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

Digital sections and digital line system – Digital line
systems

Optical transport network physical layer interfaces

CAUTION !

PREPUBLISHED RECOMMENDATION

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Recommendation ITU-T G.959.1

Optical transport network physical layer interfaces

Summary

Recommendation ITU-T G.959.1 provides physical layer inter-domain interface (IrDI) specifications for optical networks which may employ wavelength division multiplexing (WDM). The IrDIs within the optical transport network (OTN) are provided by unidirectional, point-to-point, single and multichannel line systems. Their primary purpose is to enable transversely compatible interfaces to span the boundary between two administrative domains. The IrDI specifications include intra-office, short-haul and long-haul applications, without line amplifiers.

This version of this Recommendation includes multichannel interfaces suitable for FOIC2.4 (200G striped across four physical lanes) and FOIC4.8 (400G striped across eight physical lanes).

Recommendation ITU-T G.959.1

Optical transport network physical layer interfaces

1 Scope

This Recommendation provides physical layer inter-domain interface (IrDI) specifications for optical networks that may employ wavelength division multiplexing (WDM). These interfaces may also be employed, where appropriate, as intra-domain interfaces (IaDI). The physical layer specifications are valid for non-optical transport network (non-OTN) IrDIs, while also allowing application on OTN IrDIs according to [ITU-T G.709]. In the case of a non-OTN IrDI, OTN management capabilities are not required. The IrDIs within the optical transport network (OTN) are provided by unidirectional, point-to-point, single and multichannel line systems. Their primary purpose is to enable transversely compatible interfaces to span the boundary between two administrative domains. The IrDI specifications include intra-office, short-haul and long-haul applications, without line amplifiers.

NOTE – For the purposes of this Recommendation, the term "administrative domain" is understood to mean the extent of resources that belong to a single player, such as a network operator, a service provider or an end-user. Administrative domains of different players do not overlap among themselves.

The specifications are organized according to application codes that take into account the many possible combinations of channel counts, optical tributary signal types, span distances, fibre types and system configurations. The reference configuration and application codes form the foundation for specifying the optical networking physical layer parameters.

In this Recommendation, the use of an optical supervisory channel has not been considered (except for the discussion in Appendix IV). Future versions and other new ITU-T Recommendations will further address this aspect of the OTN, possibly involving an arrangement of optical network elements on either side of an optical subnetwork interface that is more complex than point-to-point. For these applications, different parameters beyond those specified for a point-to-point configuration may be required.

This Recommendation presumes that the optical tributary signals transported within network media channels are digital rather than analogue. Specifications for systems enabling transport of analogue optical tributary signals are for further study.

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 (2016), <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), *Optical safety procedures and requirements for optical transport systems.*
- [ITU-T G.691] Recommendation ITU-T G.691 (2006), *Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers.*
- [ITU-T G.692] Recommendation ITU-T G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers.*
- [ITU-T G.693] Recommendation ITU-T G.693 (2009), *Optical interfaces for intra-office systems.*
- [ITU-T G.694.1] Recommendation ITU-T G.694.1 (2012), *Spectral grids for WDM applications: DWDM frequency grid.*
- [ITU-T G.695] Recommendation ITU-T G.695 (2015), *Optical interfaces for coarse wavelength division multiplexing applications.*
- [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.709.1] Recommendation ITU-T G.709.1/Y.1331.1 (2018), *Flexible OTN short-reach interface.*
- [ITU-T G.870] Recommendation ITU-T G.870/Y.1352 (2016), *Terms and definitions for optical transport networks.*
- [ITU-T G.872] Recommendation ITU-T G.872 (2017), *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.8251] Recommendation ITU-T G.8251 (2010), *The control of jitter and wander within the optical transport network (OTN).*
- [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).*
- [IEEE 802.3bs] IEEE Std 802.3bs-2017, *Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200 Gb/s and 400 Gb/s Operation.*

3 Terms and definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 completely standardized OTUk (OTUk): [ITU-T G.709].

3.1.2 network media channel: [ITU-T G.870].

3.1.3 optical multiplex section (OMS): Clause 8.2 of [ITU-T G.872].

3.1.4 optical supervisory channel (OSC): [ITU-T G.692].

3.1.5 optical transmission section (OTS): Clause 8.3 of [ITU-T G.872].

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 inter-domain interface (IrDI): A physical interface that represents the boundary between two administrative domains.

3.2.2 intra-domain interface (IaDI): A physical interface within an administrative domain.

3.2.3 non-optical transport network (non-OTN): Systems not compliant with the suite of OTN Recommendations indicated in [b-ITU-T G.871]. In particular, non-OTN systems may rely on client-specific overhead information for performance monitoring, management and protection switching or restoration of the single-channel client signals.

3.2.4 optical tributary signal (OTSi): Optical signal that is placed within a network media channel for transport across the optical network. This may consist of a single modulated optical carrier or a group of modulated optical carriers or subcarriers.

3.2.5 optical tributary signal class NRZ 1.25G: A class of continuous digital signals with non-return to zero (NRZ) line coding, from nominally 622 Mbit/s to nominally 1.25 Gbit/s. Optical tributary signal class NRZ 1.25G includes a signal with STM-4 bit rate according to [ITU-T G.707].

3.2.6 optical tributary signal class NRZ 2.5G: A class of continuous digital signals with non-return to zero (NRZ) line coding, from nominally 622 Mbit/s to nominally 2.67 Gbit/s. Optical tributary signal class NRZ 2.5G includes a signal with STM-16 bit rate according to [ITU-T G.707] and OTU1 bit rate according to [ITU-T G.709].

3.2.7 optical tributary signal class NRZ 10G: A class of continuous digital signals with non-return to zero (NRZ) 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].

3.2.8 optical tributary signal class NRZ 25G: A class of continuous digital signals with non-return to zero (NRZ) line coding, from nominally 9.9 Gbit/s to nominally 28 Gbit/s. Optical tributary signal class NRZ 25G includes a signal with OTL4.4 bit rate (OTU4 striped across four physical lanes) according to [ITU-T G.709] and FOIC1.4-RS lane rate according to [ITU-T G.709.1].

3.2.9 optical tributary signal class NRZ 40G: A class of continuous digital signals with non-return to zero (NRZ) line coding, from nominally 9.9 Gbit/s to nominally 43.02 Gbit/s. Optical tributary signal class NRZ 40G includes a signal with STM-256 bit rate according to [ITU-T G.707] and OTU3 bit rate according to [ITU-T G.709].

3.2.10 optical tributary signal class RZ 40G: A class of continuous digital signals with return to zero (RZ) line coding, from nominally 9.9 Gbit/s to nominally 43.02 Gbit/s. Optical tributary signal class RZ 40G includes a signal with STM-256 bit rate according to [ITU-T G.707] and OTU3 bit rate according to [ITU-T G.709].

