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**Radio Frequency over Glass
Fiber-to-the-Home Specification**

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1.0 SCOPE AND DEFINITIONS

1.1 Scope

This document defines a fiber-to-the-home system optimized for compatibility with hybrid fiber-coax (HFC) plant, using the same end equipment at both the home and at the headend or hub. The RFoG system is defined to begin where the plant becomes passive, extending from that point to the home. This interface is referred to as the Optical Hub. There are many possible variations on the structure of the optical hub, depending on the needs of the system. The RFoG system is defined to terminate at the subscriber-side interface of an RFoG Optical Network Unit (R-ONU) at the home.

The specifications in this document apply to the R-ONU and are designed to allow interoperability between R-ONUs from various manufacturers.

The following system parameters and devices are NOT specified by this document:

- Downstream transmitter and optical amplifier
- Upstream receiver
- System carrier-to-noise and distortion

Additionally, the following items are not specified for the R-ONU. The user is cautioned that there may well be variations between manufacturers.

- Physical mounting arrangement
- Weight
- Fiber management
- Element management
- Service disconnect
- Extended reach
- The optical front-end need not reject a 1577 nm 10G-EPON or a 1577 nm XG-PON downstream carrier

This document contains specifications for systems that use amplitude modulation (AM) in the upstream path and systems that use frequency modulation (FM) in the upstream path. Unless otherwise noted, this document details the requirements for AM systems. The sections that apply specifically to FM systems are so noted and do not apply to AM systems. Portions of the AM specifications that do not apply to FM systems are also noted. AM and FM systems cannot be mixed in the same optical distribution network (ODN).

1.2 Acronyms

CNR	Carrier-to-Noise Ratio
NPR	Noise Power Ratio
ODN	Optical Distribution Network
OMI	Optical Modulation Index
ONU	Optical Network Unit
RFoG	RF over Glass
R-ONU	RFoG Optical Network Unit
SBS	Stimulated Brillouin Scattering
WDM	Wave Division Multiplexer

1.3 Definitions

Noise Power Ratio: The ratio of the signal power density to the power density of the combined noise and intermodulation distortion in the channel. Essentially, NPR is the depth of notch. The signal power density is defined with the entire passband filled with energy. The power density of the noise and intermodulation distortion shall be measured by removing signal power from a range of frequencies with a notch filter while maintaining constant total signal power at the DUT input.

Nominal: Specifications or values in this document that have the word “nominal” in them are approximate and designate a suggested or theoretical value. Items noted with the word “nominal” are not normative requirements.

Optical Modulation Index (OMI): The amount that the instantaneous power of the optical carrier varies around the average power of that optical carrier. In this specification, OMI is used only for the amplitude modulation of an optical carrier by an RF signal and is generally expressed as a percent. OMI is defined to be 100% when the peak of a single sine wave that is amplitude modulated onto an optical carrier modulates the instantaneous power of that carrier from zero power to twice the average power.

Figure 1 shows the relationship between the laser optical power and the modulating current.

