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DIGITAL SYSTEMS AND NETWORKS

Transmission media and optical systems characteristics –  
Characteristics of optical systems

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## Optical interfaces for intra-office systems

Recommendation ITU-T G.693



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## **Recommendation ITU-T G.693**

### **Optical interfaces for intra-office systems**

#### **Summary**

Recommendation ITU-T G.693 provides parameters and values for optical interfaces of single channel intra-office systems of nominal 10 Gbit/s and 40 Gbit/s aggregate bit rate. Applications are specified with target distances of 0.6 and 2 km and various loss budgets for ITU-T G.652, ITU-T G.653 and ITU-T G.655 fibres. The latest version makes use of improved specifications for chromatic dispersion of these fibre types.

#### **Source**

Recommendation ITU-T G.693 was approved on 13 November 2009 by ITU-T Study Group 15 (2009-2012) under Recommendation ITU-T A.8 procedures.

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# Recommendation ITU-T G.693

## Optical interfaces for intra-office systems

### 1 Scope

The purpose of this Recommendation is to provide optical interface specifications to enable transverse (multivendor) compatibility of nominal 10 Gbit/s and 40 Gbit/s aggregate bit rate intra-office systems for link distances up to 2 km. This Recommendation defines links using optical fibres according to [ITU-T G.652], [ITU-T G.653] and [ITU-T G.655].

Parallel interface specifications may be included in future revisions.

### 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 (2005), *Characteristics of a single-mode optical fibre and cable*.
- [ITU-T G.653] Recommendation ITU-T G.653 (2006), *Characteristics of a dispersion-shifted single-mode optical fibre and cable*.
- [ITU-T G.655] Recommendation ITU-T G.655 (2006), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.
- [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.709] Recommendation ITU-T G.709/Y.1331 (2003), *Interfaces for the Optical Transport Network (OTN)*.
- [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 (2008), *Optical transport network physical layer interfaces*.
- [ITU-T G.8251] Recommendation ITU-T G.8251 (2001), *The control of jitter and wander within the optical transport network (OTN)*.

### 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 **optical tributary signal class NRZ 10G (NRZ 10G)**: [ITU-T G.959.1].
- 3.1.3 **optical tributary signal class NRZ 40G (NRZ 40G)**: [ITU-T G.959.1].

## 4 Abbreviations and acronyms

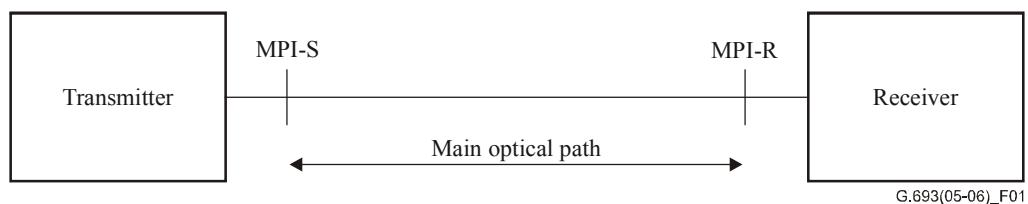
This Recommendation uses the following abbreviations and acronyms:

ASE	Amplified Spontaneous Emission
BER	Bit Error Ratio
DGD	Differential Group Delay
EX	Extinction ratio
FEC	Forward Error Correction
ffs	for further study
MLM	Multi-Longitudinal Mode
MPI	Main Path Interface
MPN	Mode Partition Noise
NA	Not Applicable
NRZ	Non-Return to Zero
ORL	Optical Return Loss
PMD	Polarization Mode Dispersion
PRBS	Pseudo-Random Binary Sequence
RMS	Root Mean Square
SDH	Synchronous Digital Hierarchy
SLM	Single-Longitudinal Mode
SMSR	Side Mode Suppression Ratio
VSR	Very Short Reach
WDM	Wavelength Division Multiplex

## 5 Classification of optical interfaces

### 5.1 Applications

This Recommendation defines optical interfaces for single-channel intra-office systems for link distances up to 2 km. These interface descriptions are intended to enable transverse (multivendor) compatibility. Figure 1 illustrates a system of the type considered in this Recommendation, and shows the reference points used to specify optical interface parameters.



NOTE – The main optical path includes fibre and connectors, and may include other passive optical devices such as photonic cross-connects.

**Figure 1 – Optical link example showing reference points defined in this Recommendation**

Parameters are specified for the transmitter at point MPI-S, for the receiver at point MPI-R, and for the main optical path between points MPI-S and MPI-R.

The main optical path for systems described in this Recommendation may include passive optical devices, e.g., photonic cross-connects, which introduce significant attenuation. Thus, values of maximum attenuation may not be inferred from the target distances of applications. In this Recommendation, attenuation categories are used to distinguish among applications which have the same source and fibre type and target distance, and are intended for the same signal class, but have different values of maximum attenuation. Four attenuation categories are defined with maximum attenuation values of 4 dB, 6 dB, 12 dB and 16 dB, respectively. A fifth category is defined (with a maximum attenuation value for further study) in case the maximum attenuation value provided by the H category is too low to cover all applications.

Appendix II shows examples of system configurations using applications defined in this Recommendation.

## 5.2 Nomenclature

Applications in this Recommendation are distinguished by application codes. Each code indicates the target distance, highest class of optical tributary signal supported, attenuation category and source and fibre type of the associated application.

Application codes have the following structure:

- W-yAz

where:

W indicates target distance:

- VSR600, VSR1000 and VSR2000, indicating target distances of 0.6 km, 1 km and 2 km, respectively.

y indicates highest class of optical tributary signal supported:

- 2 indicating NRZ 10G.
- 3 indicating NRZ 40G.

A indicates attenuation category:

- R indicating maximum attenuation of 4 dB.
- L indicating maximum attenuation of 6 dB.
- M indicating maximum attenuation of 12 dB.
- H indicating maximum attenuation of 16 dB.
- V indicating maximum attenuation of ffs dB.

The V category has been introduced in case the maximum attenuation value provided by the H category is too low to cover all applications.

z indicates the source and fibre type:

- 1 indicating nominally 1310 nm sources on ITU-T G.652 fibre;
- 2 indicating nominally 1550 nm sources on ITU-T G.652 fibre;
- 3 indicating nominally 1550 nm sources on ITU-T G.653 fibre;
- 5 indicating nominally 1550 nm sources on ITU-T G.655 fibre.

