International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.9805

(02/2022)

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

Access networks – Optical line systems for local and access networks

Coexistence of passive optical network systems

Recommendation ITU-T G.9805

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999
Metallic access networks	G.9700–G.9799
Optical line systems for local and access networks	**G.9800–G.9899**
In premises networks	G.9900–G.9999

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

Recommendation ITU-T G.9805

Coexistence of passive optical network systems

Summary

Recommendation ITU-T G.9805 presents three methods for the coexistence of multiple passive optical network (PON) generations on a common optical distribution network (ODN): coexistence element (CE), multi-PON module (MPM), and splitter-based. These methods allow the reuse of already deployed fibre and splitters when evolving a legacy PON to a higher capacity. Methods for calculating required isolation for coexistence element, filter considerations for higher speed passive optical network (HSP) and asymmetric / symmetric 10-Gigabit passive optical network optical line termination or XG(S)-PON OLT, and optical interface parameters for gigabit-capable passive optical network (G-PON) and XG(S)-PON MPM supporting classes B+, C+ and D optical path loss (OPL) are also described.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.9805	2022-02-13	15	11.1002/1000/14918

Keywords

CEx, coexistence, MPM, PON.

---

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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

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

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

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

NOTE

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

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

INTELLECTUAL PROPERTY RIGHTS

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

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

Table of Contents

Recommendation ITU-T G.9805

Coexistence of passive optical network systems

1 Scope

The purpose of this Recommendation is to establish the methods and parameters for passive optical network (PON) coexistence, where two or more PON systems share a common optical distribution network (ODN). For this purpose, this Recommendation defines and provides:

– a general reference diagram of coexistence element, and sample parameters of a discrete wavelength division multiplexing (WDM) filter that combines and isolates the gigabit-capable passive optical network (G-PON) up/down signals and enhancement bands of PON systems, radio frequency (RF) signal and optical time-domain reflectometer (OTDR) signal at the optical line termination (OLT) side;
– methods for calculating required isolation for WDM/CE/CEM devices;
– wavelength coexistence using M:N splitter;
– multi-PON module with integrated WDM;
– filter considerations for higher speed passive optical network (HSP) and XG(S)-PON/10G-EPON OLT.

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.984.2] Recommendation ITU-T G.984.2 (2019), *Gigabit-capable Passive Optical Networks (G-PON): Physical Media Dependent (PMD) layer specification.*

[ITU-T G.987] Recommendation ITU-T G.987 (2012), *10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations and acronyms.*

[ITU-T G.987.2] Recommendation ITU-T G.987.2 (2016), *10-Gigabit-capable passive optical networks (XG-PON): Physical media dependent (PMD) layer specification.*

[ITU-T G.989] Recommendation ITU-T G.989 (2014), *40-Gigabit-capable passive optical network (NG-PON2) systems: Definitions, abbreviations and acronyms*.

[ITU-T G.9804.1] Recommendation ITU-T G.9804.1 (2020), *Higher speed passive optical networks – Requirements.*

[ITU-T G.9807.1] Recommendation ITU-T G.9807.1 (2016), *10-Gigabit-capable symmetric passive optical network (XGS-PON).*

[ITU-T L.313] Recommendation ITU-T L.313/L.66 (2007), *Optical fibre cable maintenance criteria for in-service fibre testing in access networks.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 optical distribution network (ODN): [ITU-T G.9804.1].

3.1.2 optical line termination (OLT): [ITU-T G.9804.1].

3.1.3 optical network unit (ONU): [ITU-T G.9804.1].

3.1.4 wavelength division multiplexing (WDM): [ITU-T G.984.2].

3.1.5 10-Gigabit-capable passive optical network (XG-PON): [ITU-T G.987].

3.1.6 10-Gigabit passive optical network (XGS-PON): [ITU-T G.9807.1].

3.1.7 TWDM PON: [ITU-T G.989].

3.1.8 PtP WDM PON: [ITU-T G.989].

3.1.9 NG-PON2: [ITU-T G.989].

3.1.10 coexistence element (CE): [ITU-T G.989].

3.1.11 wavelength multiplexer (WM): [ITU-T G.989].

3.1.12 XGS-PON: [ITU-T G.9807.1].

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 next generation access (NGA): A possible new optical access system that coexists with gigabit-capable passive optical network (G-PON) on the same optical distribution network (ODN).

3.2.2 wavelength blocking filter (WBF): An optical filter to prevent an optical receiver from receiving unwanted optical signals with different wavelengths.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

APD	Avalanche Photo Diode
BER	Bit Error Rate
BM	Burst Mode
B-PON	Broadband Passive Optical Network
CDR	Clock Data Recovery
CE	Coexistence Element
CEM	Coexistence Element/Multiplexer
CNR	Carrier-to-Noise Ratio
DBA	Determined By Application
DFB	Distributed Feedback Laser
G-PON	Gigabit-capable Passive Optical Network
HSP	Higher Speed Passive Optical Network
LA	Limiting Amplifier

MPM	Multi-PON Module
NRZ	Non Return to Zero
NG-PON2	Next Generation Passive Optical Network phase 2
NGA	Next Generation Access
OAN	Optical Access Network
ODN	Optical Distribution Network
OLT	Optical Line Termination
ONU	Optical Network Unit
OPL	Optical Path Loss
OSA	Optical Sub-Assembly
OTDR	Optical Time-Domain Reflectometer
PMD	Physical Media Dependent
PON	Passive Optical Network
PtP WDM	Point-to-Point Wavelength Division Multiplexing
RF	Radio Frequency
TC	Transmission Convergence
TIA	Trans-Impedance Amplifier
TDM	Time Division Multiplexing
TWDM	Time and Wavelength Division Multiplexing
WBF	Wavelength Blocking Filter
WDM	Wavelength Division Multiplexing
WM	Wavelength Multiplexer
XG-PON	Asymmetric 10-Gigabit Passive Optical Network
XGS-PON	Symmetric 10-Gigabit Passive Optical Network
XG(S)-PON	XG-PON or XGS-PON

5 Conventions

None.

6 Reference architecture of coexistence methods

When a passive optical network (PON) system is migrated from a legacy PON to a next generation PON (NG PON), coexistence and smooth migration are important requirements, to protect investment and guarantee user experience. There are three types of coexistence methods supporting multiple PON systems operating in the same optical distribution network (ODN) simultaneously, including wavelength coexistence using an external coexistence element (CEx) device, wavelength coexistence using multi-PON module (MPM), and wavelength coexistence using M:N splitter.

6.1 Wavelength coexistence using external CEx device

Figure 6-1 shows a reference diagram of multiple PON systems coexisting with an external CEx device.

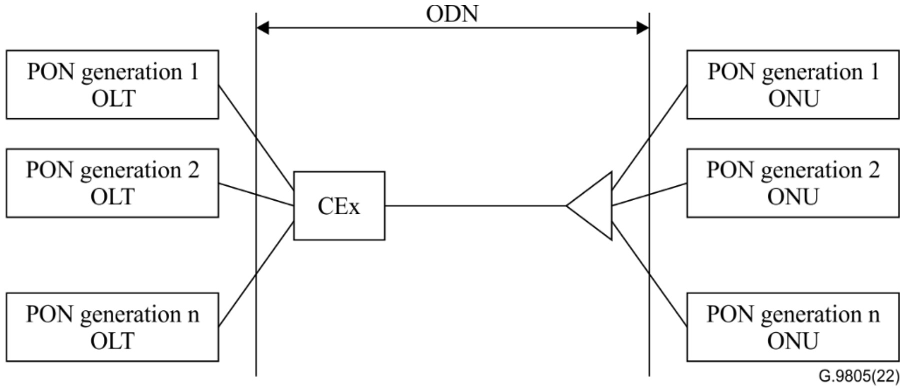

Figure 6-1 – Reference diagram of multiple PON systems coexisting with an external CEx device

The reference diagram of a generic coexistence CEx is shown in Figure 6-2. The insertion loss between the COM port and each optical line termination (OLT) port of the CEx device consumes the loss budget of the corresponding PON system. See Appendix I for examples of CEx in various coexistence scenarios.

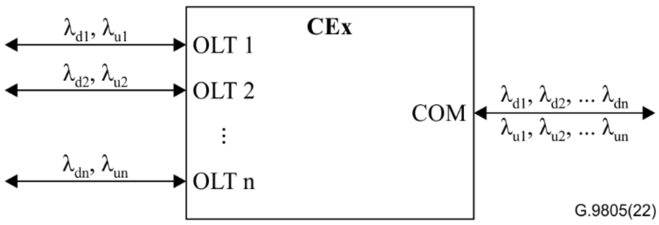

Figure 6-2 – Reference diagram of a generic CEx

6.2 Wavelength coexistence using MPM

An architectural reference diagram using the optical line termination multi-PON module or OLT MPM is shown in Figure 6-3. The wavelength division multiplexing (WDM) function supporting multiple PON systems coexistence is integrated in the OLT MPM.

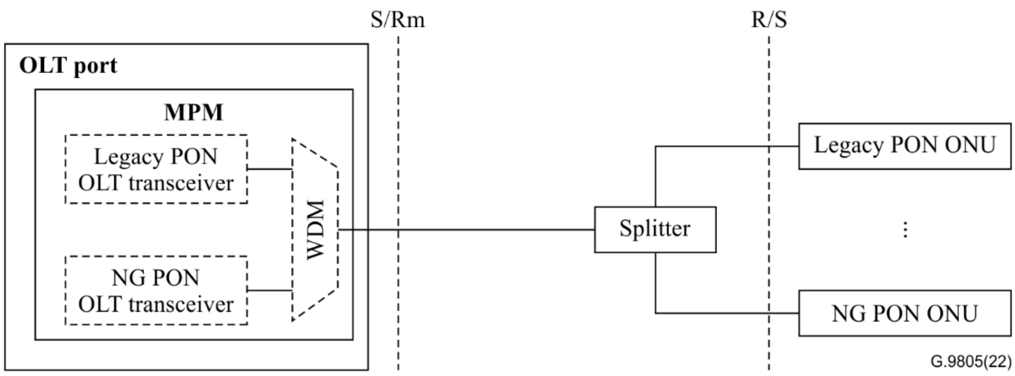

Figure 6-3 – Reference diagram employing OLT MPM

The physical media dependent (PMD) requirements for the optical interface between OLT MPM and ODN should be chosen accordingly for NG PON and legacy PON supported in the OLT MPM.

When upgrading using an OLT MPM, no external coexistence element is necessary at the OLT side, since its function has been integrated inside the OLT optical module for each PON port. Hence no extra space or associated engineering operation are required to achieve coexistence.

To accompany the OLT MPM with an integrated WDM in an upgrade scenario, a transmission convergence (TC) chipset supporting both legacy PON and NG PON may be required in the OLT configuration to support dual interfaces to the MPM.

The classes for optical path loss G-PON and XG(S)-PON MPM between S/Rm and R/S are specified in Table 6-1.

Table 6-1 – Classes for optical path loss G-PON and XG(S)-PON MPM between S/Rm and R/S

OPL class	B+	C+	D
Minimum loss	13 dB	17 dB	20 dB
Maximum loss	28 dB	32 dB	35 dB
NOTE – Optical path loss classes B+, C+ and D are generally applicable for G-PON and XG(S)-PON MPM from the S/Rm point, including both single and dual receiver's configuration.			

Key optical power parameters at the S/Rm reference point are given in Table 6-2, while all other PMD parameters are the same with corresponding values defined in [ITU-T G.984.2], [ITU-T G.987.2] and [ITU-T G.9807.1] respectively.

Table 6-2 – Key optical power parameters at the S/Rm reference point

Source	Item	Unit	Value		
	ODN class	dBm	B+	C+	D
G-PON 2.488 Gbit/s downstream, 1.244 Gbit/s upstream	Mean launched power MIN	dBm	+1.5	+3	+6
	Mean launched power MAX	dBm	+5	+7	+10
	Minimum sensitivity	dBm	–28 (BER@1E-10)	–32 (BER@1E-4)	–35 (BER@1E-4)
	Minimum overload	dBm	–8	–12	–15
XG-PON 9.95328 Gbit/s downstream, 2.48832 Gbit/s upstream	Mean launched power MIN	dBm	+1	+5	+8
	Mean launched power MAX	dBm	+5	+9	+12
	Minimum sensitivity@1E-4	dBm	–26.5	–30.5	–33.5
	Minimum overload	dBm	–6	–10	–13
XGS-PON 9.95328 Gbit/s downstream, 9.95328 Gbit/s upstream	Mean launched power MIN	dBm	+1	+5	+8
	Mean launched power MAX	dBm	+4	+8	+11
	Minimum sensitivity@1E-3	dBm	–25	–29	–32
	Minimum overload	dBm	–4	–8	–11

6.3 Wavelength coexistence using M:N splitter

Different operators deploy PON using different schemes for the outside plant, some deploy a single splitter scheme and some deploy using cascaded splitter (2 or more splitters in tandem) schemes. Figure 6-4 shows a reference diagram of coexistence with M:N splitter. The first splitter could be used as an integral part of a wavelength combining architecture. Employing a M:N splitter (for instance 2:n) as the first splitter (often located in the central office), provides that the first PON (OLT) system can be connected to input port 1, and the second PON system connected to input port M in the OLT side of M:N splitter.

