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OF ITU

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

Digital sections and digital line system – Optical line systems for local and access networks

Enhancement band for gigabit capable optical access networks

CAUTION !

PREPUBLISHED RECOMMENDATION

This prepublication is an unedited version of a recently approved Recommendation. It will be replaced by the published version after editing. Therefore, there will be differences between this prepublication and the published version.

FOREWORD

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New Recommendation G.984.5

Enhancement band for Gigabit capable Optical Access Networks

Summary

The purpose of this recommendation is to define wavelength ranges reserved for additional service signals to be overlaid via wavelength-division multiplexing (WDM) in future passive optical networks (PON) for maximizing the value of optical distribution networks (ODNs).

1 Scope

The purpose of this recommendation is to define wavelength ranges reserved for additional service signals to be overlaid via wavelength-division multiplexing (WDM) in future gigabit capable passive optical networks (G-PON) for maximizing the value of optical distribution networks (ODNs). Other PON systems, such as B-PON, have wavelength plans based on ITU-T recommendation G.983.3, which includes existing options for enhancement bands. This recommendation also defines further wavelength ranges reserved for additional service signals to be overlaid via WDM in future PONs whose wavelength allocations are based on ITU-T recommendation G.983.3.

For this purpose, this recommendation defines and provides;

- Wavelength ranges to be reserved, and
- X/S tolerance in PON optical network units (ONUs).

Appendices I and II of this recommendation provide;

- Sample parameters of a discrete WDM filter that combines and isolates the G-PON up/down signals and enhancement bands at the OLT side.
- Examples of wavelength allocation for NGA services and video distribution services.

The physical media dependent (PMD) layer specification for G-PON in the absence of an enhancement band is defined in G.984.2. PMD layer specifications for G-PON in the presence of enhancement bands are defined by the combination of G.984.2 and this recommendation. Whenever a parameter specified in G.984.2 is not explicitly mentioned in the present document, its value given in G.984.2 remains valid. Whenever a parameter is specified in both this recommendation and G.984.2, the specification in the present document takes precedence.

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.

[1] ITU-T Recommendation G.983.1 (1998), *Broadband optical access systems based on Passive Optical Networks (PON).*
[2] ITU-T Recommendation G.983.3 (2001), *A broadband optical access system with*

increased service capability by wavelength allocation.
[3] ITU-T Recommendation G.984.2 (2003), *Gigabit-capable Passive Optical Networks (GPON): Physical Media Dependent (PMD) layer specification*.
[4] ITU-T Recommendation G.984.2 Amendment 1 (2006), *Gigabit-capable Passive Optical Networks (GPON): Physical Media Dependent (PMD) layer specification. Amendment 1:Appendix III-Industry best practice for 2.488 Gbit/s downstream, 1.244 Gbit/s upstream G-PON.*
[5] ITU-T Recommendation G.671 (2005), *Transmission characteristics of optical components and subsystems.*
[6] ITU-T Recommendation G.652 (2005), *Characteristics of a single-mode optical fibre and cable.*

3 Definitions

This recommendation makes frequent use of the defined terms found in ITU-T recommendations G.983.1, G.983.3 and G.984.2. For convenience, the main definitions related to the G-PON enhancement bands are reported in this clause.

3.1 Terms defined elsewhere:

This recommendation uses the following terms defined elsewhere:

3.1.1 Optical distribution network (ODN) [ITU-T Recommendation G.984.2 (2003)]

3.1.2 Optical line termination (OLT) [ITU-T Recommendation G.984.2 (2003)]

3.1.3 Optical network unit (ONU) [ITU-T Recommendation G.984.2 (2003)]:

3.1.4 Wavelength division multiplexing (WDM) [ITU-T Recommendation G.984.2 (2003)]

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 co-exists with G-PON on the same 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:

B-PON	Broadband passive optical network
CNR	Carrier-to-noise ratio
DFB	Distributed feedback laser
G-PON	Gigabit-capable passive optical network
NGA	Next generation access
ODN	Optical distribution network
OLT	Optical line termination
ONU	Optical network unit
PMD	Physical media dependent
PON	Passive optical network
WBF	Wavelength blocking filter
WDM	Wavelength division multiplexing

5 Conventions

See ITU-T Rec. G.983.1 for the generic physical configuration of optical access network. For convenience, Figure 5/G.983.1 is reproduced below.

