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Transmission media and optical systems characteristics –
Characteristics of optical systems

Optical interfaces for coarse wavelength division multiplexing applications

Recommendation ITU-T G.695

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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

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

Recommendation ITU-T G.695

Optical interfaces for coarse wavelength division multiplexing applications

Summary

Recommendation ITU-T G.695 provides optical parameter values for physical layer interfaces of coarse wavelength division multiplexing (CWDM) applications with up to 16 channels and up to 25 Gbit/s. Applications are defined using two different methods, one using multichannel interface parameters and the other using single-channel interface parameters. Both unidirectional and bidirectional applications are specified. In this version of this Recommendation, codes for 4-channel NRZ 10G long-haul and NRZ 25G short-haul black-box applications have been added.

History

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FOREWORD

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

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

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

NOTE

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

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Table of Contents

		Page
1	Scope.....	1
2	References.....	1
3	Definitions	2
3.1	Terms defined elsewhere	2
4	Abbreviations and acronyms	3
5	Classification of optical interfaces.....	4
5.1	Applications.....	4
5.2	Reference points	4
5.3	Nomenclature	7
5.4	Multichannel interfaces at the reference points MPI-S _M and MPI-R _M	8
5.5	Single-channel interfaces at the reference points S _S and RS.....	10
6	Transverse compatibility	11
7	Parameter definitions.....	11
7.1	General information.....	13
7.2	Interface at point MPI-S _M or SS	14
7.3	Common optical path parameters (single span) from point MPI-S _M to MPI-R _M , or from S _S to RS	16
7.4	Interface at point MPI-R _M or RS	18
7.5	Additional parameters for the optical path from S _S to RS.....	20
8	Parameter values	20
9	Optical safety considerations.....	46
	Appendix I – Wavelength dependence of attenuation and chromatic dispersion	47
	I.1 Attenuation.....	47
	I.2 Chromatic dispersion	48
	Appendix II – Optical path from point RPs to RPR	50
	Appendix III – Black links containing OADMs	52
	III.1 Number of OADMs in a black link	52
	III.2 Mixed application codes.....	53
	III.3 Protection.....	54
	Appendix IV – Parameter values for 16-channel NRZ 2.5G applications.....	55
	Bibliography.....	62

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Recommendation ITU-T G.695

Optical interfaces for coarse wavelength division multiplexing applications

1 Scope

This Recommendation applies to optical interfaces for coarse wavelength division multiplexing (CWDM) optical line systems for network applications using single-mode optical fibres. This Recommendation defines and provides values for optical interface parameters of physical point-to-point and ring CWDM system applications. Their principal purpose is to enable transversely (multi-vendor) compatible interfaces.

Applications are defined using two different methods, one using multichannel interface parameters and the other using single-channel interface parameters. Both unidirectional and bidirectional applications are specified.

This Recommendation describes optical line systems that include the following features:

- Maximum number of channels: Up to 16.
- Bit-rate of signal channel: Up to NRZ 25G.

The CWDM wavelength grid is provided in [ITU-T G.694.2].

Specifications are organized according to application codes.

In the future, applications enabling full transverse compatibility at both the multichannel and single-channel interface points may be included.

2 References

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

- | | |
|---------------|---|
| [ITU-T G.652] | Recommendation ITU-T G.652 (2009), <i>Characteristics of a single-mode optical fibre and cable.</i> |
| [ITU-T G.653] | Recommendation ITU-T G.653 (2010), <i>Characteristics of a dispersion-shifted single-mode optical fibre and cable.</i> |
| [ITU-T G.655] | Recommendation ITU-T G.655 (2009), <i>Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable.</i> |
| [ITU-T G.664] | Recommendation ITU-T G.664 (2012), <i>Optical safety procedures and requirements for optical transmission systems.</i> |
| [ITU-T G.671] | Recommendation ITU-T G.671 (2012), <i>Transmission characteristics of optical components and subsystems.</i> |
| [ITU-T G.691] | Recommendation ITU-T G.691 (2006), <i>Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers.</i> |
| [ITU-T G.692] | Recommendation ITU-T G.692 (1998), <i>Optical interfaces for multichannel systems with optical amplifiers.</i> |

- [ITU-T G.694.2] Recommendation ITU-T G.694.2 (2003), *Spectral grids for WDM applications: CWDM wavelength grid*.
- [ITU-T G.707] Recommendation ITU-T G.707/Y.1322 (2007), *Network node interface for the synchronous digital hierarchy (SDH)*.
- [ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2012), *Interfaces for the optical transport network*.
- [ITU-T G.872] Recommendation ITU-T G.872 (2012), *Architecture of optical transport networks*.
- [ITU-T G.957] Recommendation ITU-T G.957 (2006), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.
- [ITU-T G.959.1] Recommendation ITU-T G.959.1 (2012), *Optical transport network physical layer interfaces*.
- [IEC 60825-1] IEC 60825-1 (2014), *Safety of laser products – Part 1: Equipment classification and requirements*.
- [IEC 60825-2] IEC 60825-2 (2010), *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined in [ITU-T G.671]:

- coarse wavelength division multiplexing (CWDM);
- optical wavelength multiplexer/demultiplexer;
- channel insertion loss;
- channel spacing;
- differential group delay;
- reflectance.