3.2.11 optical tributary signal class PAM4 50G: A class of continuous digital signals with PAM4 line coding, from nominally 53.1 Gbit/s to nominally 55.91 Gbit/s. Optical tributary signal class PAM4 50G includes a signal with FOIC2.4 and FOIC4.8 lane rate according to [ITU-T G.709.1].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

2R	Re-amplification, Reshaping
3R	Re-amplification, Reshaping, Retiming

APD	Avalanche Photodiode
BER	Bit Error Ratio
DC	Dispersion Compensation
DGD	Differential Group Delay
DWDM	Dense Wavelength Division Multiplexing
ER	Extinction ratio
FEC	Forward Error Correction
FFS	For Further Study
FWHM	Full Width at Half-Maximum
IaDI	Intra-Domain Interface
IrDI	Inter-Domain Interface
MLM	Multi-Longitudinal Mode
MPI-R	single-channel Receive Main Path Interface
MPI-R _M	Multichannel Receive Main Path Interface
MPI-S	single-channel Source Main Path Interface
MPI-S _M	Multichannel Source Main Path Interface
NA	Not Applicable
NE	Network Element
NRZ	Non-Return to Zero
OA	Optical Amplifier
OADM	Optical Add-Drop Multiplexer
OD	Optical Demultiplexer
OEO	Optical-to-Electrical-to-Optical
OM	Optical Multiplexer
OMA _{outer}	Optical Modulation Amplitude (between the outer levels for PAM4)
OMS	Optical Multiplex Section
ONE	Optical Network Element
OSC	Optical Supervisory Channel
OTL	Optical channel Transport Lane
OTN	Optical Transport Network
OTS	Optical Transmission Section
OTSi	Optical Tributary Signal
OTU _k	Optical channel Transport Unit – k
PAM4	Pulse Amplitude Modulation with 4 levels
PIN	P-type-Intrinsic-N-type
PMD	Polarization Mode Dispersion
R _M	Multichannel Receive

RMS	Root Mean Square
R _S	Single-channel Receive
RS-M	Single-channel (to Multichannel) Receive
RZ	Return to Zero
SDH	Synchronous Digital Hierarchy
SECQ	Stressed Eye Closure for PAM4
SLM	Single-Longitudinal Mode
S _M	Multichannel Source
S _{M-S}	Single-channel (from Multichannel) Source
SONET	Synchronous Optical Network
S _S	Single-channel Source
TDECQ	Transmitter and Dispersion Eye Closure for PAM4
WDM	Wavelength Division Multiplexing

5 Classification of optical interfaces

5.1 Applications

This Recommendation addresses single and multichannel optical systems and provides optical interface parameters and values for a range of inter-domain interface applications.

The majority of the application codes in this Recommendation apply to a range of optical tributary signals with bit rates within the relevant optical tributary signal class (these are termed "plural" application codes and contain the letter P). For example, the code P1I1-2D2 applies to a signal with an STM-64 bit rate according to [ITU-T G.707] and also to a signal with an OTU2 bit rate according to [ITU-T G.709].

As described in [ITU-T G.872], a standardized interconnection is required for interconnecting administrative domains in a point-to-point configuration.

Interworking between different administrative domains also requires the specification of the characteristic information that is transferred across the inter-domain interface (IrDI) as described in [ITU-T G.707] and [ITU-T G.709] or other specifications. The definition of this characteristic information, which includes signal bit rate, format and byte assignment, is outside the scope of this Recommendation.

From the transmission viewpoint, an optical link shows analogue behaviour (e.g., the optical transmission impairments due to attenuation, dispersion, fibre non-linearity, amplified spontaneous emission, etc., accumulate in a manner similar to the accumulation of noise and other impairments in analogue networks). Within digital networks, mitigation of such impairments is achieved at 3R regeneration points, located in the transmission path according to engineering guidelines designed to achieve the required link error performance objective. Similarly, within the OTN, 3R regeneration is required at certain locations to maintain the OTN error performance objectives. Currently, the 3R process typically relies on electro-optic conversion. The use of 2R regeneration, as an alternative solution to 3R regeneration for particular applications in IrDIs, is left for further study. The use of all-optical 2R/3R regeneration is also for further study.

The IrDI may be realized as either a single-channel interface or a multichannel interface. Multichannel IrDIs require additional wavelength multiplexing and demultiplexing equipment, and possibly optical amplifiers, but use fewer fibres as compared with multiple single-channel IrDIs

having equivalent capacity. Figure 5-6 indicates a single-channel IrDI. Figures 5-3, 5-4 and 5-5 indicate three types of multichannel IrDI.

This Recommendation provides the physical layer parameters and values for application codes corresponding both to the single-channel and multichannel IrDIs with 3R regenerators on both sides of the interface as shown in Figures 5-3, 5-4, 5-5 and 5-6.

The specification method used in this Recommendation is a "black-box" approach, which means that within the scope of this Recommendation, only the optical interfaces to the IrDI are specified. It is not intended to restrict or specify the internal elements 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.

Specifications are given for single-channel inter-domain interfaces with the following characteristics: channel bit rates corresponding to NRZ 2.5G, NRZ 10G, NRZ 25G, NRZ 40G and PAM4 50G, intra-office, short-haul and long-haul span distances, and unidirectional transmission. In the future, specifications are also anticipated for single-channel IrDIs with a bit rate/line coding of RZ 40G. Information concerning these possible future applications can be found in Appendix VI.

Appendix I contains a further description of single-channel client interfaces.

Specifications are also given for a multichannel inter-domain interface. This interface accommodates up to 32 channels with central frequencies conforming to the ITU-T G.694.1 grid, with channel bit rates corresponding to NRZ 2.5G and NRZ 10G, intra-office and short-haul (40 km) optical multiplex section single span distances, unidirectional transmission, and point-to-point configuration.

In the future, specifications are anticipated for a further multichannel application. It accommodates up to 32 channels with central frequencies conforming to the ITU-T G.694.1 grid, with channel bit rates corresponding to NRZ 2.5G and NRZ 10G, a long-haul (80 km) optical multiplex section span distance without line amplifiers, unidirectional transmission and point-to-point configuration.

5.2 Reference points

A set of "generic" reference points for optical network elements (ONEs) in the future OTN can be found in Appendix II.

For the purpose of this Recommendation, the relevant reference points applicable to the multichannel IrDI and the single-channel IrDI are shown in Figures 5-1 and 5-2, respectively.