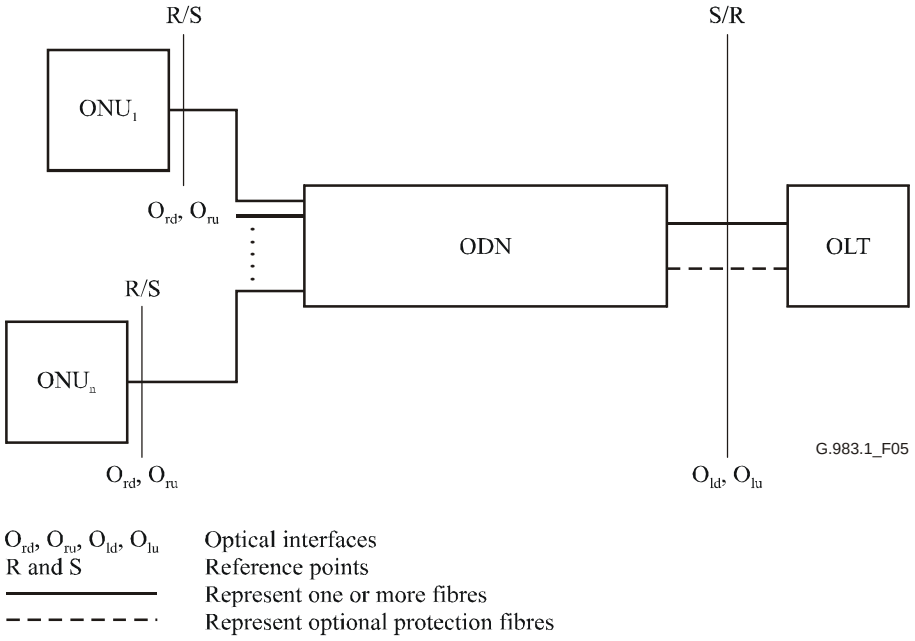


Figure 1/G.984.5 – Generic physical configuration of the optical distribution network (reproduced from Figure 5/G.983.1)

The two directions for optical transmission in the ODN are identified as follows:

– downstream direction for signals travelling from the OLT to the ONU(s);

– upstream direction for signals travelling from the ONU(s) to the OLT.

According to G.983.1, transmission in downstream and upstream directions can take place on the same fibre and components (duplex/diplex working) or on separate fibres and components (simplex working). This recommendation covers only diplex working, i.e., bi-directional transmission using different wavelengths over a single fibre.

There can be several types of ODN architectures to achieve the coexistence of G-PON and additional services including next generation access (NGA) and video distribution services. Figures 2 and 3 are reference diagrams of optical access network architectures, and assume that wavelength blocking filters (WBF) are used when G-PON, video and NGA share the same ODN.

Note that these diagrams just provide reference configurations of the ODN and WBF, and don't intend to limit future designs and implementations.

