ITUPublications
Recommendations

International Telecommunication Union
Standardization Sector

Recommendation

ITU-T G.698.6 (01/2024)

SERIES G: Transmission systems and media, digital systems and networks

Transmission media and optical systems characteristics – Characteristics of optical systems

---

Multichannel WDM applications with single-channel optical interfaces in the O-band

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.698.6

Multichannel WDM applications with single-channel optical interfaces in the O-band

Summary

Recommendation ITU-T G.698.6 provides optical parameter values for physical layer interfaces of wavelength division multiplexing (WDM) systems primarily intended for mobile fronthaul and metro applications in the O-band, optimized for 5 km transmission distances. Applications are defined using optical interface parameters and values for single-channel interfaces of multichannel WDM optical systems in point-to-point applications. This Recommendation uses a system architecture comprising a head-end equipment (HEE) connecting to the tail-end equipment (TEE) through a black link. For mobile fronthaul applications, the HEE is in a central office while the TEE is in a remote antenna site. A single bidirectional transmission fibre or a pair of unidirectional transmission fibres is used in the black link to connect the HEE to the TEE. This version of the Recommendation includes unidirectional and bidirectional WDM applications at 25 Gbit/s per channel with alternating channel wavelength spacing of 7 nm and 13 nm in the O-band.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T G.698.6	2024-01-13	15	11.1002/1000/15793

Keywords

Application codes, black link, metro networks, multivendor, O-band, optical interfaces, optical networks, 25G, WDM.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

FOREWORD

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

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

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

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

NOTE

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

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

INTELLECTUAL PROPERTY RIGHTS

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

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, 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 appropriate ITU-T databases available via the ITU-T website at http://www.itu.int/ITU-T/ipr/.

Table of Contents

Recommendation ITU-T G.698.6

Multichannel WDM applications with single-channel optical interfaces in the O-band

1 Scope

The purpose of this Recommendation is to provide optical interface specifications towards the realization of transversely compatible bidirectional medium-coarse wavelength division multiplexing (WDM) systems, primarily intended for mobile fronthaul and metro applications.

This Recommendation defines and provides values for optical interface parameters of point-to-point WDM applications on single-mode optical fibres through the use of the black link approach with both of the propagation directions sharing the same optical fibre or the same optical fibre pair end-to-end.

This Recommendation uses a system architecture comprising head-end equipment (HEE) connecting to the tail-end equipment (TEE) through a black link. For mobile fronthaul applications, the HEE is in a central office while the TEE is in a remote antenna site. A single bidirectional transmission fibre or a pair of fibres is used in the black link to connect the HEE to the TEE. This version of the Recommendation includes bidirectional and unidirectional WDM applications at 25 Gbit/s per channel with alternating channel wavelength spacing of 7 nm and 13 nm in the O-band.

For the applications in this version of the Recommendation, the black link does not contain optical amplifiers.

This Recommendation describes bidirectional WDM systems that include the following features:

– Operating wavelength band: the O-band;

– Nominal wavelength spacing: alternating between 7 nm and 13 nm;

– Nominal bit rate of signal channel: 25 Gbit/s;

– Nominal transmission distance: 5 km;

– Maximum capacity: 12 unidirectional channels or 6 bidirectional channels (12 total wavelengths) at 25 Gbit/s.

Specifications are organized according to application codes.

2 References

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

[ITU-T G.650.2] Recommendation ITU-T G.650.2 (2015), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

[ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T G.664] Recommendation ITU-T G.664 (2012), *Optical safety procedures and requirements for optical transmission systems*.

[ITU-T G.671] Recommendation ITU-T G.671 (2019), *Transmission characteristics of optical components and subsystems.*

[ITU-T G.694.1] Recommendation ITU-T G.694.1 (2020), *Spectral grids for WDM applications: DWDM frequency grid.*

[ITU-T G.698.1] Recommendation ITU-T G.698.1 (2023), *Multichannel DWDM applications with single-channel optical interfaces*.

[ITU-T G.709.4] Recommendation ITU-T G.709.4/Y.1331.4 (2020), *OTU25 and OTU50 short-reach interfaces*.

