APPLICATION NOTE

RFoG Single Dwelling Unit (SDU) Deployment Guide

An End-to-End Guide for Network/Systems Engineers and Installers

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Introduction

Intended Audience and Scope

This RFoG Single Dwelling Unit Deployment Guide is intended for network planners, system planners, engineers, installers and technicians who have responsibility for the planning, installation, configuration, and testing of an RFoG network.

This particular guide includes an overview as well as basic instructions for deployment and configuration of Aurora Networks RFoG equipment for a single (family) dwelling unit, hereafter referred to as SDU. An SDU in the context of this document is defined typically and simply as a detached structure where only one family resides, hence services from the MSO cable operator need only serve the needs of a single user or small set of users within the structure. As an example, a single home for one family within a residential neighborhood of individually separated structures qualifies as an SDU. A single office within a dedicated structure can also qualify as an SDU. Apartment, condominium, or town-homes which are individual homes or offices as part of a large multi-unit structure do not qualify as an SDU, rather they are categorized as Multi-Unit Dwellings (MDUs) which are not covered in this document.

Aurora Networks RFoG network solutions are combinations of various Aurora Networks hardware options. This guide displays and discusses a few typical network example solutions, with references to the key components and their respective functions and features. It is not the intent of this document to discuss all possible implementations of an RFoG network, nor is it the intent to suggest that the referenced examples are recommended for your specific implementation.

Aurora Networks RFoG solutions are easily upgraded to include high performance Gigabit/Gigabit Ethernet Passive Optical Networking (GPON and GEPON) solutions. These solutions will be discussed in a future deployment guide.

It is expected that the reader of this guide has read or will read the component data sheets of the referenced products to gain a thorough understanding of the various components' complete functionality, features, and parametric specifications. This guide also does not attempt to reiterate or replace the installation manuals for the hardware components referenced in this guide: however, some key installation points are discussed. The reader must refer to each respective installation manual for complete installation information.

Also, where applicable, this guide also assumes that the reader has read the documentation and/or has experience with the Aurora Networks Craft Management Software (CMS), Opti-Trace Shelf Management Software (OTS), or Element Management Software (EMS). CMS, OTS, or EMS or other network management software is integral for final configuration and use of the hardware components.

Special Notes

The following icon/graphics are used to indicate key points and cautionary statements in this document.

NOTE These notes call out important points relevant to the text.

Related Documentation

Please refer to the appendix.

Tools / Supplies / Test Equipment

Required tools and materials for installation and setup are listed in the respective hardware installation and activation guides listed in Chapter 4.

The various hardware modules discussed in this guide, and RFoG networks created by use of these modules, is monitored, configured, and managed by Aurora Networks Opti-Trace management software. The following software is required:

- Opti-Trace Element Management Software (EMS)
- Opti-Trace Shelf Management Software (OTS)
- Opti-Trace Craft Management Software (CMS) (Optional)

Test Equipment Needed

Chapter 3 discusses specific implementations, setup, and testing considerations as well as trouble shooting a complete RFoG system. The following test equipment may be helpful for testing and troubleshooting a network.

- Optical Power Meter such as EXFO FOT-10A Power Meter or equivalent
- Digital Multi-meter such as Fluke 73 Series III Digital Multi-meter or equivalent
- CATV signal level meter such as Sadelco MiniMax 800
- Portable upstream RF signal generator such as Applied Instruments Model 5112 Multi Carrier Generator
- Spectrum analyzer such as Agilent 8591C Cable TV Analyzer
- TP4000 Test Probe (adapter, GFA to F)

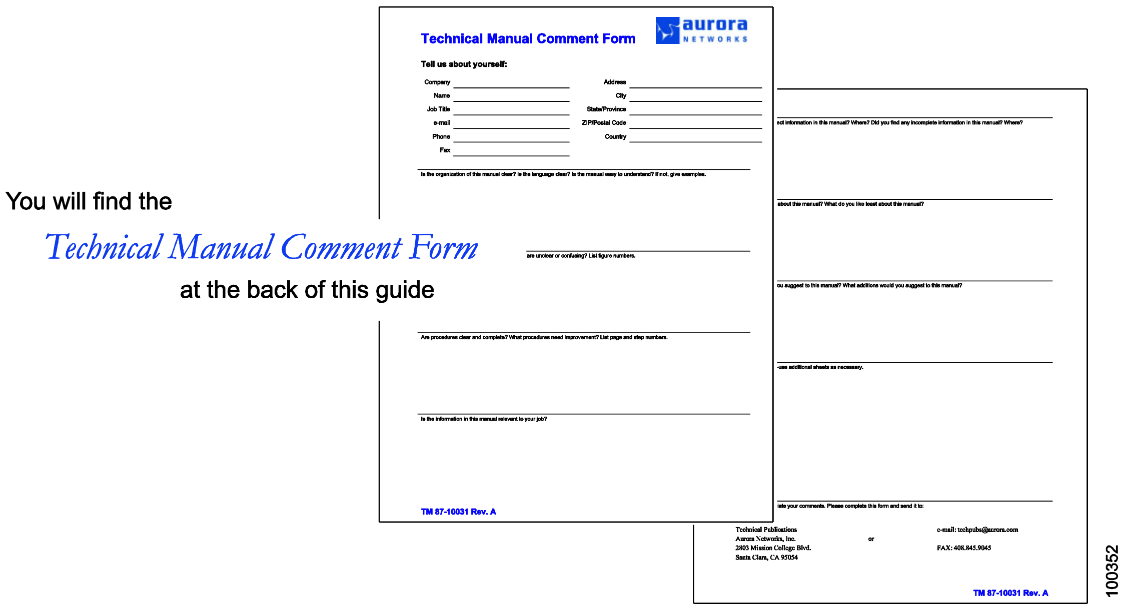
Product Support

For technical support: phone 888.AURORA6 (888.287.6726) toll free or e-mail support@aurora.com.

For questions about or comments on this manual: phone 408.235.7061 or e-mail techpubs@aurora.com.

Comments and Feedback

We have made every effort to ensure that this manual describes the product completely and correctly, and we encourage your feedback—your comments and corrections are welcome. You may submit comments using the Technical Manual Comment Form provided at the back of this manual, by mail or fax, or by sending e-mail directly to techpubs@aurora.com.



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Chapter 1 HFC and RFoG

1.1 HFC Overview

HFC (Hybrid Fiber Coax) networks within cable television deployments are commonplace with cable operators and subscribers benefitting from the key features which HFC was intended to provide. This includes pushing fiber deeper into networks down to the last mile where the fiber to coax optical to electrical conversion occurs and the coax cable takes on the task of delivering voice, video, and data services to and from the subscriber. The implementation of Aurora Networks' HFC Fiber Deep networks has played a monumental role in equipping and positioning cable operators to provide future-proof installations to which new services and capabilities can easily be added without replacing existing equipment, and only incrementally adding new equipment as needed to support additional new services.

Figure 1-1 portrays a high level conceptual view of a typical HFC topology including the CATV Headend. Note that the Fiber Node, which is the fiber to coaxial cable conversion point that resides at the peripheral edge of the fiber system, typically is located within a mile of the subscriber residence or facility. The typical Fiber Node serves 125 – 500 homes.

Figure 1-1 High Level HFC Topology

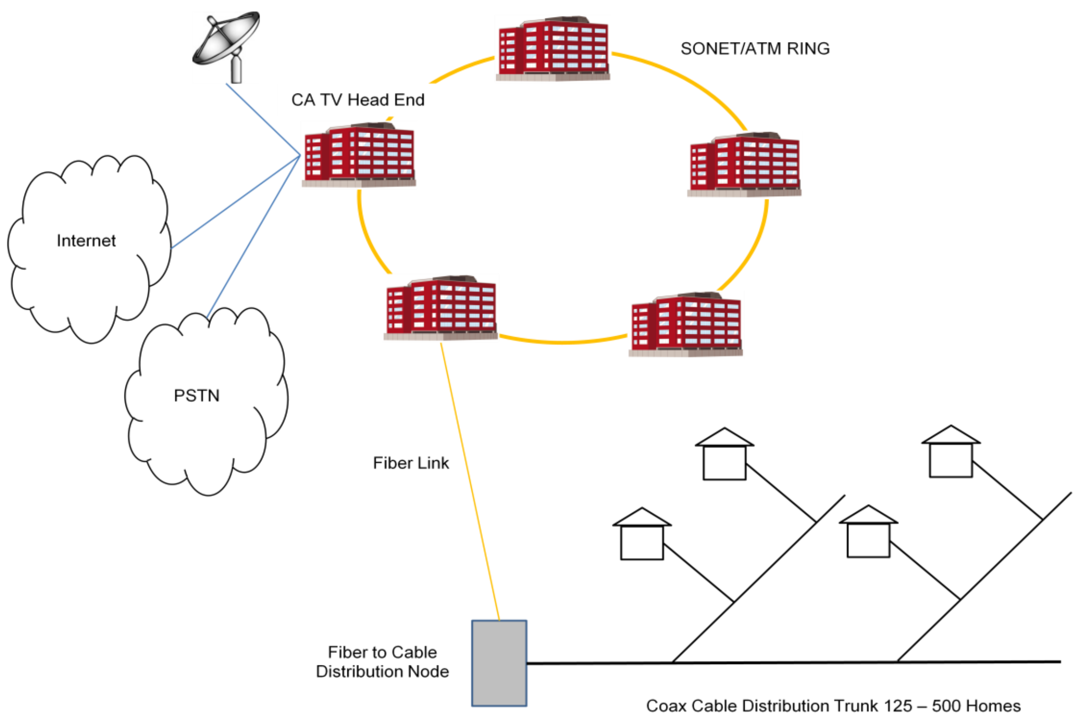
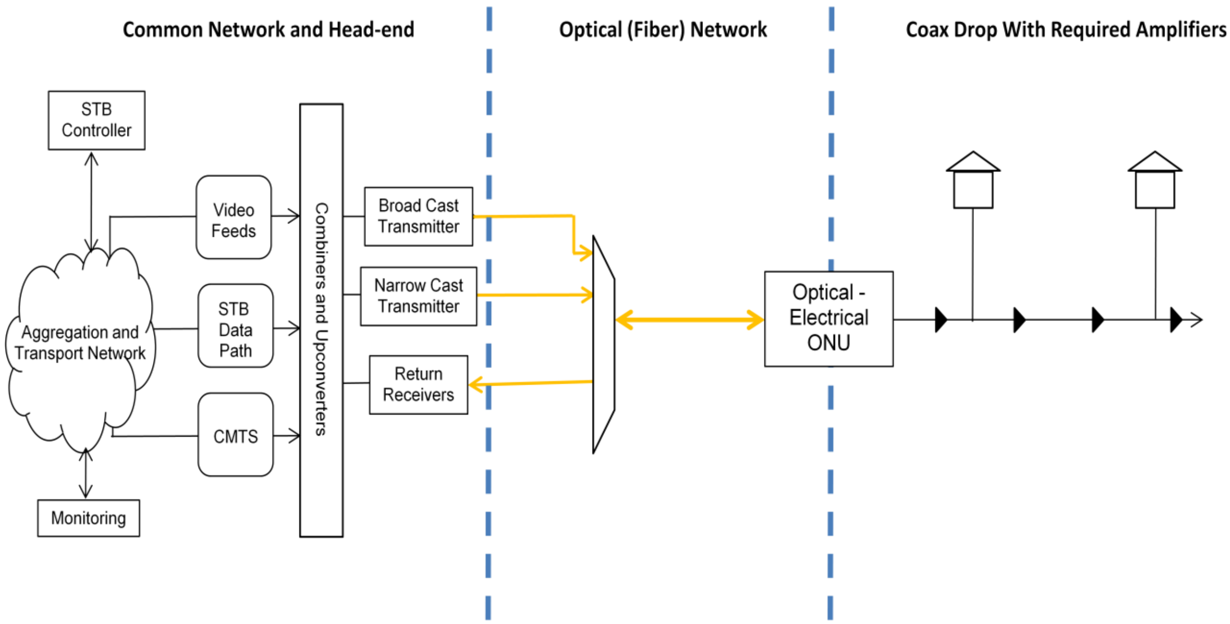