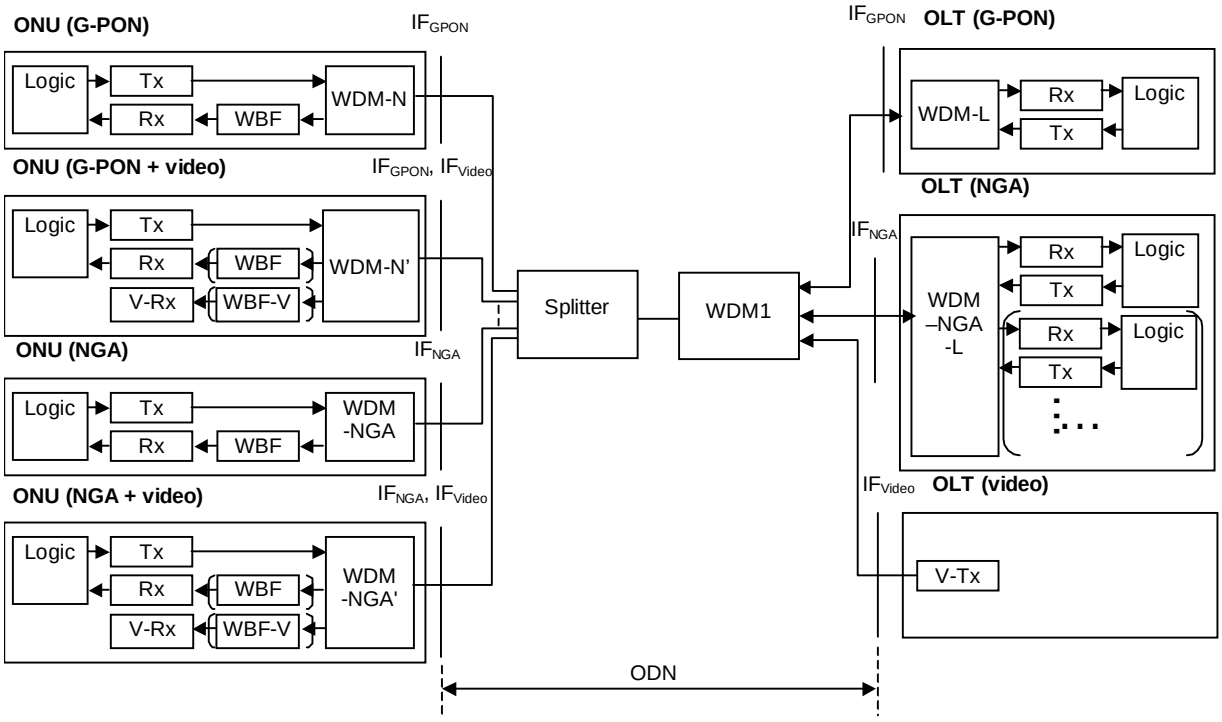


Figure 2/G.984.5 – Reference diagram 1

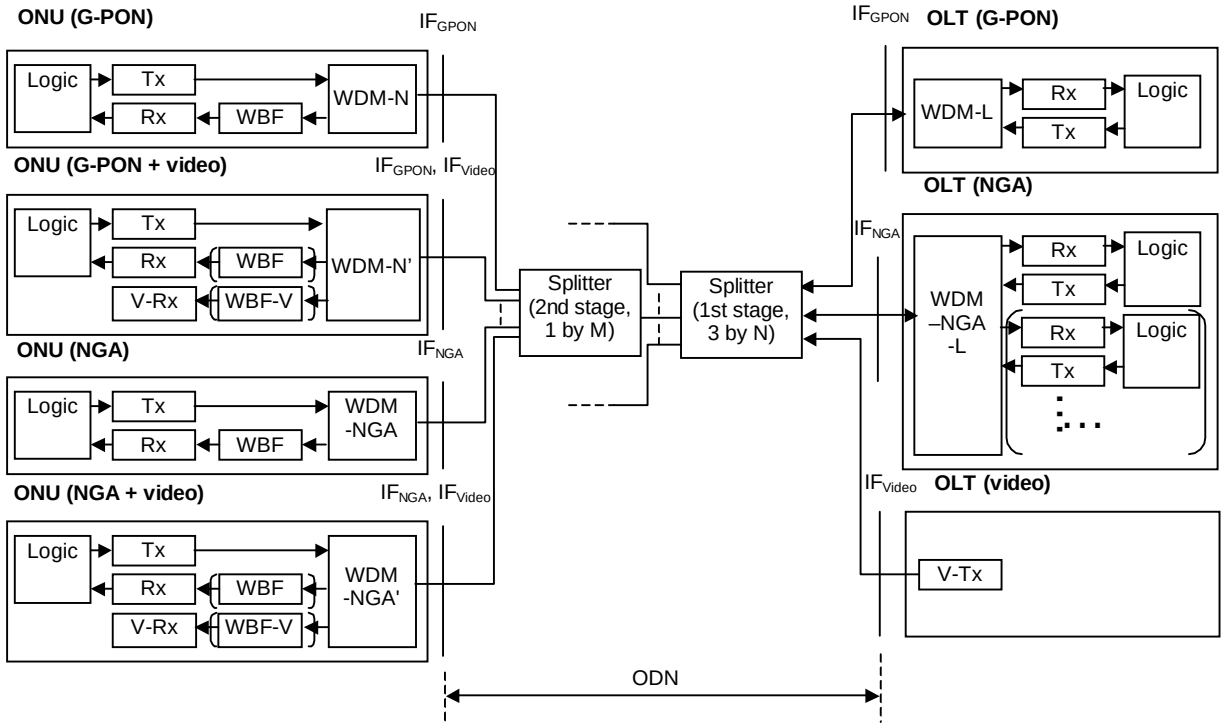


Figure 3/G.984.5 – Reference diagram 2

The following abbreviations are used in figures 2 and 3.

Tx Optical transmitter

Rx	Optical receiver
V-Tx	Video transmitter
V-Rx	Video receiver
WBF	Wavelength blocking filter for blocking interference signals to Rx.
WBF-V	Wavelength blocking filter for blocking interference signals to V-Rx.
WDM-N	WDM filter in G-PON ONU to combine/isolate the wavelengths of G-PON upstream and downstream.
WDM-N'	WDM filter in G-PON ONU to combine/isolate the wavelengths of G-PON upstream and downstream and isolate the video signal(s).
WDM-NGA	WDM filter in NGA ONU to combine/isolate the wavelengths of NGA upstream and downstream.
WDM-NGA'	WDM filter in NGA ONU to combine/isolate the wavelengths of NGA upstream and downstream and isolate the video signal(s).
WDM-L	WDM filter in G-PON OLT to combine/isolate the wavelengths of G-PON upstream and downstream.
WDM-NGA-L	WDM filter in NGA OLT to combine/isolate the wavelengths of NGA upstream and downstream of one or more channels.
WDM1	WDM filter that may be located in the central office to combine/isolate the wavelengths of G-PON and NGA signals and combine the video signals.

6 Operating wavelength

The wavelength range of the G-PON downstream signal (single fibre system) is specified in ITU-T G.984.2 as 1480nm to 1500nm and that of the G-PON upstream signal as 1260nm to 1360nm. This recommendation redefines the reserved wavelength range and specifies the tolerance for interference signals of G-PON ONUs to enable coexistence of G-PON and additional services including NGA and video services.

Figure 4 and table 1 define the wavelength allocation plan including the wavelength bands reserved for additional services. The wavelength range of the G-PON downstream signal is referred to as the "basic band." Reserved bands are referred to as the "enhancement band." Applications for the enhancement band include video services and NGA services. The wavelength range for video services remains the same as defined in ITU-T G.983.3

A guard band separates the G-PON upstream and/or basic band from the enhancement band. The interference between signals in these two bands causes signal degradation to each other, which must be kept negligible. Wavelength blocking filters (WBFs) are used to obtain the required isolation outside the guard band. The wavelength values specified in table 1 take into account guard bands that may be achievable by commercially available low-cost WBFs.

NOTE – Wavelengths in the enhancement band may be used not only for downstream but also for upstream signal transmission in the WDM scheme.