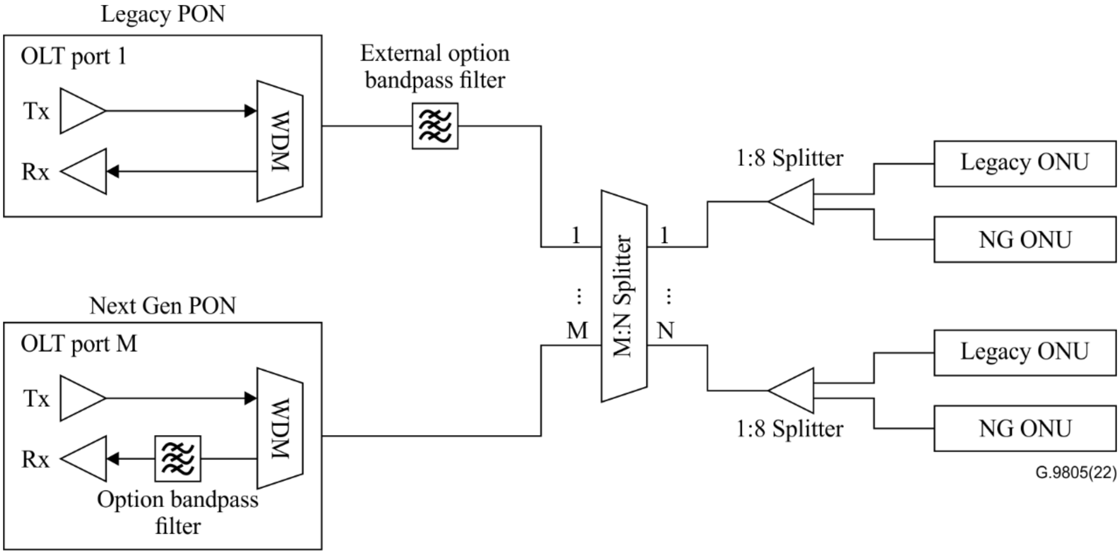

Figure 6-4 – Example of architecture reference diagram employing 2:n splitter

For the splitter approach to work, the terminating (receiving) ports must have appropriate band to band filtering, providing sufficient isolation to the interfering wavelength bands. While nowadays several OLT's have wavelength blocking filters in their receivers, this may not be the case for older implementations. In that case, external wavelength blocking mechanisms would have to be considered, such as pluggable SC type wavelength blocking filter (WBF) adapters. It is noted that as long as the OLT receiver has sufficient isolation to the interfering bands of interest, the M:N splitter scheme could even support three (3) PON coexistence by substituting the 2:n splitter with a 3:n splitter.

The M:N splitter has some of the same advantages, in that the existing fibre connections to/from the OLT equipment remain the same; however, the M:N approach require the addition of a second fibre from the new PON OLT equipment/port to the splitter's second input port. The extra loss for the addition of the second input port of the power splitter is minimal in most devices, typically less than 0.5 dB, resulting in a lower insertion loss solution to the traditional WDM approach.

Appendix I

Example of WDM1, WDM1r, CEx and CEMx characteristics

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

The WDM1, WDM1r, CEx and CEMx devices can have several different configurations depending on whether a video overlay service or an optical time-domain reflectometer (OTDR) is provided. This appendix presents several examples of device characteristics.

The examples of filters termed as "WDM1r" are to signify that they are specifications that reflect the approved newer wavelength plan for next generation access (NGA) systems. There are four examples of added wavelength service ports: none, video, OTDR and video+OTDR. There are two upstream wavelength plans for the G-PON interface that allow coexistence with NGA.

The examples of devices are termed "CEx", and support the coexistence of multiple PON systems.

The examples of devices are termed "CEM" for coexistence element/multiplexer to signify that they include the functions of CEx and partial wavelength multiplexer (WM) which combine/isolate the time and wavelength division multiplexing (TWDM) PON and point-to-point wavelength division multiplexing (PtP WDM) PON bands.

The isolation values in the following tables may be determined depending on the application and they can be calculated using the methods described in Appendix II.

In the following tables (except for Table I.2), G-PON with reduced upstream band is considered as an example. The values of insertion loss for G-PON with narrow upstream band are expected to be the same.

Table I.1 shows sample parameters of the single-fibre WDM1r filter that combines (downstream) and isolates (upstream) the G-PON up/down signals and NGA bands. Figure I.1 shows the reference diagram of the single-fibre WDM1r.

Table I.1 – Parameters for a WDM1r with G-PON and NGA ports

Specification	Value
Loss without connectors for G-PON bands	< 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for NGA bands	< 1.0 dB (1260-1280 nm and 1524-1625 nm)
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1625 nm)	DBA (see Appendix II)
Isolation – COM – NGA OLT (1290-1500 nm)	DBA (see Appendix II)
Maximum optical power	+23 dBm
Return loss	> 50 dB
Directivity	> 50 dB

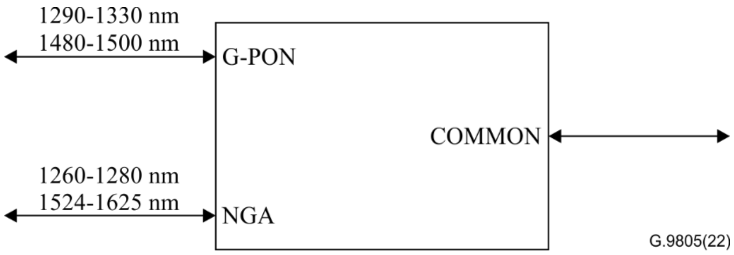

Figure I.1 – Reference diagram of a WDM1r with G-PON and NGA support

Table I.2 shows sample parameters of the single-fibre WDM1rn filter that combines (downstream) and isolates (upstream) the G-PON up/down signals and NGA bands. The WDM1rn can be used when all of the G-PON ONUs comply with the narrow upstream wavelength option. Figure I.2 shows a reference diagram of a single-fibre WDM1rn.

Table I.2 – Parameters for a WDM1rn with narrow upstream wavelength G-PON and NGA ports

Specification	Value
Loss without connectors for G-PON bands	< 0.8 dB (1300-1320 nm and 1480-1500 nm)
Loss without connectors for NGA bands	< 1.0 dB (1260-1280 nm and 1524-1625 nm)
Isolation – COM – G-PON OLT (1260-1280 and 1524-1625 nm)	DBA (see Appendix II)
Isolation – COM – NGA OLT (1300-1500 nm)	DBA (see Appendix II)
Max optical power	+23 dBm
Return loss	> 50 dB
Directivity	> 50 dB

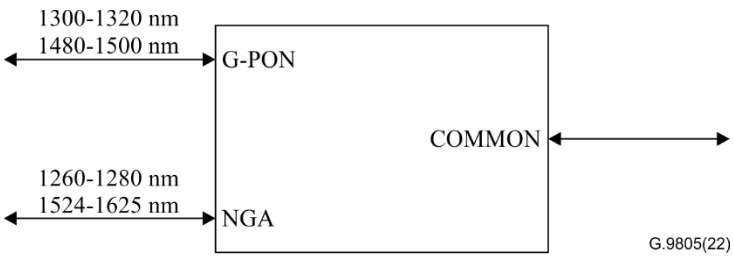

Figure I.2 – Reference diagram of a WDM1rn with narrow upstream wavelength G-PON and NGA support

Table I.3 shows sample parameters of the single-fibre WDM1r filter supporting OTDR capability. The wavelength range assumed for the OTDR is referred from [ITU-T L.313]. Note that the wavelength range of the NGA port changes when these optional ports are present. Figure I.3 shows the reference diagram of this filter.

Table I.3 – Parameters for a WDM1r with G-PON, NGA and OTDR ports

Specification	Value
Loss without connectors for G-PON bands	≤ 1.0 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for NGA bands	≤ 1.2 dB (1260-1280 nm and 1524-1581 nm)
Loss without connectors for OTDR band	≤ 1.1 dB (1625-1675 nm)
Isolation – COM – G-PON OLT (1260-1280 and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – NGA OLT (1290-1500 nm and 1600-1675 nm)	DBA (see Appendix II)
Isolation – COM – OTDR (1260-1581 nm)	DBA (see Appendix II)
Maximum optical power for G-PON or NGA ports	+23 dBm
Maximum optical power for OTDR port	For further study
Return loss	> 50 dB
Directivity	> 50 dB

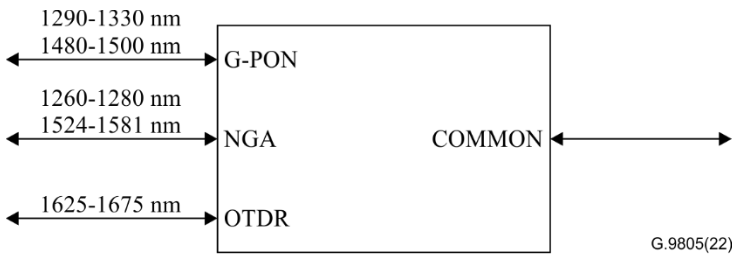

Figure I.3– Reference diagram of a WDM1r with G-PON, NGA and OTDR support

Table I.4 shows sample parameters of a single-fibre WDM1r filter supporting OTDR and video capability. Note that the wavelength range of the NGA port changes when these optional ports are present. Figure I.4 shows the reference diagram of this filter.

Table I.4 – Parameters for WDM1r with G-PON, RF video, NGA and OTDR ports

Specification	Value
Loss without connectors for G-PON bands	≤ 1.0 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for NGA bands	≤ 1.5 dB (1260-1280 nm and 1575-1581 nm)
Loss without connectors for OTDR band	≤ 1.1 dB (1625-1675 nm)
Loss without connectors for RF video band	≤ 1.7 dB (1550-1560 nm)
Isolation – COM – G-PON OLT (1260-1280 and 1550-1675 nm)	DBA (See Appendix II)
Isolation – COM – NGA OLT (1290-1560 nm and 1625-1675 nm)	DBA (see Appendix II)
Isolation – COM – OTDR (1260-1581 nm)	DBA (see Appendix II)
Isolation – COM – RF video (1260-1500 nm, 1575-1675 nm)	NA (RF is downstream only)

Table I.4 – Parameters for WDM1r with G-PON, RF video, NGA and OTDR ports

Specification	Value
Maximum optical power for G-PON or NGA ports	+23 dBm
Maximum optical power for OTDR port	For further study
Maximum optical power for RF video port	+23 dBm
Return loss	> 50 dB
Directivity	> 50 dB

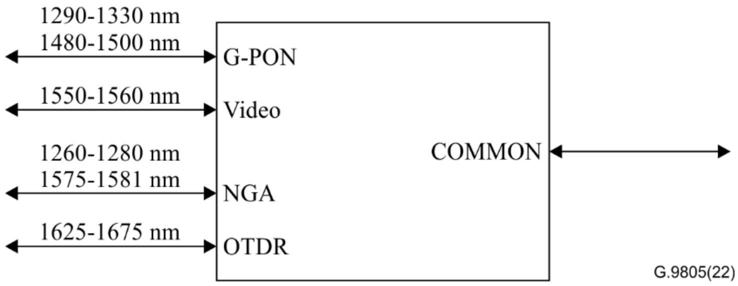

Figure I.4 – Reference diagram of a WDM1r with G-PON, RF video, NGA and OTDR support

Table I.5 shows sample parameters of a CEx supporting G-PON (reduced upstream band as an example), XG-PON1 and NG-PON2 (wide range TWDM PON upstream band and shared spectrum PtP WDM PON as an example). Figure I.5 shows the reference diagram of this device. (Note that as XG-PON1 is a deprecated name for the XG-PON system that operates at a nominal line rate of 10 Gbit/s downstream and 2.5 Gbit/s upstream, the term XG-PON1 can be regarded as the term XG-PON hereafter in the following text in Appendix I).