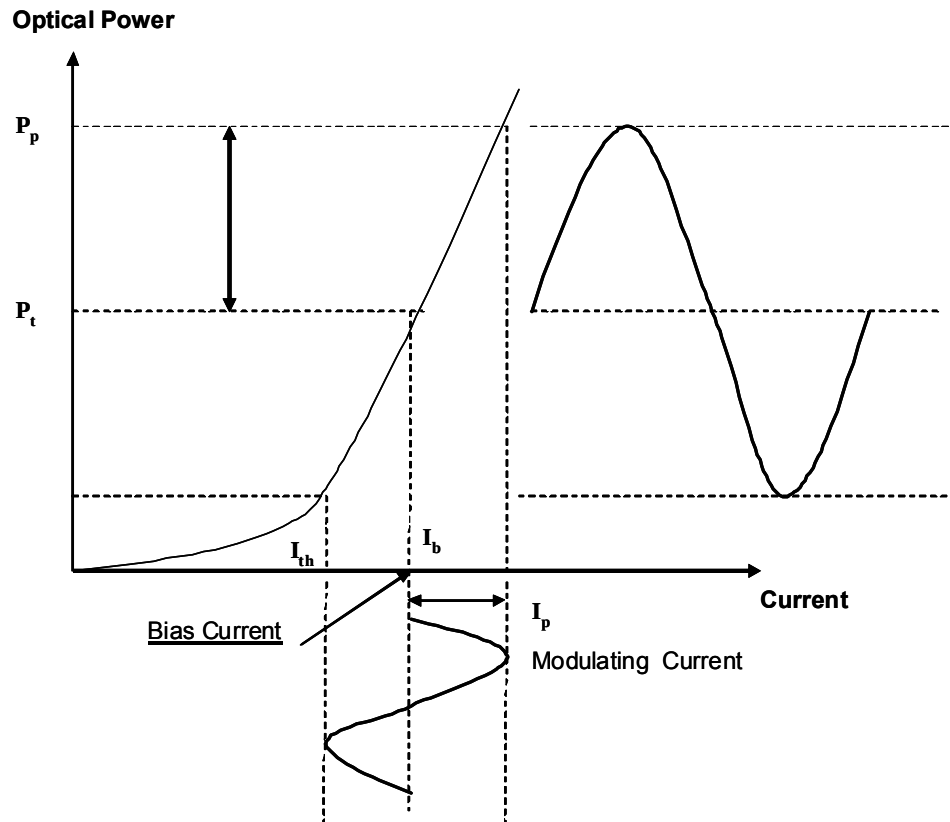


Figure 1: OMI Definition

In the optical domain, the OMI is defined as:

$OMI = (P_p - P_t) / P_t$, where

- P_p is the peak optical output power of the laser
- P_t is the optical power at the bias current

In the electrical domain, the OMI is defined as:

$OMI = I_p / (I_b - I_{th})$, where

- I_{th} is the threshold current of the laser
- I_b is bias current
- I_p is the peak modulating current

The optical and electrical definitions are equivalent.

The definition of OMI involves the peak of the signal and is easiest to measure with a simple sinusoidal signal. The OMI of any other modulating signal, $m(t)$, is defined to be the OMI that would be produced if a single sine wave of identical average RF power to $m(t)$ were modulated onto the optical carrier. In other

words, with a complex modulating signal, the exact peak is no longer referenced. The average power of the complex signal is measured and is said to have the same OMI as would be produced if that signal were replaced with a sine wave of equivalent average power.

OMI should always be measured with a CW carrier that has the same average power as the desired signal.

Unless specified as a per-channel value, OMI always refers to the modulation index of the entire RF signal.

Optical Power: Unless otherwise specified, “optical power” refers to the average power of an optical carrier. If the optical power is gated on and off, the optical power is defined as the average power during the burst, not including turn-on and turn-off transitions. Optical power measurements shall be averaged sufficiently to assure that any changes to content that is modulated onto the laser does not affect the measurement.

2.0 NORMATIVE REFERENCES

The following documents contain provisions, which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

- 47CFR15.109: 2005 Radio Frequency Devices, Unintentional Radiators, Radiated Emission Limits
- 47CFR76.605(12) 2004, Code of Federal Regulations, Multichannel Video and Cable Television Service, Technical Standards
- 47 CFR76.609(h): 1993 Code of Federal Regulations, Multichannel Video and Cable Television Service, Measurements
- 47CFR76.614: 2000 Code of Federal Regulations, Multichannel Video and Cable Television Service, Cable Television System regular monitoring
- ANSI C63.4, 2003-2009 Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
- ANSI/SCTE 01 2006 - Specification for “F” Port, Female, Outdoor
- ANSI/SCTE 02 2006 - Specification for “F” Port, Female, Indoor
- ANSI/SCTE 81 2007 - Surge Withstand Test Procedure

- ANSI/SCTE 119 2006 - Measurement Procedure for Noise Power Ratio
- GR-326-CORE, Issue 4, Generic Requirements for Single-Mode Optical Connectors and Jumper Assemblies
- GR-3120-CORE, Issue 2, Generic Requirements for Hardened Fiber Optic Connectors (HFOCs) and Hardened Fiber Optic Adapters (HFOAs)
- IEEE C62.41-1991, IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
- ITU-T G.652d, Characteristics of a Single-Mode Optical Fibre Cable
- TIA-604-3-B FOCIS-3, Fiber Optic Connector Intermateability Standard, Type SC and SC-APC

3.0 INFORMATIVE REFERENCES

The following documents may provide valuable information to the reader but are not required when complying with this standard.

- ANSI/SCTE 96 2008 - Cable Telecommunications Testing Guidelines
- GR-49-CORE, Issue 2, Generic Requirements for Outdoor Telephone Network Interface Devices
- GR-487-CORE, Issue 3, Generic Requirements for Electronic Equipment Cabinets
- IEEE Standard 802.3-2008, Carrier sense multiple access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications (Includes the EPON standard). See also subsequent corrigenda.
- IEEE Standard 802.3av-2009, IEEE Standard for Information Technology-Part 3: Amendment 1: Physical Layer Specifications and Management Parameters for 10Gb/s Passive Optical Networks, October 2009
- ITU-T G.984, Gigabit-capable passive optical networks (GPON)
- ITU-T G.987, 10-Gigabit-capable passive optical network (XG-PON) systems
- ITU-T G.652, Characteristics of a single-mode optical fibre cable
- ITU-T G.657, Characteristics of a bend-loss insensitive single-mode optical fibre and cable for the access network
- Multimedia over Coax Alliance (MoCA), <http://www.mocalliance.org>

4.0 REFERENCE ARCHITECTURE

Reference architectures for the RFoG system and for the R-ONU are shown in this section. The terminology R-ONU, for RFoG Optical Network Unit, is used to differentiate the RFoG ONU from ONUs adhering to other specifications, which typically include a digital transmitter and receiver independent of any RF components. This reference architecture comprises the minimum commonality of the system. Nothing precludes a vendor from offering additional features, but they may or may not be compatible with components from other vendors. Compatibility is limited to the issues covered in this document.