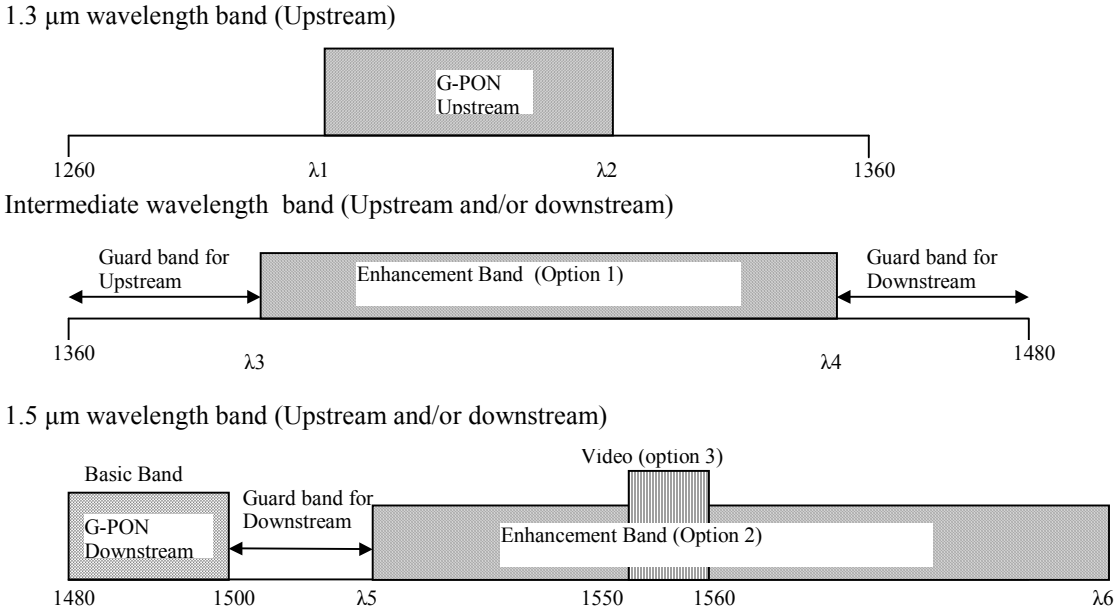


Figure 4/G.984.5 – Wavelength allocation

Table 1/G.984.5 – Parameters for wavelength allocation in Figure 1

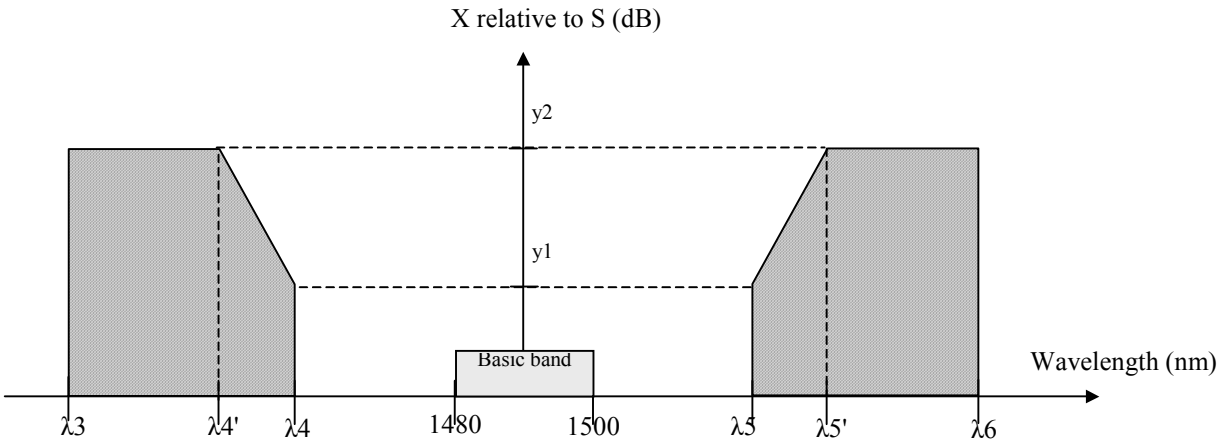
Items	Notation	Unit	Nominal value	Application examples
1.3 μm wavelength band:				For use in G-PON upstream.
– Regular wavelength band option				e.g., ONUs based on Fabry-Perot lasers
Lower limit	λ1	nm	1260	
Upper limit	λ2	nm	1360	
– Reduced wavelength band option				e.g., ONUs based on ordinary DFB lasers
Lower limit	λ1	nm	1290	
Upper limit	λ2	nm	1330	
– Narrow wavelength band option				e.g., ONUs based on wavelength selected lasers
Lower limit	λ1	nm	1300	
Upper limit	λ2	nm	1320	
Enhancement band (option 1-1)				For next generation access (NGA) Note: The values are informative. The loss in this band is not guaranteed in optical branching components for PON (i.e. power splitters) specified in G.671 nor in optical fibres specified as G.652A&B (non-low-water-peak fibres).
Lower limit	λ3	nm	1415 *(Informative)*	
Upper limit	λ4	nm	1450 *(Informative)*	
Enhancement band (option 1-2)				For next generation access (NGA) Applicable for low-water-peak fibre only. Note: The values are informative. The loss in this band is not guaranteed in optical branching components for PON (i.e. power splitters) specified in G.671.
Lower limit	λ3	nm	1400 *(Informative)*	
Upper limit	λ4	nm	1450 *(Informative)*	