For some application codes, the suffix F is added at the end of the code, to indicate that this application requires FEC bytes as specified in [ITU-T G.709] to be transmitted.

Tables 1 and 2 summarize the application codes described in this Recommendation.

**Table 1 – Classification of optical interfaces with 0.6 km target distance**

Target distance <sup>a)</sup>	0.6 km		
Attenuation category <sup>a)</sup>	R	M	
Source nominal wavelength (nm)	1310	1310	1550
Type of fibre	ITU-T G.652	ITU-T G.652 ITU-T G.653 ITU-T G.655	ITU-T G.652 ITU-T G.653 ITU-T G.655
Application codes for optical tributary signal class NRZ 10G	VSR600-2R1	VSR600-2M1	VSR600-2M2 VSR600-2M3 VSR600-2M5
Application codes for optical tributary signal class NRZ 40G	–	–	–

<sup>a)</sup> Target distances and attenuation categories are for classification and not for specification.

**Table 2 – Classification of optical interfaces with 2 km target distance**

<b>Target distance<sup>a)</sup></b>	<b>2 km</b>						
	<b>R</b>		<b>L</b>		<b>M</b>		<b>H</b>
<b>Attenuation category<sup>a)</sup></b>	1310	1550	1310	1550	1310	1550	1550
Source nominal wavelength (nm)	1310	1550	1310	1550	1310	1550	1550
Type of fibre	ITU-T G.652	ITU-T G.652 ITU-T G.653 ITU-T G.655	ITU-T G.652	ITU-T G.652 ITU-T G.653 ITU-T G.655	ITU-T G.652	ITU-T G.652 ITU-T G.653 ITU-T G.655	ITU-T G.652 ITU-T G.653 ITU-T G.655
Application codes for optical tributary signal class NRZ 10G	VSR2000-2R1	–	VSR2000-2L1F	VSR2000-2L2 VSR2000-2L3 VSR2000-2L5	–	–	–
Application codes for optical tributary signal class NRZ 40G	VSR2000-3R1 VSR2000-3R1F	VSR2000-3R2 VSR2000-3R3 VSR2000-3R5 VSR2000-3R2F VSR2000-3R3F VSR2000-3R5F	VSR2000-3L1F	VSR2000-3L2F VSR2000-3L3F VSR2000-3L5F	VSR2000-3M1	VSR2000-3M2 VSR2000-3M3 VSR2000-3M5	VSR2000-3H2 VSR2000-3H3 VSR2000-3H5

<sup>a)</sup> Target distances and attenuation categories are for classification and not for specification.

## **6 Parameter definitions**

All parameter values are worst-case values, assumed to be met over the range of standard operating conditions (i.e., temperature and humidity ranges), and they include ageing effects. The parameters are specified relative to an optical section design objective of a bit error ratio (BER) not worse than  $10^{-12}$  for any combination of parameters within the ranges given in the tables for each specified system. Except for application codes requiring FEC bytes to be transmitted (i.e., having a code with a suffix of F), achieving this BER objective shall not require the application of forward error correction. In the case of application codes requiring FEC bytes to be transmitted, the BER is required to be met only after the correction (if used) has been applied.

The optical line coding used for system interfaces in this Recommendation is binary non-return to zero (NRZ).

### **6.1 System operating wavelength range**

The operating wavelength range is the maximum allowable range for the source wavelength. Within this range, the source wavelength can be selected for different fibre-related impairments. The receiver must have the minimum operating wavelength range that corresponds to the maximum allowable range for the source wavelength.

The operating wavelength range of fibre-optic transmission systems is basically determined by the attenuation and dispersion characteristics of the various fibre and source types. A detailed discussion of these aspects can be found in [ITU-T G.957].

NOTE – When a wavelength-fixed or tuneable filter to eliminate amplified spontaneous emission (ASE) is used before the receiver, the operating wavelength band may be limited, and the transverse compatibility may not be guaranteed.

### **6.2 Transmitter**

#### **6.2.1 Source type**

Depending on attenuation/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.

#### **6.2.2 Spectral characteristics**

##### **6.2.2.1 Maximum RMS width**

The maximum root mean square (RMS) width or the standard deviation  $\sigma$  (in nm) of the spectral distribution of a multi-longitudinal mode (MLM) laser considers all laser modes, which are not more than 20 dB down from the peak mode. Only a system with an MLM laser at 1310 nm requires this specification.

##### **6.2.2.2 Maximum -20 dB width**

The maximum -20 dB spectral width (in nm) of an SLM laser is specified by the maximum full width of the central wavelength peak, measured 20 dB down from the maximum amplitude of the central wavelength under standard operating conditions.

### **6.2.2.3 Side mode suppression ratio**

The side mode suppression ratio (SMSR) is defined as the ratio of the largest peak of the total source spectrum to the second largest peak. The spectral resolution of the measurement shall be better (i.e., the optical filter bandwidth shall be less) than the maximum spectral width of the peak, as defined above. The second largest peak may be next to the main peak or far removed from it.

NOTE – Within this definition, spectral peaks that are separated from the largest peak by the clock frequency are not considered to be side modes.

The SMSR specification is intended to minimize the occurrence of BER degradations due to mode partition noise (MPN). Since MPN is a transient effect with low probability, SMSR measurements on PRBS or continuous signals may underestimate the MPN. The SMSR specification is relevant only to SLM laser sources.

### **6.2.3 Maximum mean output power**

The maximum mean output power is the maximum value of the average power of a pseudo-random data sequence coupled into fibre by the transmitter.

### **6.2.4 Minimum mean output power**

The minimum mean output power is the minimum value of the average power of a pseudo-random data sequence coupled into fibre by the transmitter.