Figure 1-2 is a simplified example of a typical HFC network with a Fiber Node connecting subscribers via coaxial cables.

Figure 1-2 Typical HFC Distribution Network



1.2 RFoG Overview: What is RFoG?

Fiber technology has well demonstrated its ability to cost effectively deliver multi-service high bandwidth capabilities now and into the future, therefore fiber technology is a good technology choice for extending the reach of HFC networks and enhancing services to provide complete and successful Fiber to the Home (FTTH) or Fiber to the Premise (FTTP) implementations. The challenge is the extension of fiber deeper into the network, all the way to the subscriber's home, while maintaining complete compatibility with the existing CMTS and DOCSIS® infrastructure, Headend back office operational and business support systems, and existing subscriber services for video, voice over IP, and broadband internet.

RFoG (or RF over Glass), began its history as a Fiber to the Home solution that was merely an extension of the traditional HFC network from the node to the premise. RF over Glass would provide the same services and functionality as a standard HFC system, using the same Headend equipment, provisioning, and other existing services. As such RFoG could be used to extend from an existing HFC system building off of an existing HFC Headend infrastructure, or to build a new system utilizing the same Headend equipment, infrastructure, and services already familiar to the cable operators. And because the fiber architecture mimics that of a Passive Optical Network (PON) architecture, it allows for simultaneous use of the same fiber for PON.

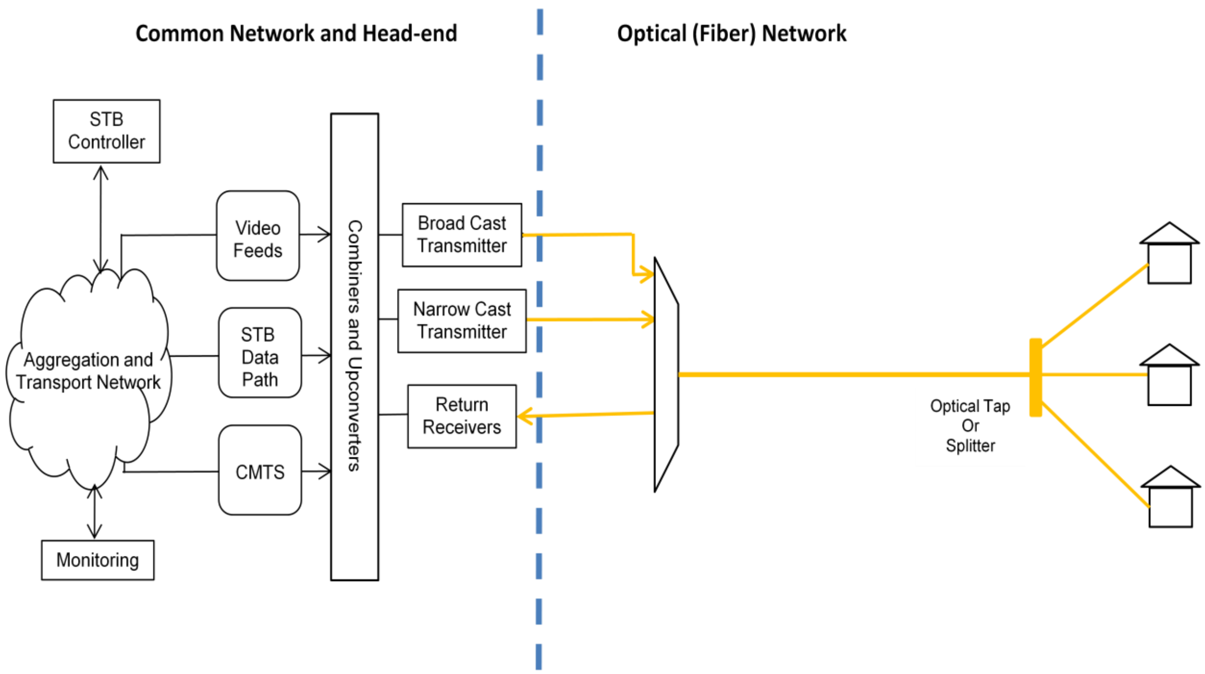
RFoG solutions available today from Aurora Networks easily meet and exceed all minimum SCTE goals of serving up to 32 subscribers up to 20 km with a 25 dB loss budget, and also include a number of additional benefits for both operators and subscribers such as:

- Delivery of fiber based high performance services well beyond the current limited distance coax plant
- Improved performance due to the fact that fiber delivers a cleaner signal because it is not susceptible to the kind of interference that historically plagues RF over coax

- Lower operating and maintenance costs for cable operators by the elimination of myriads of active RF power amplifiers and RF passives required to support the many miles of coax copper wire
- Extending the historic RFoG 20 km distance limitation to over 100 km by using new transmitter/receiver technology in the Headend, DFB lasers in the R-ONU CPEs, and implementation of RFoG Virtual Hubs (VHubs^{TM})/nodes at the edge of the fiber infrastructure of the HFC system, that also include leading edge digital return receiver/transmitter technology for long distance transmission and management of upstream services.
- Ultimately, in new RFoG installations higher bandwidth services and therefore greater numbers of simultaneous services are feasible
- Providing a relatively low cost upgrade for high speed gigabit GPON/GEPON communications technologies that will be able to handle evolving high bandwidth or bundled services as they become available. These high speed services can be offered to small/medium businesses as well as residential subscribers.

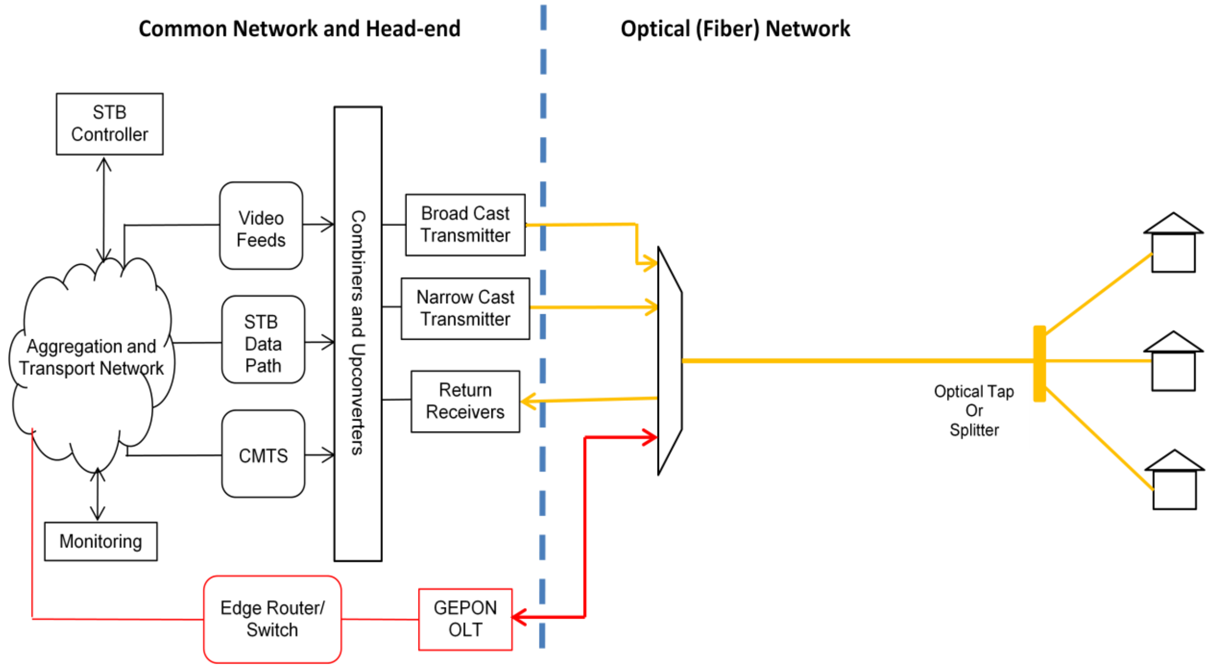
Figure 1-3 illustrates RFoG implementations where the original copper coax distribution network has been upgraded to a FTTP/FTTH network. Often this is can be done by 1) upgrading the existing HFC Fiber Node to an RFoG VHub to now manage optical-optical interface between Headend and subscribers , or 2) in a new build area, feed the fiber directly from the Headend to the new neighborhood within a 20 km proximity and use a splitter to distribute services to the subscribers. For longer distances, an RFoG VHub can distribute services to multiple subscribers more than 100 km from the Headend. In either case, the RF functions and characteristics are in place to deliver current and future services that require high speed and bandwidth all the way to the home. At the same time, Headend equipment including back office administration services equipment and DOCSIS functionality remains unaffected.