This Recommendation uses the following term defined in [ITU-T G.694.2]:

- wavelength grid.

This Recommendation uses the following term defined in [ITU-T G.709]:

- completely standardized OTUk (OTUk).

This Recommendation uses the following terms defined in [ITU-T G.872]:

- inter-domain interface (IrDI);
- 3R regeneration.

This Recommendation uses the following terms defined in [ITU-T G.957]:

- joint engineering;
- receiver sensitivity;
- transverse compatibility.

This Recommendation uses the following terms defined in [ITU-T G.959.1]:

- minimum equivalent sensitivity;
- optical tributary signal class NRZ 1.25G;
- optical tributary signal class NRZ 2.5G;

- optical tributary signal class NRZ 10G.
- optical tributary signal class NRZ 25G.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3R	Reamplification, reshaping and retiming (regeneration)
ALS	Automatic Laser Shutdown
APR	Automatic Power Reduction
APSD	Automatic Power Shutdown
ASE	Amplified Spontaneous Emission
BER	Bit Error Ratio
DGD	Differential Group Delay
EX	Extinction ratio
ffs	for further study
IrDI	Inter-Domain Interface
MPI	Main Path Interface
MPI-R _M	Multichannel Main Path Interface reference point at the CWDM network element aggregate input
MPI-S _M	Multichannel Main Path Interface reference point at the CWDM network element aggregate output
NA	Not Applicable
NE	Network Element
NRZ	Non-Return to Zero
OA	Optical Amplifier
OADM	Optical Add-Drop Multiplexer
OD	Optical Demultiplexer
OTL	Optical channel Transport Lane
OM	Optical Multiplexer
ONE	Optical Network Element
OTU _k	completely standardized Optical channel Transport Unit – k
PMD	Polarization Mode Dispersion
RP _R	Link reference point at the CWDM network element aggregate input
RP _S	Link reference point at the CWDM network element aggregate output
R _S	Single-channel reference point at the CWDM network element tributary output
S _S	Single-channel reference point at the CWDM network element tributary input
WDM	Wavelength Division Multiplexing

5 Classification of optical interfaces

5.1 Applications

This Recommendation provides the physical layer parameters and values for CWDM multichannel and single-channel interfaces in physical point-to-point and ring applications. CWDM systems can realize cost-effective applications through a combination of uncooled single mode lasers, relaxed laser wavelength selection tolerances and wide passband filters. CWDM systems can be used in transport networks for a variety of clients, services and protocols.

The specification method used in this Recommendation is categorized into two types.

The first one is a "black box" approach, which means that it is not intended to restrict or specify the internal elements and/or the connections between the elements within the black box. There are, however, functional requirements for the black box, the most important being the inclusion of 3R regeneration. This approach enables transverse compatibility at the multichannel points.

The second type is a "black link" approach which means that optical interface parameters for only (single-channel) optical tributary signals are specified. Additional informative descriptions are provided for the fibre link parameters of the multichannel section, such as maximum attenuation, chromatic dispersion and polarization mode dispersion. This approach enables transverse compatibility at the single-channel point using a direct wavelength-multiplexing configuration. However, it does not enable transverse compatibility at the multichannel points. In this approach, the optical multiplexer (OM) and optical demultiplexer (OD) are treated as a single set of optical devices and OADMs can be included.

This Recommendation considers non-amplified multichannel interfaces only; however, in the future, amplified interfaces may be considered.

5.2 Reference points

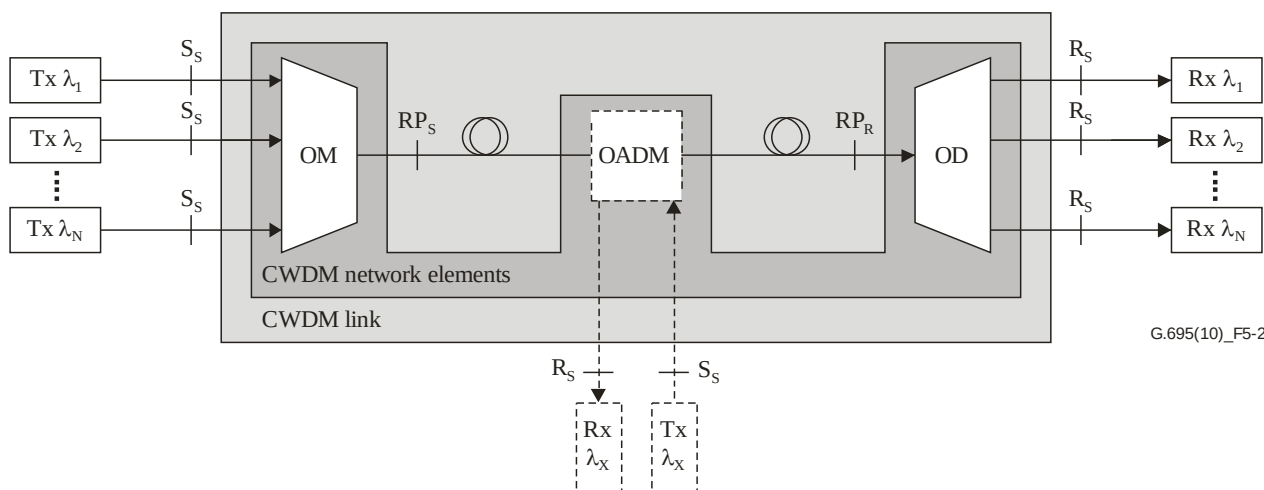
5.2.1 Unidirectional applications

Figure 5-1 shows a set of reference points for multichannel connection (MPI-S_M and MPI-R_M) only, for the use of the "black box" approach. Here the CWDM network element includes an OM and transmitters, or an OD and receivers.



