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Recommendation

ITU-T G.698.5 (01/2024)

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

Transmission media and optical systems characteristics – Characteristics of optical systems

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

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Recommendation ITU-T G.698.5

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

Summary

Recommendation ITU-T G.698.5 provides optical parameter values for physical layer interfaces of dense wavelength division multiplexing (DWDM) systems primarily intended for mobile fronthaul and metro applications in the O-band, optimized for 10-km and 20-km transmission distances. Applications are defined using optical interface parameters and values for single-channel interfaces of multichannel wavelength division multiplexing (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 is used in the black link to connect the HEE to the TEE. This version of the Recommendation includes bidirectional single-fibre WDM applications at 25 Gbit/s per channel with a nominal optical channel frequency spacing of 800 GHz.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
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Keywords

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

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Recommendation ITU-T G.698.5

Multichannel DWDM 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 dense wavelength division multiplexing (DWDM) systems in O-band, 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 end-to-end.

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 is used in the black link to connect the HEE to the TEE. This version of the Recommendation includes bidirectional single-fibre WDM applications at 25 Gbit/s per channel with a nominal optical channel frequency spacing of 800 GHz.

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 optical channel frequency spacing: 800 GHz;

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

– Nominal transmission distances: 10 km and 20 km;

– Maximum capacity: 6 bidirectional channels (at 12 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.698.4] Recommendation ITU-T G.698.4 (2023), *Multichannel bi-directional DWDM applications with port agnostic 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;

– reflectance;

– ripple.

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

– frequency grid.

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

– 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

This Recommendation defines the following term:

3.2.1 receiver sensitivity: The minimum value of average received power at point R to achieve a 1×10^{-10} BER.

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

R_S Single-channel reference point at the black link tributary output

S_S Single-channel reference point at the black link tributary input

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 HEE and the TEE. Additional specifications are provided for the black link parameters such as maximum attenuation, chromatic dispersion, ripple and polarization mode dispersion. The configurations in Figures 6-1 and 6-2 may coexist at the two ends of the black link and, as such, share the same application code. Implementers need to take care to coordinate the connection type of the transceiver and the black link.

Figure 6-1 shows the linear black link approach for bidirectional transmission applications with two fibres connecting to each transceiver according to the wavelength channel plan specified in clause 8.2.2. For mobile fronthaul applications, the HEE is in a central office while the TEE is in a remote antenna site.

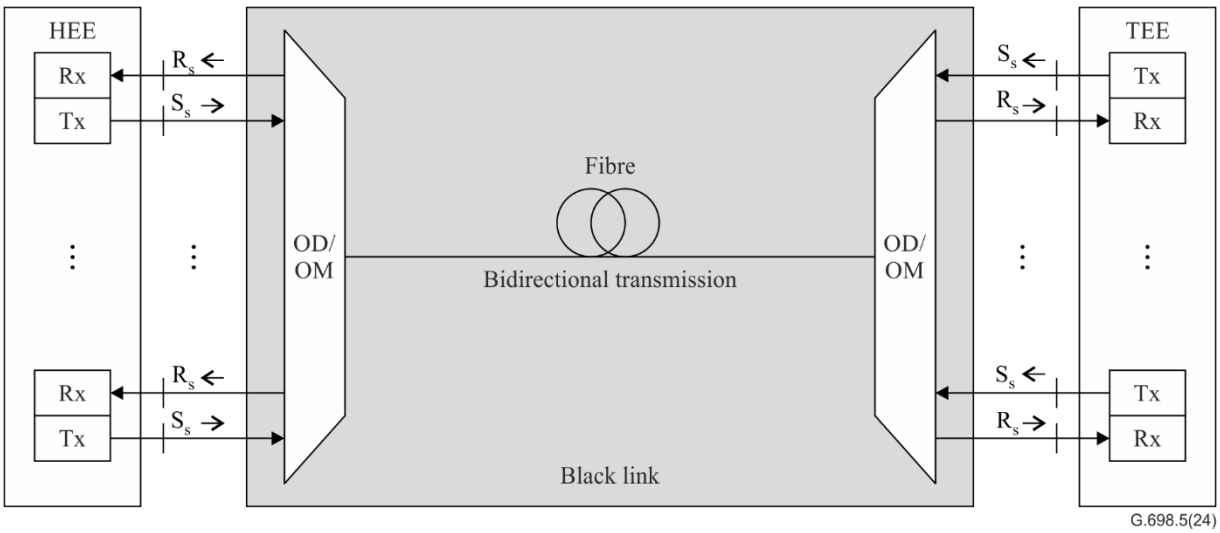

Figure 6-1 – Linear black link approach for bidirectional transmission applications with two fibres connecting to each transceiver