Basic band				For use in G-PON downstream.
Lower limit	-	nm	1480	
Upper limit	-	nm	1500	
Enhancement band (Option 2)				For next generation access (NGA) Note: The upper-limit value is determined as an operator choice from 1580 to 1625 nm considering the following factors. − Bending loss of optical fibre that increases at longer wavelengths − Loss of a filter that separates/combines a monitoring signal and NGA signal(s) (if an optical monitoring system is used)
Lower limit	λ5	nm	1530	
Upper limit	λ6	nm	1580 to 1625	
Enhancement band (Option 3)				For video distribution service.
Lower limit	-	nm	1550	
Upper limit	-	nm	1560	
NOTE 1 – Additional guard bands are needed in the case of coexistence of option 2 and option 3 (see Appendix II).				

7 X/S tolerance of G-PON ONU

The minimum optical sensitivity of a G-PON ONU must be met in the presence of the interference signals caused by NGA and/or video signals in the enhancement band specified in table 1. To minimise the effect of interference signals, G-PON ONUs need to isolate interference signals using an appropriate WBF and WDM filter. This recommendation does not specify the isolation characteristics of the WBF and WDM filters themselves, but specifies the X/S tolerance of the G-PON ONU. Here S is the optical power of the basic band signal and X is that of the interference signal(s), both measured at the point IF_{GPON} of ONU side specified in figures 2 and 3. Figure 5 shows the X/S tolerance mask that should not cause the sensitivity of the basic band receiver to fail to meet the specified limit. Implementers need to specify the isolation characteristics of the WBF and WDM filter to obtain enough isolation of the interference signal(s) to allow the sensitivity requirement to be met in the presence of this level of interference. On the other hand, the wavelengths and total optical launch power of additional services including NGA and video services must be considered with reference to figure 5 in the case of coexistence with G-PON.

The interference signal format for measuring X/S tolerance should be NRZ pseudo-random coded with the same bit rate as the G-PON downstream signal or a lower rate within the bandwidth of the basic band receiver.



Wavelength(nm)	λ3	λ4'	λ4	λ5	λ5'	λ6
	1415/1400 *(Informative)*	1441 *(Informative)*	1450 *(Informative)*	1530	1539	1580 to 1625
X relative to S (dB)	y2	y2	y1	y1	y2	y2
	22 *(Informative)*	22 *(Informative)*	7 *(Informative)*	7	22	22

S : Received power of basic band

X : Maximum total power of NGA and video received in the blocking wavelength range.

X/S in the mask (hatching area) should not cause the sensitivity of the basic band receiver to fail to meet the specified limit.

NOTE 1 – λ3 value of 1400 *(Informative)* may be applicable for low-water-peak fibre only.

Figure 5/G.984.5 – S/X tolerance mask for ONU

Appendix I

Example of WDM1 characteristics

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

Table I.1 shows sample parameters of a WDM1 filter that combines (downstream) and isolates (upstream) the G-PON up/down signals and enhancement band. Figure 6 shows the reference diagram of WDM1.

Table I.1/G.984.5 – Parameters for WDM1

Specification	Value
Loss without connectors – G-PON wavelength span	< 0.7dB (1260-1500nm)
Loss without connectors for enhancement bands	<1.0dB (1524-1625nm)
Isolation – COM – OLT (1524-1625nm)	TBD (> 30dB (higher values may be required depending on the application))
Isolation – COM – UPGRADE (1480-1500nm, 1260-1360nm)	> 30dB
Max optical power	+23dB
Return Loss	> 50dB
Directivity	> 50dB
NOTE 1 - The wavelength range of 1524-1530nm should not be used by NGA downstream signals. NOTE 2 - The specification of WDM1 in the range of 1625-1660 nm for applications such as inserting an OTDR signal onto the PON is for future study.	

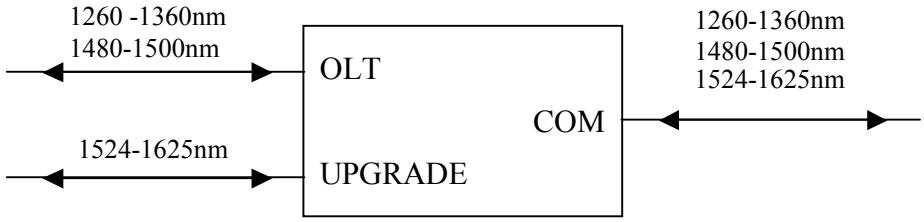


Figure 6/G.984.5 – Reference diagram of WDM1

Appendix II

Examples of wavelength allocation for NGA services and video distribution services

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

II.1 Introduction

Considering the possible network scenarios that allow the coexistence of G-PON, NGA and video services, it is assumed that additional guard bands are needed at both sides of the video band to avoid interference which could cause the degradation of video CNR performances of the video receiver. To take the guard bands for both Basic Band and video into account, the wavelength range between Basic Band and video may not be applicable for NGA downstream signals. Figure II.1 shows the wavelength plan of the 1.5 μm wavelength band for these scenarios. The ranges of the guard bands depend on the filter characteristics of the video band pass filter and the performance of the video receiver. In this section, two types of filters are considered. One is the integrated filter within the G-PON ONU transceiver such as triplexer type transceiver and the other is the discrete filter outside of the G-PON diplexer type transceiver and the video receiver. The examples of wavelength allocation and filter characteristics for each case are provided below.