Figure 5-1 – "Black box" approach

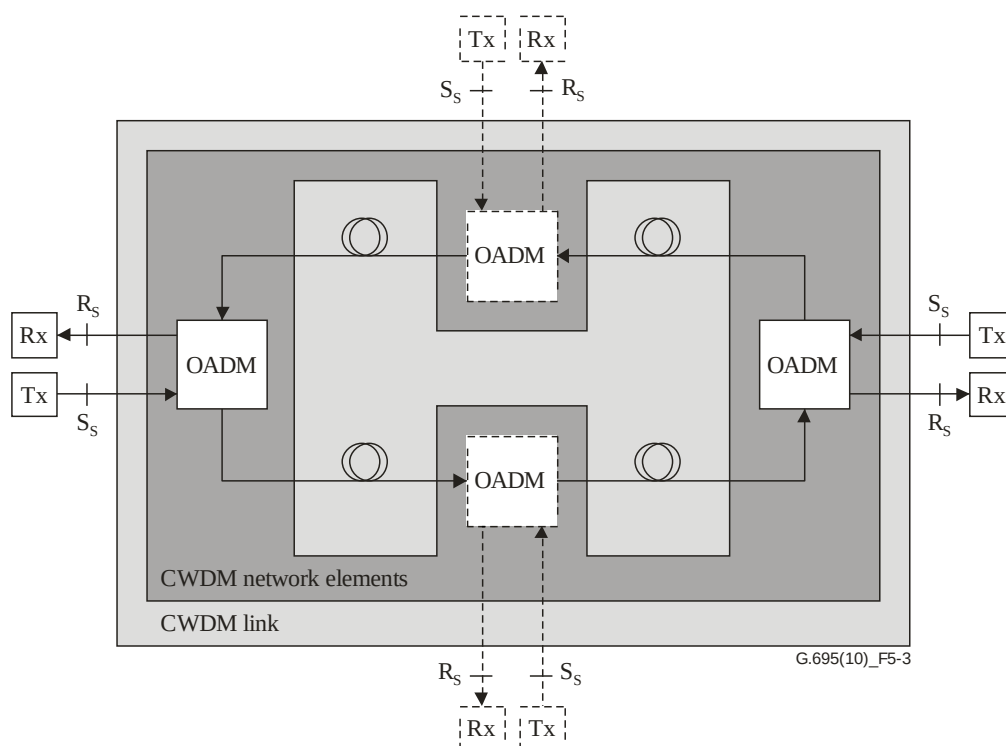
Figure 5-2 shows a set of reference points for the linear "black link" approach, for single-channel connection (SS and RS) between transmitters (Tx) and receivers (Rx). Here the CWDM network elements include an OM and an OD, which are used as a pair with the opposing element and may also include one or more OADMs.



G.695(10)_F5-2

Figure 5-2 – Linear "black link" approach

Figure 5-3 shows a corresponding set of reference points for the ring "black link" approach, for single-channel connection (SS and RS) between transmitters (Tx) and receivers (Rx). Here the CWDM network elements include two or more OADMs connected in a ring.



G.695(10)_F5-3

Figure 5-3 – Ring "black link" approach

These reference models do not include any optical amplifiers in the CWDM system. However, in the future, applications including optical amplifiers may be introduced.

The reference points in Figures 5-1, 5-2 and 5-3 are defined as follows:

- S_S is a single-channel reference point at the CWDM network element tributary input;
- R_S is a single-channel reference point at the CWDM network element tributary output;
- $MPI-S_M$ is a multichannel reference point at the CWDM network element aggregate output;
- $MPI-R_M$ is a multichannel reference point at the CWDM network element aggregate input;
- RP_S is a link reference point at the CWDM network element aggregate output;

- RP_R is a link reference point at the CWDM network element aggregate input.

Here, single-channel reference points S_S and R_S are applied to systems for the (linear or ring) "black link" approach where every path from S_S to its corresponding R_S must comply with the parameter values of the application codes in Tables 8-11 to 8-14 and Tables 8-17 to 8-22. Multichannel reference points $MPI-S_M$ and $MPI-R_M$ are applied to systems for the "black box" approach. Link reference points RP_S and RP_R are applied only to systems for the "black link" approach.

Note that $MPI-S_M$ and $MPI-R_M$ are defined to provide normative specifications for optical interfaces. On the other hand, RP_S and RP_R are only defined to provide information for fibre links and not to provide signal characteristics at these points.

5.2.2 Bidirectional applications

Figure 5-4 shows a set of reference points for multichannel connection ($MPI-S_M$ and $MPI-R_M$) only, for the use of the "black box" approach for single-fibre bidirectional applications. Here the CWDM network element includes an OM/OD, transmitters and receivers.