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

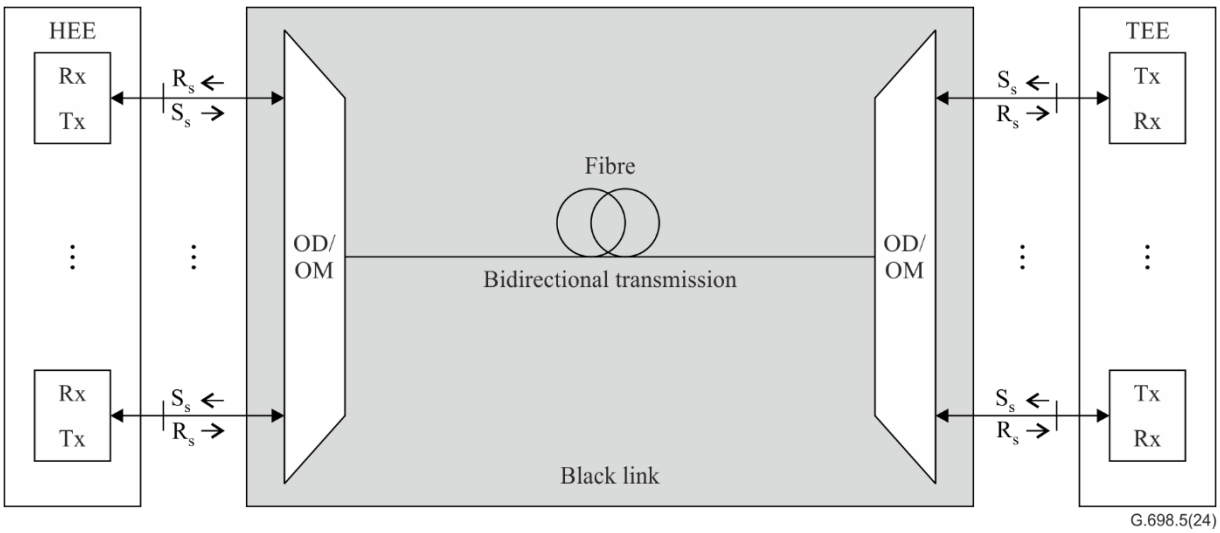

Figure 6-2 – Linear black link approach for bidirectional transmission applications with one fibre connecting to each transceiver

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. Both the HEE-side optical demultiplexer (OD) / optical multiplexer (OM) and the TEE-side OD/OM are considered to be part of the black link. The connection between the HEE-side OD/OM and the TEE-side OD/OM is bidirectional.

The reference points in Figure 6-1 and Figure 6-2 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:

Lc-s-dD-y-tz

where:

L is the indicator of WDM applications defined in this Recommendation.

c is the number of channels.

s is a number giving the channel spacing in 100 GHz:

– 8 indicating 800 GHz spacing

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

– 10 indicating short-haul up to 10 km distance;

– 20 indicating short-haul up to 20 km distance.

D is the indicator of unidirectional or bidirectional transmission:

– B 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.

The single-channel reference points S_S and R_S are intended to make multiple tributary interfaces of WDM TEEs transversely compatible with the HEE. In this case, tributary signal transmitter (Tx λ_i) and receiver (Rx λ_i) pairs may be from different vendors. Thus, TEE, black link and HEE suppliers are not necessarily the same.

8 Parameter definitions

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

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 frequency	THz	8.2.2	8.2.2
Maximum central frequency	THz	8.2.2	8.2.2
Maximum spectral excursion	GHz	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 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
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 in [ITU-T G.959.1].

8.1.2 Maximum bit-error ratio

The maximum bit-error ratio is defined 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 Ss

8.2.1 Maximum and minimum mean channel output power

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

8.2.2 Minimum and maximum central frequency

The central frequency is defined in [ITU-T G.698.1].