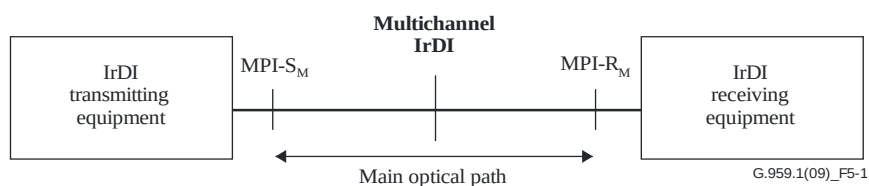


Figure 5-1 – Multichannel IrDI reference configuration

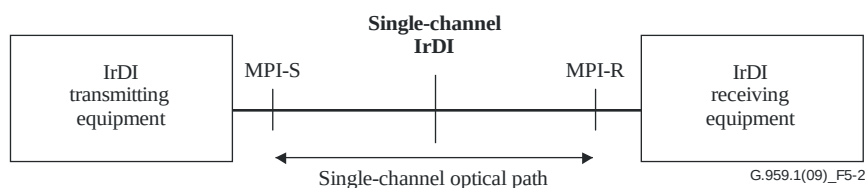


Figure 5-2 – Single-channel IrDI reference configuration

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

- MPI-S is a (single-channel) reference point just after each of the optical network element tributary interface output optical connectors.
- MPI-R is a (single-channel) reference point on the optical fibre just before each of the optical network element tributary interface input optical connectors.
- MPI-S_M is a (multichannel) reference point on the optical fibre just after the optical network element transport interface output optical connector.
- MPI-R_M is a (multichannel) reference point on the optical fibre just before the optical network element transport interface input optical connector.

A clarification of the use of the set of generic reference points that apply to both the IrDI and IaDI is given in Appendix III.

5.3 Nomenclature

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

The application code notation is constructed as follows:

PnWx-ytz

where:

- P when present, indicates a plural application code applying to an IrDI. Plural codes apply to any optical tributary signal within the defined class.
- n is the maximum number of channels supported by the application code.
- W is a letter indicating the span distance/attenuation, such as:
 - R indicating very short reach (up to 4 dB span attenuation);
 - I indicating intra-office (up to 7 dB span attenuation);
 - S indicating short-haul (11 dB span attenuation);
 - L indicating long-haul (22 dB span attenuation);
 - V indicating very long-haul (33 dB span attenuation);
 - U indicating ultra-long-haul (44 dB span attenuation).
- x is the maximum number of spans allowed within the application code.
- y indicates the highest class of optical tributary signal supported:
 - 1 indicating NRZ 2.5G;
 - 2 indicating NRZ 10G;
 - 9 indicating NRZ 25G;
 - 3 indicating NRZ 40G;
 - 7 indicating RZ 40G;
 - 4 indicating PAM4 50G.
 - Appendix V contains an explanation of how these numbers have been allocated.
- t is a letter indicating power level assumptions for the application code, such as:
 - A indicating power levels suitable for a booster amplifier in the originating optical network element (ONE) and power levels suitable for a pre-amplifier in the terminating ONE;
 - B indicating power levels suitable for a booster amplifier only are used;
 - C indicating power levels suitable for a pre-amplifier only are used;

- D indicating power levels suitable for operation with no amplifiers are used.
- z is the source and fibre type, as follows:
 - 1 indicating nominally 1 310 nm sources on ITU-T G.652 fibre;
 - 2 indicating nominally 1 550 nm sources on ITU-T G.652 fibre;
 - 3 indicating nominally 1 550 nm sources on ITU-T G.653 fibre;
 - 5 indicating nominally 1 550 nm sources on ITU-T G.655 fibre.

In this version of this Recommendation, only physical parameter values of single span IrDIs (i.e., for x = 1) have been defined.

A bidirectional system, if introduced, will be indicated by the addition of the letter B at the front of the application code. For an OTN application this would be:

BnWx-ytz

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

- F to indicate that this application requires forward error correction (FEC) bytes as specified in [ITU-T G.709] or [ITU-T G.709.1] as indicated for the application code to be transmitted.
- D to indicate that this application includes adaptive dispersion compensation.
- E to indicate that this application requires the use of a receiver which is capable of dispersion compensation.
NOTE – This may be electronic dispersion compensation.
- r to indicate a reduced target distance. These application codes are dispersion limited. The same target distances can also be achieved by means of other technical solutions, which are for further study (e.g., parallel interface approach).
- a to indicate that this code has transmitter power levels appropriate to avalanche photodiode (APD) receivers.
- b to indicate that this code has transmitter power levels appropriate to p-type-intrinsic-n-type (PIN) receivers.

This notation level may have to be augmented when other architectural and implementation alternatives are identified. Table 5-1 provides examples of application codes.

Table 5-1 – Application code examples

Example application code	Plural code?	Maximum number of channels	Maximum span attenuation	Maximum number of spans	Highest class of optical tributary signal	Power levels suitable for ONE type	Fibre type
P1I1-1D1	Yes	1	6 dB	1	NRZ 2.5G	No amplifiers	ITU-T G.652
P16S1-2C5	Yes	16	11 dB	1	NRZ 10G	Pre-amplifier only	ITU-T G.655
16S1-2B5	No	16	11 dB	1	NRZ 10G (OTU2)	Booster only	ITU-T G.655

5.4 Multichannel inter-domain interfaces

The multichannel IrDI interfaces in this Recommendation are intended to enable transverse (multi-vendor) compatibility. These interfaces may operate on ITU-T G.652, ITU-T G.653 or ITU-T G.655 fibre, simultaneously transporting up to 32 optical tributary signals (OTSis), using one of NRZ 2.5G, NRZ 10G or NRZ 25G optical tributary signal classes, depending on the particular application code. The same optical parameters apply to all the application codes listed in each individual column of Tables 8-1 to 8-5.

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

Tables 5-2 to 5-4 summarize the multichannel IrDI application codes, which are structured according to the nomenclature in clause 5.3.

Table 5-2 – Classification of multichannel inter-domain interfaces for intra-office applications

Application	Intra-office (I and R)				
Source nominal wavelength (nm)	1310 (ITU-T G.694.1 grid) (Note 2)		1550 (ITU-T G.694.1 grid) (Note 2)		
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.652	ITU-T G.653	ITU-T G.655
Target distance (km) (Note 1)	2	10	20	2	20
Optical tributary signal class NRZ 2.5G	–	–	–	–	–
Parameters given in:	–	–	–	–	–
Optical tributary signal class NRZ 10G	–	P4I1-2D1 4I1-2D1F	P16I1-2D2 P32I1-2D2	P16I1-2D3	P16I1-2D5 P32I1-2D5
Parameters given in:	–	[ITU-T G.695]	Table 8-2	Table 8-2	Table 8-2
As code:	–	C4S1-2D1	–	–	–
Optical tributary signal class NRZ 25G	–	4I1-9D1F	–	–	–
Parameters given in:	–	Table 8-5	–	–	–
Optical tributary signal class PAM4 50G	8R1-4D1F	4I1-4D1F 8I1-4D1F	–	–	–
Parameters given in:	Table 8-6	Table 8-6	–	–	–
NOTE 1 – These target distances are for classification and not for specification.					
NOTE 2 – See Table 8-2, 8-5 or 8-6.					