Figure 1-3 HFC Transition to RFoG/FTTP



Furthermore, RFoG solutions available today include the additional benefit of providing an uncomplicated migration path to higher bandwidth GPON and GEPON deployments as they are incrementally needed (Figure 1-4). Such installations are only a matter of installing the GPON/GEPON equipment within the Headend or in the VHub/node in the case of long haul implementations. The PON overlay and services ride on the same downstream and upstream fiber(s) with the RFoG signals. If the R-ONU CPE was not already PON-ready, it would also need to be upgraded to provide a PON pass through port to feed the optically equipped CPEs within the premise. (Also, the opposite is true in that an existing PON system can be expanded with RFoG video and/or data overlay.)

Figure 1-4 RFoG Upgrade to include GPON/GEPON



1.3 Short Haul vs. Long Haul

Today’s RFoG implementations are capable of delivering cost effective high performance FTTP/FTTH services on a purely passive basis sourced directly from the Headend to the subscriber premise/residence at distances of 20 km or more. Low cost optical splitters provide support of up to 32 subscribers from the same original single fiber.

The initial goal for RFoG deployments was to deliver the same services as were previously delivered by an HFC deployment at a distance up to 20 km to 32 subscribers from a single fiber to/from the Headend. While some suppliers may struggle in meeting all required specifications, improvements in the inclusive technologies from Aurora ensure that the distance is easily met while still maintaining a 25 dB loss budget with a 32-way split. A 25 dB loss budget is required in order to maintain acceptable subscriber service performance.

The key factors for determining the distance for a completely passive implementation are:

- Downstream transmit/EDFA launch power (and optical performance) from the Headend
- The number of analog channels combined: fewer analog channels means higher OMI performance and lower optical receive power needed, which translates into a longer fiber reach
- Loss in fiber, connectors, and splitter(s)
- The number of splits: fewer splits equates to smaller loss and longer fiber reach. 32 splits is the typical implementation

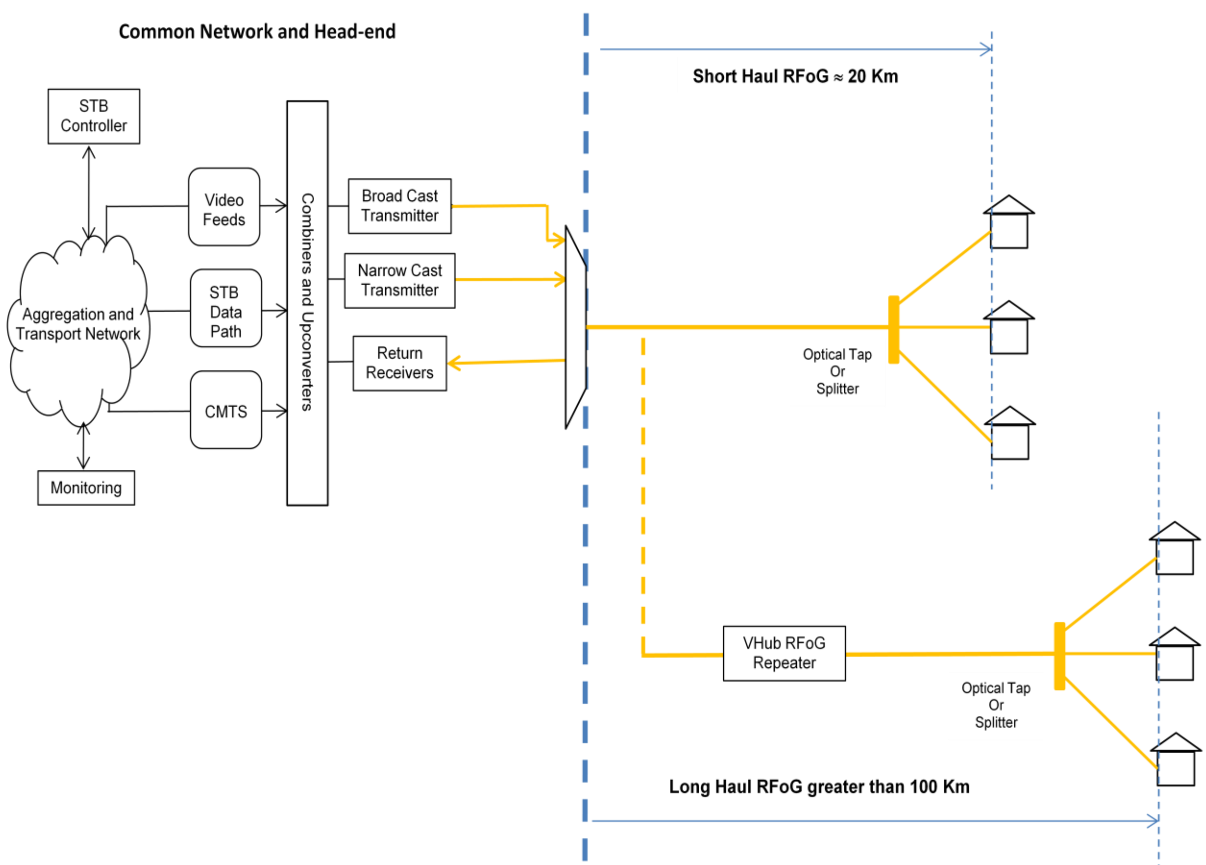
- Upstream transmit power and RF performance of the R-ONU
- Number of upstream return paths combined
- RF performance of the return receiver at the Headend
- And, last but not least, if the future addition of PON on the same fiber is anticipated, the optical loss requirements of the combined RFoG/PON network need to be taken into account

Ultimately however, even with optimal equipment available today a completely passive RFoG system which meets the performance standards and requirements does inherently have a distance limitation of around 20 km with a typical link loss budget up to 25dB, including a 32 way split.

For long haul, the addition of an active repeater (RFoG VHub, or integrated into the NC2000, or NC4000 optical node platform) emanating from the same fiber resolves the distance constraints of the short haul. On a single fiber, the signal is amplified by the VHub/node, and distances up to and over 100 km and support for up to 256 homes or more can be achieved. The VHub/node also provides technology in the upstream direction that performs an optical-electrical-optical (OEO) conversion while simultaneously being converted from an analog to digital signal format in order to drive the same long distances back to the Headend. Figure 1-5 demonstrates both a short haul and a long haul distribution network emanating from the same Headend equipment.

A key point to note is that the Headend equipment for both short and long haul implementations remains basically the same to include the video feed, CMTS data service, combiners and up converters, broadcast/narrowcast transmitters, and the WDM multiplexer. Equipment adjustments to handle RF return however will be somewhat different for short haul and long haul solutions as will be noted in later sections of this guide.