Table I.5 – Parameters for a CEx with G-PON, XG-PON1 and NG-PON2 ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for XG-PON1 bands	≤ 1.1 dB (1260-1280 nm and 1575-1581 nm)
Loss without connectors for NG-PON2 bands	≤ 1.0 dB (1524-1544 nm and 1596-1625 nm)
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – XG-PON1 OLT (1290-1560 nm and 1596-1675 nm)	DBA (see Appendix II)
Isolation – COM – NG-PON2 (1260-1500 nm, 1550-1581 nm and 1640-1675 nm)	DBA (see Appendix II)
Maximum optical power	+23 dBm
Return loss	> 50 dB
Directivity	> 50 dB

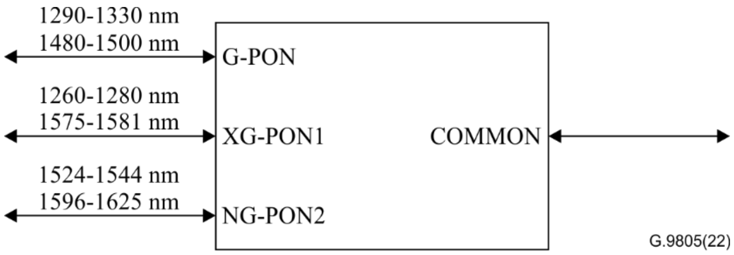

Figure I.5 – Reference diagram of a CEx with G-PON, XG-PON1 and NG-PON2 support

Table I.6 shows sample parameters of a CEx supporting G-PON (reduced upstream band as an example), XG-PON1 and NG-PON2 (wide range TWDM PON upstream band and shared spectrum PtP WDM PON as an example) and OTDR (with wavelength range of 1640-1660 nm as an example) capability. Figure I.6 shows the reference diagram of this device.

Table I.6 – Parameters for a CEx with G-PON, XG-PON1, NG-PON2 and OTDR ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for XG-PON1 bands	≤ 1.1 dB (1260-1280 nm and 1575-1581 nm)
Loss without connectors for NG-PON2 bands	≤ 1.2 dB (1524-1544 nm and 1596-1625 nm)
Loss without connectors for OTDR band	≤ 1.4 dB (1640-1660 nm)
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1675 nm)	DBA (see Appendix II) or see application case below
Isolation – COM – XG-PON1 OLT (1290-1560 nm and 1596-1675 nm)	DBA (see Appendix II) or see application case below
Isolation – COM – NG-PON2 (1260-1500 nm, 1550-1581 nm and 1640-1675 nm)	DBA (see Appendix II) or see application case below
Isolation – COM – OTDR (1260-1625 nm)	DBA (see Appendix II) or see application case below
Maximum optical power for G-PON, XG-PON1 or NG-PON2 ports	+23 dBm
Maximum optical power for OTDR port	For further study
Return loss	> 50 dB
Directivity	> 50 dB or see application case below

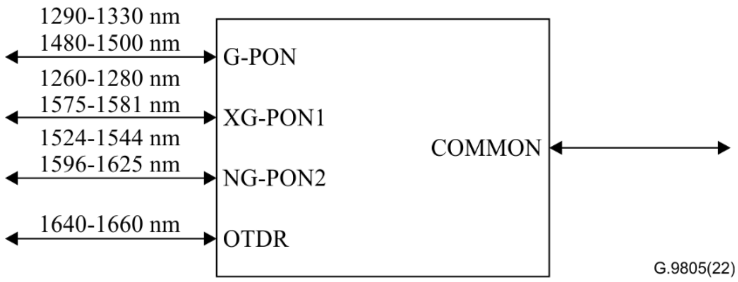

Figure I.6 – Reference diagram of a CEx with G-PON, XG-PON1, NG-PON2 and OTDR support

The assumptions for application case 1 are listed below. Isolation and directivity values are provided in Table I.6a.

Application case 1

- Total tolerated penalty (caused by finite isolation and directivity) = 0.5 dB.
- ODN maximum differential loss = 15 dB.
- ODN class = C+.
- Number of NG-PON2 channels = 8 TWDM + 8 PTP WDM.
- I_{BiDi} = 30 dB for the case when the interferer is located in the blocking band of the diplexer; I_{BiDi} = 0 dB in all other cases.
- No isolation is assumed to be provided by the NG-PON2 WM.
- ρ (photodiode responsivity) = 0.8 A/W in O band, 0.9 A/W in C band.
- NG-PON2 OPP values corresponding to the 8 ch, 20 km case.
- OTDR equipment is assumed to include an input filtering device providing 30 dB of isolation.
- OTDR pulse power = +23 dBm, ER = 10 dB, Rate = 100 Mbit/s[1].

Table I.6a – Isolation and directivity for application case 1

Specification		Value [dB]
Isolation [dB]	COM – G-PON (1260-1280 nm; 1524-1675 nm)	35
	COM – XG(S)-PON (1290-1560 nm; 1596-1675 nm)	35
	COM – NG-PON2 (1260-1500 nm; 1550-1581 nm; 1640-1675 nm)	40[2]
	COM – OTDR (1260-1625 nm)	10

[1] For the purpose of these calculations, the fact that the OTDR signal is normally pulsed and unmodulated is neglected.

Table I.6a – Isolation and directivity for application case 1

Specification		Value [dB]
Directivity (to port) [dB]	G-PON	40
	XG(S)-PON	45
	NG-PON2	55[2]
	OTDR	25
Directivity (port-to-port) [dB]	G-PON / XG(S)-PON	45
	G-PON / NG-PON2	55[2]
	G-PON / OTDR	40
	XG(S)-PON / NG-PON2	55[2]
	XG(S)-PON / OTDR	45
	NG-PON2 / OTDR	55[2]
NOTE – directivity figures can be specified equivalently per port or between ports.		

Table I.7 shows sample parameters of a CEx supporting G-PON (reduced upstream band as an example), RF video and NG-PON2 (wide range TWDM PON upstream band and shared spectrum PtP WDM PON as an example). Figure I.7 shows the reference diagram of this device.

Table I.7 – Parameters for a CEx with G-PON, RF video and NG-PON2 ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for RF video band	≤ 0.8 dB (1550-1560 nm)
Loss without connectors for NG-PON2 bands	≤ 1.0 dB (1524-1544 nm and 1596-1625 nm)
Isolation – COM – G-PON OLT (1260-1280 and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – RF video (1260-1544 nm, 1575-1675 nm)	NA (RF is downstream only)
Isolation – COM – NG-PON2 OLT (1260-1500 nm, 1550-1581 nm and 1640-1675 nm)	DBA (see Appendix II)
Maximum optical power for G-PON or NG-PON2 ports	+23 dBm
Maximum optical power for RF video port	+23 dBm
Return loss	> 50 dB
Directivity	> 50 dB

[2] This level is sufficient for a NG-PON2 TWDM system; if the NG-PON2 port is used (also) for a PTP WDM PON system, a much higher value (isolation > 55 dB, directivity > 70 dB) would be necessary or interference onto this system should be mitigated using additional means.

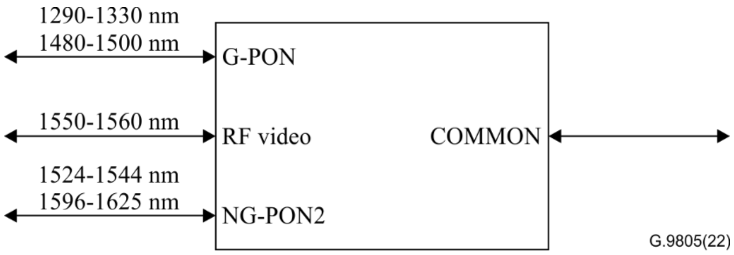

Figure I.7 – Reference diagram of a CEx with G-PON, RF video and NG-PON2 support

Table I.8 shows sample parameters of a CEx supporting G-PON (reduced upstream band as an example), RF video, NG-PON2 (wide range TWDM PON upstream band and shared spectrum PtP WDM PON as an example) and OTDR (with a wavelength range of 1640-1660 nm as an example) capability. Figure I.8 shows the reference diagram of this device.

Table I.8 – Parameters for a CEx with G-PON, RF video, NG-PON2 and OTDR ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for RF video band	≤ 1.0 dB (1550-1560 nm)
Loss without connectors for NG-PON2 bands	≤ 1.1 dB (1524-1544 nm and 1596-1625 nm)
Loss without connectors for OTDR band	≤ 1.3 dB (1640-1660 nm)
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – RF video (1260-1544 nm, 1575-1675 nm)	NA (RF is downstream only)
Isolation – COM – NG-PON2 OLT (1260-1500 nm, 1550-1581 nm and 1640-1675 nm)	DBA (see Appendix II)
Isolation – COM – OTDR (1260-1625 nm)	DBA (see Appendix II)
Maximum optical power for G-PON or NG-PON2 ports	+23 dBm
Maximum optical power for RF video port	+23 dBm
Maximum optical power for OTDR port	For further study
Return loss	> 50 dB
Directivity	> 50 dB

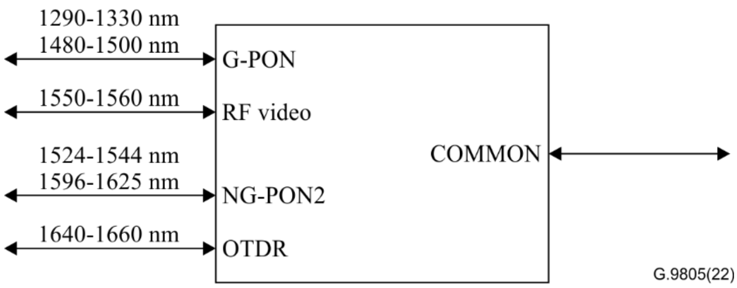

Figure I.8 – Reference diagram of a CEx with G-PON, RF video, NG-PON2 and OTDR support

Table I.9 shows sample parameters of a CEMx supporting G-PON (reduced upstream band as an example), XG-PON1, TWDM PON (wide range upstream band as an example) and PtP WDM PON (shared spectrum as an example) capability. Figure I.9 shows the reference diagram of this device.

Table I.9 – Parameters for a CEMx with G-PON, XG-PON1, TWDM PON and PtP WDM PON ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for XG-PON1 bands	≤ 1.1 dB (1260-1280 nm and 1575-1581 nm)
Loss without connectors for TWDM PON bands	≤ 1.2 dB (1524-1544 nm and 1596-1603 nm)
Loss without connectors for PtP WDM PON band	≤ 1.3 dB (1606-1625 nm)
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – XG-PON1 OLT (1290-1560 nm and 1596-1675 nm)	DBA (see Appendix II)
Isolation – COM – TWDM PON OLT (1260-1500 nm, 1550-1581 nm and 1606-1675 nm)	DBA (see Appendix II)
Isolation – COM – PtP WDM PON OLT (1260-1603 nm and 1640-1675 nm)	DBA (see Appendix II)
Maximum optical power	+23 dBm
Return Loss	> 50 dB
Directivity	> 50 dB

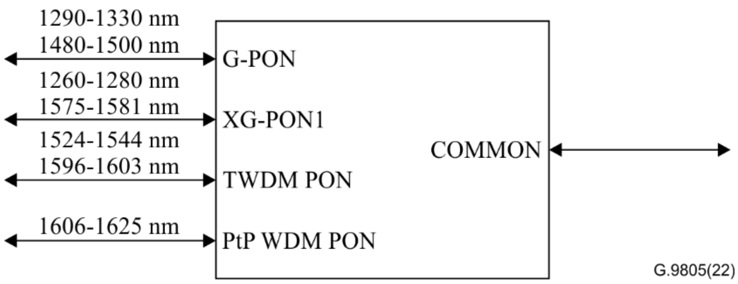

Figure I.9 – Reference diagram of a CEMx with G-PON, XG-PON, TWDM PON and PtP WDM PON support

Table I.10 shows sample parameters of a CEMx supporting G-PON (reduced upstream band as an example), XG-PON1, TWDM PON (wide range upstream band as an example), PtP WDM PON (shared spectrum as an example) and OTDR (with wavelength range of 1640-1660 nm as an example) capability. Figure I.10 shows the reference diagram of this device.

Table I.10 – Parameters for a CEMx with G-PON, XG-PON, TWDM PON, PtP WDM PON and OTDR ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for XG-PON1 bands	≤ 1.1 dB (1260-1280 nm and 1575-1581 nm)
Loss without connectors for TWDM PON bands	≤ 1.4 dB (1524-1544 nm and 1596-1603 nm)
Loss without connectors for PtP WDM PON band	≤ 1.3 dB (1606-1625 nm)
Loss without connectors for OTDR band	≤ 1.6 dB (1640-1660 nm)
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – XG-PON1 OLT (1290-1560 nm and 1596-1675 nm)	DBA (see Appendix II)
Isolation – COM – TWDM PON OLT (1260-1500 nm, 1550-1581 nm and 1606-1675 nm)	DBA (see Appendix II)
Isolation – COM – PtP WDM PON OLT (1260-1603 nm and 1640-1675 nm)	DBA (see Appendix II)
Isolation – COM – OTDR (1260-1625 nm)	DBA (see Appendix II)
Maximum optical power for G-PON, XG-PON, TDM PON or PtP WDM PON ports	+23 dBm
Maximum optical power for OTDR port	For further study
Return loss	> 50 dB
Directivity	> 50 dB

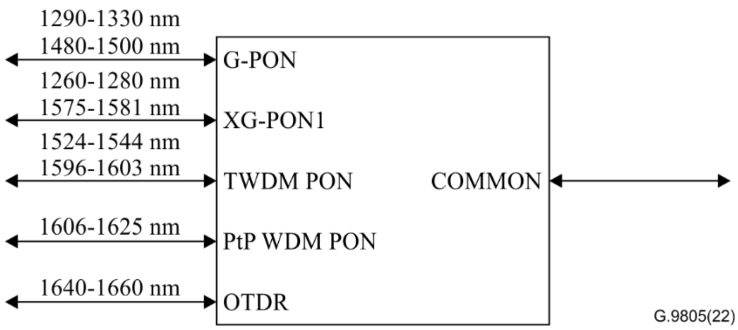

Figure I.10 – Reference diagram of a CEMx with G-PON, XG-PON, TWDM PON, PtP WDM PON and OTDR support

Table I.11 shows sample parameters of a CEMx supporting G-PON (reduced upstream band as an example), RF video, TWDM PON (wide range upstream band as an example) and PtP WDM PON (shared spectrum as an example) capability. Figure I.11 shows the reference diagram of this device.

