured matrix elements for certain WDM devices are arranged more compactly and clearly in two, two-dimensional matrices which consist of fewer elements than the three-dimensional matrix *A*.

Clause 3.4.3 defines a three-dimensional ($n \times n \times k$) logarithmic transfer matrix *A* of a WDM device with general matrix elements a_{srw}. The three-dimensional matrix is presented by *k* two-dimensional planes only to indicate the three-dimensionality in a drawing.

The two-dimensional logarithmic transfer matrices *M*, *D* and *B* use the matrix elements defined in clause 3.2:

a_{ioc} = matrix element for channel insertion loss at channel wavelength λ_c in MUX, DMUX or MUX-part of a bidirectional device (see 3.2.2 or 3.2.11);

a_{doc} = matrix element for channel insertion loss at channel wavelength λ_c in DMUX-part of a bidirectional device (see 3.2.13);

a_{iox} = matrix element for unidirectional (far end) crosstalk attenuation at crosstalk (isolation) wavelength λ_x in a DMUX (see 3.2.12);

a_{mox} = matrix element for bidirectional (near end) crosstalk attenuation at crosstalk (isolation) wavelength λ_x between MUX input port *m* and DMUX output port *o* of a bidirectional device. (See 3.2.14).

The two-dimensional logarithmic transfer matrices *Mr*, *Dr* and *Br* for optical return losses use the matrix element:

a_{iic} = matrix element for return loss of a WDM device, where *i* is the input port number and *c* the channel wavelength number (see 3.2.3, Note 2);

– The defined structures of the two, two-dimensional logarithmic transfer matrices per WDM device,

  e.g. *M* and *Mr*, *D* and *Dr* and *B* and *Br* with the above matrix elements, are given in I.2, for 4λ-MUX, 4λ-DMUX, 4λ-MUX/DMUX1 and 4λ-DMUX/MUX2.

I.2 Definitions of two-dimensional logarithmic transfer matrices *M*, *D*, *B*, *Mr*, *Dr* and *Br*

The definitions of two-dimensional transfer matrices are based on the following assumptions:

- The two-dimensional logarithmic transfer matrices *M*, *D*, *B*, *Mr*, *Dr* and *Br* are based on the modified matrix elements a_{iow} with input port number $i = 1,...,k$ and output port number $o = 1$ for a MUX and with input port number $i = 1$ and output port number $o = 1, ..., k$ for a DMUX and with wavelength number $w = 1, ..., k$. *k* is the total number of wavelengths. The assumption here is, that for a MUX the total number *k* of input ports is equal to the total number *k* of wavelengths, and for a DMUX the total number *k* of output ports is equal to the total number *k* of wavelengths.

The corresponding definition for the three-dimensional transfer matrix *A* is given in 3.4.3.

- For each output port of a DMUX there are assumed one channel wavelength λ_c signal and k–1 crosstalk (isolation) wavelengths λ_x ($\neq \lambda_c$) signals.

Arranging the various two-dimensional logarithmic transfer matrices *M*, *D*, *B*, *Mr*, *Dr* and *Br* with the matrix elements a_{ioc}, a_{iox}, a_{doc}, a_{mox} and a_{iic} results in each WDM-device being represented by two two-dimensional logarithmic transfer matrices:

– I.2.1 kλ-MUX by *M* and *Mr*

– I.2.2 kλ-DMUX by *D* and *Dr*

– I.2.3 4λ-MUX/DMUX1 by *B*1 and *Br*1 and

– I.2.4 4λ-DMUX/MUX2 by *B*2 and *B*r2.

I.2.1 $k\lambda$-MUX

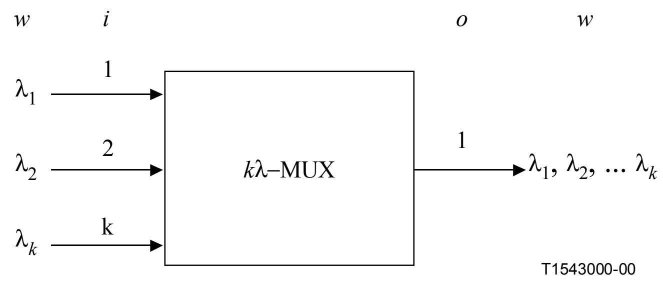

Figure I.1/G.671 – $k\lambda$-MUX port numbering

Figure I.1 illustrates the port numbering of a $k\lambda$-MUX device. The parameters of this device are represented as an (i,w)-matrix M with output port number $o = 1$ as shown in Figure I.2 and an (i,w)-matrix Mr for return losses with output purt number $o = 1$ as shown in Figure I.3.