Figure 1-5 Short Haul versus Long Haul Implementation



1.4 Single Family Dwelling Units vs. Multi Family Dwelling Units

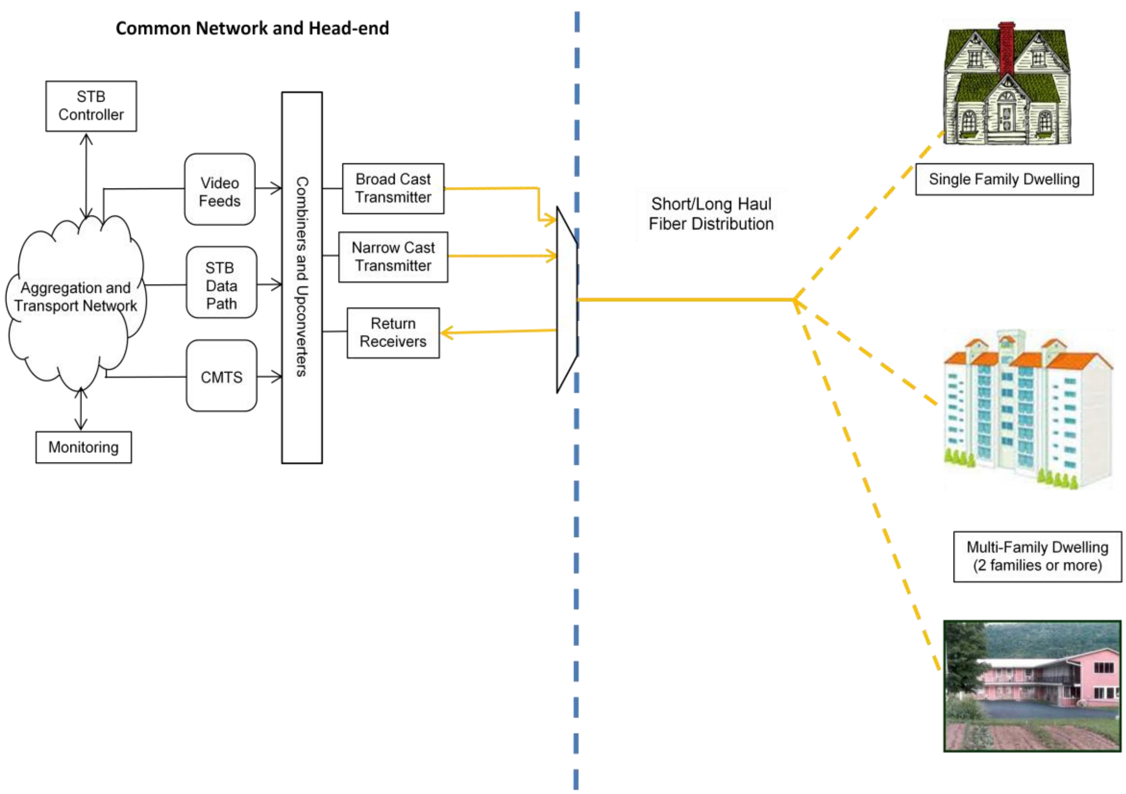
Because a goal of cable operators is to provide services to (and collect revenue from) residents and businesses across a given area, RFoG deployments need to provide equal services and performance levels to single family homes as well as to small, medium, and large buildings that house hundreds or thousands of families as would be found in large city apartment, condominium, townhouse buildings. Regardless of the physical size or capacity of the building or building complex, subscribers or potential subscribers expect the same level of services and performance levels to address current and future needs.

Implementations for multi-family dwellings can be quite different and more complex than those of SDU installations, depending on the number of subscribers supported, specific building architectures, and other factors. In either case of single or multi-family dwelling installations, as in the case of short and long haul installations, the Headend equipment remains largely the same. Aurora Networks provides cost effective leading edge solutions for single and multi-family dwellings.

Figure 1-6 demonstrates that single dwelling units and multi dwelling units can rely on the same Headend network.

This guide specifically focuses on SDU solutions and implementations.

Figure 1-6 Single Family Dwelling versus Multi-Family Dwelling



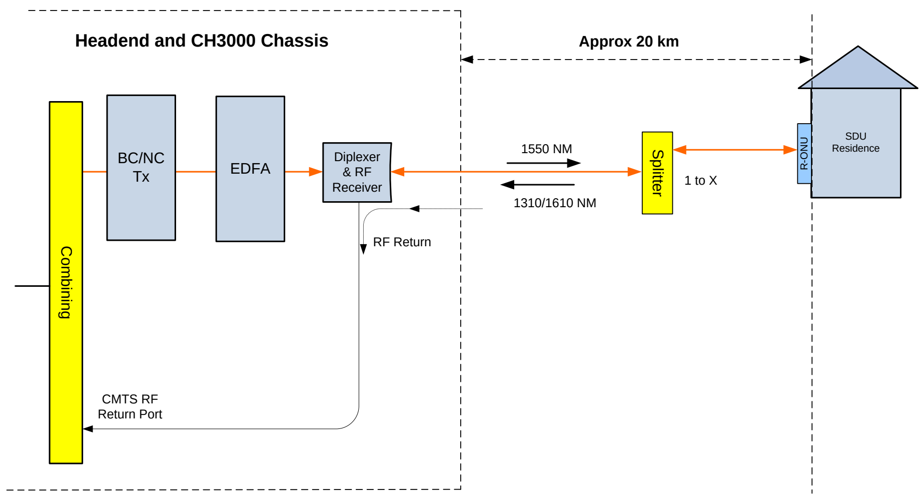
Chapter 2 Aurora Networks SDU Installation Options

2.1 Basic Short Haul Implementation (≈20 km)

Figure 2-1 is a reference diagram that portrays the basic elements for an Aurora RFoG implementation for a short haul SDU structure whether it is a family residence or small office. The reference architecture within the Headend consists of a downstream optical transmitter, either broadcast, or narrowcast, or both, operating nominally at 1550 nm, plus EDFA amplification as necessary to serve the intended reach with the appropriate performance levels. The Headend also consists of a return receiver with an integrated optical diplexer which passes the 1550 nm downstream signal and also receives and separates (filters) the upstream optical signals coming from the subscriber R-ONU CPE at either 1310* nm or 1610* nm, and converts the signals back to analog RF signals. The signals are then fed into the into the CMTS processing equipment where traditional CMTS processes and functions are managed. All of this functionality can easily be imposed on a single fiber link between the subscriber CPE and the Headend.

*1310 nm currently is more cost effective due to the wide availability of active and passive components at this wavelength, however 1610 nm is more future proof as it permits overlay with IEEE 802.ah GEPON, IEEE 802.av 10GEPON, and ITU G.984 GPON standards.

Figure 2-1 Simple Reference Diagram for Short Haul RFoG



In the field, on the opposite end of the fiber link and conveniently located near the subscriber dwelling there is typically an optical splitter that would fan out the downstream signal to provide parallel services to multiple SDUs. Depending on the local situation, the splitter could be at the Headend, or 2, 4, and 8 way splitters could be distributed over the distance to the SDU premise, or a 32-way splitter could be located in the subscribers' neighborhood. Typically, as Figure 2-1 indicates, one splitter is installed within close proximity to the subscriber.

At the customer site, an RFoG Optical Network Unit (R-ONU) CPE is required. The R-ONU CPE consists of an optical transceiver with an optical receiver for the 1550 nm downstream signals and a transmitter for the 1310 or 1610 nm upstream signals. The R-ONU CPE provides the optical communication link for the various peripheral CPEs within the premise to support video, voice, and data services as needed by the subscriber. The R-ONU passes the necessary upstream signals to support DOCSIS 2.0 or DOCSIS 3.0 requirements to manage incumbent and future MSO Headend services. In a short haul implementation, the 1310 or 1610 nm upstream signal is then extracted by the RF return diplexer/receiver module in the Headend, and is converted back to an RF analog signal which is subsequently fed to the CMTS related equipment where standard CMTS processes and functions are managed.

Overall the system easily meets the ANSI SCTE 174 2010 RFoG goals of providing optical service to 32 subscribers on a 20 km link within a loss budget of no more than 25dB.

Where Figure 2-1 is a generic reference diagram for a short haul RFoG implementation, Chapter 4 provides a series of tables that describe Aurora equipment that can be included in a complete RFoG end to end solution. It is up to the cable operator to determine the best combination of hardware modules to use, depending on the specific needs. Aurora Networks provides significant consultative expertise in RFoG network and hardware design and planning.

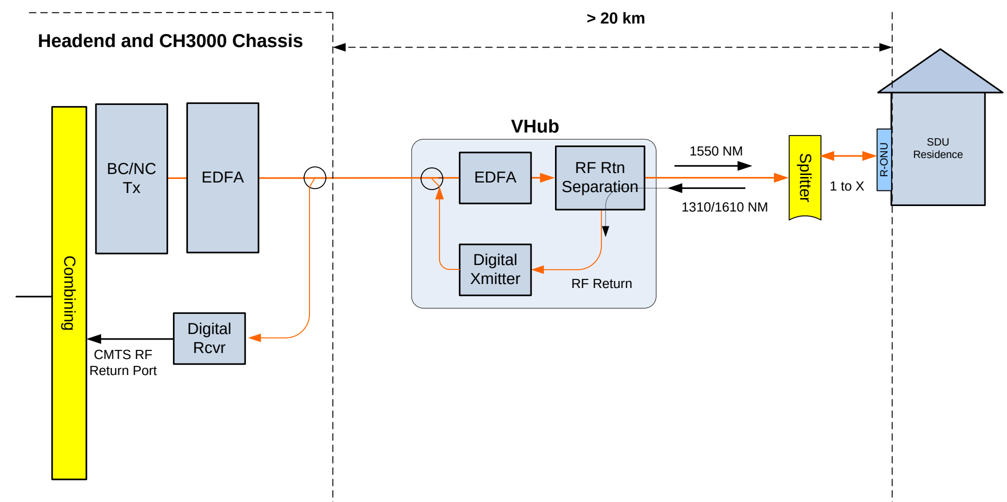
Chapter 5, Figure 5-1 of this document shows a more detailed block diagram of a short haul RFoG implementation that serves up to 4096 homes.

2.2 Basic Long Haul Implementation (≥20 km)

Figure 2-2 is a reference diagram that notes the basic elements for an Aurora RFoG implementation for a significantly longer haul SDU service. Typically, minimal changes at the Headend as compared to the short haul implementation are required to support this long haul service. The same fiber extending from the Headend to the premise in the short haul implementation is now fed to a weatherproof strand or pedestal mounted RFoG VHub based on the Aurora NC4000, or NC2000 node platform which serves as an amplification and distribution mechanism extending service from the same fiber to serve 256 or more homes at distances possibly to 100 km or more from the Headend.

Extending from the VHub/node, the amplified signal on the fiber then is sent to an optical splitter typically located near the subscriber premises, where each splitter leg provides service for one SDU home. A single Aurora Networks VHub node can include an 8 port FA4527S EDFA amplifier followed by an 8-port OR4148H optical combiner-splitter-RF return receiver. With each port followed in the field by a 1 by 32 splitter, high performance service to a total of 256 SDU homes can be provided at lengths well beyond distances achieved by short haul installations.

Figure 2-2 Simple Reference Diagram for Long Haul RFoG



In the upstream path the RF return separation now takes place in the VHub/node using an RFoG--RF return/diplexer receiver. The return RF from the separated 1310 or 1610 nm upstream wavelength is then fed into a digital return transmitter in the node, which is then sent to the Headend, having been combined onto the downstream fiber using a WDM combiner which fits comfortably within the VHub/node housing.