Table I.11 – Parameters for a CEMx with G-PON, RF video, TWDM PON and PtP WDM PON ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for RF video band	≤ 1.2 dB (1550-1560 nm)
Loss without connectors for TWDM PON bands	≤ 1.1 dB (1524-1544 nm and 1596-1603 nm)
Loss without connectors for PtP WDM PON band	≤ 0.9 dB (1606-1625 nm)
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – RF video (1260-1544 nm and 1575-1675 nm)	NA (RF is downstream only)
Isolation – COM – TWDM PON OLT (1260-1500 nm, 1550-1581 nm and 1606-1675 nm)	DBA (see Appendix II)
Isolation – COM – PtP WDM PON OLT (1260-1603 nm and 1640-1675 nm)	DBA (see Appendix II)
Maximum optical power for G-PON, TWDM PON or PtP WDM PON ports	+23 dBm
Maximum optical power for RF video port	+23 dBm
Return loss	> 50 dB
Directivity	> 50 dB

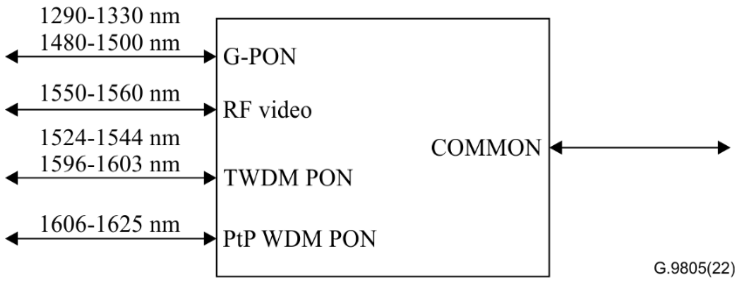

Figure I.11 – Reference diagram of a CEMx with G-PON, RF video, TWDM PON and PtP WDM PON support

Table I.12 shows sample parameters of a CEMx supporting G-PON (reduced upstream band as an example), RF video, TWDM PON (wide range upstream band as an example), PtP WDM PON (shared spectrum as an example) and OTDR (with a wavelength range of 1640-1660 nm as an example) capability. Figure I.12 shows the reference diagram of this device.

Table I.12 – Parameters for a CEMx with G-PON, RF video, TWDM PON, PtP WDM PON and OTDR ports

Specification	Value
Loss without connectors for G-PON bands	≤ 0.8 dB (1290-1330 nm and 1480-1500 nm)
Loss without connectors for RF video band	≤ 1.2 dB (1550-1560 nm)
Loss without connectors for TWDM PON bands	≤ 1.3 dB (1524-1544 nm and 1596-1603 nm)
Loss without connectors for PtP WDM PON band	≤ 0.9 dB (1606-1625 nm)
Loss without connectors for OTDR band	≤ 1.5 dB (1640-1660 nm)

Table I.12 – Parameters for a CEMx with G-PON, RF video, TWDM PON, PtP WDM PON and OTDR ports

Specification	Value
Isolation – COM – G-PON OLT (1260-1280 nm and 1524-1675 nm)	DBA (see Appendix II)
Isolation – COM – RF video (1260-1544 nm, 1575-1675 nm)	NA (RF is downstream only)
Isolation – COM – TWDM PON OLT (1260-1500 nm, 1550-1581 nm and 1606-1675 nm)	DBA (see Appendix II)
Isolation – COM – PtP WDM PON OLT (1260-1603 nm and 1640-1675 nm)	DBA (see Appendix II)
Isolation – COM – OTDR (1260-1625 nm)	DBA (see Appendix II)
Maximum optical power for G-PON, TWDM PON or PtP WDM PON ports	+23 dBm
Maximum optical power for RF video port	+23 dBm
Maximum optical power for OTDR port	For further study
Return loss	> 50 dB
Directivity	> 50 dB

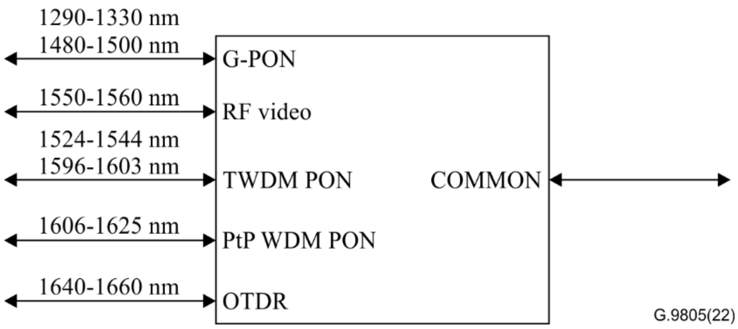

Figure I.12 – Reference diagram of a CEMx with G-PON, RF video, TWDM PON, PtP WDM PON and OTDR support

The reference diagram of a generic 2-port coexistence CEx is shown in Figure I.13. Table I.13 shows parameter specifications for the 2-port CEx with OLT1 and OLT2 ports. Table I.14 and Table I.15 show sample parameters for port isolation requirements and port directivity requirements of the 2-port CEx with OLT1 and OLT2 ports.

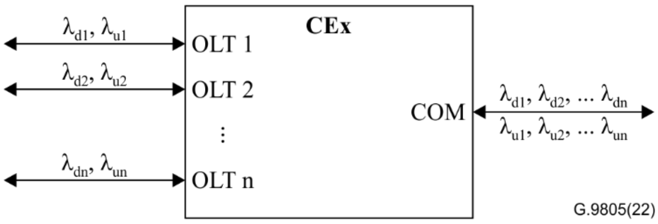

Figure I.13 – Reference diagram of a generic 2-port coexistence CEx

Table I.13 – Parameter specifications for a 2-port CEx with OLT1 and OLT2 ports

Specification	Value
Loss w/o connectors for OLT1 band	< 0.8 dB (1290-1500 nm)
Loss w/o connectors for OLT2 bands	< 1.0 dB (1260-1280 nm and 1524-1625 nm)
Isolation COM – OLT1 port (1260-1280 nm and 1524-1625 nm)	See Table I.16
Isolation COM – OLT2 port (1290-1500 nm)	See Table I.16
Maximum optical power	+23 dBm
Return loss	> 50 dB
Directivity	See Table I.17

Table I.14 – Isolation requirements for different PON pairings of a generic 2-port coexistence CEx

OLT1		**OLT2**		**Isolation *[dB]* (Note 1)**		
					[COM to OLT2]	
System	**OPL class**	**System**	**OPL class**	**[COM to OLT1]**	**OLT 2 w/o defined X/S tolerance**	**OLT2 w/ defined X/S tolerance (Note 2)**
G-PON	C+	XG-PON	E1	36.29	36.45	21.70
G-PON	C+	XGS-PON	E1	32.27	35.86	22.20
50G TDM PON (50G 10G)	N1	XG-PON	N1	24.80	34.06	26.30
50G TDM PON (50G 25G)	N1	XGS-PON	N1	26.22	31.05	26.30
50G TDM PON (50G 10G)	N1	XG-PON	N1	26.80	39.49	26.80
50G TDM PON (50G 25G)	N1	XGS-PON	N1	28.22	36.48	26.80
50G TDM PON (50G 10G)	N1	10G-EPON	PR30	25.80	38.84	
50G TDM PON (50G 25G)	N1	10G-EPON	PR30	27.22	35.83	

NOTE 1 – Here it is assumed that the CEx has a maximum insertion loss of 0.8 dB and 1.0 dB for COM-to-OLT-1 and COM-to-OLT-2, respectively. Furthermore, the tolerable crosstalk penalty assumption is 0.1 dB (this is considered negligible for implementation).

NOTE 2 – In compliance with the optional (but recommended to implement) XG(S)-PON OLT X/S tolerance masks as defined in clause 10.1 of [ITU-T G.987.2] and Annex B.10.3 in [ITU-T G.9807.1], respectively.

Table I.15 – Directivity requirements for different PON pairings of a generic 2-port coexistence CEx

OLT1		OLT2		Directivity *[dB]* (Note 1)		
System	OPL class	System	OPL class	[OLT2 to OLT1]	[OLT1 to OLT2]	
					OLT 2 w/o defined X/S tolerance	OLT 2 w/ defined X/S tolerance (Note 2)
G-PON	C+	XG-PON	E1	50.27	55.45	40.70
G-PON	C+	XGS-PON	E1	49.27	54.86	41.20
50G TDM PON (50G 10G)	N1	XG-PON	N1	37.00	43.24	41.50
50G TDM PON (50G 25G)	N1	XGS-PON	N1	38.42	43.24	41.50
50G TDM PON (50G 10G)	N1	XG-PON	N1	36.00	48.67	42.00
50G TDM PON (50G 25G)	N1	XGS-PON	N1	37.42	48.67	42.00
50G TDM PON (50G 10G)	N1	10G-EPON	PR30	36.00	For further study	
50G TDM PON (50G 25G)	N1	10G-EPON	PR30	37.42	For further study	

NOTE 1 – Here it is assumed that the CEx has a maximum insertion loss of 0.8 dB and 1.0 dB for COM-to-OLT-1 and COM-to-OLT-2, respectively. Furthermore, the tolerable crosstalk penalty assumption is 0.1 dB (this is considered negligible for implementation).

NOTE 2 – In compliance with the optional (but recommended to implement) XG(S)-PON OLT X/S tolerance masks as defined in clause 10.1 of [ITU-T G.987.2] and clause B.10.3 in [ITU-T G.9807.1], respectively.

Appendix II

Methods for calculating required isolation for WDM/CE/CEM devices

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

This appendix provides guidance to implementers of WDM1r, CEx and CEMx components concerning the isolation requirements. It is not appropriate to specify a single value for the isolation requirement for each WDM1r, CE and CEM device, as it depends on the particular operational use case, so a simple formula is provided below to enable implementers to derive indicative isolation values.

By way of example, Figure II.1 shows the assumed network topology for calculating the required isolation for the G-PON port of a WDM device enabling coexistence with XG(S)-PON. The G-PON ONUs are assumed to be at the maximum differential loss expected in the deployment and the XG(S)-PON ONU is at the minimum loss i.e., their relative ODN losses are equal to the maximum expected differential loss in the ODN. Note that this does not need to be the same as the maximum differential loss supported in [ITU-T G.984.2], [ITU-T G.987.2] and [ITU-T G.9807.1] if the ODN design is such that it limits the expected differential loss. The expected differential loss may be limited for example by ODN component specification or by limiting drop fibre lengths.

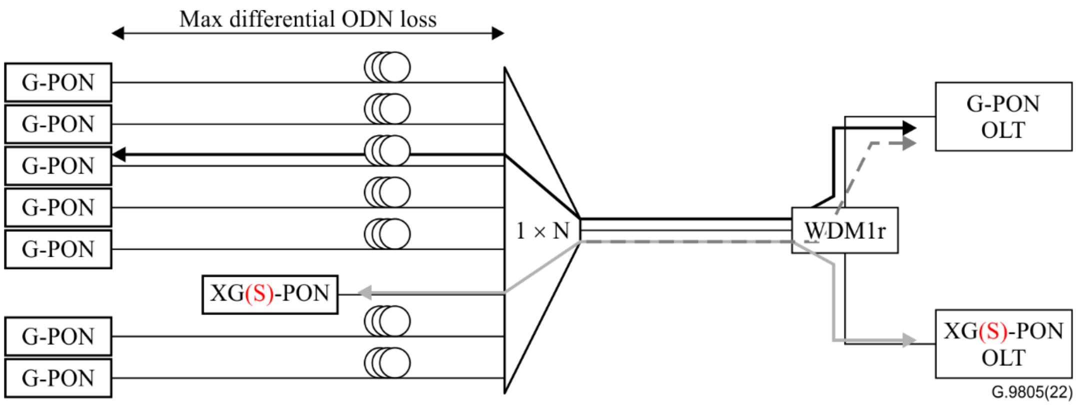

Figure II.1 – Network topology assumed for calculating the required isolation for the G-PON port of a WDM device enabling coexistence with XG-PON

In addition to being at the highest loss, the G-PON ONUs are assumed to be transmitting at the lowest power permitted in [ITU-T G.984.2]. The XG(S)-PON ONU is transmitting at the highest power permitted in [ITU-T G.987.2] or [ITU-T G.9807.1].