### **6.2.5 Extinction ratio**

The extinction ratio (EX) is defined as:

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

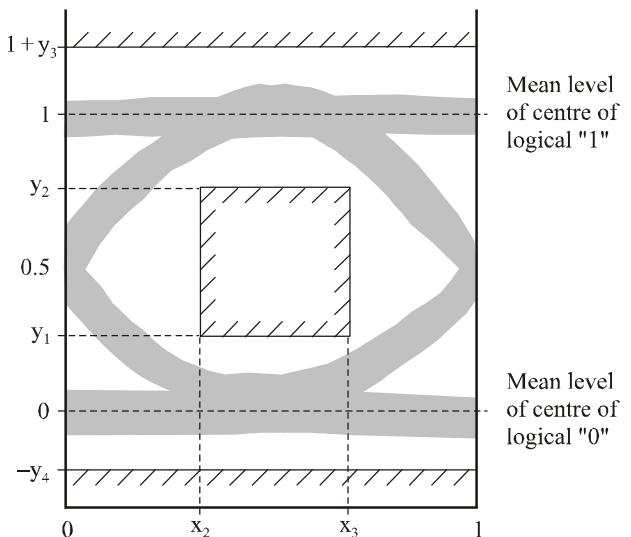
In the above definition of EX, A is the average optical power level at the centre of a logical "1" and B is the average optical power level at the centre of a logical "0". The convention adopted for optical logic levels is:

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

### **6.2.6 Eye pattern mask**

In this Recommendation, general transmitter pulse shape characteristics including rise time, fall time, pulse overshoot, pulse undershoot, and ringing, all of which should be controlled to prevent excessive degradation of the receiver sensitivity, are specified in the form of a mask of the transmitter eye diagram at point MPI-S. For the purpose of an assessment of the transmit signal, it is important to consider not only the eye opening, but also the overshoot and undershoot limitations. The parameters specifying the mask of the transmitter eye diagram are shown in Figure 2.

Acceptable transmitter eye diagrams must avoid crossing any of the hatched lines. The test arrangement is as specified for STM-64 in Annex A of [ITU-T G.691]. Filter tolerances for the NRZ 10G optical reference receiver are as specified for STM-64 in Annex A of [ITU-T G.691]. Filter tolerances for a NRZ 40G optical reference receiver are for further study.



	NRZ 10G 1310 nm region	NRZ 10G 1550 nm region	NRZ 40G
$x_3 - x_2$	0.2	0.2	0.2
$y_1$	0.25	0.25	0.25
$y_2$	0.75	0.75	0.75
$y_3$	0.4	0.25	0.25
$y_4$	0.25	0.25	0.25

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NOTE –  $x_2$  and  $x_3$  of the rectangular eye mask need not be equidistant with respect to the vertical axes at 0 UI and 1 UI.

**Figure 2 – Mask of the eye diagram for the optical transmit signal**

### 6.3 Optical path

To ensure system performance for each of the applications considered in Table 1, it is necessary to specify attenuation and dispersion characteristics of the optical path between points MPI-S and MPI-R.

#### 6.3.1 Maximum attenuation

The maximum attenuation is the maximum path attenuation where the system in question operates under end-of-life conditions at a BER of  $10^{-12}$  (or as given by the application code), under worst-case transmit-side signal and dispersion. Attenuation specifications are assumed to be worst-case values, including losses due to splices, connectors, optical attenuators (if used), other passive optical devices, e.g., photonic cross-connect and any additional cable margin to cover allowances for degradation of any connectors, optical attenuators or other passive optical devices between points MPI-S and MPI-R, if used.

#### 6.3.2 Minimum attenuation

Minimum attenuation is the minimum path attenuation that allows the system in question, operating under worst-case transmit-side conditions, to achieve a BER no worse than  $10^{-12}$  (or as given by the application code).

### **6.3.3 Dispersion**

#### **6.3.3.1 Maximum chromatic dispersion at upper and lower wavelength limit**

These two parameters define the maximum uncompensated value of the main path chromatic dispersion that the system shall be able to tolerate.

For wavelengths between the upper and lower wavelength limits, the maximum dispersion is linearly interpolated between the values given for the wavelength extremes. Where the maximum dispersion values are the same, this value is required to be met across the entire wavelength range.

For ITU-T G.652 fibre, the required maximum dispersion tolerance at the upper and lower wavelength limits is set to a value equal to the target distance times the maximum dispersion coefficient for ITU-T G.652 fibre at those wavelengths. For ITU-T G.653 fibre, the required maximum dispersion tolerance is set to plus or minus a value equal to the target distance times the highest absolute value of the maximum dispersion coefficient for ITU-T G.653.B fibre at the upper or lower wavelength limits. For ITU-T G.655 fibre, the required maximum dispersion tolerance at the upper and lower wavelength limits is set to a value equal to the target distance times the maximum dispersion coefficient for ITU-T G.655.E fibre at those wavelengths.

These are considered worst-case dispersion values for the relevant fibre types.

The maximum chromatic dispersion value includes contributions from fibre and all other elements present in the optical path. In the case that these passive optical devices introduce additional chromatic dispersion, the achievable link distance may be reduced. Alternatively, an application with a higher chromatic dispersion tolerance may be used to overcome this restriction.

The allowed penalty for the optical path considers all deterministic effects due to chromatic dispersion as well as the penalty due to the maximum differential group delay.

#### **6.3.3.2 Maximum differential group delay**

Differential group delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. More information on this topic can be found in [ITU-T G.691].

In this Recommendation, the maximum differential group delay is defined to be the value of DGD that the system must tolerate with a maximum sensitivity degradation of 1 dB.

### **6.3.4 Reflections**

Reflections are caused by refractive index discontinuities along the optical path. If not controlled, they can degrade system performance through their disturbing effect on the operation of the optical source or amplifier, or through multiple reflections which lead to interferometric noise at the receiver. In this Recommendation, reflections from the optical path are controlled by specifying the:

- minimum optical return loss (ORL) of the cable plant at point MPI-S, including any connectors; and
- maximum discrete reflectance between points MPI-S and MPI-R.

Reflectance denotes the reflection from any single discrete reflection point, whereas the return loss is the total returned power from the entire fibre, including both discrete reflections and distributed backscattering such as Rayleigh scattering.

Measurement methods for reflections are described in Appendix I of [ITU-T G.957]. For the purpose of reflectance and return loss measurements, points MPI-S and MPI-R are assumed to coincide with the endface of each connector plug. It is recognized that this does not include the actual reflection performance of the respective connectors in the operational system. These reflections are assumed to have the nominal value of reflection for the specific type of connectors used.