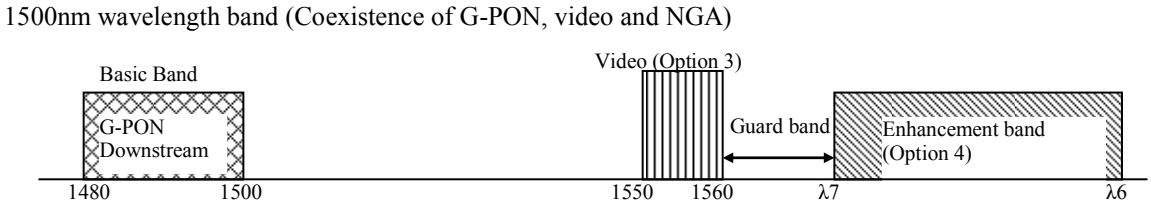


Figure II.1/G.984.5 – Wavelength allocation

II.2 Case 1 : Integrated filter for video

Figure II.2 shows an example configuration of a G-PON ONU using a triplexer type transceiver including an integrated video filter. This figure does not intend to limit filter configurations of the triplexer. Filter configurations may be different in each implementation and also depend on the implementations of optics (e.g. micro-optics or PLC-based). In this figure, the isolation values at Reference point are sum of the isolation values of WDM filter and WBF in front of the V-Rx. Figure II.3 shows an example of isolation and Table II.1 shows an example of wavelength allocation including tentative wavelength value of λ7 in Figure II.3. One of the example isolation values of y3 in Figure II.3 is 30dB with reference to the realistic isolation performances of an integrated filter. Service operators and implementers should take the actual filter characteristics and performance of the video receiver into account when considering additional enhanced services.

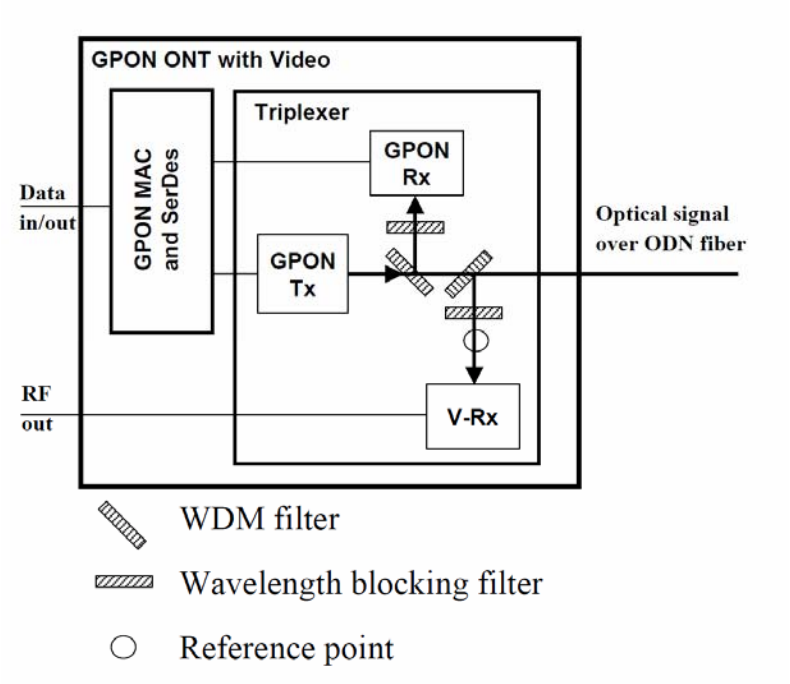


Figure II.2/G.984.5 – Example configuration of G-PON ONU with video (Case 1)