On the OLT side, the internal diplexer of the G-PON OLT transceiver may also add some isolation that could be taken into account if known by the implementer. This is illustrated in Figure II.2. Other sources of intrinsic OLT isolation may also be considered e.g., any additional filtering in the Rx path or additional filtering inserted between the WDM and the OLT. If the isolation is not known, or if a worse case assumption is preferred, then the isolation of this diplexer (and other elements after the WDM) may be set to zero.

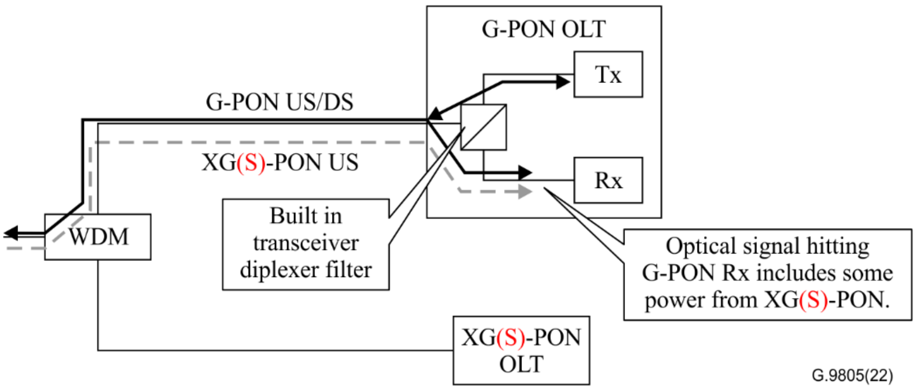

Figure II.2 – Isolation factors to consider at the OLT

To derive the required isolation, the allowed crosstalk ratio is to be calculated at the tolerable penalty in the particular deployment scenario being considered (this is a design choice for the implementer and is not specified by ITU-T Recommendations). The following equation, taken from [b-ITU-T G-Sup.39], for inter-channel crosstalk power penalty may be used to derive the allowed crosstalk.

For a single interfering channel:

$$P_C = 10\log_{10}\left(1 - 10^{\frac{C_C}{10}} \frac{r+1}{r-1}\right) \quad \text{dB} \qquad \text{(II-1)}$$

where r is the linear extinction ratio.

Using this formula, the chart shown in Figure II.3 can be plotted from which the allowed crosstalk for the system design penalty assumption can be extracted. This chart shows the calculation for G-PON, XG-PON and NG-PON2 (both 2.5G and 10G US). The source of the difference between each system is the minimum extinction ratio specification in each case i.e., 10 dB, 8.2 dB and 6 dB for G-PON, XG-PON/NG-PON2(2.5G) and NG-PON2(10G) respectively.

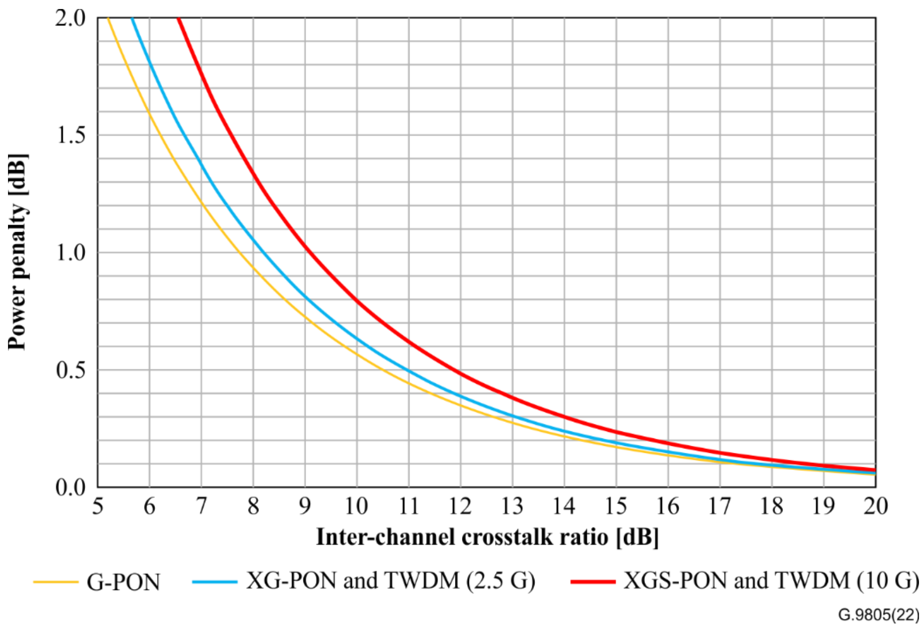

Figure II.3 – Power penalty as a function of inter-channel crosstalk ratio

The following formula (II-2) may be derived for calculating the required isolation in terms of the allowed crosstalk, differential ODN loss, launch power difference between ONUs (G-PON (min) – XG-PON (max)), diplexer (or other WDM to Rx path) isolation and bandwidth ratio. All parameters are in dB.

$$I_{WDM} = XT(dB) - \Delta P + \Delta ODN - I_{BiDi} - B_{comp} \quad \text{(II-2)}$$

I_{WDM}: Port isolation at the interferer wavelength for the WDM device enabling coexistence

XT: Allowed inter-channel crosstalk power ratio in dB

ΔP: ONU launch power ratio in dB between the target signal (minimum) and the interfering signal (maximum)

ΔODN: ODN loss difference in dB for the target signal (minimum) and the interfering signal (maximum)

I_{BiDi}: Isolation in the receive path (external to the WDM used for coexistence) at the interferer wavelength e.g., from the internal transceiver diplexer (BiDi)

B_{comp}: Relative bandwidth compensation factor to account for signal bandwidth difference between the target signal and the interfering signal as given by:

$$B_{comp}(dB) = 10\log\left(R_{\text{int}} / R_{target} \right) \quad \text{(II-3)}$$

To illustrate the application of the formula, worked examples are given below:

Example 1

For a 0.5 dB penalty to G-PON in a G-PON and XG-PON coexistence scenario the permitted inter-channel crosstalk (XT) is approximately 10 dB (from Figure II.3).

For a B+/N1 class ODN, the power ONU launch difference (ΔP) is 0.5 dBm − 7 dBm = −6.5 dB.

The designed ODN loss differential (ΔODN) is 5 dB.

The post WDM isolation (I_{BiDi}) is assumed to be 2 dB.

The bit-rate compensation factor (B_{comp}) is 10log (2.5/1.25) = 3 dB.

So, the required WDM isolation (I_{WDM}) at the G-PON port for the XG-PON US wavelength is:

10 − (−6.5) + 5 − 2 − 3= <u>16.5 dB.</u>

Example 2

For a 0.1 dB penalty to G-PON in a G-PON and XG-PON coexistence scenario, the permitted inter-channel crosstalk (XT) is approximately 17 dB (from Figure II.3).

For a B+/N1 class ODN The power ONU launch difference (ΔP) is 0.5 dBm − 7 dBm = −6.5 dB.

The designed ODN loss differential (ΔODN) is 10 dB.

The post WDM isolation (I_{BiDi}) is assumed to be 0 dB.

The bit-rate compensation factor (B_{comp}) is 10log (2.5/1.25) = 3 dB.

So, the required WDM isolation (I_{WDM}) at the G-PON port for the XG-PON US wavelength is:

17 − (−6.5) + 10 − 0 − 3 = <u>30.5 dB.</u>

To extend the above equation for the required WDM isolation to include multichannel systems (e.g., NG-PON2) acting as the interferer, the number of interfering channels (N) can be included as a parameter.

$$I_{WDM} = XT - \Delta P + \Delta ODN - I_{BiDi} - B_{comp} + 10\log(N) \qquad \text{(II-4)}$$

The simple analysis above assumes there is one interfering system where all the interferers are at the same line rate and power. In the event that the three systems (e.g., G-PON, XG-PON and NG-PON2) are to coexist, the analysis becomes more complex.

[b-ITU-T G-Sup.39] addresses the multi-interferer case (eq. 9-30 of [b-ITU-T G-Sup.39]), but only for a high number of equal power interferers, hence the multi-interferer formula is clearly not applicable to the PON coexistence scenario, in which the number of interferers is limited and the power differences may be high.

As a first approximation, the single interferer formula is therefore used (eq. 9.28 of [b-ITU-T G-Sup.39]), assuming the interferers add in power (for multi-channel systems, like NG-PON2, each channel is considered as a separate interferer). Although this approach may require further validation, consideration can be taken of the fact that most practical scenarios result in a single dominant interferer, hence the approximation error should be limited. More rigorous approaches are left for further study.

With the above assumptions and referring to the CEx model (see Figure II.4) and definitions listed below, a simple mathematical derivation leads to the following formulas that can be used to calculate the required per port isolation and directivity figures, once a tolerated penalty value has been defined. The formulas have been derived assuming either an equal isolation/directivity of each port against each interferer or an equal crosstalk level from each interferer. Note that linear quantities are used in all formulas, unless otherwise stated.

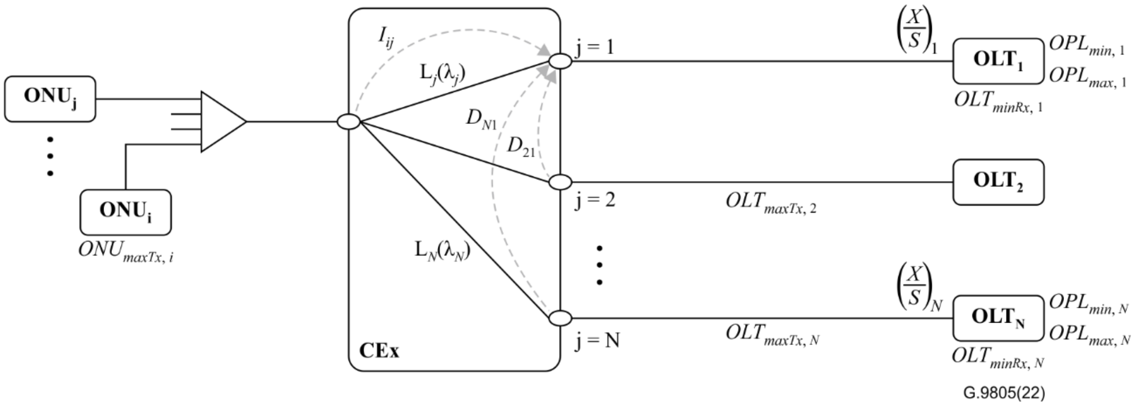

Figure II.4 – CEx model for isolation and directivity calculations

N : Number of coexisting systems

j, i : CEx ports corresponding to victim signal j and interfering signal i

I_{ij} : Isolation (blocking band loss) of port j against band i (i.e., the loss encountered by interferer i when it traverses the CEx from common port to port j)

D_{ij} : Directivity of port i to port j (i.e., the loss encountered by interferer i when it traverses the CEx from port i to port j)

$L_{min/max,j}(\lambda_j)$: Maximum (and minimum) insertion (pass band) loss of (common port to) port j at the victim wavelength λ_j

$L_j(\lambda_i)$: Insertion (pass band) loss of (common port to) port j at the interferer wavelength λ_i; (equivalent to the isolation I_{ij})

ρ_i, ρ_j : Photodiode responsivities at the interferer and victim signal wavelengths respectively

R_i, R_j : Bit rates of the interferer and victim signals respectively

$ONU_{maxTX,i}$: Maximum ONU_i transmitter power of interfering signal

$OLT_{minRX,j}$: Sensitivity of victim signal OLT Rx at port j

$OLT_{maxTX,i}$: Maximum OLT transmitter power of interfering signal from port i

$OPL_{min,j}$: Minimum Optical Path Loss supported by the OPL class of the OLT transceiver at port j

$OPL_{max,j}$: Maximum Optical Path Loss supported by the OPL class of the OLT transceiver at port j

C_j : Crosstalk to (victim signal) port j

r_j : Extinction ratio of victim signal j

P_c : Tolerated crosstalk penalty on victim signal j.