For each optical channel, different ranges of frequencies are used in the head end (HE) to tail end (TE) and TE-to-HE directions. The channel frequencies in the two directions are paired.

In application codes L12-8-10B-9-D1 and L12-8-20B-9-D1, the nominal bidirectional optical channel frequencies and their pairing are set according to Table 8-2.

Table 8-2 – Nominal bidirectional optical channel frequencies and their pairing for L12-8-10B-9-D1 and L12-8-20B-9-D1 applications codes

Bidirectional channel	From HEE to TEE			From TEE to HEE		
	Channel index (Note)	Central frequency (THz)	Central wavelength (nm)	Channel index (Note)	Central frequency (THz)	Central wavelength (nm)
1	f_2	235.4	1273.54	f_1	236.2	1269.23
2	f_4	233.8	1282.26	f_3	234.6	1277.89
3	f_6	232.2	1291.10	f_5	233.0	1286.66
4	f_7	231.4	1295.56	f_8	230.6	1300.05
5	f_{10}	229.0	1309.14	f_9	229.8	1304.58
6	f_{12}	227.4	1318.35	f_{11}	228.2	1313.73
NOTE – $f_m = 237.0 - 0.8 \times m$ (THz), m = 1 to 12; each pair of channels on the same row in Table 8-2 can share a single bidirectional fibre to reach their corresponding HEE/TEE Tx/Rx.						

8.2.3 Maximum spectral excursion

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

8.2.4 Minimum channel extinction ratio

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

8.2.5 Eye mask

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

8.3 Optical path from Ss to Rs

8.3.1 Maximum and minimum channel insertion loss

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

8.3.2 Maximum ripple

The ripple is defined 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 in [ITU-T G.959.1].

8.3.5 Maximum discrete reflectance between S_S and R_S

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

8.3.6 Maximum differential group delay

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

8.3.7 Maximum interchannel crosstalk at R_S

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

8.3.8 Maximum interferometric crosstalk at Rs

The interferometric crosstalk is defined 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 in [ITU-T G.959.1].

8.4.2 Receiver sensitivity

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

8.4.3 Maximum optical path penalty

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

8.4.4 Maximum reflectance of receiver or optical network element

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

9 Parameter values

Table 9-1 shows parameter values for L12-8-10B-9-D1 and L12-8-20B-9-D1 application codes.

Table 9-1 – Optical specifications for 10-km and 20-km application codes L12-8-10B-9-D1 and L12-8-20B-9-D1

Parameter	Units	L12-8-10B-9-D1	L12-8-20B-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	5.5	5.5
Minimum mean channel output power	dBm	0	2
Central frequencies of all the channels	THz	$f_m = 237.0 - 0.8 \times m$, m = 1 to 12	
Central frequencies of the HE-to-TE channels	–	f_2, f_4, f_6, f_7, f_{10}, f_{12}	

Table 9-1 – Optical specifications for 10-km and 20-km application codes L12-8-10B-9-D1 and L12-8-20B-9-D1

Parameter	Units	L12-8-10B-9-D1	L12-8-20B-9-D1
Central frequencies of the TE-to-HE channels	–	f_1, f_3, f_5, f_8, f_9, f_{11}	
Maximum spectral excursion	GHz	±200	
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	10.7	15.9
Minimum channel insertion loss (Note 2)	dB	2.5	2.5
Maximum ripple	dB	2	
Chromatic dispersion range	ps/nm	−50 to +15	−100 to +30
Minimum optical return loss at S_S	dB	20	
Maximum discrete reflectance between S_S and R_S	dB	−26	
Maximum differential group delay	ps	10.3	
Maximum inter-channel crosstalk at Rs	dB	−25	
Maximum interferometric crosstalk at Rs	dB	−45	
Interface at point R_s			
Maximum mean channel input power	dBm	3	3
Minimum mean channel input power	dBm	−10.7	−13.9
Maximum optical path penalty (Note 3)	dB	2	2.5
Receiver sensitivity (Note 4)	dBm	−12.7	−16.4
Maximum reflectance of optical network element	dB	−26	

NOTE 1 – The 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.

NOTE 3 – The optical path penalty contains the penalties from chromatic dispersion, PMD, crosstalk and FWM.

NOTE 4 – The receiver sensitivity is measured with transmitter set at the maximum power and with the minimum optical return loss of the black link.

10 Optical safety considerations

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

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