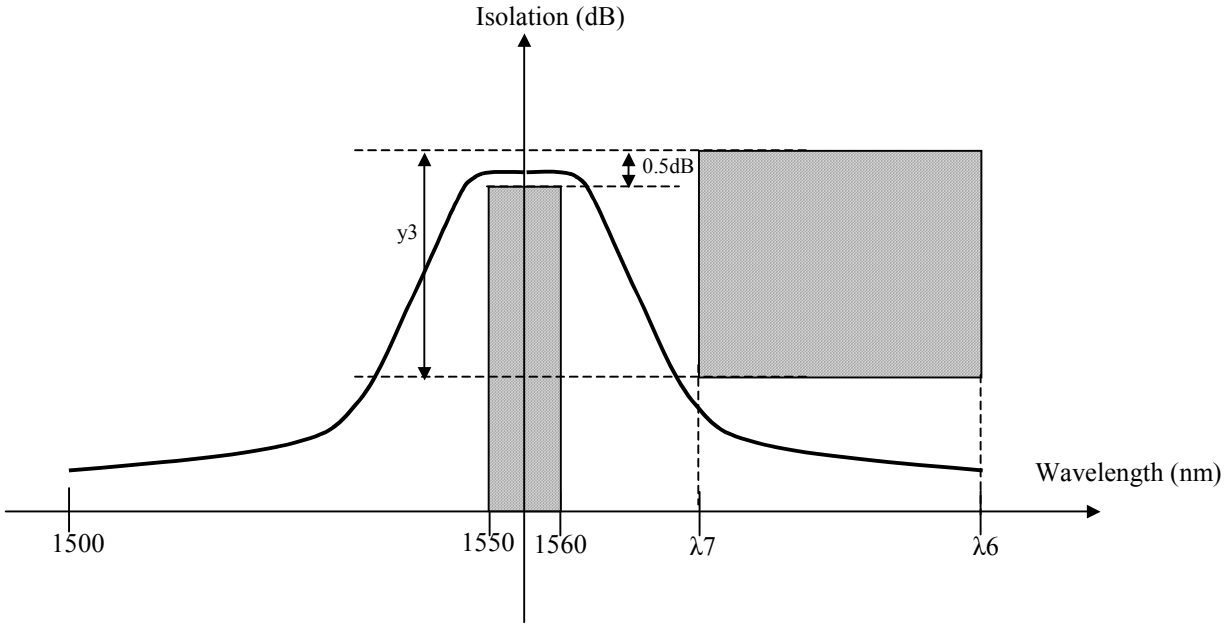


Figure II.3/G.984.5 – Example of integrated filter characteristics for video

Table II.1/G.984.5 – Example of wavelength allocation (Case 1)

Items	Notation	Unit	Nominal value	Application examples
Enhancement band (Option 3)				For video distribution service.
Lower limit	-	nm	1550	
Upper limit	-	nm	1560	
Enhancement band (Option 4)				For next generation access (NGA)

Lower limit	λ7	nm	TBD (1574 or 1575)	
Upper limit	λ6	nm	1580 to 1625	
NOTE 1 – Typically applied to the integrated filters inside the triplexer type optical transceiver.				

II.3 Case 2 : Discrete WDM filter for video

Figures II.4 and II.5 show example configurations of a G-PON ONU (and a video ONU) using discrete WDM filters. These figures do not intend to limit filter configurations. In these figures, the isolation values at Reference point are sum of the isolation values of discrete WDM filter and WBF in front of the V-Rx. Figure II.6 shows an example of isolation and Table II.2 shows an example of wavelength allocation. One of the example isolation values of y4 in Figure II.6 is 35dB with reference to the realistic isolation performances of a discrete filter. Service operators and implementers should take actual filter characteristics and performance of the video receiver into account when considering additional enhanced services.

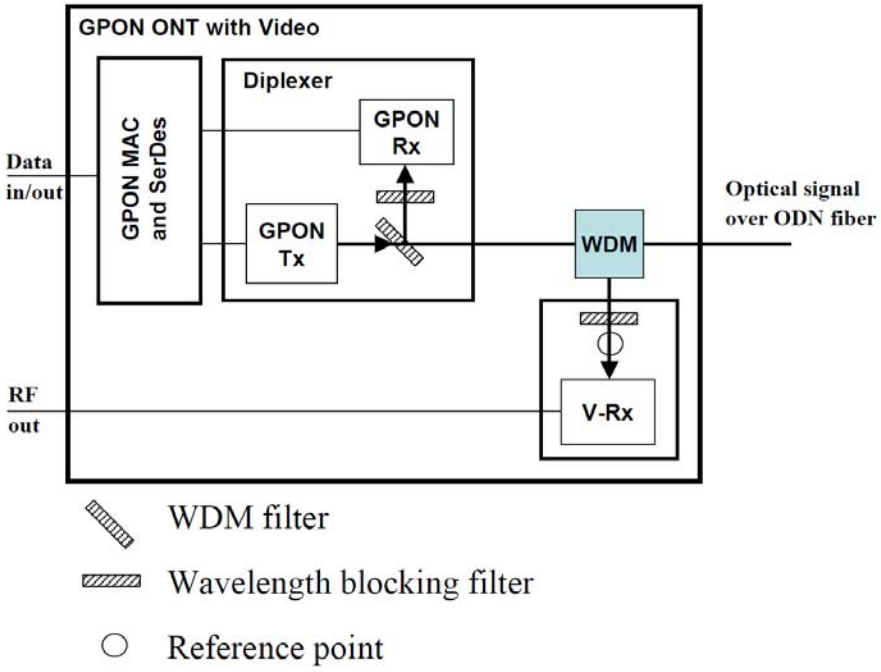


Figure II.4/G.984.5 – Example configuration of G-PON ONU with video (Case 2)