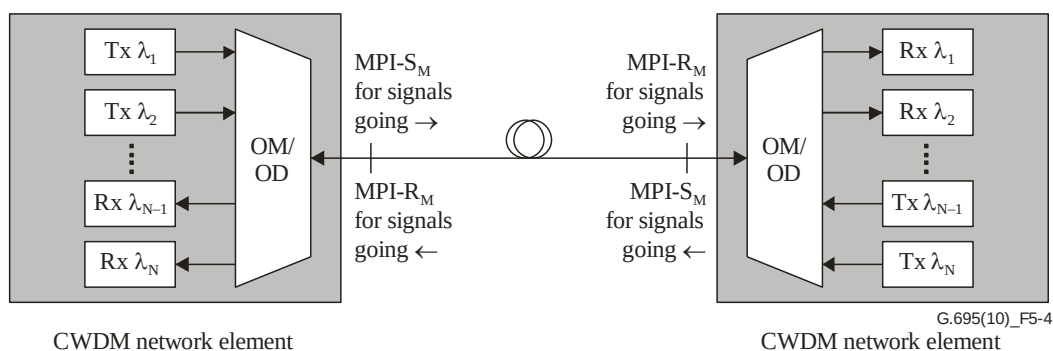


Figure 5-4 – "Black box" approach for bidirectional applications

Figure 5-5 shows a set of reference points for the single-fibre bidirectional linear "black link" approach, for single-channel connection (S_S and R_S) between transmitters (Tx) and receivers (Rx). Here the CWDM network elements include an OM/OD, which is used as a pair with the opposing element and may also include one or more OADMs.

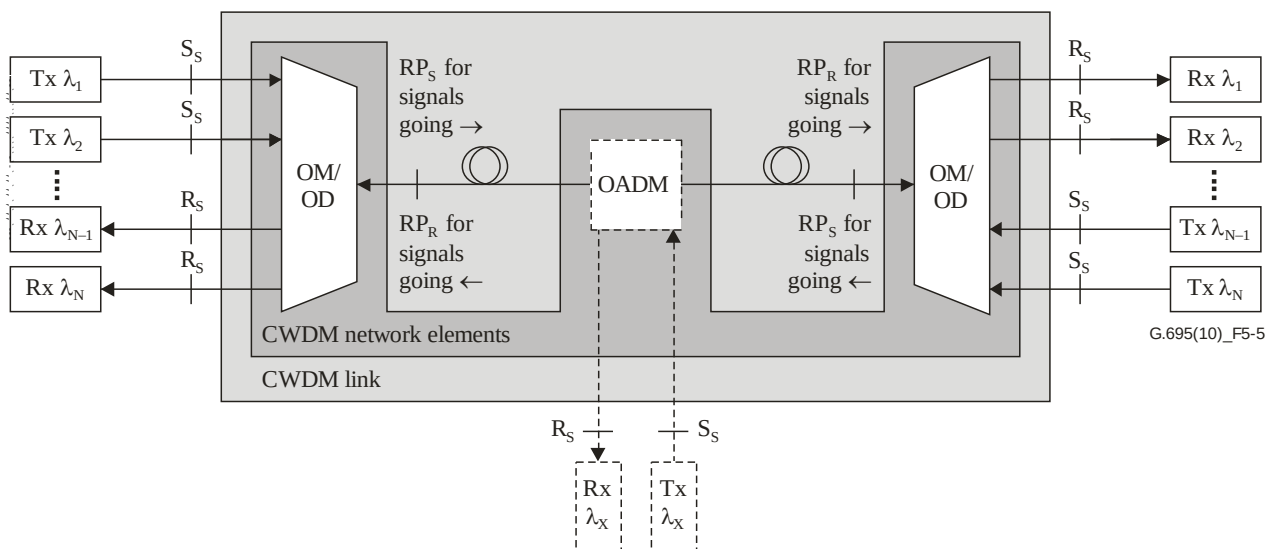


Figure 5-5 – Linear "black link" approach for bidirectional applications

Figure 5-6 shows a corresponding set of reference points for the single-fibre bidirectional ring "black link" approach, for single-channel connection (S_S and R_S) between transmitters (Tx) and receivers (Rx). Here the CWDM network elements include two or more OADMs connected in a ring.