Table 5-3 – Classification of multichannel inter-domain interfaces for short-haul applications

Application	Short-haul (S)		
Source nominal wavelength (nm)	1 550 (ITU-T G.694.1 grid) (Note 2)		
Type of fibre	ITU-T G.652	ITU-T G.653	ITU-T G.655
Target distance (km) (Note 1)	40	40	40
Optical tributary signal class NRZ 2.5G	P16S1-1D2 P32S1-1D2	–	P16S1-1D5 P32S1-1D5
Parameters given in:	Table 8-1	–	Table 8-1

Optical tributary signal class NRZ 10G	P16S1-2B2 P16S1-2C2 P32S1-2B2 P32S1-2C2	P16S1-2C3	P16S1-2B5 P16S1-2C5 P32S1-2B5 P32S1-2C5
Parameters given in:	Table 8-3	Table 8-3	Table 8-3
NOTE 1 – These target distances are for classification and not for specification. NOTE 2 – See Table 8-1 or 8-3.			

Table 5-4 – Classification of multichannel inter-domain interfaces for long-haul applications

Application	Long-haul (L)		
Source nominal wavelength (nm)	1310 (ITU-T G.694.1 grid) (Note 2)	1550 (ITU-T G.694.1 grid) (Note 2)	
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.655
Target distance (km) (Note 1)	40	80	80
Optical tributary signal class NRZ 2.5G	–	P16L1-1A2	P16L1-1A5
Parameters given in:	–	Table 8-4	Table 8-4
Optical tributary signal class NRZ 10G	–	P16L1-2A2	P16L1-2A5
Parameters given in:	–	Table 8-4	Table 8-4
Optical tributary signal class NRZ 25G	4L1-9C1F 4L1-9D1F	–	–
Parameters given in:	Table 8-5	–	–
NOTE 1 – These target distances are for classification and not for specification. NOTE 2 – See Table 8-4 or 8-5.			

Applications with power levels appropriate to pre-amplifiers only contain the letter C in the application code and are illustrated in Figure 5-3.

Applications with power levels appropriate to booster amplifiers only contain the letter B in the application code and are illustrated in Figure 5-4.

Applications with power levels suitable for operation with no amplifiers contain the letter D in the application code and are illustrated in Figure 5-5.