[ITU-T G.957] Recommendation ITU-T G.957 (2006), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*

[ITU-T G.959.1] Recommendation ITU-T G.959.1 (2018), *Optical transport network physical layer interfaces*.

[ITU-T G.972] Recommendation ITU-T G.972 (2020), *Definition of terms relevant to optical fibre submarine cable systems*.

[IEC 60825-1] IEC 60825-1:2014, *Safety of laser products – Part 1: Equipment classification and requirements.*

[IEC 60825-2] IEC 60825-2:2021, *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 elsewhere:

3.1.1 Term defined in [ITU-T G.650.2]

– differential group delay.

3.1.2 Terms defined in [ITU-T G.671]:

– channel insertion loss;

– channel spacing;

– dense wavelength division multiplexing (DWDM);

– differential group delay;

– reflectance;

– ripple.

3.1.3 Term defined in [ITU-T G.694.1]:

– frequency grid.

3.1.4 Terms defined in [ITU-T G.957]:

– receiver sensitivity;

– transverse compatibility.

3.1.5 Terms defined in [ITU-T G.959.1]:

– optical tributary signal;

– optical tributary signal class NRZ 25G.

3.1.6 Term defined in [ITU-T G.972]

– dense wavelength division multiplexing (DWDM).

3.2 Terms defined in this Recommendation

None

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BER Bit-Error Ratio

DWDM Dense Wavelength Division Multiplexing

FEC Forward Error Correction

HEE Head-End Equipment

NRZ Non-Return to Zero

OD Optical Demultiplexer

OM Optical Multiplexer

TEE Tail-End Equipment

WDM Wavelength Division Multiplexing

5 Conventions

None.

6 Classification of optical interfaces

6.1 Applications

This Recommendation provides the physical layer parameters and values for single-channel interfaces of WDM multichannel optical systems in physical point-to-point single fibre applications. These WDM systems are primarily intended to be used in mobile fronthaul and metropolitan area networks for a variety of clients, services and protocols.

The specification method in this Recommendation uses a black link approach which means that optical interface parameters for only (single-channel) optical tributary signals are specified at the tail-end equipment (TEE). Additional specifications are provided for the black link parameters such as maximum attenuation, chromatic dispersion, ripple and polarization mode dispersion.

Figure 6-1 shows the linear black link approach for unidirectional transmission applications with one fibre connecting to each transmitter according to the unidirectional wavelength channel plan specified in clause 8.2.2.

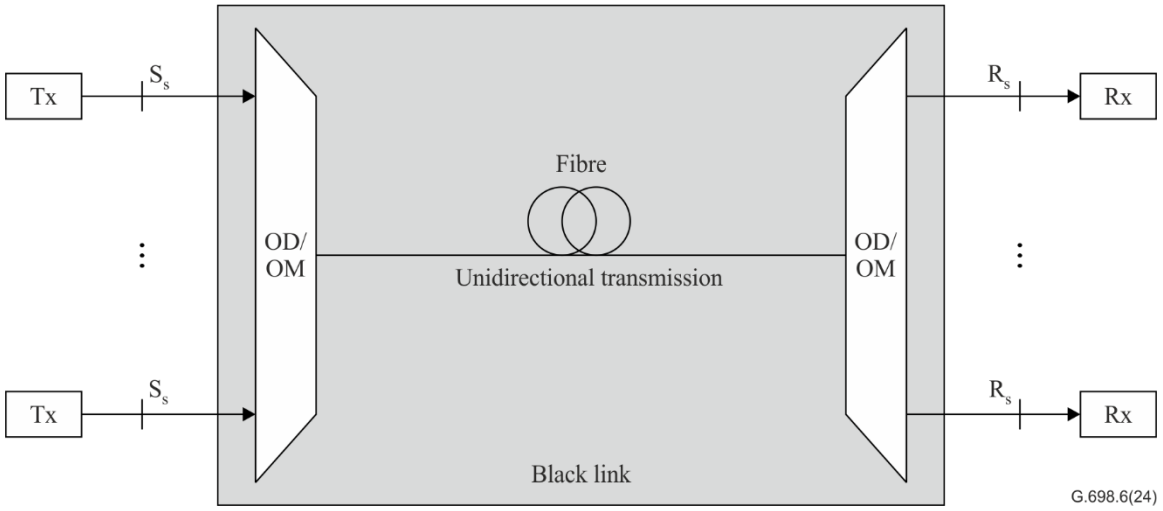

Figure 6-1 – Linear "black link" approach for unidirectional transmission applications