Isolation formulas

For the condition of uniform isolation: $I_{ij} = I_j, \forall j \neq i$:

(i) For OLT ports without wavelength blocking filters for which the tolerable crosstalk ratio (C_j) for a given power penalty must be calculated for the victim port:

$$I_{ij} = L_j(\lambda_i) = \frac{1}{OLT_{minRx,j} \cdot OPL_{max,j}} \cdot \frac{min\left[\left(\frac{OPL_{max,j}}{L_{max,j}(\lambda_j)}\right)_{j=1\ to\ N}\right]}{max\left[\left(\frac{OPL_{min,j}}{L_{min,j}(\lambda_j)}\right)_{j=1\ to\ N}\right]} \cdot \frac{L_{max,j}(\lambda_j)}{C_j} \cdot \sum_{i=1,(i\neq j)}^{N} \frac{ONU_{maxTx,i}}{max\left[1,\frac{R_i}{R_j}\right]} \cdot \frac{\rho_i}{\rho_j} \quad \text{(III-5)}$$

(ii) For OLT ports with wavelength blocking filters (see Appendix IV) for which the X/S tolerance of the victim port is known:

$$I_{ij} = L_j(\lambda_i) = \frac{1}{OLT_{minRx,j} \cdot OPL_{max,j}} \cdot \frac{min\left[\left(\frac{OPL_{max,j}}{L_{max,j}(\lambda_j)}\right)_{j=1\ to\ N}\right]}{max\left[\left(\frac{OPL_{min,j}}{L_{min,j}(\lambda_j)}\right)_{j=1\ to\ N}\right]} \cdot \frac{L_{max,j}(\lambda_j)}{\left(\frac{X}{S}\right)_j} \cdot \sum_{i=1,(i\neq j)}^{N} ONU_{maxTx,i} \quad \text{(III-6)}$$

Directivity formulas

For the condition of uniform directivity: $D_{ij} = D_j, \forall j \neq i$

(i) For OLT ports without wavelength blocking filters for which the tolerable crosstalk ratio (C_j) for a given power penalty must be calculated for the victim port:

$$D_{ij} = \frac{1}{OLT_{minRx,j} \cdot OPL_{max,j}} \cdot min\left[\left(\frac{OPL_{max,j}}{L_{max,j}(\lambda_j)}\right)_{j=1\ to\ N}\right] \cdot \frac{L_{max,j}(\lambda_j)}{C_j} \cdot \sum_{i=1,(i\neq j)}^{N} \frac{OLT_{maxTx,i}}{max\left[1,\frac{R_i}{R_j}\right]} \cdot \frac{\rho_i}{\rho_j} \quad \text{(III-7)}$$

(ii) For OLT ports with wavelength blocking filters (see Appendix IV) for which the X/S tolerance of the victim port is known:

$$D_{ij} = \frac{1}{OLT_{minRx,j} \cdot OPL_{max,j}} \cdot min\left[\left(\frac{OPL_{max,j}}{L_{max,j}(\lambda_j)}\right)_{j=1\ to\ N}\right] \cdot \frac{L_{max,j}(\lambda_j)}{\left(\frac{X}{S}\right)_j} \cdot \sum_{i=1,(i\neq j)}^{N} OLT_{maxTx,i} \quad \text{(III-8)}$$

The tolerated crosstalk C_j in the above formulas can be calculated by inverting the single interferer formula, eq. 9.28 of [b-ITU-T G-Sup.39]): and with an additional change of the sign (–Pc):

$$C_j = \frac{r_j - 1}{r_j + 1}\left(1 - 10^{\frac{-P_c}{10}}\right) \quad \text{(III-9)}$$

where r_j is the extinction ratio of the victim signal and P_c is the tolerated crosstalk penalty expressed in decibels. Note that penalty caused by eye opening reduction is already included in the isolation and directivity formulas through the OPP or receiver sensitivity terms, hence the effective value of *r* defined by eq. 9.29 of [b-ITU-T G-Sup.39], must not be used here.

To illustrate the application of the above isolation and directivity equations, worked examples are given below:

Example 1

For a penalty P_c = 0.1 dB in a B+ G-PON and N1 XGS-PON coexistence scenario, the maximum inter-channel crosstalk (C_j) is –17.3 dB for G-PON.

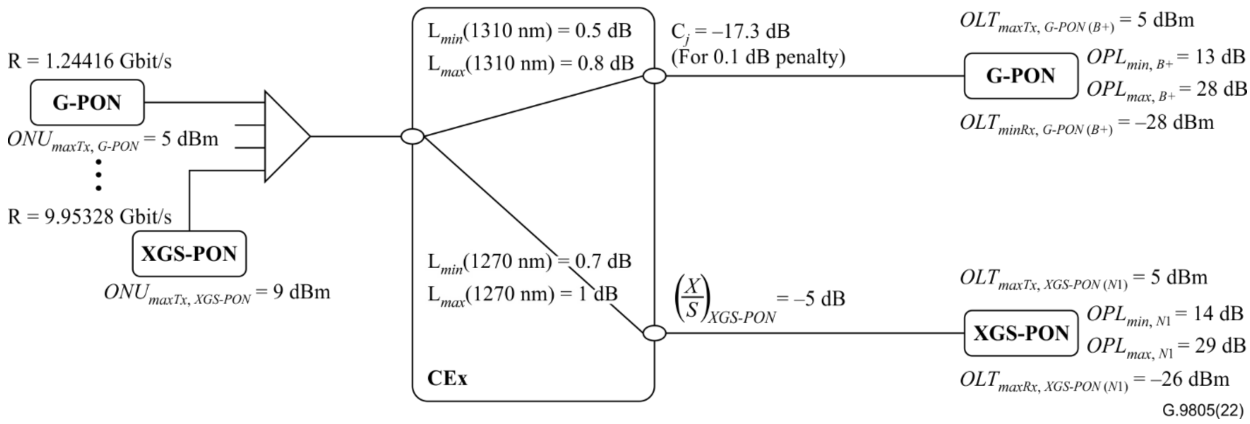

Figure II.5 – 2-port CEx worked example

The relevant parameters for this example scenario are shown in Table II.1. It is assumed that the responsivity of the victim Rx is the same at both the victim and interferer wavelengths as both are in the O-band.

Table II.1 – 2-port CEx worked example parameters

Parameter	Value	Unit	Comment
Bit rate of victim	1.24416	Gbit/s	G-PON US line-rate (Note 1)
Bit rate of interferer	9.95328	Gbit/s	XGS-PON US line-rate (Note 2)
Victim OLT Rx sense	–28.0	dBm	min for B+ G-PON OLT (Note 1)
Max OPL of victim OLT port	28.0	dB	max ODN loss of B+ OPL class (Note 1)
Max OPL of interferer OLT port	29.0	dB	max ODN loss of N1 OPL class (Note 2)
Min OPL of victim OLT port	13.0	dB	min ODN loss of B+ OPL class (Note 1)
Min OPL of interferer OLT port	14.0	dB	min ODN loss of N1 OPL class (Note 2)
Min loss of victim OLT port	0.5	dB	G-PON port of CEx (Note 3)
Min loss of interferer OLT port	0.7	dB	XGS-PON port of CEx (Note 3)
Max loss of victim OLT port	0.8	dB	G-PON port of CEx (Note 3)
Max loss of interferer OLT port	1.0	dB	XGS-PON port of CEx (Note 3)
Max allowed X/S of the victim OLT port	–17.3	dB	As calculated as no X/S defined for G-PON OLT (Note 4)
Launch power max interfering ONU	9.0	dBm	Max for XGS-PON ONU (Note 2)
NOTE 1 – See [ITU-T G.984.2]. NOTE 2 – See [ITU-T G.9807.1]. NOTE 3 – Estimated values for the purpose of this worked example.			

NOTE 4 – See equation 9.28 of [b-ITU-T G-Sup.39].

The equation for isolation can be expressed in dB for a 2 port CEx as follows:

$$I_{21}(dB) = -OLT_{minRx,1}(dBm) - OPL_{max,1}(dB) + min\left[\left(OPL\_max_j\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] - max\left[\left(OPL\_min_j\ (dB) - L_{min,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - C_1(dB) + ONU_{maxTx,2}(dBm) - max\left[1,\frac{R_2}{R_1}\right](dB)\ + 10log\left(\frac{\rho_2}{\rho_1}\right)$$

For G-PON as the victim at port 1:

$$I_{21}(dB) = -(-28\ dBm) - 28\ dB + min[(28\ dB - 0.8\ dB), (29\ dB - 1\ dB)] - max[(13\ dB - 0.5\ dB), (14\ dB - 0.7\ dB)] + 0.8\ dB - (-17.3\ dB) + 9\ dBm - max\left[0, 10log\left(\frac{9.95328}{1.24416}\right)\right](dB) + 0\ dB$$

$$I_{21}(dB) = 28\ dBm - 28\ dB + 27.2\ dB - 13.3\ dB + 0.8\ dB + 17.3\ dB + 9d\ Bm\ - 9\ dB = \mathbf{32\ dB}$$

For the XGS-PON port of the CEx, in the case that a blocking filter has been implemented with (X/S) = –5 dB, the required isolation in dB is given as follows:

$$I_{21}(dB) = -OLT_{minRx,1}(dBm) - OPL_{max,1}(dB) + min\left[\left(OPL\_max_j\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] - max\left[\left(OPL\_min_j\ (dB) - L_{min,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - \left(\frac{X}{S}\right)_1(dB) + ONU_{maxTx,2}(dBm)$$

$$I_{21}(dB) = -(-26\ dBm) - 29dB + min[(29\ dB - 1\ dB), (28\ dB - 0.8\ dB)] - max[(14\ dB - 0.7\ dB), (13\ dB - 0.5\ dB)] + 1\ dB - (-5\ dB) + 5\ dBm$$

$$I_{21}(dB) = 26\ dBm - 29\ dB + 27.2\ dB - 13.3\ dB + 1\ dB + 5\ dB + 5\ dBm = \mathbf{21.9\ dB}$$

In the case of directivity, the dB form of the equation is given as follows for this 2-port CEx example:

$$D_{21}(dB) = -OLT_{minRx,1}(dB) - OPL_{max,1}(dB) + min\left[\left(OPL_{max,j}\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - C_1(dB) + OLT_{maxTx,2}(dBm)) - max\left[0,10log\left(\frac{R_2}{R_1}\right)\right] + 10log\left(\frac{\rho_2}{\rho_1}\right)$$

The interference to the G-PON signal comes from the N1 OPL class XGS-PON OLT Tx at +5 dBm (max).

$$D_{21}(dB) = -(-28\ dBm) - 28\ dB + min[(28\ dB - 0.8\ dB), (29\ dB - 1\ dB)] + 0.8\ dB - (-17.3\ dB) + 5\ dBm - max\left[0, 10log\left(\frac{9.95328}{1.24416}\right)\right](dB) + 0\ dB$$

$D_{21}(dB) = 28\ dBm - 28\ dB + 27.2\ dB + 0.8\ dB + 17.3\ dB + 5\ dBm - 9\ dB + 0\ dB$ = **41.3 *dB***

In this scenario the G-PON upstream victim signal is in the 1300 nm spectral region and the interferer is at 1577 nm and, for such a wide wavelength separation, it is likely that the responsivity of the victim receiver will be different at these wavelengths. If the receiver module responsivity difference is purely due to the absorption coefficient in the photodiode (i.e., not due to other wavelength dependent losses in between the S/R reference point and the detector), then one might expect about 10% higher responsivity at the longer wavelength for InGaAs based detectors. This would result in about 0.5 dB additional directivity requirement. However, the exact responsivity difference must be determined by application.

For XGS-PON, in the case that a blocking filter has been implemented with (X/S) = –5 dB, the required directivity in dB is given as follows:

$$D_{21}(dB) = -OLT_{minRx,1}(dBm) - OPL_{max,1}(dB) + min\left[\left(OPL_{max,j}\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - \left(\frac{X}{S}\right)_1 (dB) + OLT_{maxTx,2}(dBm)$$

$$D_{21}(dB) = -(-26\ dBm) - 29\ dB + min[(29\ dB - 1\ dB), (28\ dB - 0.8\ dB)] + 1\ dB - (-5\ dB) + 5\ dBm$$

$$D_{21}(dB) = 26\ dBm - 29\ dB + 27.2\ dB + 1\ dB + 5\ dB + 5\ dBm = \mathbf{35.2\ dB}$$

Example 2

For a penalty P_c = 0.1 dB in a N1 50G/25G HS-PON and N1 XGS-PON coexistence scenario, the HS-PON has a mandatory X/S for OLT as −5 dB (wavelength option 2), for the XGS-PON, there are two cases:

a) No OLT X/S tolerance specification: XGS-PON tolerates –18.66 dB maximum crosstalk (Ci) to achieve 0.1 dB penalty

b) With OLT X/S tolerance specification as defined in [ITU-T G.9807.1]: X/S = −5 dB

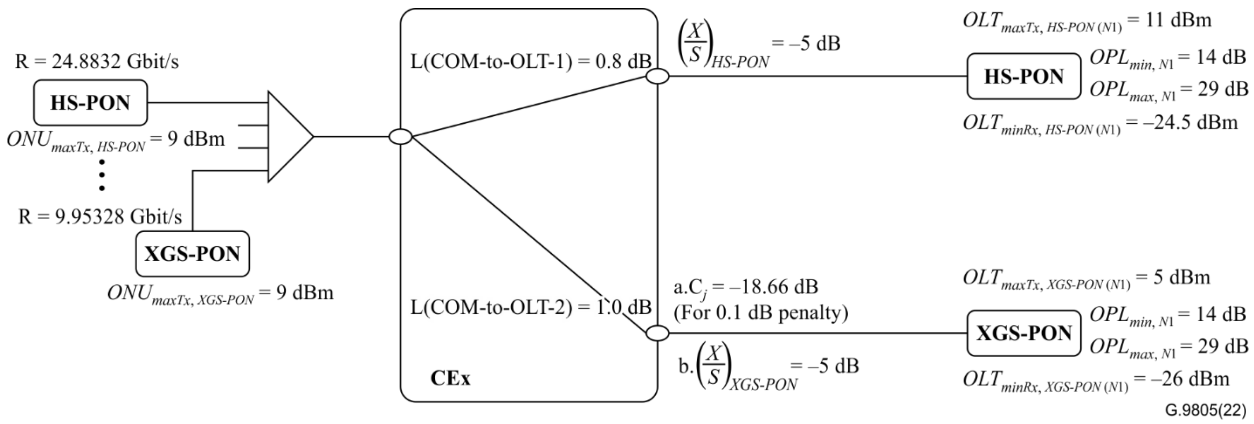

Figure II.6 – 2-port CEx worked example

The relevant parameters for this example scenario are shown in Table II.2.