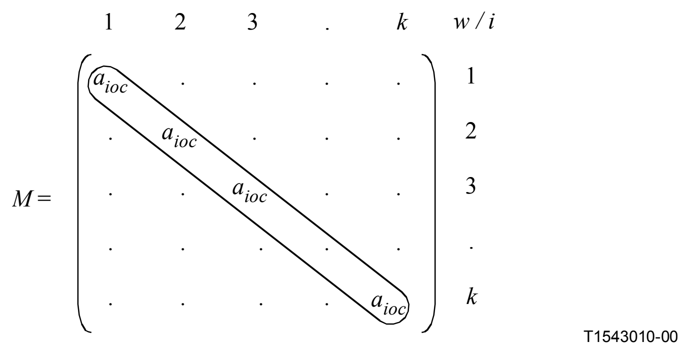

Figure I.2/G.671 – Matrix M for a $k\lambda$-MUX

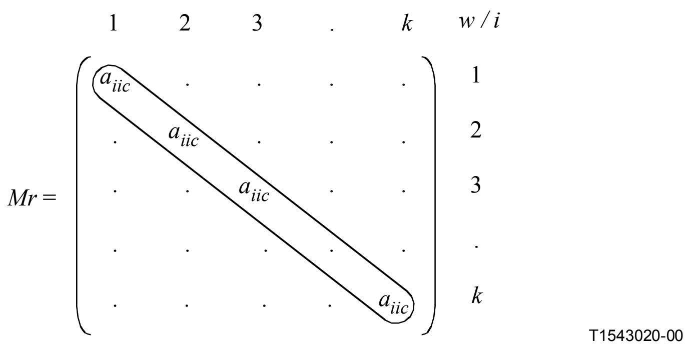

Figure I.3/G.671 – Matrix Mr for a $k\lambda$-MUX

I.2.2 *k*λ-DMUX

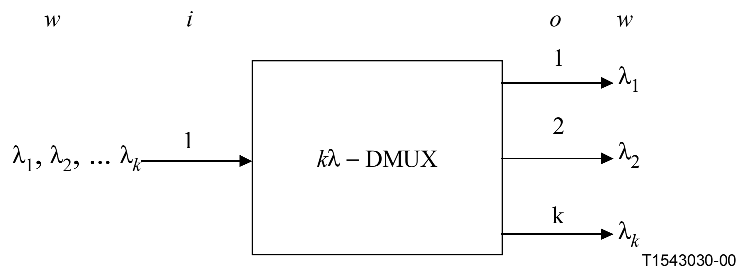

Figure I.4/G.671 – *k*λ-DMUX port numbering

Figure I.4 illustrates the port numbering of a *k*λ-DMUX device. The parameters of this device are represented as an (*o*,*w*)-matrix *D* with input port number $i = 1$ as shown in Figure I.5 and an (*o*,*w*)-matrix *Dr* for return losses with input port number $i = 1$ as shown in Figure I.6.

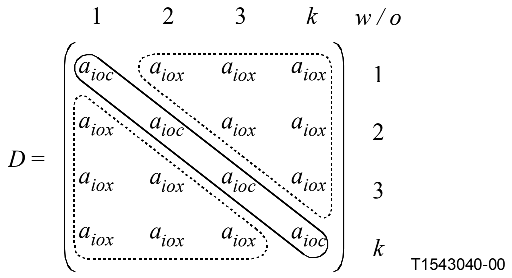

Figure I.5/G.671 – Matrix *D* for *k*λ-DMUX

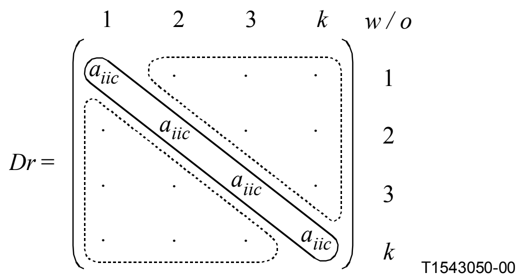

Figure I.6/G.671 – Matrix *Dr* for a *k*λ-DMUX

I.2.3 4λ-MUX/DMUX1

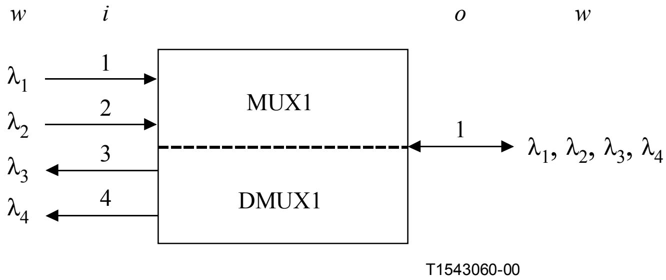

Figure I.7/G.671 – 4λ-MUX/DMUX1 port numbering

Figure I.7 illustrates the port numbering of a bidirectional 4λ-MUX/DMUX1. Signals with lower wavelengths λ_1 and λ_2 are at the inputs of MUX1. Signals with higher wavelengths λ_3 and λ_4 are at the outputs of DMUX1.