Figure 6-2 shows the linear black link approach for bidirectional transmission applications with two fibres connecting to each transceiver according to the bidirectional wavelength channel plan specified in clause 8.2.2.

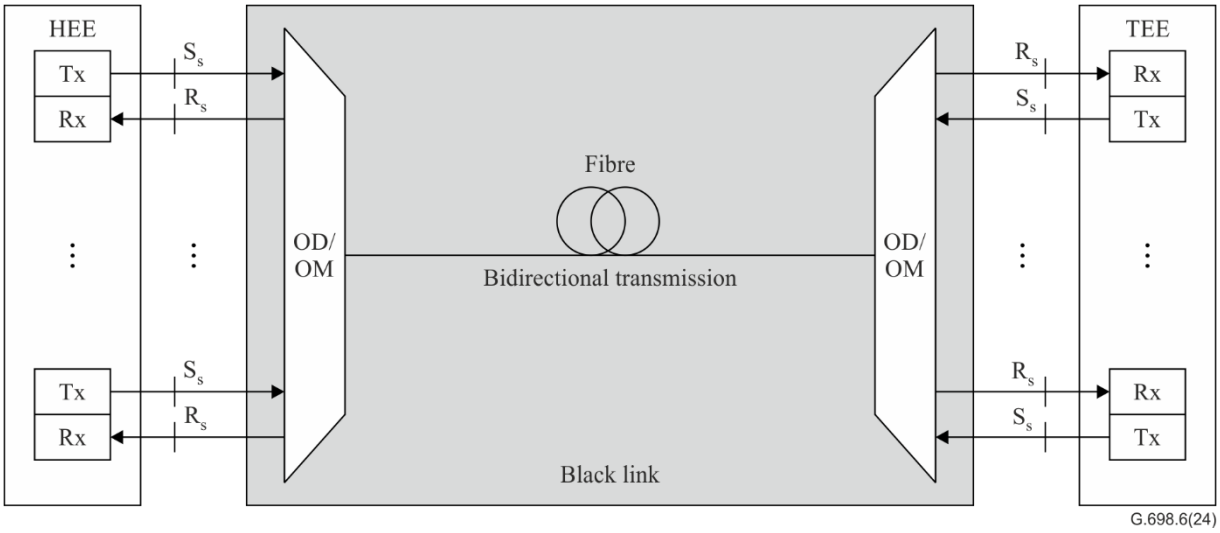

Figure 6-2 – Linear black link approach for bidirectional transmission applications with two fibres connecting to each transceiver

Figure 6-3 shows the linear black link approach for bidirectional transmission applications with one fibre connecting to each transceiver according to the bidirectional wavelength channel plan specified in clause 8.2.2.