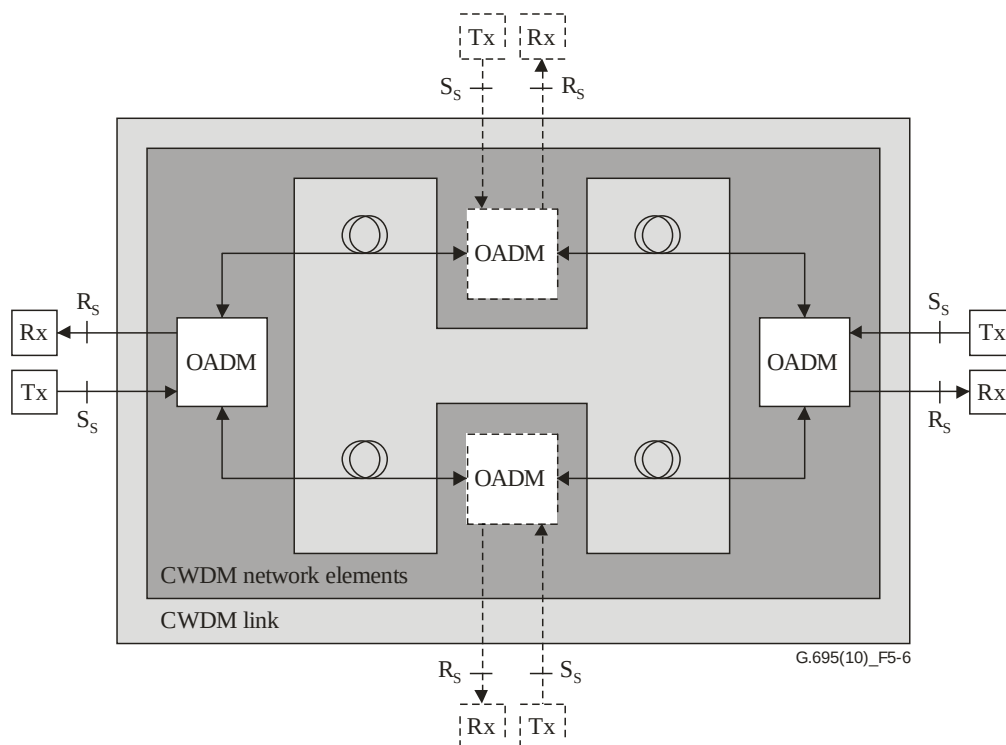


Figure 5-6 – Ring "black link" approach for bidirectional applications

The reference points in Figures 5-4, 5-5 and 5-6 are as defined in clause 5.2.1.

5.3 Nomenclature

The application code identifies the network, implementation and architectural characteristics of an application.

The application code notation is constructed as follows:

$$\text{CnWx-ytz}$$

Where:

- C** is the indicator of CWDM applications.
- n** is the maximum number of channels supported by the application code.
- W** is a letter indicating the span distance such as:
 - **S** indicating short-haul;
 - **L** indicating long-haul.
- x** is the maximum number of spans allowed within the application code.

NOTE – In the current version of this Recommendation, $x = 1$ for all applications.

- y** indicates the highest class of optical tributary signal supported:
 - **0** indicating NRZ 1.25G;
 - **1** indicating NRZ 2.5G;
 - **2** indicating NRZ 10G.
- t** is a placeholder letter indicating the configuration supported by the application code. In the current version of this Recommendation, the only value used is:
 - **D** indicating that the application does not contain any optical amplifiers.
- z** indicates the fibre types, as follows:
 - **1** indicating operation only in the 1310 nm region on ITU-T G.652 fibre;

- **2** indicating operation on ITU-T G.652 fibre;
- **3** indicating operation on ITU-T G.653 fibre;
- **5** indicating operation on ITU-T G.655 fibre.

A bidirectional system is indicated by the addition of the letter **B** at the front of the application code. For CWDM application codes this will be:

B-CnW_x-ytz

A system using the "black link" approach is indicated by the addition of the letter **S** at the front of the application code. For CWDM application codes this will be:

S-CnW_x-ytz

For some application codes, a suffix is added to the end of the code defined as follows:

- **F** to indicate that this application requires FEC bytes as specified in [ITU-T G.709] to be transmitted.

5.4 Multichannel interfaces at the reference points MPI-S_M and MPI-R_M

The multichannel interfaces described in clauses 5.4.1 and 5.4.2 are intended to enable transverse compatibility. These interfaces may operate on ITU-T G.652, ITU-T G.653 or ITU-T G.655 fibre, simultaneously transporting up to 16 channels, using either NRZ 1.25G, NRZ 2.5G or NRZ 10G optical tributary signals, depending on the particular application code.

Further requirements related to transverse compatibility can be found in clause 6.

Tables 5-1 to 5-5 summarize the multichannel application codes, which are structured according to the nomenclature in clause 5.3.

Table 5-1 – Classification of 4-channel unidirectional multichannel interfaces

Application	Short-haul (S)			Long-haul (L)		
Type of fibre	ITU-T G.652	ITU-T G.653	ITU-T G.655	ITU-T G.652	ITU-T G.653	ITU-T G.655
Optical tributary signal class NRZ 1.25G	–	–	–	–	–	–
Target distance for class NRZ 1.25G (km) ^a	–	–	–	–	–	–
Optical tributary signal class NRZ 2.5G	C4S1-1D2	C4S1-1D3	C4S1-1D5	C4L1-1D2	C4L1-1D3	C4L1-1D5
Target distance for class NRZ 2.5G (km) ^a	37	37	37	69	72	72
Optical tributary signal class NRZ 10G	C4S1-2D1	–	–	C4L1-2D1	–	–
Target distance for class NRZ 10G (km) ^a	10	–	–	40	–	–
Optical tributary signal class NRZ 25G	C4S1-9D1F					
Target distance for class NRZ 25G (km) ^a	2					

a) These target distances are for classification and not for specification.