Table II.2 – 2-port CEx worked example parameters

Parameter	Value	Unit	Comment
Bit rate of victim	24.8832	Gbit/s	HS-PON US line-rate (Note 1)
Bit rate of interferer	9.95328	Gbit/s	XGS-PON US line-rate (Note 2)
Victim OLT Rx sense	–24.5	dBm	min for N1 HS-PON OLT (Note 1)
Max OPL of victim OLT port	29.0	dB	max ODN loss of N1 OPL class (Note 1)
Max OPL of interferer OLT port	29.0	dB	max ODN loss of N1 OPL class (Note 2)

Table II.2 – 2-port CEx worked example parameters

Parameter	Value	Unit	Comment
Min OPL of victim OLT port	14.0	dB	min ODN loss of N1 OPL class (Note 1)
Min OPL of interferer OLT port	14.0	dB	min ODN loss of N1 OPL class (Note 2)
Min Loss of victim OLT port	0.8	dB	HS-PON port of CEx (Note 3)
Min Loss of interferer OLT port	1.0	dB	XGS-PON port of CEx (Note 3)
Max Loss of victim OLT port	0.8	dB	HS-PON port of CEx (Note 3)
Max Loss of interferer OLT port	1.0	dB	XGS-PON port of CEx (Note 3)
X/S of the victim OLT port	–5	dB	X/S defined for HS-PON OLT (Wavelength option 2) (Note 1)
X/S of the interferer OLT port	–5	dB	X/S defined for XGS-PON OLT (Note 2)
Launch power max interfering ONU	9.0	dBm	Max for XGS-PON ONU (Note 2)
NOTE 1 – See [ITU-T G.9804.3]. NOTE 2 – See Amendment 2 to [ITU-T G.9807.1]. NOTE 3 – Estimated values for the purpose of this worked example.			

The equation for isolation can be expressed in dB for a 2 port CEx as follows:

$$\begin{aligned} I_{21}(dB) = {} & -OLT_{minRx,1}(dBm) - OPL_{max,1}(dB) + min\left[\left(OPL\_max_j\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] \\ & - max\left[\left(OPL\_min_j\ (dB) - L_{min,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - C_1(dB) \\ & + ONU_{maxTx,2}(dBm) - max\left[1, \tfrac{R_2}{R_1}\right](dB)\ + 10log\left(\frac{\rho_2}{\rho_1}\right) \end{aligned}$$

For HS-PON as the victim at port 1 that a blocking filter has been implemented with (X/S) = –5 dB, the required isolation in dB is given as follows:

$$\begin{aligned} I_{21}(dB) = {} & -OLT_{minRx,1}(dBm) - OPL_{max,1}(dB) + min\left[\left(OPL\_max_j\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] \\ & - max\left[\left(OPL\_min_j\ (dB) - L_{min,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - \left(\frac{X}{S}\right)_1(dB) \\ & + ONU_{maxTx,2}(dBm) \end{aligned}$$

$$\begin{aligned} I_{21}(dB) = {} & -(-24.5\ dBm) - 29\ dB + min[(29\ dB - 0.8\ dB), (29\ dB - 1\ dB)] \\ & - max[(14\ dB - 0.8\ dB), (14\ dB - 1\ dB)] + 0.8\ dB - (-5\ dB) + 9\ dBm \end{aligned}$$

$$I_{21}(dB) = 24.5\ dBm - 29\ dB + 28\ dB - 13.2\ dB + 0.8\ dB + 5\ dB + 9\ dBm = \mathbf{25.10\ dB}$$

a) For the XGS-PON port of the CEx without OLT X/S tolerance specification, the required isolation in dB is given as follows:

$$\begin{aligned} I_{21}(dB) = {} & -(-26\ dBm) - 29\ dB + min[(29\ dB - 0.8\ dB), (29\ dB - 1\ dB)] \\ & - max[(14\ dB - 1\ dB), (14\ dB - 0.8\ dB)] + 1\ dB - (-18.66\ dB) + 9\ dBm \\ & - max\left[0, 10log\left(\tfrac{24.8832}{9.95328}\right)\right](dB) + 0\ dB \end{aligned}$$

$$I_{21}(dB) = 26\ dBm - 29\ dB + 28\ dB - 13.2\ dB + 1\ dB + 18.66\ dB + 9\ dBm - 3.98\ dB = \mathbf{36.48\ dB}$$

b) For the XGS-PON port of the CEx with OLT X/S tolerance specification (X/S) = –5 dB, the required isolation in dB is given as follows:

$$\begin{aligned} I_{21}(dB) = {} & -(-26\ dBm) - 29\ dB + min[(29\ dB - 0.8\ dB), (29\ dB - 1\ dB)] \\ & - max[(14\ dB - 1\ dB), (14\ dB - 0.8\ dB)] + 1\ dB - (-5\ dB) + 9\ dBm \end{aligned}$$

$$I_{21}(dB) = 26\ dBm - 29\ dB + 28\ dB - 13.2\ dB + 1\ dB + 5\ dB + 9\ dBm = \mathbf{26.80\ dB}$$

In the case of directivity, the dB form of the equation is given as follows for this 2-port CEx example:

$$D_{21}(dB) = -OLT_{minRx,1}(dB) - OPL_{max,1}(dB) + min\left[\left(OPL_{max,j}\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - C_1(dB) + OLT_{maxTx,2}(dBm)) - max\left[0, 10log\left(\frac{R_2}{R_1}\right)\right] + 10log\left(\frac{\rho_2}{\rho_1}\right)$$

For HS-PON, a blocking filter has been implemented with (X/S) = –5 dB, the required directivity in dB is given as follows:

$$D_{21}(dB) = -OLT_{minRx,1}(dBm) - OPL_{max,1}(dB) + min\left[\left(OPL_{max,j}\ (dB) - L_{max,j}(\lambda_j)dB\right)_{j=1\ to\ 2}\right] + L_{max,1}(\lambda_1)\ dB - \left(\frac{X}{S}\right)_1 (dB) + OLT_{maxTx,2}(dBm)$$

$$D_{21}(dB) = -(-24.5\ dBm) - 29\ dB + min[(29\ dB - 0.8\ dB)\ , (29\ dB - 1\ dB)]\ + 0.8\ dB - (-5\ dB) + 5\ dBm$$

$$D_{21}(dB) = 24.5\ dBm - 29\ dB + 28\ dB + 0.8\ dB + 5\ dB + 5\ dBm = \mathbf{34.30\ dB}$$

a) For XGS-PON without OLT X/S tolerance specification, the required directivity in dB is given as follows:

$$D_{21}(dB) = -(-26\ dBm) - 29\ dB + min[(29\ dB - 0.8\ dB), (29\ dB - 1\ dB)] + 1\ dB - (-18.66\ dB) + 11\ dBm - max\left[0, 10log\left(\frac{49.7664}{9.95328}\right)\right](dB) + 0\ dB$$

$$D_{21}(dB) = 26\ dBm - 29\ dB + 28\ dB + 1\ dB + 18.66\ dB + 11\ dBm - 6.99\ dB = \mathbf{48.67\ dB}$$

b) For the XGS-PON port with OLT X/S tolerance specification (X/S) = –5 dB, the required directivity in dB is given as follows:

$$D_{21}(dB) = -(-26\ dBm) - 29\ dB + min[(29\ dB - 0.8\ dB), (29\ dB - 1\ dB)] + 1\ dB - (-5\ dB) + 11\ dBm$$

$$D_{21}(dB) = 26\ dBm - 29\ dB + 28\ dB + 1\ dB + 5\ dB + 11\ dBm = \mathbf{42.00\ dB}$$

Appendix III

Multi-PON module with integrated WDM

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

External WDM1, WDM1r, CEx and CEMx devices discussed in Appendix I provide a good way to support coexistence and smooth migration. However, these external WDM approaches introduce extra insertion loss in the ODN. For example, loss without connectors for G-PON bands is less than 0.8 dB in Table I.2 and Table I.3 of Appendix I, applied and counted in the ODN design. This is a challenge in ODN cases with tight optical margins. Furthermore, it is advantageous for some operators to have an upgrade approach that replaces existing line cards in the OLT chassis with new line cards in order to upgrade to multiple PON technologies integrated into the MPM. The MPM method can simplify the upgrade engineering and reduce the probability of manual operational error during migration.

An example reference diagram for the OLT MPM function is shown in Figure III.1.

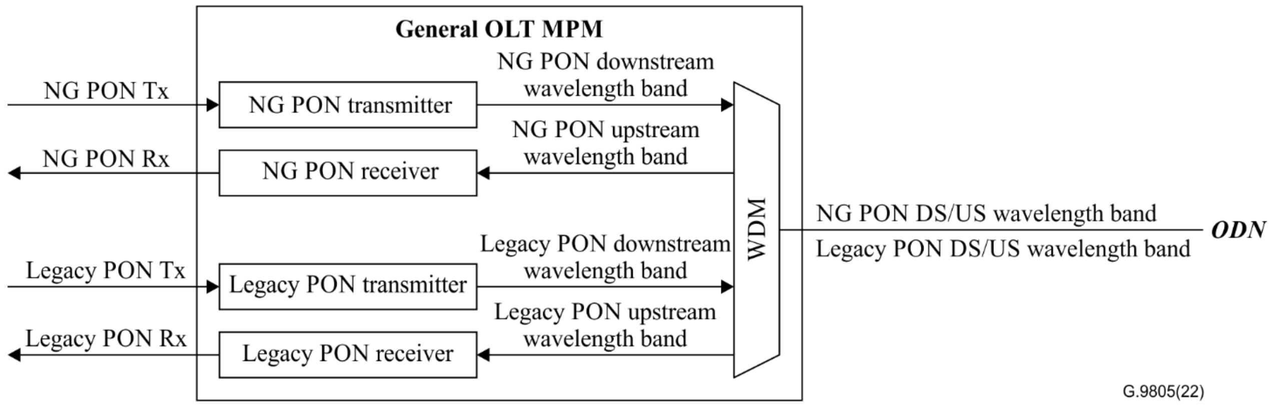

Figure III.1 – Example reference diagram for OLT MPM with integrated WDM

An example reference diagram of G-PON/XG-PON OLT MPM with integrated WDM is shown in Figure III.2.

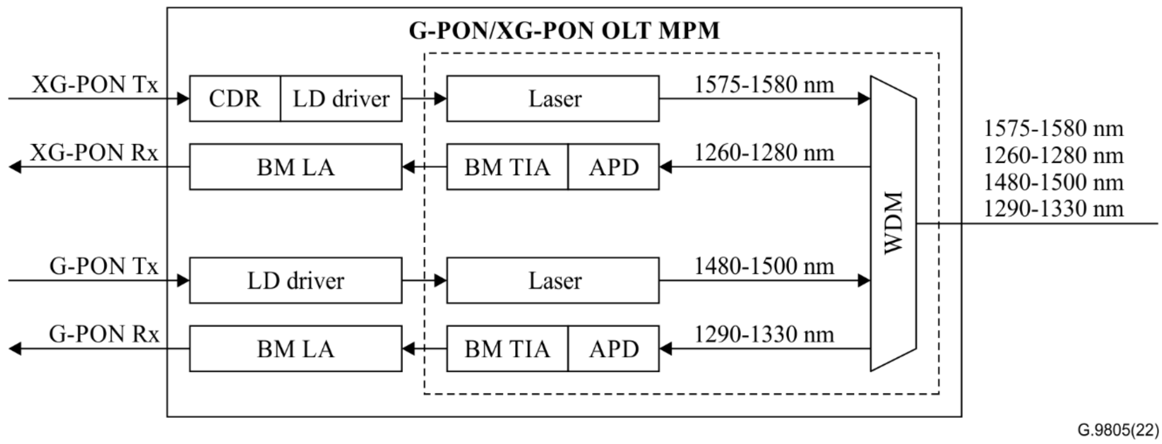

Figure III.2 – Reference diagram of G-PON/XG-PON OLT MPM with integrated WDM

By employing G-PON/XG-PON OLT MPM in the migration scenario, G-PON ONUs and XG-PON ONUs coexist in the same ODN and simultaneously operate with a common OLT in the corresponding standards-based wavelength bands. The narrow option can be supported as well as the reduced wavelength options of G-PON shown in Figure III.2.