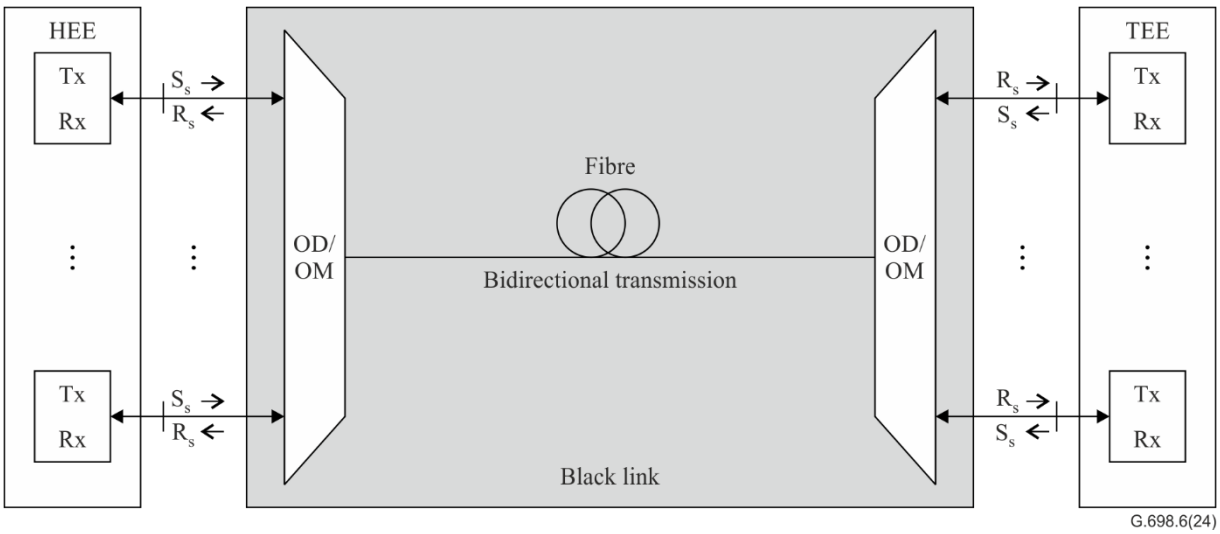

Figure 6-3 – Linear black link approach for bidirectional transmission applications with one fibre connecting to each transceiver

Configurations with two fibres connecting to each transceiver at one end of the black link and with a single fibre connecting to each transceiver at the other end of the black link are allowed.

6.2 Reference points

The system architecture comprises a HEE connecting to the TEE through a black link. The HEE houses a set of transmitters and receivers. A single bidirectional fibre or a pair of fibres is used to connect a pair of head-end transmitter (Tx) and receiver (Rx) with one or two ports of the black link. Connection between the head-end-side (HE- side) OD/OM and a tail-end-side (TE-side) OD/OM is also bidirectional. Both the HE-side OD/OM and the TE-side OD/OM are considered to be part of the black link.

The reference points in Figure 6-1 are defined as follows:

– S_S is a single-channel reference point at the black link tributary input;

– R_S is a single-channel reference point at the black link tributary output.

At the S_S interface, a single-channel signal enters the black link from an optical transmitter.

At the R_S interface, a single-channel signal exits the black link towards an optical receiver.

6.3 Nomenclature

The application code notation is constructed as follows:

Mc-dD-y-tz

where:

M: is the indicator of WDM applications as specified in this Recommendation.

c: is the number of channels.

d: is a number indicating the span distance in km, such as:

– 5 indicating short-haul up to 5 km distance.

D: is the indicator of unidirectional or bidirectional transmission:

– U indicating unidirectional transmission;

– B indicating bidirectional transmission.

y: indicates the highest class of optical tributary signal supported:

– 9 indicating NRZ 25G.

t: indicates the configuration supported by the application code. In the current version of this Recommendation, the only value used is:

– D indicating that the black link does not contain any optical amplifiers.

z: indicates the fibre types. In the current version of this Recommendation, the only value used is:

– 1 indicating ITU-T G.652 fibre.

7 Transverse compatibility

This Recommendation specifies parameters in order to enable transverse (i.e., multivendor) compatible line systems for point-to-point applications at single-channel reference points S_S and R_S of the black link.

8 Parameter definitions

The parameters in Table 8-1 are defined at the interface points and the definitions are provided in the following clauses.

