

SCTE • ISBE[®]

S T A N D A R D S

Interface Practices Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 174 2018

**Radio Frequency over Glass
Fiber-to-the-Home (RFoG) Specification
Extension**

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1. Introduction

1.1. Executive Summary

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.

1.2. Scope

The specifications in this document define the performance requirements that 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

1.3. Benefits

The benefits of this standard are:

- Defines the performance of the R-ONU so equipment manufacturers have a guideline for the requirements and design of the R-ONU
- Allows for interoperability between equipment manufacturers
- Describes the overall RFoG System and provides guidelines for system design and performance
- Discusses Optical Beat Interference (OBI) and means of mitigating OBI

1.4. Intended Audience

The intended audiences for this standard are equipment manufacturers, service providers, design engineers, system engineers and system integrators.

1.5. Areas for Further Investigation or to be Added in Future Revisions

This document provides specifications or procedures for frequencies up to 1218 MHz. DOCSIS 3.1 specifications include operation at frequencies up to 1218 MHz, and optionally, to 1794 MHz. Specifications or procedures for frequencies above 1218 MHz should be considered in a future revision of this document.

Future revisions of this document should also include frequency splits of 204/254 MHz and review the R-ONU turn on/off RF levels and timing for full DOCSIS 3.1 and OFDM compatibility.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- ANSI/SCTE 01 2015, Specification for “F” Port, Female, Outdoor
- ANSI/SCTE 02 2015, Specification for “F” Port, Female, Indoor
- ANSI/SCTE 119 2011, Measurement Procedure for Noise Power Ratio

2.2. Standards from Other Organizations

- 47CFR15.109 2012 Radio Frequency Devices, Unintentional Radiators, Radiated Emission Limits
- 47CFR76.605(12) 2012, Code of Federal Regulations, Multichannel Video and Cable Television Service, Technical Standards
- 47 CFR76.609(h) 2012 Code of Federal Regulations, Multichannel Video and Cable Television Service, Measurements
- 47CFR76.614 2012 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
- 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

2.3. Published Materials

- No normative references are applicable.

3. Informative References

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

3.1. SCTE References

- ANSI/SCTE 96 2013, Cable Telecommunications Testing Guidelines
- ANSI/SCTE 81 2012, Surge Withstand Test Procedure

3.2. Standards from Other Organizations

- IEEE Standard 802.3-2012, Carrier sense multiple access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications (Includes the EPON standard). See also subsequent corrigenda.
- 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

3.3. Published Materials

- GR-49-CORE, Issue 2, Generic Requirements for Outdoor Telephone Network Interface Devices
- GR-487-CORE, Issue 3, Generic Requirements for Electronic Equipment Cabinets
- Multimedia over Coax Alliance (MoCA), <http://www.mocalliance.org>

4. Compliance Notation

<i>Shall</i>	This word or the adjective “ <i>required</i> ” means that the item is an absolute requirement of this specification.
<i>shall not</i>	This phrase means that the item is an absolute prohibition of this specification.
<i>Forbidden</i>	This word means the value specified shall never be used.
<i>Should</i>	This word or the adjective “ <i>recommended</i> ” means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
<i>should not</i>	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
<i>May</i>	This word or the adjective “ <i>optional</i> ” means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
<i>deprecated</i>	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of the standard. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

CNR	carrier-to-noise ratio
NPR	noise power ratio
ODN	optical distribution network
OMI	optical modulation index
ONU	optical network unit
ONT	optical network terminal
PON	passive optical network

RFoG	rf over glass
R-ONU	rfog optical network unit
SBS	stimulated brillouin scattering
WDM	wave division multiplexer

5.2. 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 <i>shall</i> 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.
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 <i>shall</i> be averaged sufficiently to assure that any changes to content that is modulated onto the laser does not affect the measurement.
Crosstalk	The ratio of a desired signal to an undesired signal, measured at a defined point in a system. Note that it is expressed as a positive number. Normally it is applied in the electrical domain.
Isolation	The ratio of a signal in a desired direction, to the same signal in a defined undesired direction. It is expressed as a positive number, and it <i>shall</i> be clear whether it is measured in the electrical or optical domain.

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

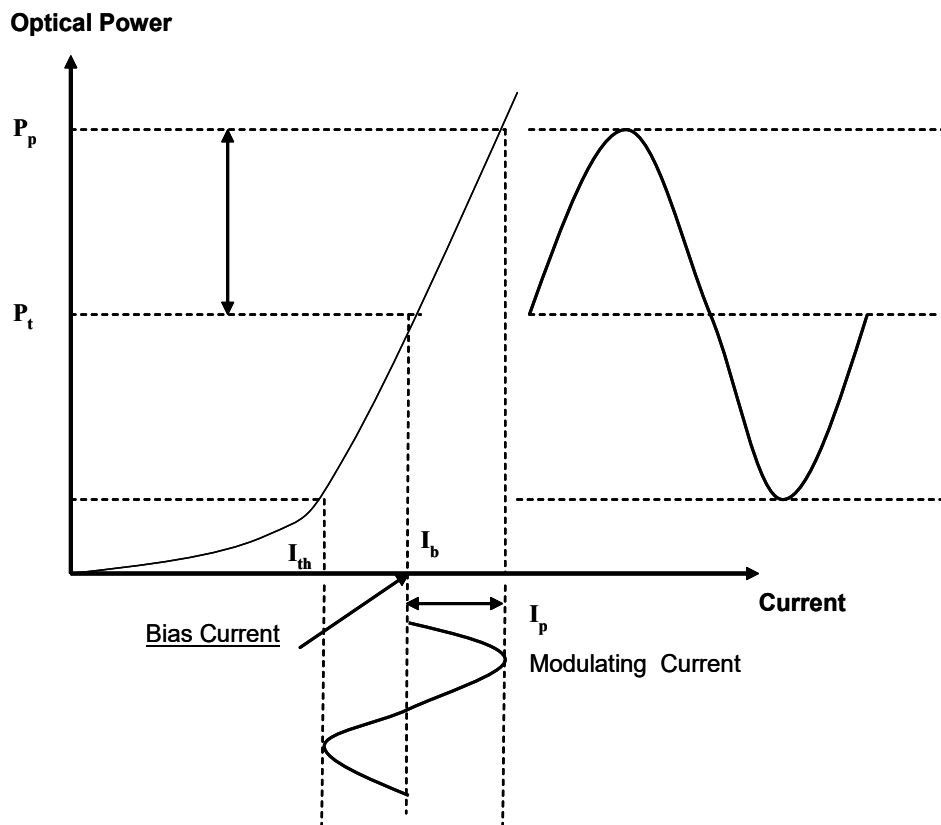


Figure 1 - OMI Definition

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.

Verification Example for both equations with a laser with a slope efficiency of .1W/A:

$$I_{th} = 10 \text{ mA}$$

$$I_b = 30 \text{ mA}$$

$$I_p = 1 \text{ mA}$$

$$P_p = 2.1 \text{ mW}$$

$$P_t = 2.0 \text{ mW}$$

In the optical domain: $OMI = (P_p - P_t) / P_t$

$$OMI = (2.1 - 2.0) / 2.0 = 0.05$$

In the electrical domain: $OMI = I_p / (I_b - I_{th})$

$$OMI = 1 / (30 - 10) = 0.05$$

6. 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.

6.1. 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.