At the Headend, the upstream RF return signal is separated from the downstream signal through an optical filter, and fed into a digital receiver where it is converted back into RF. The consequent signal is then supplied to the CMTS related equipment where standard CMTS processes and functions are managed.

The addition of the VHub/node solves the traditional RFoG upstream distance limitation as the VHub/node includes technology that receives and regenerates the upstream digital optical signal sufficiently to match the downstream distance to the Headend. In many implementations the return is combined on the same fiber as the downstream signal. The VHub/node also provides the ability to increase the single fiber distribution and services to support up to 256 homes or more, including consolidation of the upstream RF return for each.

The total combined distance from the Headend through the VHub/node to the R-ONU CPE can be 100 km or more. Implementations of long haul solutions require careful system design for location of the VHub/node with respect to the Headend at one end of the system, and the subscriber premise R-ONU CPE at the other end of the system. Chapter 3 Section 3.3 discusses the parametric signal level requirements for VHub/node RF and R-ONU CPE, which ultimately determines the overall distance end to end.

Where Figure 2-2 is a generic reference diagram for a long haul RFoG implementation, Chapter 4 provides a series of tables describing various Aurora equipment that could be included in a complete RFoG end to end solution. It is up to the cable operator to determine the best combination of hardware modules to use, depending on the specific needs. Again, Aurora Networks can provide significant consultative expertise in RFoG network and hardware design and planning.

Chapter 5, Figure 5-2 of this document shows a more detailed block/schematic diagram of a long haul RFoG implementation that serves up to 2048 homes, all driven from a single transmitter at the Headend.

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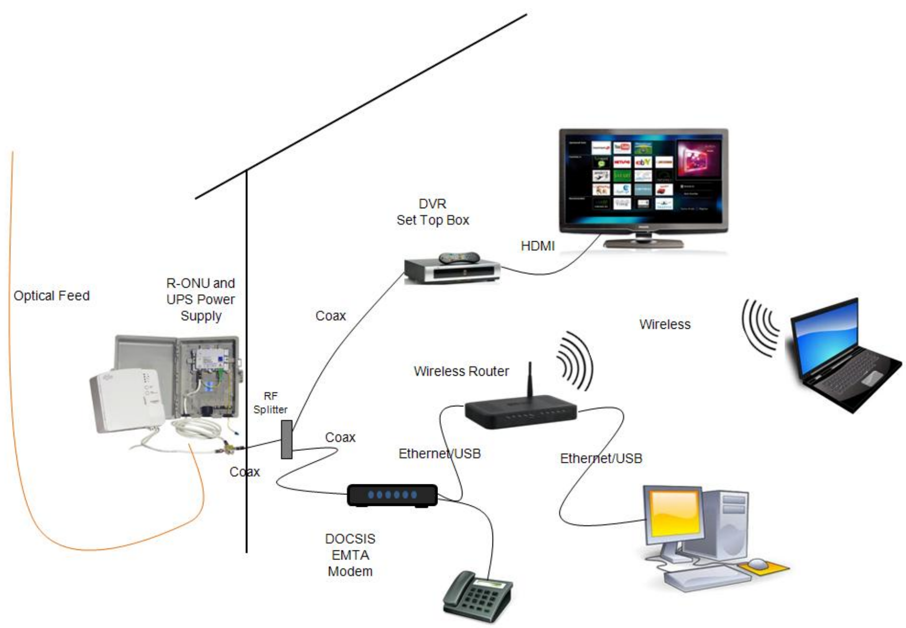
2.3 RFoG - Optical Network Units for SDU Implementations

At the subscriber end, the R-ONU CPE, which typically is located conveniently on a premise exterior or interior wall, provides a physical connection and interface between the provider's optical network and the various subscriber CPEs within the premise. As important as providing the physical connection, the R-ONU CPE also performs the optical to electrical conversion for the downstream 1550 nm signal, and electrical to optical conversion for the 1310 or 1610 nm upstream signal. Aurora Networks R-ONU CPE units support any RFoG solution that uses standard industry wavelengths to and from the premises transporting traditional RF services and the MSO incumbent DOCSIS cable modem traffic. Aurora Networks R-ONU CPEs are optimized for upstream performance to support DOCSIS 3.0 requirements using thermally stable DFB (Distributed Feed Back) laser transmitters, which provide increased dynamic range and lower Relative Intensity Noise (RIN) for an exceptional and consistent Noise Performance Ratio (NPR) performance over varying link conditions, temperature, and return path loading as compared to R-ONU CPEs utilizing traditional FP* (Fabry-Perot) lasers. A microcontroller ensures stable laser turn on/off and Optical Modulation Index (OMI) stability over varying temperatures, which exceed SCTE specifications.

For more information regarding Aurora R-ONU CPE performance enhancements, please read the various RFoG related white papers available from Aurora noted in the Appendix "Other Related RFoG Documentation".

*Some available R-ONU CPEs utilizing FP lasers have exhibited limited NPR dynamic range and temperature stability and as a result have difficulty in meeting or do not meet DOCSIS 3.0 system performance requirements.

Figure 2-3 R-ONU and other CPE Components and Connections



Regarding planning for and implementing RFoG support for an SDU, the single greatest difference between an SDU and MDU implementation is the R-ONU CPE RF output level, and of course the methods of distributing the service within the buildings. As discussed earlier the short haul or long haul optical feeder and distribution networks for RFoG implementation are relatively uncaring about whether they serve an SDU or an MDU, except to say that appropriate feeder support (bandwidth, fiber, etc.) from the Headend must be put in place to serve the larger number of subscribers in an MDU. (MDU implementation will be covered in a separate document.) SDU implementations typically are simpler since the service coming from the Headend is basically terminated at and limited to one single subscriber within one premise, needing only to accommodate the various CPE components within that specific premise location.

Table 1 portrays Aurora Networks R-ONU CPE modules specifically for SDU residential or single small offices. The complete specifications of each are exhibited in the following pages.

Table 1 R-ONUs for SDU Implementations

RF Pass-bands (MHz)		Return Wavelength and Part Number	
Forward	**Return**	**1310 nm**	**1610 nm**
54-1002	5-42	CP8013U-02-10	CP8015U-02-10
85-1002	5-65	CP8043U-02-10	CP8045U-02-10
72-1002	5-60	CP8063U-02-10	CP8065U-02-10

2.3.1 Aurora Networks R-ONU CPE Specifications

CP8013U-02-10 R-ONU CPE

The ANSI SCTE 174 2010 compliant CP8013U-02-10 supports a 5-42 MHz return RF passband on a 1310 nm optical wavelength, with a 54-1002 MHz forward passband on a 1550 nm nominal optical wavelength.

The device provides an optical return output power of 3.0 ± 1.0 dBm, with a dynamic range of 18 dB @ 30dB NPR. This is measured with 35 MHz loading and -20 dBm into the input of the OR3144H RF Return/diplexer receiver at the headend.

Optional accessories include an AC wall adapter or battery-backed UPS power supplies and weatherproof outdoor enclosures. The CP8013U-02-10 works with all power supplies.

Table 2 CP8013U-02-10 R-ONU CPE Specifications

Performance	Physical
Downstream **Optical Receiver** • Input wavelength: 1540–1565 nm • Input power range, nominal: 0 to –6 dBm **RF Performance** • RF passband: 54 to 1002 MHz • RF output level, min: 19 dBmV/ch (at 1002 MHz) • Slope (54–1002 MHz): 5 ±2 dB • Flatness (54–1002 MHz), excluding slope, max: ±1.5 dB • Output return loss: 16 dB • Output level stability: ±2.0 dB (over +0 to –6 dBm input power) • CNR: > 48 dB • CSO: > 60 dB (at 0 dBm input power) • CTB: > 60 dB (at 0 dBm input power) • Typical system performance, 3.1% OMI, -5dBm, 20 km, 1x32 splitter **Return Path** **Optical Transmitter** • Transmission wavelength: 1310 nm ± 50 nm • Output power: 3.0 ± 1.0 dBm **RF Performance** • Passband: 5–42 MHz • RF input range: 15–45 dBmV (35% OMI @ 39 dBmV) • Squelch threshold: 13 dBmV • Dynamic range @ 30 dB NPR: 18 dB (35 MHz loading and –20 dBm input to OR3144H receiver) • Input return loss: 16 dB (within passband)	**Dimensions** • 6.3” W x 3.8” H x 1.5” D (16 cm x 9.65 cm x 3.8 cm) • Weight: 1.0 lb (0.5 kg) **Environmental** • Operating temperature range: –40º to +65ºC (–40º to 149ºF) • Storage temperature range: –40º to +85ºC (–40º to 185ºF) • Humidity: 5% to 95% non–condensing **Power Requirements** • 300 mA max at +12 VDC nominal • Power consumption, typical: 2.5 W **Connectors** • Optical interface: SC/APC recessed female fiber connector • Combined RF and DC interface: 75 ohm coax “F-female” • Pass-through VDC power port: 75 ohm coax “F-female” **Status Indicator LED** • Green = optical input power ≥ -14 dBm (+/- 1dB) • Red = optical input power < -14 dBm (+/- 1dB) **Standards and Certifications** • EMI/EMC complies with FCC Class B and ANSI/SCTE 174 2010 • CE mark certified • US/C 60950-1, IEC/EN 60950-1 • Class 1 laser product per IEC 60825-1 and FDA 21 CFR 1040.10/11 • Compliant with surge requirements of ANSI/SCTE 174 2010

CP8015U-02-10 R-ONU CPE

The ANSI SCTE 174 2010 compliant CP8015U-02-10 supports a 5-42 MHz return RF passband on a 1610 nm optical wavelength, with a 54-1002 MHz forward passband on a 1550 nm nominal optical wavelength.