Table 5-2 – Classification of 4-channel bidirectional multichannel interfaces

Application	Short-haul (S)	Long-haul (L)	
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.653
Optical tributary signal class NRZ 1.25G	–	B-C4L1-0D2	B-C4L1-0D3
Target distance for class NRZ 1.25G (km) ^{a)}	–	90	90
Optical tributary signal class NRZ 2.5G	–	B-C4L1-1D2	B-C4L1-1D3
Target distance for class NRZ 2.5G (km) ^{a)}	–	80	83
^{a)} These target distances are for classification and not for specification.			

Table 5-3 – Classification of 8-channel multichannel interfaces

Application	Short-haul (S)	Long-haul (L)	
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.653
Optical tributary signal class NRZ 1.25G	–	B-C8L1-0D2	B-C8L1-0D3
Target distance for class NRZ 1.25G (km) ^{a)}	–	64	64
Optical tributary signal class NRZ 2.5G	C8S1-1D2 B-C8S1-1D2	C8L1-1D2 B-C8L1-1D2	B-C8L1-1D3
Target distance for class NRZ 2.5G (km) ^{a)}	27	55	58
Optical tributary signal class NRZ 10G	–	B-C8L1-2D2F	B-C8L1-2D3F
Target distance for class NRZ 10G (km) ^{a)}	–	55	58
^{a)} These target distances are for classification and not for specification.			

Table 5-4 – Classification of 12-channel multichannel interfaces

Application	Short-haul (S)	Long-haul (L)	
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.653
Optical tributary signal class NRZ 1.25G	–	B-C12L1-0D2	–
Target distance for class NRZ 1.25G (km) ^{a)}	–	42	–
Optical tributary signal class NRZ 2.5G	–	B-C12L1-1D2	–
Target distance for class NRZ 2.5G (km) ^{a)}	–	38	–
^{a)} These target distances are for classification and not for specification.			

Table 5-5 – Classification of 16-channel multichannel interfaces

Application	Short-haul (S)	Long-haul (L)	
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.653
Optical tributary signal class NRZ 1.25G	–	–	–
Target distance for class NRZ 1.25G (km) ^{a)}	–	–	–
Optical tributary signal class NRZ 2.5G	C16S1-1D2 B-C16S1-1D2	C16L1-1D2 B-C16L1-1D2	–
Target distance for class NRZ 2.5G (km) ^{a)}	20	42	–
^{a)} These target distances are for classification and not for specification.			

5.4.1 Non-amplified multichannel interfaces

The non-amplified multichannel interfaces in this Recommendation are specified in Tables 8-1 to 8-10, 8-15 and 8-16.

5.4.2 Amplified multichannel interfaces

Amplified multichannel interfaces may be introduced into this Recommendation in the future.

5.5 Single-channel interfaces at the reference points Ss and Rs

The single-channel interfaces described in clause 5.5.1 are intended to enable transverse compatibility at the single-channel interfaces at either end of the CWDM link, as shown in Figures 5-2, 5-3, 5-5 and 5-6.

Further requirements related to transverse compatibility can be found in clause 6.

Tables 5-6 and 5-7 summarize the single-channel application codes, which are structured according to the nomenclature in clause 5.3. Expected distances for a variety of CWDM network element insertion loss values are provided in Appendix II, and information concerning black links containing OADMs is given in Appendix III.

Table 5-6 – Classification of 4-channel multichannel systems with single-channel interfaces

Application	Short-haul (S)	Long-haul (L)
Type of fibre	ITU-T G.652, ITU-T G.653, ITU-T G.655	ITU-T G.652, ITU-T G.653, ITU-T G.655
Optical tributary signal class NRZ 2.5G	S-C4S1-1D2 S-C4S1-1D3 S-C4S1-1D5	S-C4L1-1D2 S-C4L1-1D3 S-C4L1-1D5
Optical tributary signal class NRZ 10G	S-C4S1-2D2F S-C4S1-2D3F S-C4S1-2D5F	S-C4L1-2D2, S-C4L1-2D2F S-C4L1-2D3, S-C4L1-2D3F S-C4L1-2D5, S-C4L1-2D5F

Table 5-7 – Classification of 8-channel multichannel systems with single-channel interfaces

Application	Short-haul (S)	Long-haul (L)
Type of fibre	ITU-T G.652, ITU-T G.653, ITU-T G.655	ITU-T G.652, ITU-T G.653, ITU-T G.655
Optical tributary signal class NRZ 2.5G	S-C8S1-1D2 S-C8S1-1D3 S-C8S1-1D5	S-C8L1-1D2 S-C8L1-1D3 S-C8L1-1D5
Optical tributary signal class NRZ 10G	S-C8S1-2D2F S-C8S1-2D3F S-C8S1-2D5F	S-C8L1-2D2, S-C8L1-2D2F S-C8L1-2D3, S-C8L1-2D3F S-C8L1-2D5, S-C8L1-2D5F

5.5.1 Non-amplified multichannel systems with single-channel interfaces

The non-amplified multichannel systems with single-channel interfaces in this Recommendation are specified in Tables 8-11 to 8-14 and Tables 8-17 to 8-22.

5.5.2 Amplified multichannel systems with single-channel interfaces

Amplified multichannel systems with single-channel interfaces may be introduced into this Recommendation in the future.