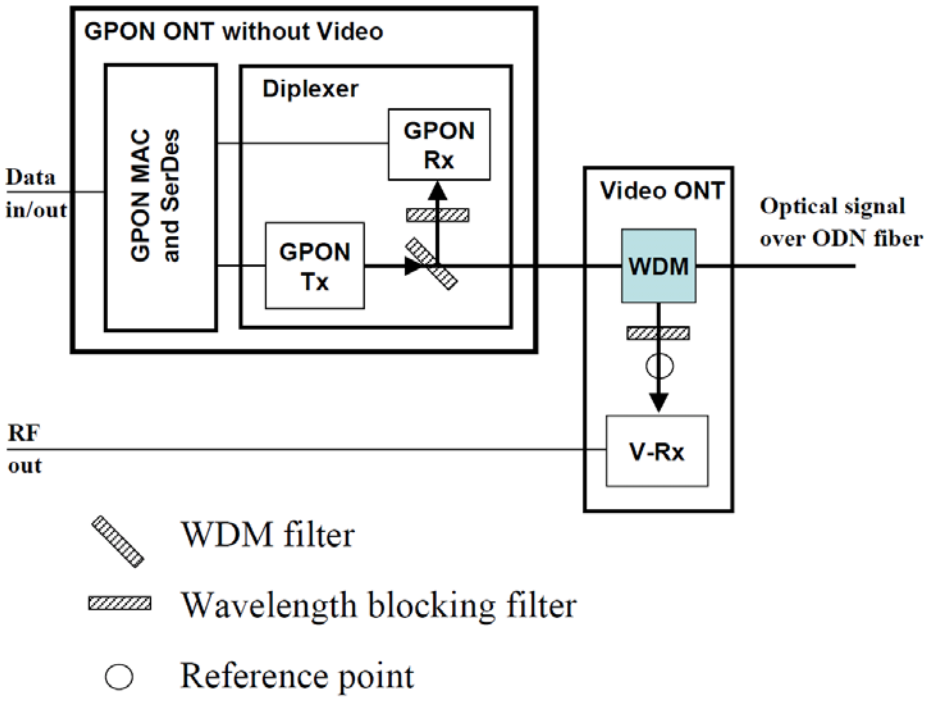


Figure II.5/G.984.5 – Example configuration of G-PON ONU and video ONU (Case 2)

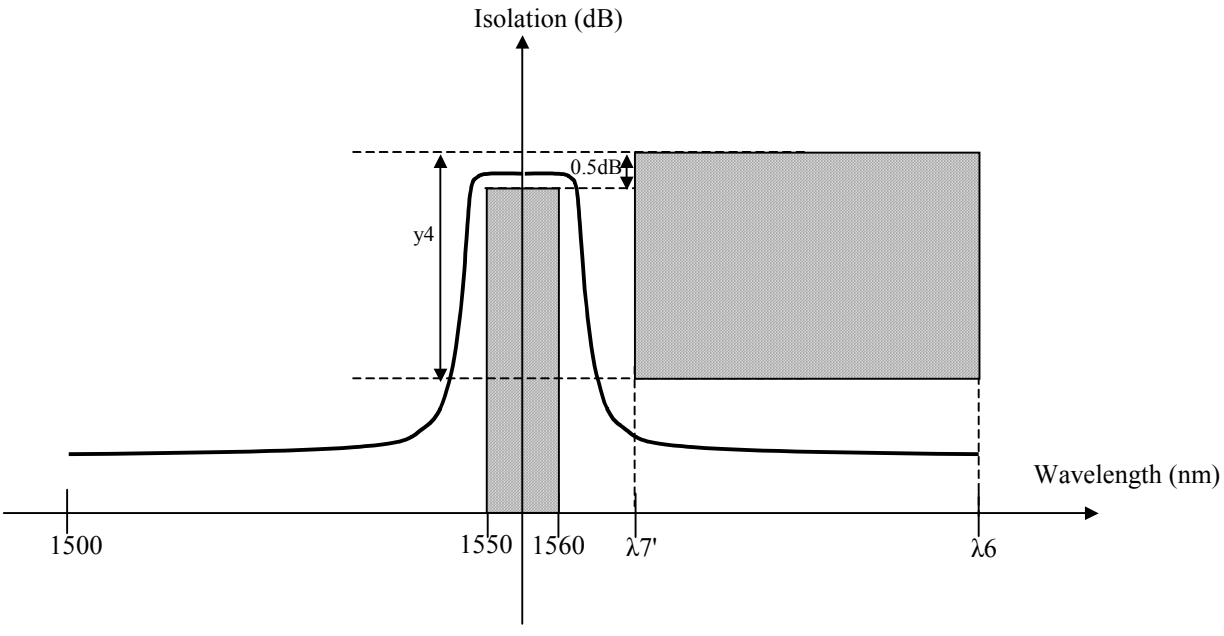


Figure II.6/G.984.5 – Example of discrete filter characteristics for video ONU

Table II.2/G.984.5 – Example of wavelength allocation (Case 2)

Items	Notation	Unit	Nominal value	Application examples
Enhancement band (Option 3)				For video distribution service.
Lower limit	–	nm	1550	
Upper limit	–	nm	1560	
Enhancement band (Option 5)				For next generation access (NGA)
Lower limit	λ7'	nm	For further study	
Upper limit	λ6	nm	1580 to 1625	