4.1 System

Figure 2 illustrates the reference architecture of the system. In the reference architecture, the optical hub, the start of the RFoG system, comprises a downstream optical transmitter operating nominally on 1550 nm, optical amplification and splitting as appropriate, and an upstream optical receiver which receives upstream optical signals on λ_{up} nm (defined below), and converts them to RF form. The wave division multiplexer used to combine and separate the two wavelengths is part of the ODN, consistent with the ODN definition in EPON and GPON.

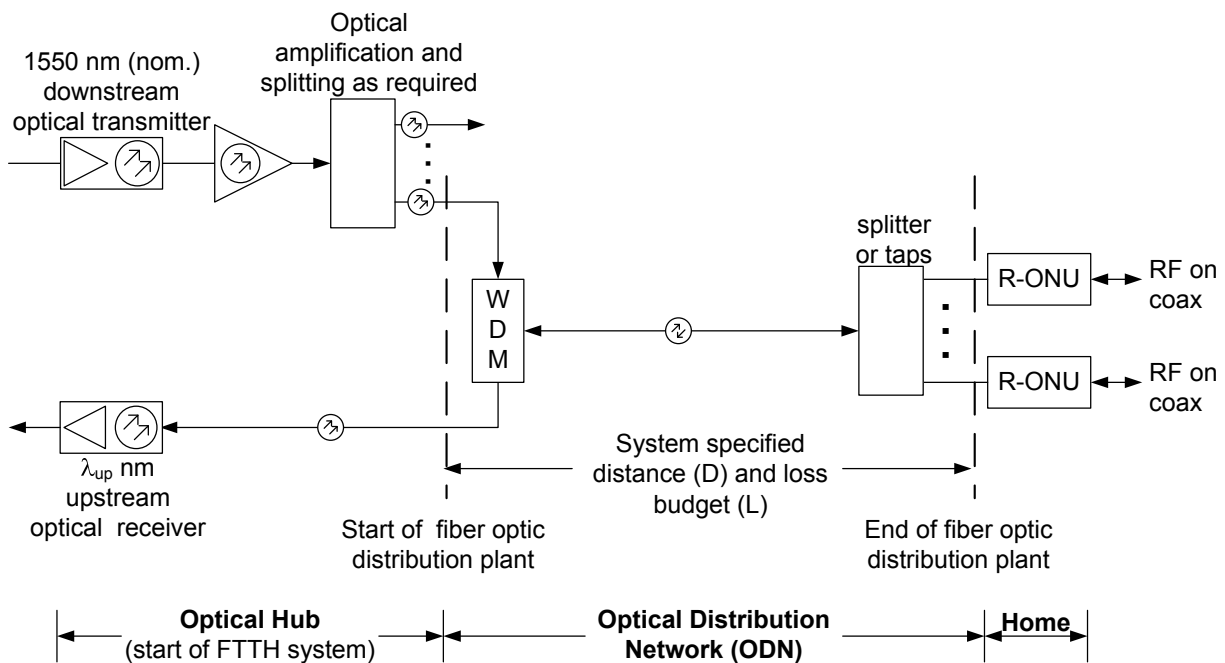


Figure 2: RFoG Reference Architecture

The Optical Hub may take on many other forms according to the needs of the system. For example, it may comprise only optical amplification and splitting in the downstream direction, with optical combining and demodulation followed by

digital conversion in the upstream direction. The form of the optical hub is not controlled by this document. Specifications contained herein apply only between the start of the optical distribution network (ODN) and the RF coax output from the R-ONU. The system designer is responsible for making sure that the effects of any signal degradation at the Optical Hub or upstream of it, are properly accounted in the network design. Upstream system performance will vary by choice of Upstream Optical Receiver hardware. Receiver noise performance and technology choice determines interoperability. The ODN is defined to start at the input to the WDM at the optical hub and to end at the pigtail on the R-ONU at the home.

The ODN is shown with a single point splitter. However, the ODN may also be implemented as a series of optical taps or as a multi-layer splitter, such as a 1:4 split followed by a set of 1:8 splitters at a different location. So long as the maximum distance, loss budget, and split ratio are respected, the architecture of the splitting is at the discretion of the operator.