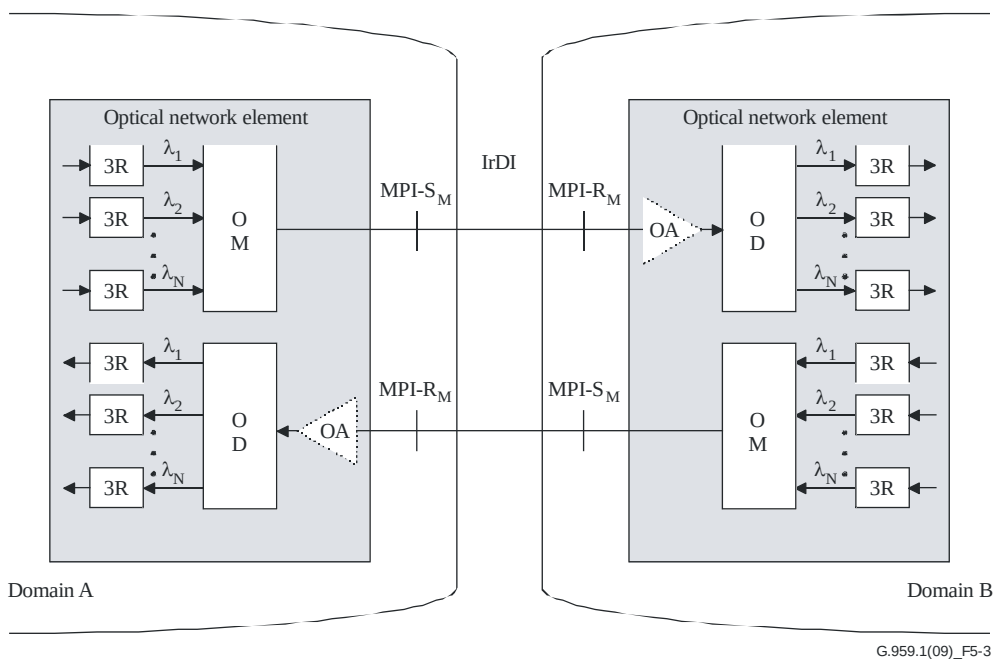


Figure 5-3 – Multichannel IrDI applications using pre-amplifiers

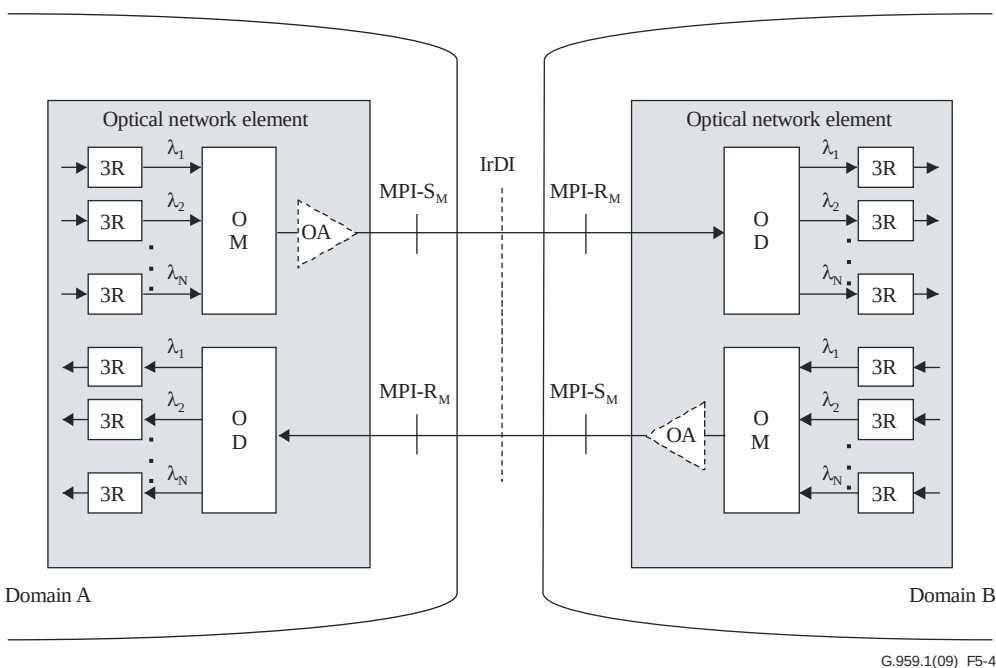


Figure 5-4 – Multichannel IrDI applications using booster amplifiers

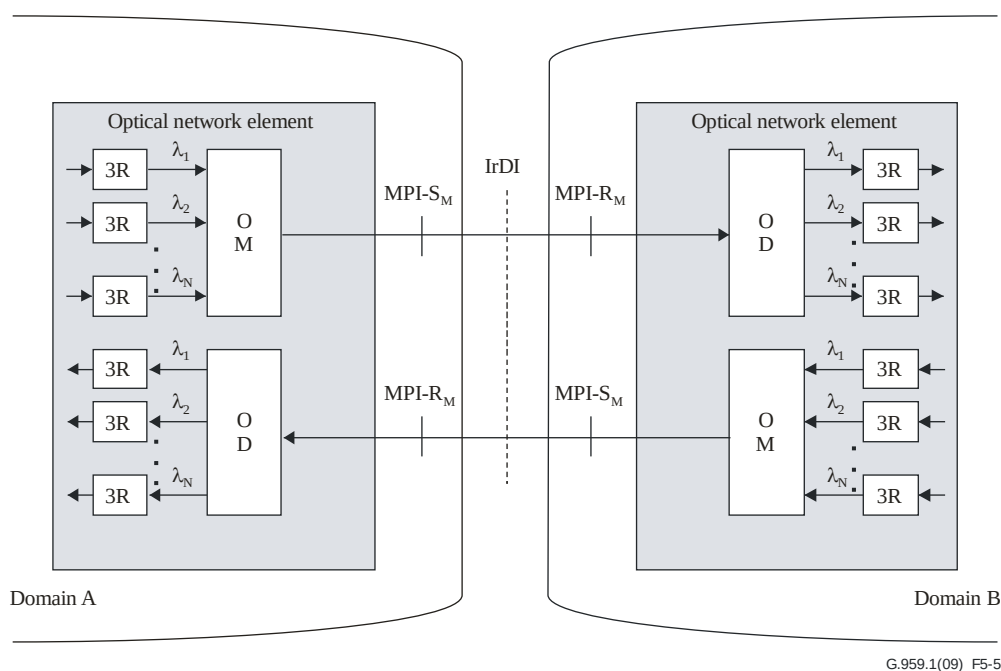


Figure 5-5 – Non-amplified multichannel IrDI applications

5.5 Single-channel inter-domain interfaces

Single-channel inter-domain interfaces are illustrated in Figure 5-6.

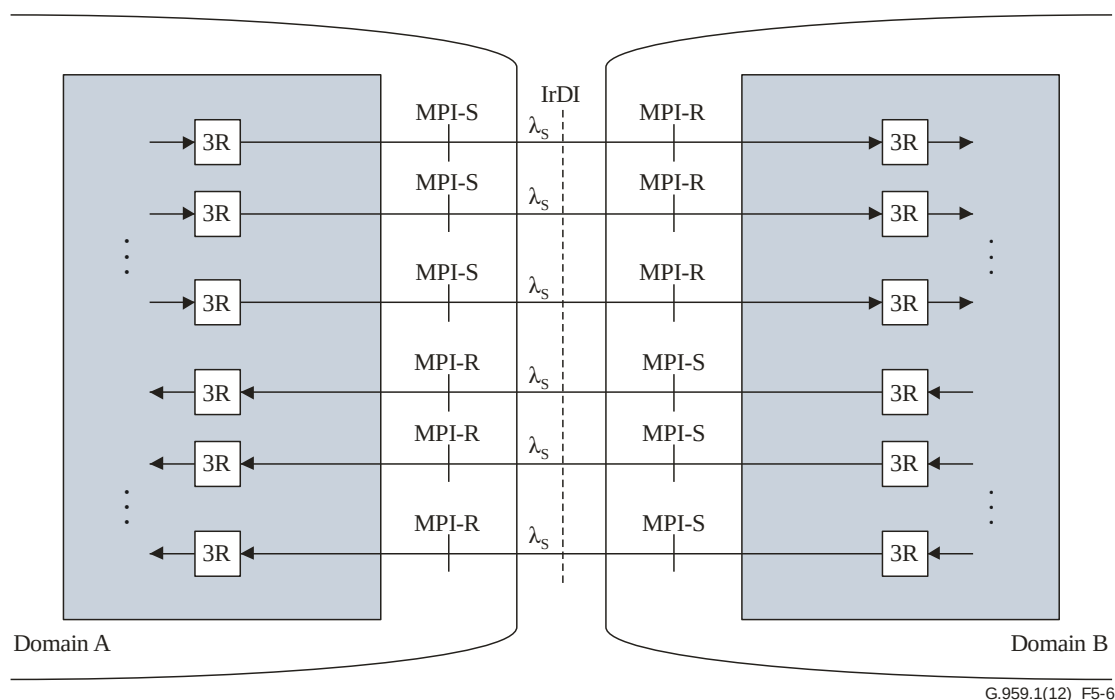


Figure 5-6 – Single-channel IrDI applications

These interfaces are intended to enable transverse (multi-vendor) compatibility and may operate on ITU-T G.652, ITU-T G.653 or ITU-T G.655 fibres using either NRZ 2.5G, NRZ 10G or NRZ 40G optical tributary signals, depending on the particular application code.

The applications do not cover all possible combinations of distance category, optical tributary signal class, nominal source wavelength and fibre type. The included applications are intended to satisfy a broad range of network requirements with low-cost implementations. Tables 5-5 to 5-9 summarize

the single-channel IrDI application codes, which are structured according to the nomenclature in clause 5.3.

Parameter values for intra-office, short-haul, long-haul, very long-haul and ultra-long-haul applications are given in clause 8.2. For optical tributary signal class NRZ 2.5G applications, in most instances the values in clause 8.2 are similar to or the same as values for applications found in [ITU-T G.957], except that the ITU-T G.957 values have been modified, where necessary, to achieve a bit error ratio (BER) of less than or equal to 10^{-12} . For optical tributary signal class NRZ 10G applications, in most instances the values in clause 8.2 are the same as values for applications previously found in [ITU-T G.691].