Table 8-1 – Physical layer parameters for multichannel bidirectional WDM applications

Parameter	Units	For HEE to TEE defined in:	For TEE to HEE defined in:
General information			
Bit-rate/line coding of optical tributary signals	–	8.1.1	8.1.1
Maximum bit-error ratio	–	8.1.2	8.1.2
Fibre type	–	8.1.3	8.1.3
Interface at point S_S			
Maximum mean channel output power	dBm	8.2.1	8.2.1
Minimum mean channel output power	dBm	8.2.1	8.2.1
Minimum central wavelength	nm	8.2.2	8.2.2
Maximum central wavelength	nm	8.2.2	8.2.2
Maximum spectral excursion	nm	8.2.3	8.2.3
Minimum channel extinction ratio	dB	8.2.4	8.2.4
Eye mask	–	8.2.5	8.2.5
Optical path from point S_S to R_S			
Maximum channel insertion loss	dB	8.3.1	8.3.1
Minimum channel insertion loss	dB	8.3.1	8.3.1
Maximum ripple	dB	8.3.2	8.3.2
Chromatic dispersion range	ps/nm	8.3.3	8.3.3
Minimum optical return loss at S_S	dB	8.3.4	8.3.4
Maximum discrete reflectance between S_S and R_S	dB	8.3.5	8.3.5
Maximum differential group delay	ps	8.3.6	8.3.6
Maximum inter-channel crosstalk at R_S	dB	8.3.7	8.3.7
Maximum interferometric crosstalk at Rs	dB	8.3.8	8.3.8

Table 8-1 – Physical layer parameters for multichannel bidirectional WDM applications

Parameter	Units	For HEE to TEE defined in:	For TEE to HEE defined in:
Interface at point R_S			
Maximum mean channel input power	dBm	8.4.1	8.4.1
Minimum mean channel input power	dBm	8.4.1	8.4.1
Receiver sensitivity	dBm	8.4.2	8.4.2
Maximum optical path penalty	dB	8.4.3	8.4.3
Maximum reflectance of receiver or optical network element	dB	8.4.4	8.4.4

8.1 General information

8.1.1 Bit-rate/line coding of optical tributary signals

The bit-rate/line coding of optical tributary signals is defined as in [ITU-T G.959.1].

8.1.2 Maximum bit-error ratio

The maximum bit-error ratio is defined as in [ITU-T G.698.1].

8.1.3 Fibre type

Currently, the only single-mode optical fibre type is that defined in [ITU-T G.652].

8.2 Interface at point S_S

8.2.1 Maximum and minimum mean channel output power

The mean channel output power is defined as in [ITU-T G.959.1].

8.2.2 Minimum and maximum central wavelength

In application code M12-5U-9-D1, the nominal optical channel wavelengths are set according to Table 8-2.

Table 8-2 – Nominal optical channel wavelengths for M12-5U-9-D1

Channel number	Nominal central wavelength (nm)
1	1267.5
2	1274.5
3	1287.5
4	1294.5
5	1307.5
6	1314.5
7	1327.5
8	1334.5
9	1347.5
10	1354.5
11	1367.5
12	1374.5

In application code M12-5B-9-D1, the nominal optical channel wavelengths are paired according to Table 8-3, in which each pair of channels on the same row share a single bidirectional fibre to reach their corresponding HEE/TEE Tx/Rx.

Table 8-3 – Wavelength pairing for bidirectional M12-5B-9-D1

Direction	Channel number	Nominal central wavelength (nm)	Direction	Channel number	Nominal central wavelength (nm)
From HE to TE	1	1267.5	From TE to HE	2	1274.5
	3	1287.5		4	1294.5
	5	1307.5		6	1314.5
	7	1327.5		8	1334.5
	9	1347.5		10	1354.5
	11	1367.5		12	1374.5

8.2.3 Maximum spectral excursion

The maximum spectral excursion is defined as in [ITU-T G.698.1].

8.2.4 Minimum channel extinction ratio

The minimum channel extinction ratio is defined as in [ITU-T G.698.1].

8.2.5 Eye mask

The eye mask is defined as in [ITU-T G.959.1].

8.3 Optical path from S_S to R_S

8.3.1 Maximum and minimum channel insertion loss

The channel insertion loss is defined as in [ITU-T G.698.1].

8.3.2 Maximum ripple

The ripple is defined as in [ITU-T G.698.1].

8.3.3 Chromatic dispersion range

This parameter defines the range between the minimum and the maximum values of the optical path chromatic dispersion that the system shall be able to tolerate.

8.3.4 Minimum optical return loss at S_S

The minimum optical return loss is defined as in [ITU-T G.959.1].