The device provides an optical return output power of 3.0 ± 1.0 dBm, with a dynamic range of 18 dB @ 30dB NPR. This is measured with 35 MHz loading and -20 dBm into the input of the OR3144H RF Return/diplexer receiver at the Headend.

Optional accessories include an AC wall adapter or battery-backed UPS power supplies and weatherproof outdoor enclosures. The CP8015U-02-10 works with all power supplies.

Table 3 CP8015U-02-10 R-ONU CPE Specifications

Performance	Physical
Downstream **Optical Receiver** • Input wavelength: 1540–1565 nm • Input power range, nominal: +0 to –6 dBm **RF Performance** • RF passband: 54 to 1002 MHz • RF output level, min: 19 dBmV/ch (at 1002 MHz) • Slope (54–1002 MHz): 5 ±2 dB • Flatness (54–1002 MHz), excluding slope, max: ±1.5 dB • Output return loss: 16 dB • Output level stability: ±2.0 dB (over +0 to –6 dBm input power) • CNR: > 48 dB • CSO: > 60 dB (at 0 dBm input power) • CTB: > 60 dB (at 0 dBm input power) • Typical system performance 3.1% OMI, -5dBm, 20 km, 1x32 splitter **Return Path** **Optical Transmitter** • Transmission wavelength: 1610 nm ± 3 nm • Output power: 3.0 ± 1.0 dBm **RF Performance** • Passband: 5–42 MHz • RF input range: 15–45 dBmV (35% OMI @ 39 dBmV) • Squelch threshold: 13 dBmV • Dynamic range @ 30 dB NPR: 18 dB (35 MHz loading and –20 dBm input to OR3144H receiver) • Input return loss: 16 dB (within passband)	**Dimensions** • 6.3” W x 3.8” H x 1.5” D (16 cm x 9.65 cm x 3.8 cm) • Weight: 1.0 lb (0.5 kg) **Environmental** • Operating temperature range: –40º to +65ºC (–40º to 149ºF) • Storage temperature range: –40º to +85ºC (–40º to 185ºF) • Humidity: 5% to 95% non–condensing **Power Requirements** • 300 mA max at +12 VDC nominal • Power consumption, typical: 2.5 W **Connectors** • Optical interface: SC/APC recessed female fiber connector • Combined RF and DC interface: 75 ohm coax “F-female” • Pass-through VDC power port: 75 ohm coax “F-female” **Status Indicator LED** • Green = optical input power ≥ -14 dBm (+/- 1dB) • Red = optical input power < -14 dBm (+/- 1dB) **Standards and Certifications** • EMI/EMC complies with FCC Class B and ANSI/SCTE 174 2010 • CE mark certified • US/C 60950-1, IEC/EN 60950-1 • Class 1 laser product per IEC 60825-1 and FDA 21 CFR 1040.10/11 • Compliant with surge requirements of ANSI/SCTE 174 2010

CP8043U-02-10 R-ONU CPE

The ANSI SCTE 174 2010 compliant CP8043U-02-10 supports a 5-65 MHz return RF passband on a 1310 nm optical wavelength, with an 85-1002 MHz forward passband on a 1550 nm nominal optical wavelength.

The device provides an optical return output power of 3.0 ± 1.0 dBm, with a dynamic range of 15.5 dB @ 30dB NPR. This is measured with 60 MHz loading and -20 dBm into the input of the OR3144H RF Return/diplexer receiver at the Headend.

Optional accessories include an AC wall adapter or battery-backed UPS power supplies and weatherproof outdoor enclosures. The CP8043U-02-10 works with all power supplies.

Table 4 CP8043U-02-10 R-ONU CPE Specifications

Performance	Physical
Downstream **Optical Receiver** • Input wavelength: 1540–1565 nm • Input power range, nominal: +0 to –6 dBm **RF Performance** • RF passband: 85 to 1002 MHz • RF output level, min: 79 dBµV/ch (at 1002 MHz) • Slope (85–1002 MHz): 5 ±2 dB • Flatness (85–1002 MHz), excluding slope, max: ±1.5 dB • Output return loss: 16 dB • Output level stability: ±2.0 dB (over +1 to –6 dBm input power) • CNR: > 48 dB • CSO: > 60 dB (at 0 dBm input power) • CTB: > 60 dB (at 0 dBm input power) • Typical system performance, 3.1% OMI, -5dBm, 20 km, 1x32 splitter **Return Path** **Optical Transmitter** • Transmission wavelength: 1310 nm ± 50 nm • Output power: 3.0 ± 1.0 dBm **RF Performance** • Passband: 5–65 MHz • RF input range: 75 - 105 dBµV (35% OMI @ 99 dBµV) • Squelch threshold: 73 dBµV • Dynamic range @ 30 dB NPR: 15.5 dB (60 MHz loading and –20 dBm input to OR3144H receiver) • Input return loss: 16 dB (within passband)	**Dimensions** • 6.3” W x 3.8” H x 1.5” D (16 cm x 9.65 cm x 3.8 cm) • Weight: 1.0 lb (0.5 kg) **Environmental** • Operating temperature range: –40º to +65ºC (–40º to 149ºF) • Storage temperature range: –40º to +85ºC (–40º to 185ºF) • Humidity: 5% to 95% non–condensing **Power Requirements** • 300 mA max at +12 VDC nominal • Power consumption, typical: 2.5 W **Connectors** • Optical interface: SC/APC recessed female fiber connector • Combined RF and DC interface: 75 ohm coax “F-female” • Pass-through VDC power port: 75 ohm coax “F-female” **Status Indicator LED** • Green = optical input power ≥ -14 dBm (+/- 1dB) • Red = optical input power < -14 dBm (+/- 1dB) **Standards and Certifications** • EMI/EMC complies with FCC Class B and ANSI/SCTE 174 2010 • CE mark certified • US/C 60950-1, IEC/EN 60950-1 • Class 1 laser product per IEC 60825-1 and FDA 21 CFR 1040.10/11 • Compliant with surge requirements of ANSI/SCTE 174 2010

CP8045U-02-10 R-ONU CPE

The ANSI SCTE 174 2010 compliant CP8045U-02-10 supports a 5-65 MHz return RF passband on a 1610 nm optical wavelength, with an 85-1002 MHz forward passband on a 1550 nm nominal optical wavelength.

The device provides an optical return output power of 3.0 ± 1.0 dBm, with a dynamic range of 15.5 dB @ 30dB NPR. This is measured with 60 MHz loading and -20 dBm into the input of the OR3144H RF Return/diplexer receiver at the Headend.

Optional accessories include an AC wall adapter or battery-backed UPS power supplies and weatherproof outdoor enclosures. The CP8045U-02-10 works with all power supplies.

Table 5 CP8045U-02-10 R-ONU CPE Specifications

Performance	Physical
Downstream **Optical Receiver** • Input wavelength: 1540–1565 nm • Input power range, nominal: +0 to –6 dBm **RF Performance** • RF passband: 85 to 1002 MHz • RF output level, min: 79 dBµV/ch (at 1002 MHz) • Slope (85–1002 MHz): 5 ±2 dB • Flatness (85–1002 MHz), excluding slope, max: ±1.5 dB • Output return loss: 16 dB • Output level stability: ±2.0 dB (over +0 to –6 dBm input power) • CNR: > 48 dB • CSO: > 60 dB (at 0 dBm input power) • CTB: > 60 dB (at 0 dBm input power) • Typical system performance, 3.1% OMI, -5dBm, 20 km, 1x32 splitter **Return Path** **Optical Transmitter** • Transmission wavelength: 1610 nm ± 3 nm • Output power: 3.0 ± 1.0 dBm **RF Performance** • Passband: 5–65 MHz • RF input range: 75 - 105 dBµV (35% OMI @ 99 dBµV) • Squelch threshold: 73 dBµV • Dynamic range @ 30 dB NPR: 15.5 dB (60 MHz loading and -20 dBm input to the OR3144H) • Input return loss: 16 dB (within passband)	**Dimensions** • 6.3” W x 3.8” H x 1.5” D (16 cm x 9.65 cm x 3.8 cm) • Weight: 1.0 lb (0.5 kg) **Environmental** • Operating temperature range: –40º to +65ºC (–40º to 149ºF) • Storage temperature range: –40º to +85ºC (–40º to 185ºF) • Humidity: 5% to 95% non–condensing **Power Requirements** • 300 mA max at +12 VDC nominal • Power consumption, typical: 2.5 W **Connectors** • Optical interface: SC/APC recessed female fiber connector • Combined RF and DC interface: 75 ohm coax “F-female” • Pass-through VDC power port: 75 ohm coax “F-female” **Status Indicator LED** • Green = optical input power ≥ -14 dBm (+/- 1dB) • Red = optical input power < -14 dBm (+/- 1dB) **Standards and Certifications** • EMI/EMC complies with FCC Class B and ANSI/SCTE 174 2010 • CE mark certified • US/C 60950-1, IEC/EN 60950-1 • Class 1 laser product per IEC 60825-1 and FDA 21 CFR 1040.10/11 • Compliant with surge requirements of ANSI/SCTE 174 2010

CP8063U-02-10 R-ONU CPE

The ANSI SCTE 174 2010 compliant CP8063U-02-10 supports a 5-60 MHz return RF passband on a 1310 nm optical wavelength, with a 72-1002 MHz forward passband on a 1550 nm nominal optical wavelength.

The device provides an optical return output power of 3.0 ± 1.0 dBm, with a dynamic range of 16 dB @ 30dB NPR. This is measured with 55 MHz loading and -20 dBm into the input of the OR3144H RF Return/diplexer receiver at the Headend.

Optional accessories include an AC wall adapter or battery-backed UPS power supplies and weatherproof outdoor enclosures. The CP8063U-02-10 works with all power supplies.