The maximum number of connectors, or other discrete reflection points which may be included in the optical path (e.g., for distribution frames, or WDM components), must be such as to allow the specified overall optical return loss to be achieved. If this cannot be done using connectors meeting the maximum discrete reflections cited in Tables 3 and 4, then connectors having better reflection performance must be employed. Alternatively, the number of connectors must be reduced. It may also be necessary to limit the number of connectors, or to use connectors having improved reflectance performance in order to avoid unacceptable impairments due to multiple reflections.

In Tables 3 and 4, the value of  $-27$  dB maximum discrete reflectance between points MPI-S and MPI-R is intended to minimize the effects of multiple reflections (e.g., interferometric noise). The value for maximum receiver reflectance is chosen to ensure acceptable penalties due to multiple reflections for all likely system configurations involving multiple connectors, etc. Systems employing fewer or higher performance connectors produce fewer multiple reflections and, consequently, are able to tolerate receivers exhibiting higher reflectance.

## 6.4 Receiver

### 6.4.1 Sensitivity

Receiver sensitivity is defined as the minimum value of mean received power at point MPI-R to achieve a  $1 \times 10^{-12}$  BER. This must be met with a transmitter with worst-case values of transmitter eye mask, extinction ratio, optical return loss at point MPI-S, receiver connector degradations and measurement tolerances. The definition of receiver sensitivity under worst-case conditions is further discussed in Annex A of [ITU-T G.691].

The receiver sensitivity does not have to be met in the presence of dispersion, optical crosstalk or reflections. These effects are specified separately in the allocation of maximum optical path penalty.

NOTE – The receiver sensitivity does not have to be met in the presence of transmitter jitter in excess of the appropriate jitter generation limit (e.g., [ITU-T G.8251] for OTN optical tributary signals).

The receiver sensitivities specified in Tables 3 and 4 are worst-case, end-of-life values. Start-of-life sensitivities must be adequate to account for receiver ageing and environmental conditions.

### 6.4.2 Overload

Receiver overload is the maximum acceptable value of the received average power at point MPI-R for a  $1 \times 10^{-12}$  BER.

### 6.4.3 Path penalty

The path penalty is the apparent reduction of receiver sensitivity due to distortion of the signal waveform during its transmission over the path. It is manifested as a shift of the system's BER-curves towards higher input power levels. This corresponds to a positive path penalty. Negative path penalties may exist under some circumstances, but should be small (a negative path penalty indicates that a less than perfect transmitter eye has been partially improved by the path dependent distortions). Ideally, the BER-curves should only be translated, but shape variations are not uncommon, and may indicate the emergence of BER-floors. Since the path penalty is a change in the receiver's sensitivity, it is measured at a BER-level of  $10^{-12}$ .

For application codes requiring FEC bytes to be transmitted (i.e., having a code with a suffix of F), both receiver sensitivities (with and without the degradation due to the optical path) are measured after the error correction (if used) has been applied.

A maximum path penalty of  $1$  dB for low-dispersion systems is allowed. The path penalties are not made proportional to the target distances to avoid operating systems with high penalties.

The average value of the random dispersion penalties due to PMD is included in the allowed path penalty. In this respect, the transmitter/receiver combination is required to tolerate an actual DGD of 0.3 bit period with a maximum sensitivity degradation of 1 dB (with 50% of optical power in each principal state of polarization). For a well-designed receiver, this corresponds to a penalty of 0.1-0.2 dB for a DGD of 0.1 bit period. The actual DGD that may be encountered in operation is a randomly varying fibre/cable property, and cannot be specified in this Recommendation. This subject is further discussed in Appendix I of [ITU-T G.691].

Any additional sensitivity degradation due to optical crosstalk (e.g., caused by non-ideal switching) is assumed to be small enough to be included within the path penalty value. Cases where this is not true are for further study. Optical crosstalk penalty is further discussed in Appendix I.

## 7 Optical parameter values

Optical parameter values for applications shown in Tables 1 and 2 are given in Tables 3 to 6. Except for application codes requiring FEC bytes to be transmitted (i.e., having a code with a suffix of F), systems which comply with these values should not require forward error correction in order to satisfy BER objectives. In the case of application codes requiring FEC bytes to be transmitted, the BER is required to be met only after the correction (if used) has been applied.

Tables 3 to 6 include columns in which more than one application code is shown in the heading. Where the row entries in these columns contain a single value, it applies to all of the application codes. Where the row contains multiple entries, the values apply to the application codes in the same order as they appear in the column heading.

For those applications which were previously specified in [ITU-T G.691] or [ITU-T G.959.1], any differences between ITU-T G.693 parameter values and the values in the superseded [ITU-T G.691] and [ITU-T G.959.1] application codes are given in Appendix III.

**Table 3 – Optical interface parameters specified for applications with 0.6 km target distance**

Application code	Unit	VSR600-2R1	VSR600-2M1	VSR600-2M2 VSR600-2M3 VSR600-2M5
<b>ITU-T G.691 application code</b>		I-64.1r		
<b>ITU-T G.959.1 application code</b>		P1I1-2D1r		
<b>Target distance</b>	m	600	600	600
<b>Bit rate/line coding of optical signals</b>	–	NRZ 10G	NRZ 10G	NRZ 10G
<b>Fibre type</b>	–	G.652	G.652	G.652 G.653 G.655
<b>Transmitter at reference point MPI-S</b>				
Source type		MLM	MLM	SLM
Operating wavelength range	nm	1268-1360	1268-1360	1530-1565
Maximum mean output power	dBm	-1	+5	+2
Minimum mean output power	dBm	-6	+2	-1
Spectral characteristics:				
– maximum RMS width ( $\sigma$ )	nm	3	3	NA
– maximum -20 dB width	nm	NA	NA	ffs
– minimum SMSR	dB	NA	NA	30