**Table 5-5 – Classification of single-channel inter-domain interfaces
for intra-office applications**

Application	Intra-office (I)					
Source nominal wavelength (nm)	1 310		1 550			
Type of fibre	ITU-T G.652		ITU-T G.652		ITU-T G.653	ITU-T G.655
Optical tributary signal class NRZ 2.5G	–	P1I1-1D1	–	–	–	–
Target distance for class NRZ 2.5G (km) (Note 1)	–	2	–	–	–	–
Parameters given in:	–	Table 8-7	–	–	–	–
Optical tributary signal class NRZ 10G	P1I1-2D1r	P1I1-2D1	P1I1-2D2r	P1I1-2D2	P1I1-2D3	P1I1-2D5
Target distance for class NRZ 10G (km) (Note 1)	0.6	2	2	25	25	25
Parameters given in:	[ITU-T G.693] (Note 2)	[ITU-T G.693] (Note 2)	[ITU-T G.693] (Note 2)	Table 8-10	Table 8-10	Table 8-10
As code:	VSR600-2R1	VSR2000-2R1	VSR2000-2L2			
Optical tributary signal class NRZ 40G	–	P1I1-3D1 1I1-3D1F			P1I1-3D3	P1I1-3D5
Target distance for class NRZ 40G (km) (Note 1)	–	10			10	5 (Note 3)
Parameters given in:	–	Table 8-16			Table 8-16	Table 8-16
NOTE 1 – These target distances are for classification and not for specification.						
NOTE 2 – These applications (which were specified in a previous version of this Recommendation) are now contained in [ITU-T G.693].						
NOTE 3 – This is for ITU-T G.655.D fibre. If ITU-T G.655.E fibre is used then the target distance is reduced.						

**Table 5-6 – Classification of single-channel inter-domain interfaces
for short-haul applications**

Application	Short-haul (S)			
Source nominal wavelength (nm)	1 310	1 550		
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.653	ITU-T G.655
Optical tributary signal class NRZ 2.5G	P1S1-1D1	P1S1-1D2	–	–
Target distance for class NRZ 2.5G (km) (Note ¹)	20	40	–	–
Parameters given in:	Table 8-7	Table 8-7	–	–
Optical tributary signal class NRZ 10G	P1S1-2D1	P1S1-2D2a,b 1S1-2D2bF	P1S1-2D3a,b 1S1-2D3bF	P1S1-2D5a,b 1S1-2D5bF
Target distance for class NRZ 10G (km) (Note ¹)	20	40	40	40
Parameters given in:	Table 8-11	Table 8-11	Table 8-12	Table 8-12
Optical tributary signal class NRZ 40G	P1S1-3D1 1S1-3D1F	P1S1-3C2	P1S1-3C3	P1S1-3C5
Target distance for class NRZ 40G (km) (Note ¹)	20	40	40	40
Parameters given in:	Table 8-17	Table 8-18	Table 8-18	Table 8-18
NOTE – These target distances are for classification and not for specification.				

**Table 5-7 – Classification of single-channel inter-domain interfaces
for long-haul applications**

Application	Long-haul (L)			
Source nominal wavelength (nm)	1 310	1 550		
Type of fibre	ITU-T G.652	ITU-T G.652	ITU-T G.653	ITU-T G.655
Optical tributary signal class NRZ 2.5G	P1L1-1D1	P1L1-1D2 1L1-1D2F	–	–
Target distance for class NRZ 2.5G (km) (Note)	40	80	–	–
Parameters given in:	Table 8-8	Table 8-8	–	–
Optical tributary signal class NRZ 10G	P1L1-2D1	P1L1-2D2 1L1-2D2F P1L1-2D2E 1L1-2D2FE		
Target distance for class NRZ 10G (km) (Note)	40	80		
Parameters given in:	Table 8-13	Table 8-13 Table VII.1		

Table 5-7 – Classification of single-channel inter-domain interfaces for long-haul applications

Application	Long-haul (L)			
Optical tributary signal class NRZ 40G	P1L1-3C1 1L1-3C1F	P1L1-3A2 1L1-3C2F 1L1-3C2FD	P1L1-3A3 1L1-3C3F 1L1-3C3FD	P1L1-3A5 1L1-3C5F 1L1-3C5FD
Target distance for class NRZ 40G (km) (Note)	40	80	80	80
Parameters given in:	Table 8-17	Table 8-18	Table 8-18	Table 8-18
Optical tributary signal class RZ 40G	–	P1L1-7A2	P1L1-7A3	P1L1-7A5
Target distance for class RZ 40G (km) (Note)	–	80	80	80
Parameters given in:	–	Table VI.1	Table VI.1	Table VI.1
NOTE – These target distances are for classification and not for specification.				

Table 5-8 – Classification of single-channel inter-domain interfaces for very long-haul applications

Application	Very long-haul (V)		
Source nominal wavelength (nm)	1 550		
Type of fibre	ITU-T G.652	ITU-T G.653	ITU-T G.655
Optical tributary signal class NRZ 10G	P1V1-2C2 1V1-2C2F P1V1-2B2E 1V1-2B2FE	–	P1V1-2B5 1V1-2B5F
Target distance for class NRZ 10G (km) (Note)	120	–	120
Parameters given in:	Table 8-14 Table VII.1	–	Table 8-14
NOTE – These target distances are for classification and not for specification.			

Table 5-9 – Classification of single-channel inter-domain interfaces for ultra-long-haul applications

Application	Ultra-long-haul (U)		
Source nominal wavelength (nm)	1 550		
Type of fibre	ITU-T G.652	ITU-T G.653	ITU-T G.655
Optical tributary signal class NRZ 2.5G	P1U1-1A2 1U1-1B2F	P1U1-1A3 1U1-1B3F	P1U1-1A5 1U1-1B5F
Target distance for class NRZ 2.5G (km) (Note)	160	160	160
Parameters given in:	Table 8-9	Table 8-9	Table 8-9
NOTE – These target distances are for classification and not for specification.			

5.6 Management signal implementations

Although no overhead implementation is required of the current IrDI, the need for signals to manage the OTSIs, as well as the optical multiplex section (OMS) and optical transmission section

(OTS) is foreseen for future OTN realization. Considerations of physical implementations of such signals are presented in Appendix IV.

6 Transverse compatibility

The goal for the IrDI in this Recommendation is to specify parameters in order to enable transverse (i.e., multi-vendor) compatible line systems for short-haul and long-haul point-to-point applications.

Inter-domain interfaces are intended to interconnect two different administrative domains. Such domains may consist of equipment from two different vendors. The two administrative domains may also belong to two different network operators.

- Transverse (multi-vendor) compatibility is enabled for all IrDIs having exactly the same application code nWx-ytz. As an example, a P16S1-2B2 interface from one vendor, implemented in domain A, can be connected with a P16S1-2B2 interface of another vendor, installed in domain B. Care must also be taken to match the optical tributary signal bit rate and format.
- Interconnection of 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 power levels, maximum dispersion and minimum or maximum attenuation. As an example, an interface P16S1-2B2 (booster amplifier power levels) in domain A should not be interconnected with an interface P16S1-2C2 (pre-amplifier power levels) in domain B without additional measures, e.g., adding an attenuator. In this example, the booster amplifier type interface output power may be +15 dBm (see Table 8-3) and the attenuation may be 0 dB. Thus, the input power to the pre-amplifier type interface is +15 dBm. However, the maximum receiver input power of the pre-amplifier type interface must not exceed +5 dBm (see Table 8-3) and the receiver is overloaded by up to 10 dB. Care must also be taken to match the optical tributary signal bit rate and format.