An example reference diagram of G-PON/XG-PON OLT MPM with dual-rate receiver and triplexer optical sub-assembly (OSA) is shown in Figure III.3. The triplexer OSA is used to simplify the components assembly to make it easier and more compact. One G-PON transmitter, one XG-PON transmitter and one G-PON/XG-PON dual rate receiver are connected to the WDM (G-PON and XG-PON share one receiver).

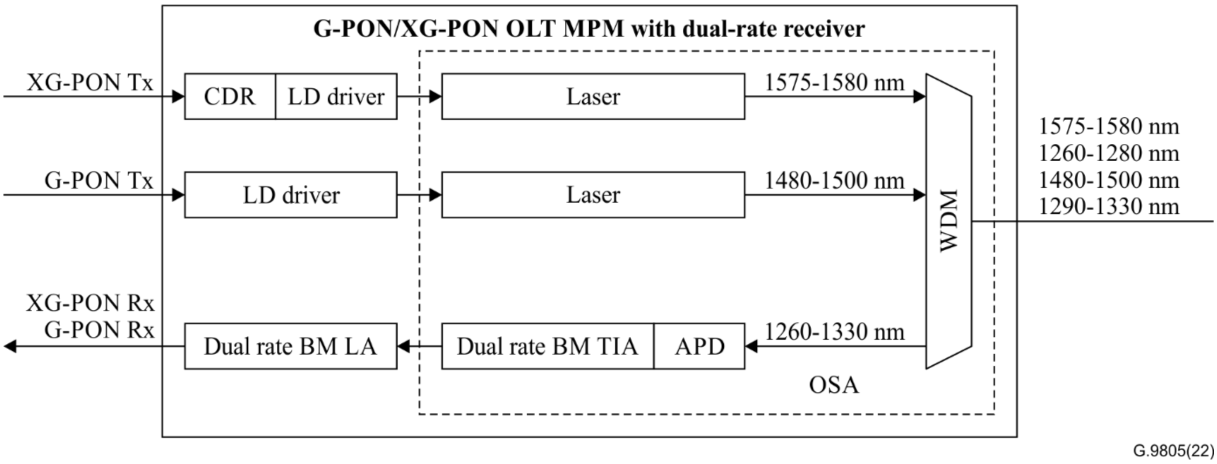

Figure III.3 – Reference diagram of G-PON/XG-PON OLT MPM with dual-rate receiver and WDM

The PMD requirements for the ODN optical interface should ensure that the legacy G-PON and XG-PON ONUs can work on the legacy ODN.

An example reference diagram of G-PON/XG-PON/XGS-PON OLT MPM with WDM is shown in Figure III.4. The WDM is used to support all three types of ONU on the same ODN. The G-PON transmitter and receiver, XGS-PON transmitter and dual rate receiver (also supporting XG-PON ONUs) are connected to the internal WDM.

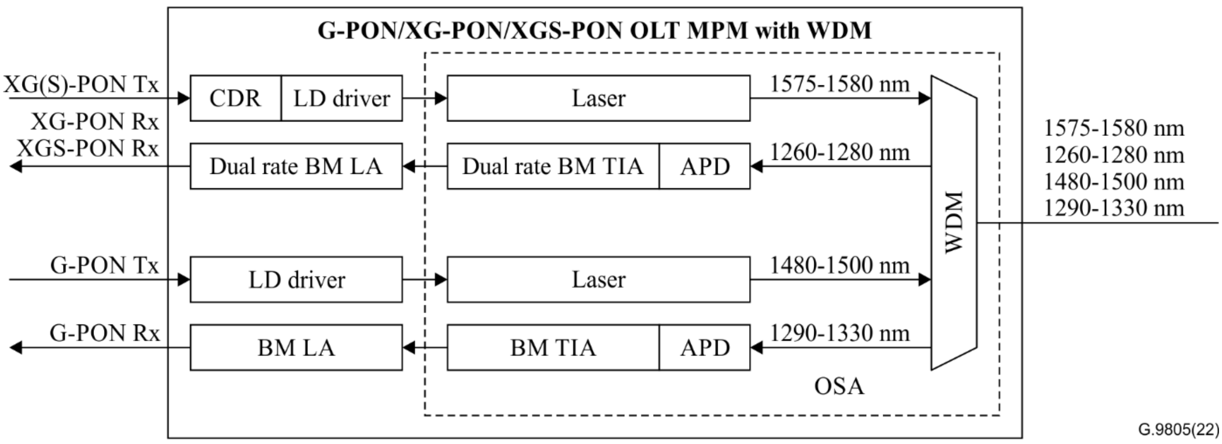

Figure III.4 – Reference diagram of G-PON/XG-PON/XGS-PON OLT MPM with WDM

The PMD requirements for the optical interface should ensure that the legacy G-PON, XG-PON and XGS-PON ONUs can work on the legacy ODN. If the support of XG-PON ONUs is not required on the ODN, then the dual rate receiver can be simplified to a single rate XGS-PON receiver.

An example reference diagram of G-PON/XG-PON/XGS-PON OLT MPM with triple-rate receiver is shown in Figure III.5. The OSA is used to make the components assembly easier and more compact. One G-PON transmitter, one XG-PON/XGS-PON transmitter, and one G-PON/XG-PON/XGS-PON triple rate receiver are connected to the WDM inside the OSA (GPON/XG-PON/XGS-PON share one receiver).

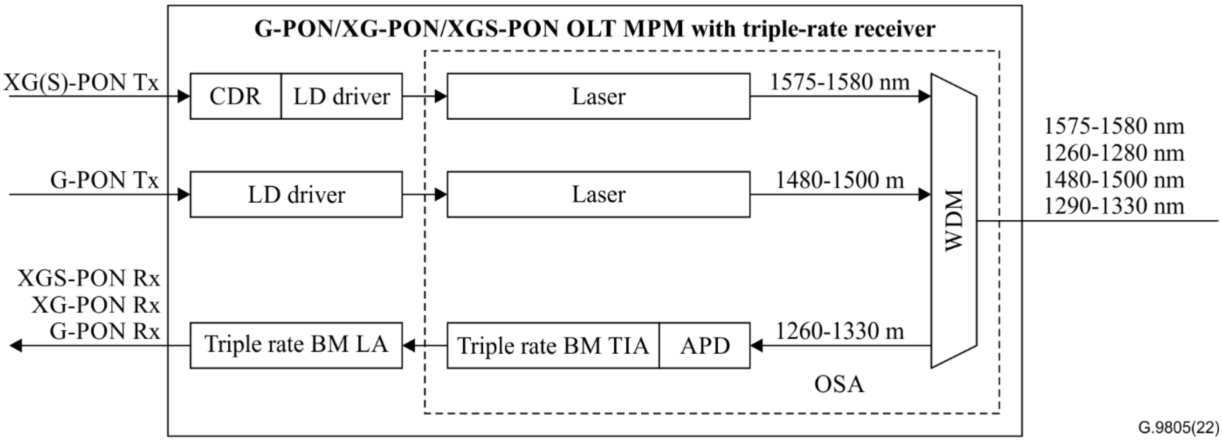

Figure III.5 – Reference diagram of G-PON/XG-PON/XGS-PON OLT MPM with triple-rate receiver

The PMD requirements for the ODN optical interface should ensure that the legacy G-PON, XG-PON and XGS-PON ONUs can work on the legacy ODN. If the XG-PON ONUs are not required, then the triple rate receiver can be simplified to a dual-rate G-PON/XGS-PON receiver.

One advantage of a single Rx MPM configuration is a reduction in the number of components. It also reduces the filtering losses and so enables higher OPL classes with lower power consumption. Moreover, there is no interoperability issue in using such modules and the key goal of co-existence (i.e., simultaneous operation of G-PON and XG-PON in the same ODN) is still guaranteed. Other benefits of co-existence, such as more aggregate upstream bandwidth, are dependent on the use case of each operator. There is no change to the BWmap structure, but it does require co-ordination between the G-PON DBA and the XG(S)-PON DBA engines to construct each respective BWmap.

Appendix IV

Filter considerations for XG(S)-PON OLT and HSP OLT

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

The minimum optical sensitivity requirements of a XG(S)-PON OLT or HSP OLT must be met in the presence of the interference signals caused by coexisting PON system and/or video signals. To minimize the effect of interference signals, XG(S)-PON OLT or HSP OLT need to isolate interference signals using an appropriate WBF and WDM filter. Figure IV.1 shows the optical reference diagram for XG(S)-PON and HSP.

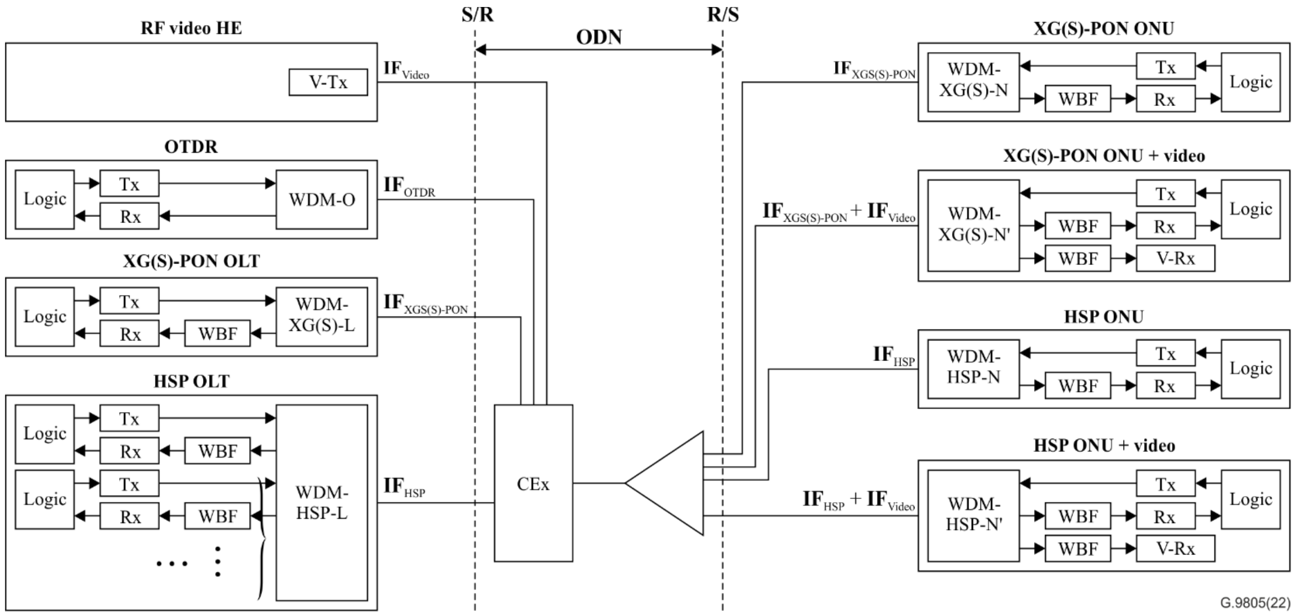

Figure IV.1 – Optical reference diagram for XG(S)-PON and HSP

The following abbreviations are used in Figure IV.1:

CEx	Coexistence element, be used to combine/isolate the wavelengths of XG(S)-PON and HSP signals and which occasionally combines the video signals and/or OTDR signals
Rx	Optical receiver
Tx	Optical transmitter
V-Rx	Video receiver
V-Tx	Video transmitter
WBF	Wavelength blocking filter for blocking interference signals to Rx
WBF-V	Wavelength blocking filter for blocking interference signals to V-Rx
WDM-XG(S)-L	WDM filter in XG(S)-PON OLT to combine/isolate the wavelengths of XG(S)-PON upstream and downstream
WDM-XG(S)-N	WDM filter in XG(S)-PON ONU to combine/isolate the wavelengths of XG(S)-PON upstream and downstream
WDM-XG(S)-N'	WDM filter in XG(S)-PON ONU to combine/isolate the wavelengths of XG(S)-PON upstream and downstream and isolate the video signal(s)

WDM-HSP-L	WDM filter in HSP OLT to combine/isolate the wavelengths of HSP upstream and downstream
WDM-HSP-N	WDM filter in HSP ONU to combine/isolate the wavelengths of HSP upstream and downstream
WDM-HSP-N'	WDM filter in HSP ONU to combine/isolate the wavelengths of HSP upstream and downstream and isolate the video signal(s)
WDM-HSP-O	WDM filter in HSP OLT to combine/isolate the wavelengths of HSP upstream and downstream.

Bibliography

[b-ITU-T G-Sup.39] ITU-T G-series Recommendations – Supplement 39 (2016), *Optical system design and engineering considerations*.

SERIES OF ITU-T RECOMMENDATIONS

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

Printed in Switzerland
Geneva, 2022