**Table 3 – Optical interface parameters specified for applications with 0.6 km target distance**

Application code	Unit	VSR600-2R1	VSR600-2M1	VSR600-2M2 VSR600-2M3 VSR600-2M5
Minimum EX	dB	6	6	8.2
<b>Main optical path, MPI-S to MPI-R</b>				
Maximum attenuation	dB	4	12	12
Minimum attenuation	dB	0	6 <sup>a)</sup>	3 <sup>a)</sup>
Maximum chromatic dispersion at upper wavelength limit <sup>b)</sup>	ps/nm	±3.4	±3.4	11.3 for G.652 <sup>c)</sup> ±2 for G.653 +6.1 for G.655
Maximum chromatic dispersion at lower wavelength limit	ps/nm	±3.4	±3.4	10.1 for G.652 <sup>c)</sup> ±2 for G.653 +5.0 for G.655
Maximum DGD	ps	30	30	30
Minimum ORL of cable plant at MPI-S, including any connectors	dB	14	14	14
Maximum discrete reflectance between MPI-S and MPI-R	dB	-27	-27	-27
Polarization-dependent loss	dB	ffs	ffs	ffs
<b>Receiver at reference point MPI-R</b>				
Minimum sensitivity (BER of $1 \times 10^{-12}$ )	dBm	-11	-11	-14
Minimum overload	dBm	-1	-1	-1
Maximum optical path penalty	dB	1	1	1
Maximum reflectance of receiver, measured at MPI-R	dB	-14	-14	-14
a) This value of minimum attenuation is highly undesirable. A value of 0 dB is desired and should be sought as technology matures.				
b) In the case that passive optical devices in the main optical path introduce additional chromatic dispersion, the achievable link distance may be reduced. Alternatively, an application with a higher chromatic dispersion tolerance may be used to overcome this restriction.				
c) This application can also be used on ITU-T G.653 and ITU-T G.655 fibre.				

**Table 4 – Optical interface parameters specified for applications with 2 km target distance and attenuation category R**

Application code	Unit	VSR2000-2R1	VSR2000-3R1 <sup>d)</sup>	VSR2000-3R1F <sup>d, f)</sup>	VSR2000-3R2 <sup>e)</sup> VSR2000-3R3 <sup>d)</sup> VSR2000-3R5 <sup>d)</sup>	VSR2000-3R2F <sup>e, f)</sup> VSR2000-3R3F <sup>d, f)</sup> VSR2000-3R5F <sup>d, f)</sup>
<b>ITU-T G.691 application code</b>		I-64.1				
<b>ITU-T G.959.1 application code</b>		P1I1-2D1				
<b>Target distance</b>	km	2	2	2	2	2
<b>Bit rate/line coding of optical signals</b>	–	NRZ 10G	NRZ 40G	NRZ OTU3 FEC enabled	NRZ 40G	NRZ OTU3 FEC enabled
<b>Fibre type</b>	–	G.652	G.652	G.652	G.652 G.653 G.655	G.652 G.653 G.655
<b>Transmitter at reference point MPI-S</b>						
Source type		SLM	SLM	SLM	SLM	SLM
Operating wavelength range	nm	1290-1330	1290-1330	1290-1330	1530-1565	1530-1565
Maximum mean output power	dBm	-1	+3	+3	+3	+3
Minimum mean output power	dBm	-6	0	0	0	0
Spectral characteristics:						
– maximum RMS width ( $\sigma$ )	nm	NA	NA	NA	NA	NA
– maximum -20 dB width	nm	1	ffs	ffs	ffs	ffs
– minimum SMSR	dB	30	35	35	35	35
Minimum EX	dB	6	8.2	8.2	8.2	8.2

**Table 4 – Optical interface parameters specified for applications with 2 km target distance and attenuation category R**

Application code	Unit	VSR2000-2R1	VSR2000-3R1 <sup>d)</sup>	VSR2000-3R1F <sup>d, f)</sup>	VSR2000-3R2 <sup>e)</sup> VSR2000-3R3 <sup>d)</sup> VSR2000-3R5 <sup>d)</sup>	VSR2000-3R2F <sup>e, f)</sup> VSR2000-3R3F <sup>d, f)</sup> VSR2000-3R5F <sup>d, f)</sup>
<b>Main optical path, MPI-S to MPI-R</b>						
Maximum attenuation	dB	4	4	4	4	4
Minimum attenuation	dB	0	0	0	0	0
Maximum chromatic dispersion at upper wavelength limit <sup>a)</sup>	ps/nm	–6.6 to +5.3	–6.6 to +5.3	–6.6 to +5.3	+38 for G.652 <sup>b)</sup> –6.6 to +6.1 for G.653 +20.3 for G.655	+38 for G.652 <sup>b)</sup> –6.6 to +6.1 for G.653 +20.3 for G.655
Maximum chromatic dispersion at lower wavelength limit	ps/nm	–6.6 to +5.3	–6.6 to +5.3	–6.6 to +5.3	+34 for G.652 <sup>b)</sup> –6.6 to +6.1 for G.653 +16.6 for G.655	+34 for G.652 <sup>b)</sup> –6.6 to +6.1 for G.653 +16.6 for G.655
Maximum DGD	ps	30	7.5	7.5	7.5	7.5
Minimum ORL of cable plant at MPI-S, including any connectors	dB	14	24	24	24	24
Maximum discrete reflectance between MPI-S and MPI-R	dB	–27	–27	–27	–27	–27
Polarization-dependent loss	dB	ffs	ffs	ffs	ffs	ffs

**Table 4 – Optical interface parameters specified for applications with 2 km target distance and attenuation category R**

Application code	Unit	VSR2000-2R1	VSR2000-3R1 <sup>d)</sup>	VSR2000-3R1F <sup>d, f)</sup>	VSR2000-3R2 <sup>e)</sup> VSR2000-3R3 <sup>d)</sup> VSR2000-3R5 <sup>d)</sup>	VSR2000-3R2F <sup>e, f)</sup> VSR2000-3R3F <sup>d, f)</sup> VSR2000-3R5F <sup>d, f)</sup>
<b>Receiver at reference point MPI-R</b>						
Minimum sensitivity (BER of $1 \times 10^{-12}$ )	dBm	-11	-5	-5	-6 for G.652 -5 for G.653 -5 for G.655	-6 for G.652 -5 for G.653 -5 for G.655
Minimum overload	dBm	-1	+3	+3	+3	+3
Maximum optical path penalty	dB	1	1 <sup>c)</sup>	1 <sup>c)</sup>	2 <sup>c)</sup> for G.652 1 <sup>c)</sup> for G.653 1 <sup>c)</sup> for G.655	2 <sup>c)</sup> for G.652 1 <sup>c)</sup> for G.653 1 <sup>c)</sup> for G.655
Maximum reflectance of receiver, measured at MPI-R	dB	-14	-27	-27	-27	-27