4.2 RFoG Optical Network Unit (R-ONU)

Figure 3 illustrates the ONU reference architecture. The ONU comprises a wave division multiplexer (WDM) which separates the downstream optical signal at 1550 nm nominal and the upstream optical signal at λ_{up} nm. The downstream receiver recovers RF downstream signals from the 1550 nm (nominal) downstream optical carrier and supplies them to the output via a diplexer.

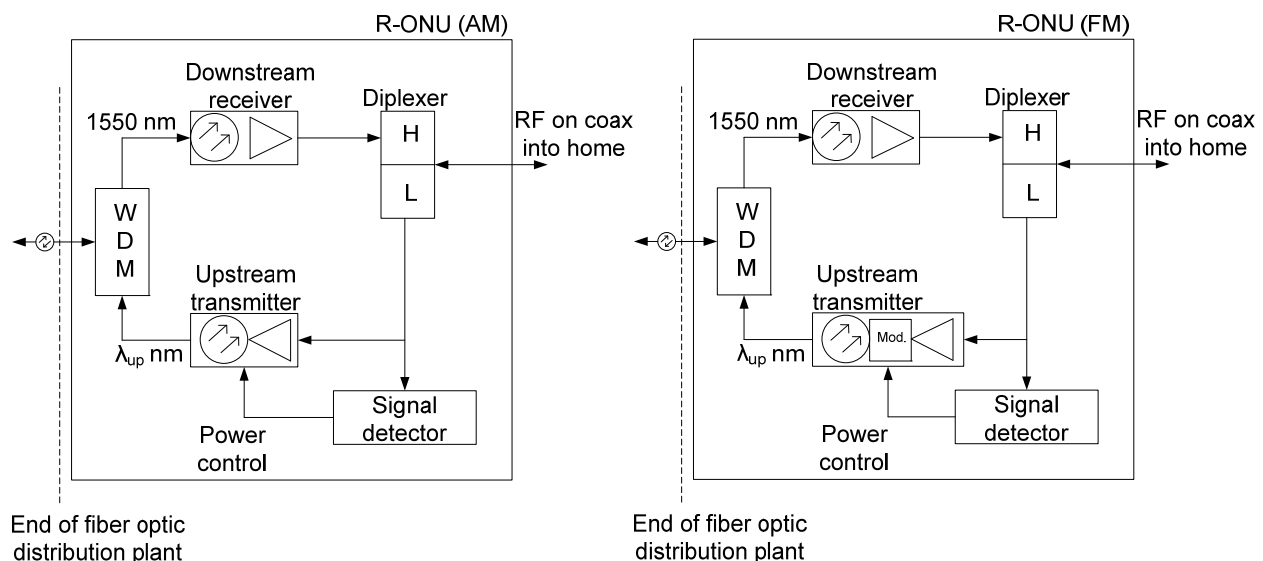


Figure 3: RFoG ONU Reference Architecture

The low port of the diplexer supplies upstream signals to an upstream transmitter whose output is at λ_{up} nm. It also supplies signals to a signal detector, whose job

it is to turn on the upstream transmitter when RF signals in the upstream band are detected at a level exceeding a specified minimum threshold.

4.3 Upstream Wavelength, λ_{up}

The specification permits either of two upstream wavelengths λ_{up} . One permitted wavelength is 1310 nm nominal, and the other is 1610 nm nominal. Use of 1610 nm permits an optional overlay of an RFoG system with either an IEEE 802.3-2008 / IEEE 802.3av-2009 (EPON) system or an ITU G.984 / ITU G.987 (GPON) system, both of which use 1310 nm or lower wavelengths for upstream data communications. Both upstream wavelengths will work with the same physical network. Note that if the 1310 nm upstream wavelength is used for RFoG, then neither EPON nor GPON will coexist in the same physical passive optical network.

For compatibility with 10G-EPON or XG-PON systems, the 1610 nm upstream option may be used, but will need an external optical trap at 1577 nm (nominal) to eliminate that downstream carrier. Alternatively a manufacturer may offer an R-ONU with a built-in optical trap, or the operator may choose to deploy RFoG and 10G-EPON or XG-PON on separate networks with co-located splitting.

5.0 SYSTEM SPECIFICATIONS

The Optical Distribution Network shall meet the requirements in Table 1.

Table 1: ODN Specifications

Specification	Value
Operating distance, optical hub to R-ONU (D) for 1:32 split ratio ^{1,2}	0 - 20 km
Highest loss budget under which the system must operate (L)	25 dB ³
Lowest loss budget under which the system must operate	5 dB lower than the highest loss. If the system design has even less loss (e.g., if the split ratio is low) then the system design must make up the loss. See Section 10.0, "Implementation Notes" for a discussion of the minimum loss budget.
Assumed optical fiber type	ITU G.652 B or later, or ITU G.657

Note 1: Longer distances may be possible, but the designer should keep the distance limits of EPON and GPON in mind if migration to either standard is contemplated.