8.3.5 Maximum discrete reflectance between S_S and R_S

The maximum discrete reflectance is defined as in [ITU-T G.959.1].

8.3.6 Maximum differential group delay

The maximum differential group delay is defined as in [ITU-T G.698.1].

8.3.7 Maximum inter-channel crosstalk at R_S

The inter-channel crosstalk is defined as in [ITU-T G.698.1].

8.3.8 Maximum interferometric crosstalk at Rs

The interferometric crosstalk is defined as in [ITU-T G.698.1].

8.4 Interface at point R_S

8.4.1 Maximum and minimum mean channel input power

The mean channel input power is defined as in [ITU-T G.959.1].

8.4.2 Receiver sensitivity

The receiver sensitivity is defined as in [ITU-T G.698.1].

8.4.3 Maximum optical path penalty

The maximum optical path penalty is defined as in [ITU-T G.698.1].

8.4.4 Maximum reflectance of receiver or optical network element

The maximum reflectance of receiver is defined as in [ITU-T G.698.1].

9 Parameter values

Table 9-1 shows parameter values for M12-5U-9-D1 and M12-5B-9-D1 application codes.

Table 9-1 – Optical specifications for 12-channel unidirectional and bidirectional application codes M12-5U-9-D1 and M12-5B-9-D1

Parameter	Units	12-channel unidirectional application M12-5U-9-D1	12-channel bidirectional application M12-5B-9-D1
General information			
Maximum numbers of channels	–	12	
Bit-rate / line coding of optical tributary signals	–	25.78125 Gb/s ± 100 ppm / 25G NRZ	
Maximum bit-error ratio (Note 1)	–	10^{-12}	
Fibre type	–	G.652	
Interface at point S_S			
Maximum mean channel output power	dBm	4	
Minimum mean channel output power	dBm	−3	
Central wavelengths of all the channels	nm	1267.5, 1274.5, 1287.5, 1294.5, 1307.5, 1314.5, 1327.5, 1334.5, 1347.5, 1354.5, 1367.5, 1374.5.	From the HEE to the TEE: 1267.5, 1287.5, 1307.5, 1327.5, 1347.5, 1367.5. From the TEE to the HEE: 1274.5, 1294.5, 1314.5, 1334.5, 1354.5, 1374.5.
Maximum spectral excursion	nm	±2.5	
Minimum channel extinction ratio	dB	3.5	
Eye mask	–	NRZ 25G Ratio	
Optical path from point S_S to R_S			
Maximum channel insertion loss (Note 2)	dB	8.4	

Table 9-1 – Optical specifications for 12-channel unidirectional and bidirectional application codes M12-5U-9-D1 and M12-5B-9-D1

Parameter	Units	12-channel unidirectional application M12-5U-9-D1	12-channel bidirectional application M12-5B-9-D1
Minimum channel insertion loss (Note 2)	dB	2.0	
Maximum ripple	dB	2	
Chromatic dispersion range	ps/nm	−27 to +35	
Minimum optical return loss at S_S		20	
Maximum discrete reflectance between S_S and R_S		−26	
Maximum differential group delay	ps	10.3	
Maximum inter-channel crosstalk at R_S		−25	
Maximum interferometric crosstalk at R_S		−45	
Interface at point R_S			
Maximum mean channel input power	dBm	2.0	
Minimum mean channel input power	dBm	−11.4	
Maximum optical path penalty	dB	2	
Receiver sensitivity	dBm	−13.4	
Maximum reflectance of optical network element	dB	−26	
NOTE 1 – The bit-error ratio (BER) for these application codes is required to be met only after RS10(528,514) has been applied, as in the OTU25u-RS FEC specification in [ITU-T G.709.4]. NOTE 2 – The channel insertion loss refers to the trunk optical path loss, containing the cabled optical fibre attenuation, connection and splice loss, and OM/OD insertion loss.			

10 Optical safety considerations

See [ITU-T G.664], [IEC 60825-1] and [IEC 60825-2] for optical safety considerations.

SERIES OF ITU-T RECOMMENDATIONS

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

Published in Switzerland
Geneva, 2024