6 Transverse compatibility

This Recommendation specifies parameters in order to enable transverse (i.e., multivendor) compatibility at multichannel reference points MPI-S_M and MPI-R_M of the "black box" approach CWDM network elements (NEs), and at single-channel reference points S_S and R_S of the "black link" approach CWDM NEs.

The multichannel reference points MPI-S_M and MPI-R_M are intended to interconnect two aggregate interfaces of CWDM NEs, which may be from two different vendors.

The single-channel reference points S_S and R_S are intended to make multiple tributary interfaces of CWDM NEs transversely compatible. In this case, multiple tributary signal transmitters ($\text{Tx } \lambda_i$) and receivers ($\text{Rx } \lambda_i$) may be from many different vendors. Note that CWDM NEs (OM and OD) for the "black link" approach are from a single vendor, and considered as a single set of optical devices.

Transverse (multivendor) compatibility is enabled for:

- All multichannel reference points MPI-S_M and MPI-R_M of "black box" approach CWDM NEs having exactly the same application code.
Interconnection of aggregate interfaces with different application codes is a matter of joint engineering. Care must be taken particularly with respect to critical parameters that must be matched, e.g., MPI-S_M output power, MPI-R_M input power, etc.
- All single-channel reference points S_S and R_S of "black link" approach CWDM NEs having exactly the same application code.
Coexistence of tributary interfaces with different application codes is a matter of joint engineering. Care must be taken particularly with respect to critical parameters that must be consistent, e.g., S_S output power and R_S input power, S_S bit rate/line coding and R_S bit rate/line coding, etc.

7 Parameter definitions

The parameters in Tables 7-1 and 7-2 are defined at the interface points, and the definitions are provided in the clauses below.

**Table 7-1 – Physical layer parameters and values for CWDM applications
using the "black box" approach**

Parameter	Units	Defined in
General information		
Maximum number of channels	–	7.1.1
Bit rate/line coding of optical tributary signals	–	7.1.2
Maximum bit error ratio	–	7.1.3
Fibre type	–	7.1.4
Interface at point MPI-S_M		
Maximum mean channel output power	dBm	7.2.1
Minimum mean channel output power	dBm	7.2.1
Maximum mean total output power	dBm	7.2.2
Central wavelength	nm	7.2.3
Channel spacing	nm	7.2.4
Maximum central wavelength deviation	nm	7.2.5
Minimum channel extinction ratio	dB	7.2.6
Eye mask	–	7.2.7
Optical path from point MPI-S_M to MPI-R_M		
Maximum attenuation	dB	7.3.1
Minimum attenuation	dB	7.3.2
Chromatic dispersion range	ps/nm	7.3.3
Minimum optical return loss at MPI-S _M	dB	7.3.4
Maximum discrete reflectance between MPI-S _M and MPI-R _M	dB	7.3.5
Maximum differential group delay	ps	7.3.6
Interface at point MPI-R_M		
Maximum mean channel input power	dBm	7.4.1
Minimum mean channel input power	dBm	7.4.2
Maximum mean total input power	dBm	7.4.3
Maximum optical path penalty	dB	7.4.4
Minimum equivalent sensitivity	dBm	7.4.7
Maximum reflectance of optical network element	dB	7.4.5

**Table 7-2 – Physical layer parameters and values for CWDM applications
using the "black link" approach**

Parameter	Units	Defined in
General information		
Maximum number of channels	–	7.1.1
Bit rate/line coding of optical tributary signals	–	7.1.2
Maximum bit error ratio	–	7.1.3
Fibre type	–	7.1.4
Interface at point S_s		
Maximum mean channel output power	dBm	7.2.1
Minimum mean channel output power	dBm	7.2.1
Central wavelength	nm	7.2.3
Channel spacing	nm	7.2.4
Maximum central wavelength deviation	nm	7.2.5
Minimum channel extinction ratio	dB	7.2.6
Eye mask	–	7.2.7
Optical path from point S_s to R_s		
Maximum channel insertion loss	dB	7.5.1
Minimum channel insertion loss	dB	7.5.1
Chromatic dispersion range	ps/nm	7.3.3
Minimum optical return loss at S _s	dB	7.3.4
Maximum discrete reflectance between S _s and R _s	dB	7.3.5
Maximum differential group delay	ps	7.3.6
Maximum inter-channel crosstalk at R _s	dB	7.5.2
Maximum interferometric crosstalk at R _s	dB	7.5.3
Interface at point R_s		
Maximum mean channel input power	dBm	7.4.1
Receiver sensitivity	dBm	7.4.6
Maximum optical path penalty	dB	7.4.4
Maximum reflectance of receiver	dB	7.4.5

7.1 General information

7.1.1 Maximum number of channels

The maximum number of optical channels that may be simultaneously present at an interface.

For bidirectional applications, the maximum number of channels is expressed in the form $n/2 + n/2$ where n is the maximum number of channels supported by the application code, and $n/2$ is the number of channels in each direction.

It should be noted that, if it is desired to be able to upgrade a link with a certain maximum channel count to a configuration with a higher maximum channel count, then the set of parameter values specified for the higher channel count application code should be met for the initial link.

As an example, a system designed according to a 4-channel application code cannot be upgraded to an 8-channel system. Such an option should be implemented by under-equipping an 8-channel system and using the set of parameter values for an 8-channel application code.