The parameters of a bidirectional 4λ-MUX/DMUX1 are represented by an (*i*/*o*,*w*)-matrix *B*1 as shown in Figure I.8 and an (*i*/*o*,*w*) matrix *Br*1 for return losses as shown in Figure I.9.

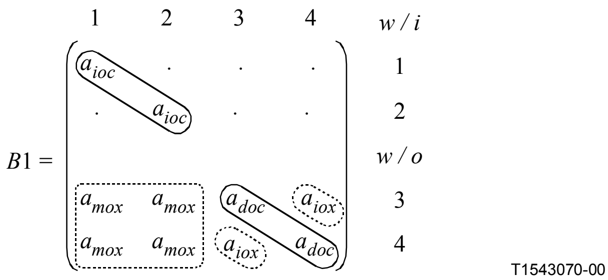

Figure I.8/G.671 – Matrix *B*1 for a 4λ-MUX/DMUX1

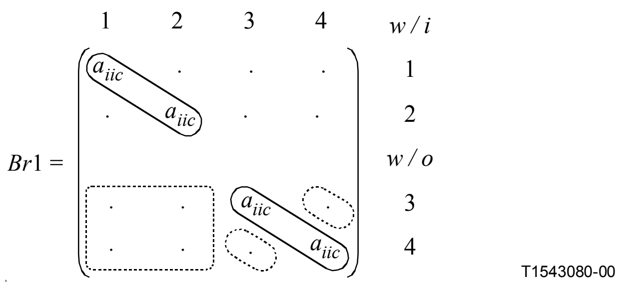

Figure I.9/G.671 – Matrix *Br*1 for a 4λ-MUX/DMUX1

I.2.4 4λ-DMUX/MUX2

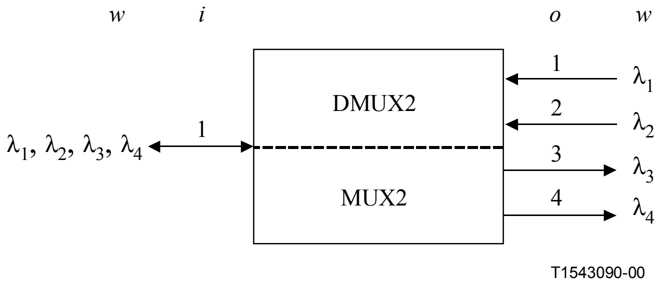

Figure I.10/G.671 – 4λ-DMUX/MUX2 port numbering

Figure I.10 illustrates the port numbering of a bidirectional 4λ-DMUX/MUX2. Signals with lower wavelengths λ_1 and λ_2 are at the outputs of DMUX2. Signals with higher wavelengths λ_3 and λ_4 are at the inputs of MUX2.

The parameters of a bidirectional 4λ-DMUX/MUX2 are represented by an (*o*/*i*,*w*)-matrix *B*2 as shown in Figure I.11 and an (*i*/*o*,*w*) matrix *Br*2 for return losses as shown in Figure I.12.

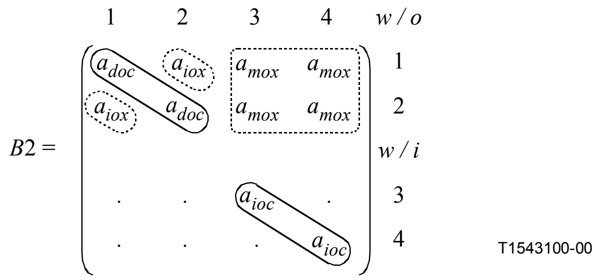

Figure I.11/G.671 – Matrix *B*2 for a 4λ-DMUX/MUX2

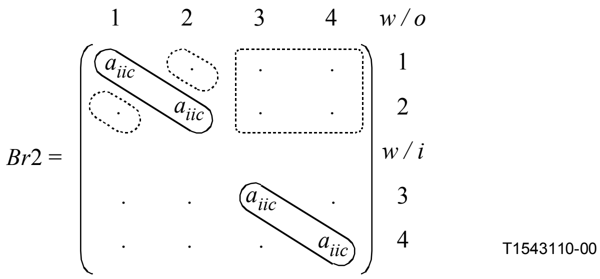

Figure I.12/G.671 – Matrix *Br*2 for a 4λ-DMUX/MUX2

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