Table 6 CP8063U-02-10 R-ONU CPE Specifications

Performance	Physical
Downstream **Optical Receiver** • Input wavelength: 1540–1565 nm • Input power range, nominal: +0 to –6 dBm **RF Performance** • RF passband: 72 to 1002 MHz • RF output level, min: 19 dBmV/ch (at 1002 MHz) • Slope (72–1002 MHz): 5 ±2 dB • Flatness (72–1002 MHz), excluding slope, max: ±1.5 dB • Output return loss: 16 dB • Output level stability: ±2.0 dB (over +0 to –6 dBm input power) • CNR: > 48 dB • CSO: > 60 dB (at 0 dBm input power) • CTB: > 60 dB (at 0 dBm input power) • Typical system performance, 3.1% OMI, -5 dBm, 20 km, 1x32 splitter **Return Path** **Optical Transmitter** • Transmission wavelength: 1310 nm ± 50 nm • Output power: 3.0 ± 1.0 dBm **RF Performance** • Passband: 5–60 MHz • RF input range: 15 - 45 dBmV (35% OMI @ 39 dBmV) • Squelch threshold: 13 dBmV • Dynamic range @ 30 dB NPR: 16 dB (55 MHz loading, –20 dBm input to OR3144H receiver) • Input return loss: 16 dB (within passband)	**Dimensions** • 6.3” W x 3.8” H x 1.5” D (16 cm x 9.65 cm x 3.8 cm) • Weight: 1.0 lb (0.5 kg) **Environmental** • Operating temperature range: –40º to +65ºC (–40º to 149ºF) • Storage temperature range: –40º to +85ºC (–40º to 185ºF) • Humidity: 5% to 95% non–condensing **Power Requirements** • 300 mA max at +12 VDC nominal • Power consumption, typical: 2.5 W **Connectors** • Optical interface: SC/APC recessed female fiber connector • Combined RF and DC interface: 75 ohm coax “F-female” • Pass-through VDC power port: 75 ohm coax “F-female” **Status Indicator LED** • Green = optical input power ≥ -14 dBm (+/- 1dB) • Red = optical input power < -14 dBm (+/- 1dB) **Standards and Certifications** • EMI/EMC complies with FCC Class B and ANSI/SCTE 174 2010 • CE mark certified • US/C 60950-1, IEC/EN 60950-1 • Class 1 laser product per IEC 60825-1 and FDA 21 CFR 1040.10/11 • Compliant with surge requirements of ANSI/SCTE 174 2010

CP8065U-02-10 R-ONU CPE

The ANSI SCTE 174 2010 compliant CP8065U-02-10 supports a 5-60 MHz return RF passband on a 1610 nm optical wavelength, with a 72-1002 MHz forward passband on a 1550 nm nominal optical wavelength.

The device provides an optical return output power of 3.0 ± 1.0 dBm, with a dynamic range of 16 dB @ 30dB NPR. This is measured with 55 MHz loading and -20 dBm into the input of the OR3144H RF Return/diplexer receiver at the Headend.

Optional accessories include an AC wall adapter or battery-backed UPS power supplies and weatherproof outdoor enclosures. The CP8065U-02-10 works with all power supplies.

Table 7 CP8065U-02-10 R-ONU CPE Specifications

Performance	Physical
Downstream **Optical Receiver** • Input wavelength: 1540–1565 nm • Input power range, nominal: +0 to –6 dBm **RF Performance** • RF passband: 72 to 1002 MHz • RF output level, min: 19 dBmV/ch (at 1002 MHz) • Slope (72–1002 MHz): 5 ±2 dB • Flatness (72–1002 MHz), excluding slope, max: ±1.5 dB • Output return loss: 16 dB • Output level stability: ±2.0 dB (over +0 to –6 dBm input power) • CNR: > 48 dB • CSO: > 60 dB (at 0 dBm input power) • CTB: > 60 dB (at 0 dBm input power) • Typical system performance, 3.1% OMI, -5dBm, 20 km, 1x32 splitter **Return Path** **Optical Transmitter** • Transmission wavelength: 1610 nm ± 3 nm • Output power: 3.0 ± 1.0 dBm **RF Performance** • Passband: 5–60 MHz • RF input range: 15- 45 dBmV (35% OMI @ 39 dBmV) • Squelch threshold: 13 dBmV • Dynamic range @ 30 dB NPR: 16 dB (55 MHz loading and –20 dBm input to OR3144H receiver) • Input return loss: 16 dB (within passband)	**Dimensions** • 6.3” W x 3.8” H x 1.5” D (16 cm x 9.65 cm x 3.8 cm) • Weight: 1.0 lb (0.5 kg) **Environmental** • Operating temperature range: –40º to +65ºC (–40º to 149ºF) • Storage temperature range: –40º to +85ºC (–40º to 185ºF) • Humidity: 5% to 95% non–condensing **Power Requirements** • 300 mA max at +12 VDC nominal • Power consumption, typical: 2.5 W **Connectors** • Optical interface: SC/APC recessed female fiber connector • Combined RF and DC interface: 75 ohm coax “F-female” • Pass-through VDC power port: 75 ohm coax “F-female” **Status Indicator LED** • Green = optical input power ≥ -14 dBm (+/- 1dB) • Red = optical input power < -14 dBm (+/- 1dB) **Standards and Certifications** • EMI/EMC complies with FCC Class B and ANSI/SCTE 174 2010 • CE mark certified • US/C 60950-1, IEC/EN 60950-1 • Class 1 laser product per IEC 60825-1 and FDA 21 CFR 1040.10/11 • Compliant with surge requirements of ANSI/SCTE 174 2010

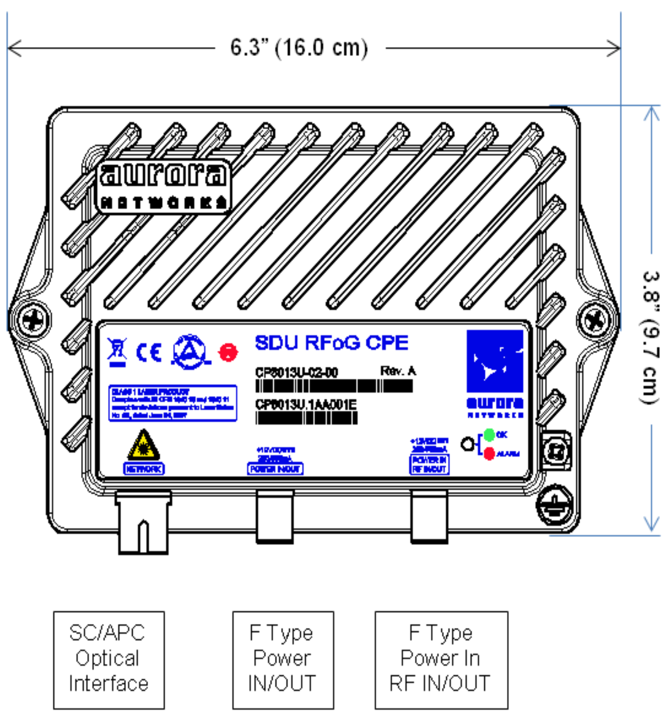
R-ONU CPE Modules for SDU Implementation

Figure 2-4 displays a photograph of a CP80xx-02-10 series SDU R-ONU CPE. The CP80xx-02-10 R-ONU CPEs can comfortably be housed in Aurora's CE8300H outdoor enclosure or CC8300H indoor enclosure, as shown in Figure 2-8. Refer to Technical Note TN-11-014 (document number 87-10650) for the complete installation instructions on SDU CPEs.

Figure 2-4 CP80xx-02

Figure 2-5 shows a top-view outline drawing of the CP80xx-02 family of SDU CPEs to include the R-ONU physical dimensions and connection ports.