<sup>a)</sup> In the case that passive optical devices in the main optical path introduce additional chromatic dispersion, the achievable link distance may be reduced. Alternatively, an application with a higher chromatic dispersion tolerance may be used to overcome this restriction.  
<sup>b)</sup> This application can also be used on ITU-T G.653 and ITU-T G.655 fibre.  
<sup>c)</sup> The method used to verify this penalty is for further study.  
<sup>d)</sup> A receiver in compliance with this application is required to operate in any of the application codes VSR2000-3R1, VSR2000-3R3 or VSR2000-3R5. It shall, as a minimum, operate over the wavelength range of 1290-1330 nm as well as the range 1530-1565 nm.  
<sup>e)</sup> A receiver in compliance with application VSR2000-3R2 will operate in either of the application codes VSR2000-3R3 or VSR2000-3R5. It will also operate in the application code VSR2000-3R1 if its operating wavelength range includes 1290-1330 nm.  
<sup>f)</sup> The BER for this application is required to be met only after the error correction (if used) has been applied. The BER at the input of the FEC decoder can, therefore, be significantly higher than  $10^{-12}$ .

**Table 5 – Optical interface parameters specified for applications with 2 km target distance and attenuation category L**

Application code	Unit	VSR2000-2L1F <sup>f)</sup>	VSR2000-2L2 VSR2000-2L3 VSR2000-2L5	VSR2000-3L1F <sup>d, f)</sup>	VSR2000-3L2F <sup>e, f)</sup> VSR2000-3L3F <sup>d, f)</sup> VSR2000-3L5F <sup>d, f)</sup>
<b>ITU-T G.691 application code</b>			I-64.2r		
<b>ITU-T G.959.1 application code</b>			P1I1-2D2r		
<b>Target distance</b>	km	2	2	2	2
<b>Bit rate/line coding of optical signals</b>	–	NRZ OTU2 FEC enabled	NRZ 10G	NRZ OTU3 FEC enabled	NRZ OTU3 FEC enabled
<b>Fibre type</b>	–	G.652	G.652 G.653 G.655	G.652	G.652 G.653 G.655
<b>Transmitter at reference point MPI-S</b>					
Source type		SLM	SLM	SLM	SLM
Operating wavelength range	nm	1290-1330	1530-1565	1290-1330	1530-1565
Maximum mean output power	dBm	–1	–1	+3	+3
Minimum mean output power	dBm	–6	–5	0	0
Spectral characteristics:					
– maximum RMS width ( $\sigma$ )	nm	NA	NA	NA	NA
– maximum –20 dB width	nm	1	ffs	ffs	ffs
– minimum SMSR	dB	30	30	35	35
Minimum EX	dB	6	8.2	8.2	8.2

**Table 5 – Optical interface parameters specified for applications with 2 km target distance and attenuation category L**

Application code	Unit	VSR2000-2L1F <sup>f)</sup>	VSR2000-2L2 VSR2000-2L3 VSR2000-2L5	VSR2000-3L1F <sup>d, f)</sup>	VSR2000-3L2F <sup>e, f)</sup> VSR2000-3L3F <sup>d, f)</sup> VSR2000-3L5F <sup>d, f)</sup>
<b>Main optical path, MPI-S to MPI-R</b>					
Maximum attenuation	dB	6	6	6	6
Minimum attenuation	dB	0	0	0	0
Maximum chromatic dispersion at upper wavelength limit <sup>a)</sup>	ps/nm	-6.6 to +5.3	+38 for G.652 <sup>b)</sup> -6.6 to +6.1 for G.653 +20.3 for G.655	-6.6 to +5.3	+38 for G.652 <sup>b)</sup> -6.6 to +6.1 for G.653 +20.3 for G.655
Maximum chromatic dispersion at lower wavelength limit	ps/nm	-6.6 to +5.3	+34 for G.652 <sup>b)</sup> -6.6 to +6.1 for G.653 +16.6 for G.655	-6.6 to +5.3	+34 for G.652 <sup>b)</sup> -6.6 to +6.1 for G.653 +16.6 for G.655
Maximum DGD	ps	30	30	7.5	7.5
Minimum ORL of cable plant at MPI-S, including any connectors	dB	14	24	24	24
Maximum discrete reflectance between MPI-S and MPI-R	dB	-27	-27	-27	-27
Polarization-dependent loss	dB	ffs	ffs	ffs	ffs

**Table 5 – Optical interface parameters specified for applications with 2 km target distance and attenuation category L**

Application code	Unit	VSR2000-2L1F <sup>b)</sup>	VSR2000-2L2 VSR2000-2L3 VSR2000-2L5	VSR2000-3L1F <sup>d, f)</sup>	VSR2000-3L2F <sup>e, f)</sup> VSR2000-3L3F <sup>d, f)</sup> VSR2000-3L5F <sup>d, f)</sup>
<b>Receiver at reference point MPI-R</b>					
Minimum sensitivity (BER of $1 \times 10^{-12}$ )	dBm	-13	-13	-7	-8 for G.652 -7 for G.653 -7 for G.655
Minimum overload	dBm	-1	-1	+3	+3
Maximum optical path penalty	dB	1	2	1 <sup>c)</sup>	2 <sup>c)</sup> for G.652 1 <sup>c)</sup> for G.653 1 <sup>c)</sup> for G.655
Maximum reflectance of receiver, measured at MPI-R	dB	-14	-27	-27	-27

<sup>a)</sup> In the case that passive optical devices in the main optical path introduce additional chromatic dispersion, the achievable link distance may be reduced. Alternatively, an application with a higher chromatic dispersion tolerance may be used to overcome this restriction.  
<sup>b)</sup> This application can also be used on ITU-T G.653 and ITU-T G.655 fibre.  
<sup>c)</sup> The method used to verify this penalty is for further study.  
<sup>d)</sup> A receiver in compliance with this application is required to operate in any of the application codes VSR2000-3L1, VSR2000-3L3 or VSR2000-3L5. It shall, as a minimum, operate over the wavelength range of 1290-1330 nm as well as the range 1530-1565 nm.  
<sup>e)</sup> A receiver in compliance with application VSR2000-3L2 will operate in either of the application codes VSR2000-3L3 or VSR2000-3L5. It will also operate in the application code VSR2000-3L1 if its operating wavelength range includes 1290-1330 nm.  
<sup>f)</sup> The BER for this application is required to be met only after the error correction (if used) has been applied. The BER at the input of the FEC decoder can, therefore, be significantly higher than  $10^{-12}$ .