7 Parameter definitions

7.1 System operating wavelength range

The operating wavelength ranges for multichannel applications within this Recommendation are not necessarily restricted to those found within [ITU-T G.692]. Specifically, operating wavelength ranges may exceed those found in [ITU-T G.692] (e.g., 1 525–1 625 nm).

In addition, future use of the 1 285–1 330 nm amplification range should not be precluded.

The operating wavelength ranges for single-channel applications within this Recommendation are not necessarily restricted to those found within [ITU-T G.957] or [ITU-T G.691].

7.2 Parameters

The parameters in Table 7-1 are defined at the interface points. The parameter definitions are provided in clauses 7.2.1 to 7.2.4.

Table 7-1 – Physical layer parameters for single-channel and multichannel IrDIs

Parameter	Units	For Tables 8-1 to 8-5 specified in:	For Table 8-6 specified in:	For Tables 8-7 to 8-17 specified in:	For Table 8-18 specified in:	For Table VI.1 specified in:
General information						
Maximum number of channels	–	7.2.1.1	7.2.1.1	7.2.1.1	7.2.1.1	7.2.1.1
Bit rate/line coding of optical tributary signals	–	7.2.1.2	7.2.1.2	7.2.1.2	7.2.1.2	7.2.1.2
Maximum bit error ratio	–	7.2.1.3	7.2.1.3	7.2.1.3	7.2.1.3	7.2.1.3
Fibre type	–	7.2.1.4	7.2.1.4	7.2.1.4	7.2.1.4	7.2.1.4
Interface at point MPI-S_M or MPI-S						
Maximum mean (channel) output power	dBm	7.2.2.1	7.2.2.1	7.2.2.1	7.2.2.1	7.2.2.1
Minimum mean (channel) output power	dBm	7.2.2.1	7.2.2.1	7.2.2.1	7.2.2.1	7.2.2.1
Maximum mean total output power	dBm	7.2.2.2	7.2.2.2	NA	NA	NA
Central frequency	THz	7.2.2.3	7.2.2.3	7.2.2.3	7.2.2.3	7.2.2.3
Channel spacing	GHz	7.2.2.4	7.2.2.4	NA	NA	NA
Maximum spectral excursion	GHz	7.2.2.5	7.2.2.5	7.2.2.5	7.2.2.5	7.2.2.5
Operating wavelength range	nm	NA	NA	7.2.2.6	NA	7.2.2.6
Source type		NA	NA	7.2.2.7	7.2.2.7	7.2.2.7
Maximum duty cycle	%	NA	NA	NA	NA	7.2.2.8
Minimum duty cycle	%	NA	NA	NA	NA	7.2.2.8
Maximum RMS width (σ)	nm	NA	NA	7.2.2.9	NA	NA
Maximum –20 dB width	nm	NA	NA	7.2.2.10	NA	NA
Maximum spectral power density	mW/ 10 MHz	NA	NA	7.2.2.11	7.2.2.11	7.2.2.11
Minimum side mode suppression ratio	dB	NA	NA	7.2.2.12	7.2.2.12	7.2.2.12
Minimum (channel) extinction ratio	dB	7.2.2.13	7.2.2.13	7.2.2.13	7.2.2.13	7.2.2.13
Eye mask	–	7.2.2.14	NA	7.2.2.14	7.2.2.14	7.2.2.15
Maximum channel output OMA _{outer}	dBm	NA	7.2.2.16	NA	NA	NA
Minimum channel output OMA _{outer}	dBm	NA	7.2.2.16	NA	NA	NA
Maximum TDECQ	dB	NA	7.2.2.17	NA	NA	NA
Minimum channel OMA _{outer} minus TDECQ	dBm	NA	7.2.2.18	NA	NA	NA
Optical path (single span) from point MPI-S_M to MPI-R_M, or MPI-S to MPI-R						
Maximum attenuation	dB	7.2.3.1	7.2.3.1	7.2.3.1	7.2.3.1	7.2.3.1
Minimum attenuation	dB	7.2.3.2	7.2.3.2	7.2.3.2	7.2.3.2	7.2.3.2

Table 7-1 – Physical layer parameters for single-channel and multichannel IrDIs

Parameter	Units	For Tables 8-1 to 8-5 specified in:	For Table 8-6 specified in:	For Tables 8-7 to 8-17 specified in:	For Table 8-18 specified in:	For Table VI.1 specified in:
Maximum chromatic dispersion at upper wavelength limit	ps/nm	7.2.3.3	7.2.3.3	7.2.3.3	7.2.3.3	7.2.3.3
Maximum chromatic dispersion at lower wavelength limit	ps/nm	7.2.3.3	7.2.3.3	7.2.3.3	7.2.3.3	7.2.3.3
Maximum chromatic dispersion deviation	ps/nm	NA	NA	NA	7.2.3.4	7.2.3.4
Minimum optical return loss at MPI-S _M or MPI-S	dB	7.2.3.5	7.2.3.5	7.2.3.5	7.2.3.5	7.2.3.5
Maximum discrete reflectance between MPI-S _M and MPI-R _M , or MPI-S and MPI-R	dB	7.2.3.6	7.2.3.6	7.2.3.6	7.2.3.6	7.2.3.6
Maximum differential group delay	ps	7.2.3.7	7.2.3.7	7.2.3.7	7.2.3.7	7.2.3.7
Interface at point MPI-R_M or MPI-R						
Maximum mean (channel) input power	dBm	7.2.4.1	7.2.4.1	7.2.4.1	7.2.4.1	7.2.4.1
Minimum mean channel input power	dBm	7.2.4.2	7.2.4.2	NA	NA	NA
Maximum mean total input power	dBm	7.2.4.3	7.2.4.3	NA	NA	NA
Maximum channel power difference	dB	7.2.4.4	7.2.4.4	NA	NA	NA
Maximum optical path penalty	dB	7.2.4.5	NA	7.2.4.5	7.2.4.5	7.2.4.5
Minimum equivalent sensitivity	dBm	7.2.4.6	NA	NA	NA	NA
Maximum reflectance of optical network element	dB	7.2.4.7	7.2.4.7	7.2.4.7	7.2.4.7	7.2.4.7
Minimum sensitivity	dBm	NA	NA	7.2.4.8	7.2.4.8	7.2.4.8
Maximum channel input OMA _{outer}	dBm	NA	7.2.4.9	NA	NA	NA
Minimum channel input OMA _{outer}	dBm	NA	7.2.4.9	NA	NA	NA
Maximum multi-path interference penalty allowance	dB	NA	7.2.4.10	NA	NA	NA
Minimum equivalent sensitivity (OMA _{outer} minus SECQ)	dBm	NA	7.2.4.11	NA	NA	NA
NA: not applicable; RMS: root mean square						

7.2.1 General information

7.2.1.1 Maximum number of channels

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

7.2.1.2 Bit rate/line coding of optical tributary signals

Optical tributary signal class NRZ 2.5G applies to continuous digital signals with non-return to zero (NRZ) 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 NRZ line coding, from nominally 2.4 Gbit/s to nominally 10.71 Gbit/s.