7.1.2 Bit rate/line coding of optical tributary signals

Optical tributary signal class NRZ 1.25G applies to continuous digital signals with non-return to zero line coding, from nominally 622 Mbit/s to nominally 1.25 Gbit/s. Optical tributary signal class NRZ 2.5G applies to continuous digital signals with non-return to zero line coding, from nominally 622 Mbit/s to nominally 2.67 Gbit/s. Optical tributary signal class NRZ 10G applies to continuous digital signals with non-return to zero line coding, from nominally 2.4 Gbit/s to nominally 10.76 Gbit/s. Optical tributary signal class NRZ 10G includes a signal with STM-64 bit rate according to [ITU-T G.707], OTU2 bit rate according to [ITU-T G.709] and OTL3.4 bit rate (OTU3 striped across four physical lanes) according to [ITU-T G.709].

7.1.3 Maximum bit error ratio

The parameters are specified relative to an optical section design objective of a bit error ratio (BER) not worse than the value specified by the application code. This value applies to each optical channel under the extreme case of optical path attenuation and dispersion conditions in each application. The possible effect on the definition of this parameter due to the presence of forward error correction (e.g., in an OTUk) has not been considered in the present version of this Recommendation.

7.1.4 Fibre type

Single mode optical fibre types are chosen from those defined in [ITU-T G.652], [ITU-T G.653] and [ITU-T G.655].

7.2 Interface at point MPI-S_M or S_S

7.2.1 Maximum and minimum mean channel output power

The mean launched power of each optical channel at reference point MPI-S_M or S_S is the average power of a pseudo-random data sequence coupled into the fibre or the CWDM link. It is given as a range (maximum and minimum) to allow for some cost optimization and to cover allowances for operation under the standard operating conditions, connector degradations, measurement tolerances and aging effects.

7.2.2 Maximum mean total output power

The maximum value of the mean launched optical power at point MPI-S_M.

NOTE – Optical safety aspects have been considered in determining the values given in this Recommendation, since it is desirable to avoid the need for automatic power reduction (APR), automatic power shutdown (APSD), or automatic laser shutdown (ALS) procedures, for cost reasons.

7.2.3 Central wavelength

The nominal single-channel wavelengths on which the digital coded information of the particular optical channels are modulated by use of the NRZ line code (as defined in [ITU-T G.957] and [ITU-T G.691]).

The central wavelengths are based on the wavelength grid given in [ITU-T G.694.2]. The allowed central wavelengths for the multichannel CWDM network element are specified in Tables 8-1 to 8-22.

Note that the value of "c" (speed of light in a vacuum) that should be used for converting between frequency and wavelength is 2.99792458×10^8 m/s.

7.2.4 Channel spacing

The nominal difference in wavelength between two adjacent channels. All possible tolerances of actual wavelengths are considered in clause 7.2.5.

7.2.5 Maximum central wavelength deviation

The difference between the nominal central wavelength and the actual central wavelength. The central wavelength deviation is determined mainly by two factors. First, the laser manufacturer is allowed a wavelength variation around the nominal wavelength in order to achieve a higher yield and/or relax fabrication tolerances. Second, the use of uncooled lasers will cause the wavelength to change with temperature within the specified temperature range of the laser.

Also included in the central wavelength deviation are all the processes that affect the instantaneous value of the source central wavelength over a measurement interval appropriate to the channel bit rate. These processes include source chirp, information bandwidth, broadening due to self-phase modulation, and effects due to aging.

Maximum central wavelength deviation in CWDM point-to-point systems is provided in Tables 8-1 to 8-22.

7.2.6 Minimum channel extinction ratio

The extinction ratio (EX) is defined in [b-ITU-T G.693] for a single-channel parameter, as:

$$EX = 10 \times \log_{10}(A/B)$$

In the above definition of EX, A is the average optical power level at the centre of a logical "1" and B is the average optical power level at the centre of a logical "0". The convention adopted for optical logic levels is:

- emission of light for a logical "1";
- no emission for a logical "0".

The minimum channel extinction ratio is not required to be met in the presence of a fourth-order Bessel-Thomson filter.

For multichannel interfaces, two alternative methods can be used for the verification of this parameter as in [ITU-T G.959.1]:

- Method A can be used when single-channel reference points are accessible at the transmit end of the link for verification. For this method, the procedures described in [ITU-T G.957] and [ITU-T G.691] are used. The configuration for this method is contained in Annex A of [ITU-T G.959.1];
- Method B employs a reference optical bandpass filter to isolate the individual transmitted signal. The characteristics of the reference optical bandpass filter are contained in Annex B of [ITU-T G.959.1].

7.2.7 Eye mask

The definition and filter limits for this parameter are found in [ITU-T G.959.1]. This definition can be directly applied to single-channel interfaces of the "black link" approach. In the case of the multichannel interfaces of the "black box" approach, two alternative methods can be used as in [ITU-T G.959.1]:

- Method A can be used when single-channel reference points are accessible at the transmit end of the link for verification. For this method, the procedures described in [ITU-T G.957] and [ITU-T G.691] are used. The configuration for this method is contained in Annex A of [ITU-T G.959.1];