**Table 6 – Optical interface parameters specified for applications with 2 km target distance and attenuation categories M and H**

Application code	Unit	VSR2000-3M1	VSR2000-3M2 VSR2000-3M3 VSR2000-3M5	VSR2000-3H2 VSR2000-3H3 VSR2000-3H5
<b>ITU-T G.691 application code</b>				
<b>ITU-T G.959.1 application code</b>				
<b>Target distance</b>	km	2	2	2
<b>Bit rate/line coding of optical signals</b>	–	NRZ 40G	NRZ 40G	NRZ 40G
<b>Fibre type</b>	–	G.652	G.652 G.653 G.655	G.652 G.653 G.655
<b>Transmitter at reference point</b>				
<b>MPI-S</b>				
Source type		SLM	SLM	SLM
Operating wavelength range	nm	1290-1330	1530-1565	1530-1565
Maximum mean output power	dBm	+10	+3	+3
Minimum mean output power	dBm	+8	0	0
Spectral characteristics:				
– maximum RMS width ( $\sigma$ )	nm	NA	NA	NA
– maximum –20 dB width	nm	ffs	ffs	ffs
– minimum SMSR	dB	35	35	35
Minimum EX	dB	8.2	7	7
<b>Main optical path, MPI-S to MPI-R</b>				
Maximum attenuation	dB	12	12	16
Minimum attenuation	dB	8 <sup>a)</sup>	3 <sup>a)</sup>	3
Maximum chromatic dispersion at upper wavelength limit <sup>b)</sup>	ps/nm	–6.6 to +5.3	+38 for G.652 <sup>c)</sup> –6.6 to +6.1 for G.653 +20.3 for G.655	+38 for G.652 <sup>c)</sup> –6.6 to +6.1 for G.653 +20.3 for G.655
Maximum chromatic dispersion at lower wavelength limit	ps/nm	–6.6 to +5.3	+34 for G.652 <sup>c)</sup> –6.6 to +6.1 for G.653 +16.6 for G.655	+34 for G.652 <sup>c)</sup> –6.6 to +6.1 for G.653 +16.6 for G.655
Maximum DGD	ps	7.5	7.5	7.5
Minimum ORL of cable plant at MPI-S, including any connectors	dB	24	24	24
Maximum discrete reflectance between MPI-S and MPI-R	dB	–27	–27	–27
Polarization-dependent loss	dB	ffs	ffs	ffs

**Table 6 – Optical interface parameters specified for applications with 2 km target distance and attenuation categories M and H**

Application code	Unit	VSR2000-3M1	VSR2000-3M2 VSR2000-3M3 VSR2000-3M5	VSR2000-3H2 VSR2000-3H3 VSR2000-3H5
<b>Receiver at reference point MPI-R</b>				
Minimum sensitivity (BER of $1 \times 10^{-12}$ )	dBm	-5	-14 for G.652 -13 for G.653 -13 for G.655	-18 for G.652 -17 for G.653 -17 for G.655
Minimum overload	dBm	+2	0	0
Maximum optical path penalty	dB	1 <sup>d)</sup>	2 <sup>d)</sup> for G.652 1 <sup>d)</sup> for G.653 1 <sup>d)</sup> for G.655	2 <sup>d)</sup> for G.652 1 <sup>d)</sup> for G.653 1 <sup>d)</sup> for G.655
Maximum reflectance of receiver, measured at MPI-R	dB	-27	-27	-27

a) This value of minimum attenuation is highly undesirable. A value of 0 dB is desired and should be sought as technology matures.  
 b) In the case that passive optical devices in the main optical path introduce additional chromatic dispersion, the achievable link distance may be reduced. Alternatively, an application with a higher chromatic dispersion tolerance may be used to overcome this restriction.  
 c) This application can also be used on ITU-T G.653 and ITU-T G.655 fibre.  
 d) The method used to verify this penalty is for further study.

## 8 Optical engineering approach

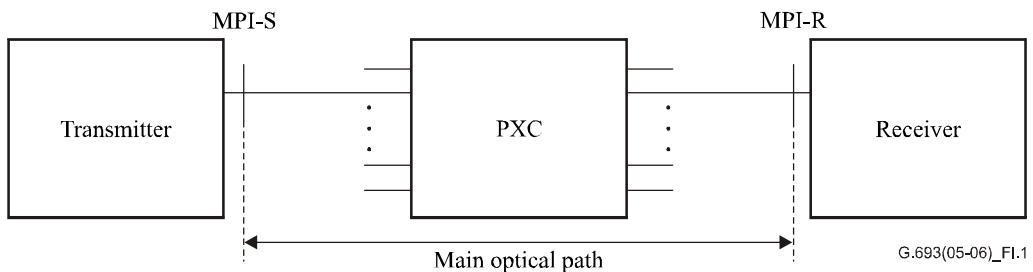
For a worst-case design approach, the relationships among maximum/minimum mean output power, maximum/minimum attenuation, minimum overload, minimum sensitivity and maximum optical path penalty are shown in Figure 3 of [ITU-T G.957].

## Appendix I

### Optical crosstalk impact

(This appendix does not form an integral part of this Recommendation)

Some of the applications in this Recommendation are intended to support the inclusion of a passive photonic cross-connect in the main optical path as depicted in Figure I.1. Photonic cross-connects may introduce non-negligible optical crosstalk due to non-ideal switching.



**Figure I.1 – Optical link example showing use of a passive photonic cross-connect (PXC) between MPI-S and MPI-R**

Optical crosstalk is the ratio of the total disturbing power, under all specified conditions, to the power in the desired signal, at the MPI-R reference point in Figure I.1, within the optical bandwidth of the optical receiver, expressed in dB.