Optical tributary signal class NRZ 25G applies to continuous digital signals with NRZ line coding, from nominally 9.9 Gbit/s to nominally 28 Gbit/s.

Optical tributary signal class NRZ 40G applies to continuous digital signals with NRZ line coding, from nominally 9.9 Gbit/s to nominally 43.02 Gbit/s.

Optical tributary signal class RZ 40G applies to continuous digital signals with return to zero line coding, from nominally 9.9 Gbit/s to nominally 43.02 Gbit/s.

Optical tributary signal class PAM4 50G applies to continuous digital signals with PAM4 line coding, from nominally 53.1 Gbit/s to nominally 55.91 Gbit/s. The mapping from the input stream of bits to PAM4 optical symbols and back to the output stream of bits is performed according to 120.5.7, 122.5.2 and 122.5.3 of [IEEE 802.3bs].

For OTN optical tributary signals, NRZ 2.5G includes the OTU1 bit rate, NRZ 10G includes the OTU2 bit rate and both NRZ 40G and RZ 40G include the OTU3 bit rate defined in [ITU-T G.709].

For an application that has a P (for plural) at the beginning of the application code, the parameter values are the same for any bit rate within the range of the applicable optical tributary signal class. When an optical system uses one of these plural codes, therefore, it is necessary to specify both the application code and also the exact bit rate of the system. In other words, there is no requirement for equipment compliant with one of the plural codes to operate over the complete range of bit rates specified for its optical tributary signal class.

7.2.1.3 Maximum bit error ratio

The parameters are specified relative to an optical section design objective of a BER not worse than the value specified by the application code. This value applies to each OTSi under the extreme case of optical path attenuation and dispersion conditions in each application. In the case of application codes requiring FEC bytes to be transmitted (i.e., having a code with a suffix of F), the BER is required to be met only after the correction (if used) has been applied. For all other application codes, the BER is required to be met without the use of FEC.

Further information on BER in relation to FEC can be found in [b-ITU-T G-Sup.39].

7.2.1.4 Fibre type

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

7.2.2 Interface at point MPI-S_M or MPI-S

7.2.2.1 Maximum and minimum mean (channel) output power

The mean launched power of each OTSi at reference point MPI-S_M or MPI-S is the average power of a pseudo-random data sequence coupled into the fibre from the ONE. 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.

7.2.2.2 Maximum mean total output power

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

7.2.2.3 Central frequency

The nominal channel frequency on which the digital coded information of the particular OTSi is modulated by use of the NRZ line code, RZ line code or PAM4 line code.

The central frequencies are based on the frequency grid given in [ITU-T G.694.1]. The allowed central frequencies for the multichannel IrDI are specified in Tables 8-1 to 8-6.

Note that the value of c (speed of light in a vacuum) that should be used for converting between frequency and wavelength is $2.997\,924\,58 \times 10^8$ m/s.

7.2.2.4 Channel spacing

The channel spacing is defined to be the nominal difference in frequency between two adjacent channels. All possible tolerances of actual frequencies are considered in clause 7.2.2.5.

7.2.2.5 Maximum spectral excursion

This is the maximum acceptable difference between the nominal central frequency of the channel and the -15 dB points of the transmitter spectrum furthest from the nominal central frequency measured at point MPI-S_M. This is illustrated in Figure 7-1.

NOTE – The measurement of the -15 dB points of the transmitter spectrum should be performed with a nominal resolution bandwidth of 0.01 nm.

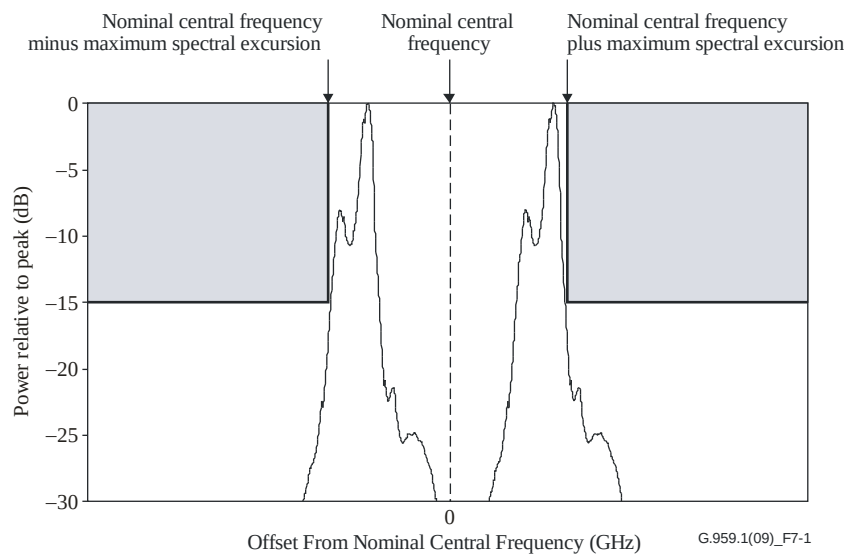


Figure 7-1 – Illustration of maximum spectral excursion

7.2.2.6 Operating wavelength range

The system operating wavelength range depends on the source characteristics, transmission fibre characteristics (attenuation, chromatic dispersion) and on the gain bandwidth of an optical amplifier (if used).

7.2.2.7 Source type

Depending on the attenuation and dispersion characteristics and hierarchical level of each application code, feasible transmitter devices include multi-longitudinal mode (MLM) lasers and single-longitudinal mode (SLM) lasers. For each of the applications, this Recommendation indicates a nominal source type. It is understood that the indication of a nominal source type in this Recommendation is not a requirement and that SLM devices can be substituted for any application showing MLM as the nominal source type without any degradation in system performance.

7.2.2.8 Maximum and minimum duty cycle

For further study.

7.2.2.9 Maximum RMS width

The maximum root-mean-square (RMS) width or the standard deviation σ (in nanometres) of the spectral distribution of an MLM laser considers all laser modes which are not more than 20 dB