Optical system performance may be affected by the level of optical crosstalk in the signal arriving at the receiver. Excessive optical crosstalk at the receiver will cause the performance of the system to deteriorate by an amount defined to be the crosstalk penalty.

Further study is needed to quantify the allowable optical crosstalk penalty.

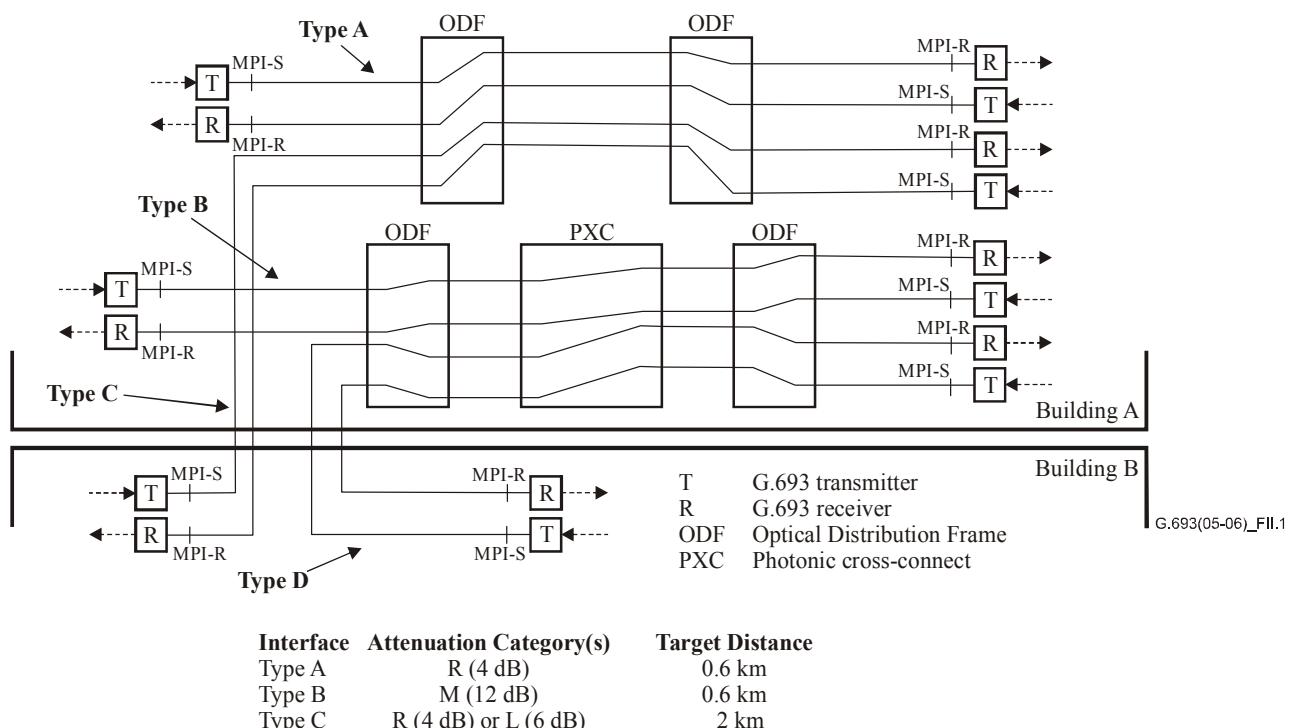
## Appendix II

### Examples of system configurations using applications defined in this Recommendation

(This appendix does not form an integral part of this Recommendation)

The applications defined in this Recommendation are characterized by relatively short target distances, i.e., less than or equal to 2 km. One consequence of this characteristic is that main optical path total attenuation will, in general, be dominated by the loss contributions of connectors and passive optical devices rather than by fibre loss.

Figure II.1 shows configurations corresponding to several applications defined in this Recommendation, with different combinations of attenuation category and target distance. The figure illustrates that, in selecting an application, the choice of attenuation category is determined by the devices in the main optical path, e.g., whether or not a photonic cross-connect is present, while the choice of target distance is determined by the relative proximity of the equipments which the ITU-T G.693 interface interconnects.



**Figure II.1 – Examples of system configurations using applications defined in this Recommendation**

## Appendix III

### **Differences in parameter values between ITU-T G.693 application codes and equivalent ITU-T G.691 and ITU-T G.959.1 codes**

(This appendix does not form an integral part of this Recommendation)

Several application codes in this Recommendation are equivalent to application codes which were specified in previous versions of [ITU-T G.691] and [ITU-T G.959.1]. In some instances, the parameter values in this Recommendation differ from those in the equivalent ITU-T G.691 and ITU-T G.959.1 application codes, which are now superseded by this Recommendation. Tables III.1, III.2 and III.3 below indicate all such differences between ITU-T G.693 parameter values and corresponding values in the equivalent ITU-T G.691 and ITU-T G.959.1 application codes.

**Table III.1 – Parameter value differences between VSR600-2R1 (this Recommendation), P1I1-2D1r [ITU-T G.959.1] and I-64.1r [ITU-T G.691] application codes**

Application code/ Recommendation	Unit	VSR600-2R1/ G.693	P1I1-2D1r/ G.959.1	I-64.1r/ G.691
Operating wavelength range	nm	1268-1360	1260-1360	1260-1360

**Table III.2 – Parameter value differences between VSR2000-2R1 (this Recommendation) and P1I1-2D1 [ITU-T G.959.1] application codes**

Application code/ Recommendation	Unit	VSR2000-2R1/ G.693	P1I1-2D1/ G.959.1
Maximum chromatic dispersion	ps/nm	6.6	NA

**Table III.3 – Parameter value differences between VSR2000-2L2 (this Recommendation), P1I1-2D2r [ITU-T G.959.1] and I-64.2r [ITU-T G.691]**

Application code/ Recommendation	Unit	VSR2000-2L2/ G.693	P1I1-2D2r/ G.959.1	I-64.2r/ G.691
Operating wavelength range	nm	1530-1565	1500-1580	(same as G.693)
Maximum attenuation	dB	6	7	7
Minimum sensitivity	dBm	-13	-14	-14





## **SERIES OF ITU-T RECOMMENDATIONS**

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