Figure 2-5 CP80xx-02 Outline Drawing, Top View

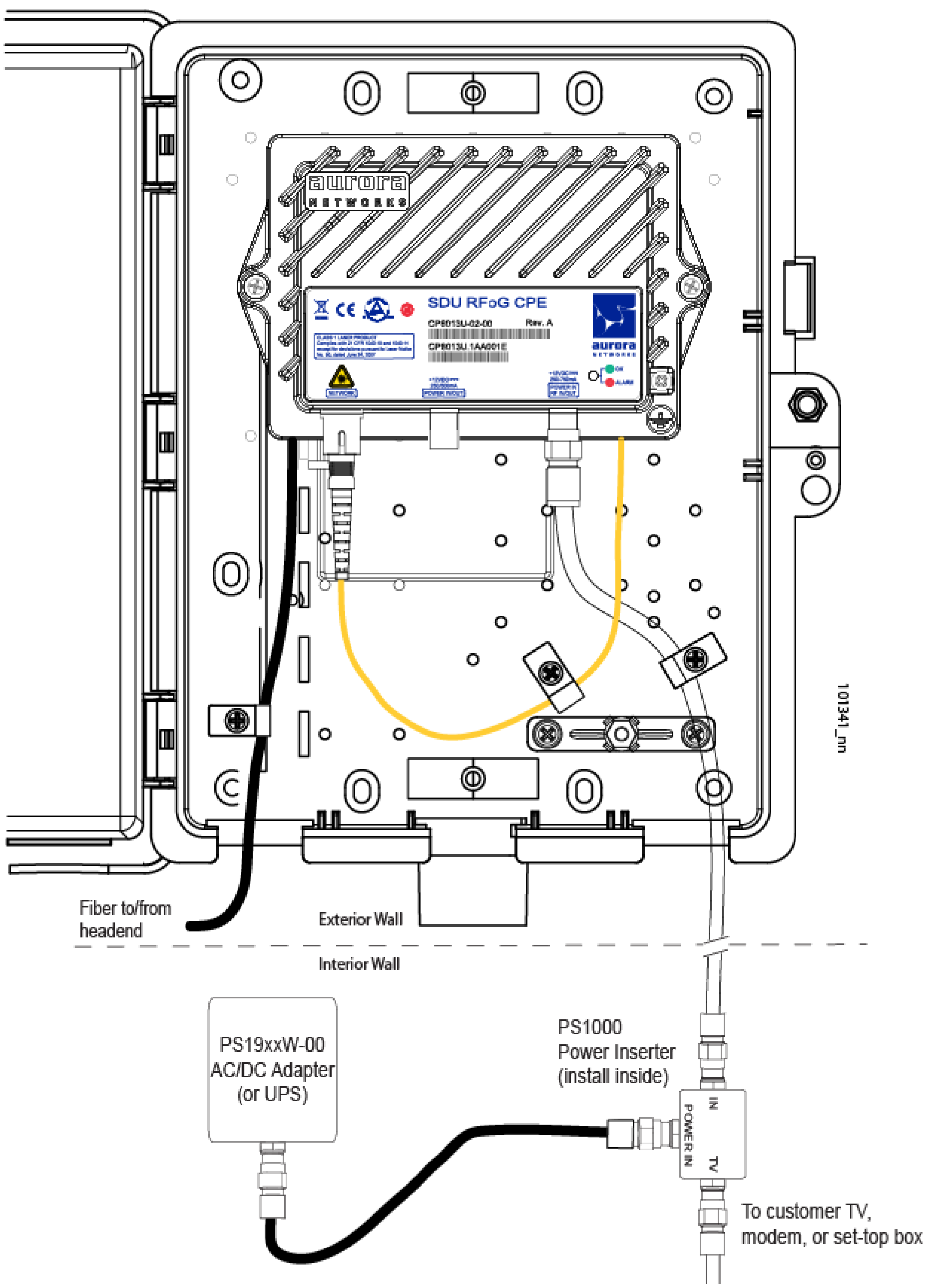


With reference to Figure 2-5, the SC/APC optical interface connects the R-ONU CPE to the network fiber coming from and going to the Headend distribution network.

When the CP80xx-02 is mounted outdoors, the F Type Power In RF IN/OUT connector is used to accommodate a 12 volt DC input coming from a PS1000 Power Inserter and an RF in/out feed to the subscriber's TV, Set Top Box, Modem, etc. (Figure 2-6). This configuration, with the R-ONU is mounted outdoors and the PS1000 (and power supply) mounted indoors, facilitates the need for only one hole (for a single coax) in the exterior wall through which the DC power and RF Feed must pass. The PS1000 power inserter does introduce some minimal loss in this configuration.

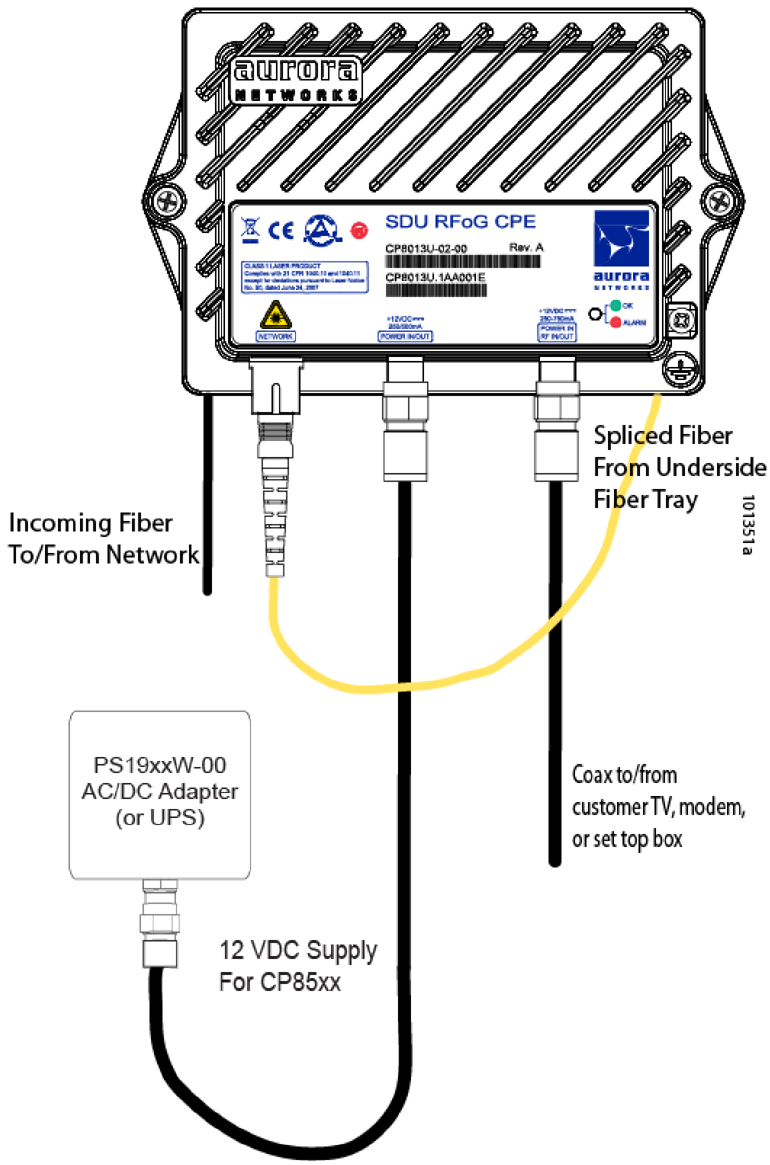
Note that in both Figure 2-6 and 2-7, the fiber coming in from the Headend network (shown in black) is spliced to a 2 or 3 mm jacket fiber (shown in yellow) in a CE8302H-IND fiber reel/tray that is mounted underneath the R-ONU. (Figure 2-8). Refer to the R-ONU installation technical note for more information.

Figure 2-6 Typical Outside R-ONU Installation with PS1000 Power Inserter



The F Type Power IN/OUT connector is typically used as the 12 volt DC input coming directly from a PS19XX wall mount AC adaptor (or PS18XX Uninterruptable power supply) when the R-ONU is mounted indoors. In this configuration the F Type Power In-RF IN/OUT connector is used only as the RF in/out to the subscriber's TV, Set Top Box, Modem, etc. The PS1000 Power Inserter is not needed in this configuration. (Figure 2-7)

Figure 2-7 Typical Indoor Installation; no PS1000 Power Inserter Required



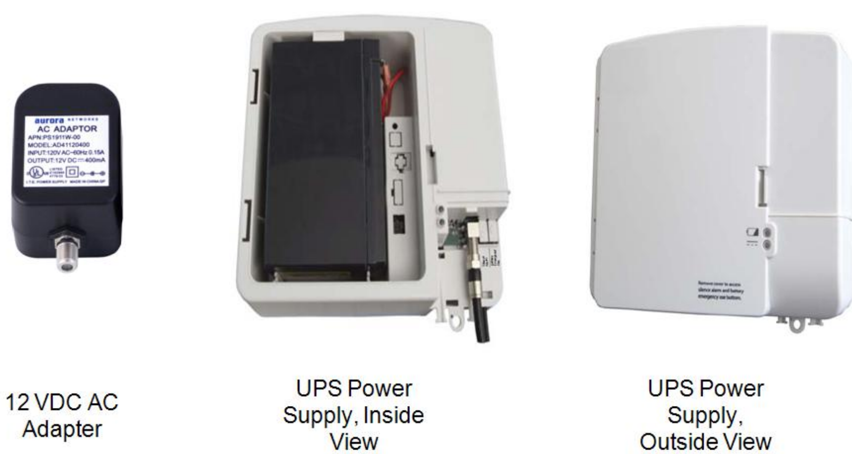
Enclosures and Power Supplies for Aurora R-ONU CPEs

Figure 2-8 displays available mounting options for Aurora SDU R-ONU CPE modules. Check document number 87-10611 “RFoG. RFPON Accessories SDU and MDU Housing Options” data sheet for details and specifications.

Figure 2-8 Aurora R-ONU CPE Enclosures and Mounting Bracket

Figure 2-9 displays available powering options for Aurora SDU R-ONU CPE modules. Check 87-10592 “RFoG/FRPON Accessories SDU and MDU Powering Options” data sheet for details and specifications.

Figure 2-9 Aurora Power Supplies



AC Wall Adapter and Interruptible Power Supply Specifications

AC Wall Adapters

PS1911W-00 (USA Voltage & Connector)
120 VAC adapter with 12 VDC output on “F” connector
• Output: 500 mA @ 12 VDC nom. (6 W)
• Operating input voltage: 108–132 V_{rms}
• Operating frequency: 60 Hz
• Input current, max: 150 mA
• AC input connector: NEMA 1-15P
• DC output connector: F-female
• Surge protection: 1 kV min (per IEEE/ANSI C62.41)
• Safety: UL 13210 / CSA C22.2 No. 223-M91
• Operating temperature: –10º to +40ºC (+14º to +104ºF)
• Storage temperature: –20º to +80ºC (–4º to +176ºF)
• Humidity: 5% to 95% non–condensing
• Dimensions: 2.3” W x 3.0” H x 2.0” D
(5.8 cm x 7.6 cm x 5.0 cm)
• Weight, typical: 1 lb (0.45 kg)

PS1912W-00 (Europe/Latin America Voltage & Connector)
230 VAC EU type adapter with 12 VDC output on “F” connector
• Output: 500 mA @ 12 VDC nom. (6 W)
• Operating input voltage: 207–253 V_{rms}
• Operating frequency: 50 Hz
• Input current, max: 150 mA
• AC input connector: CEE 7/16
• DC output connector: F-female
• Surge protection: 1 kV min (per EN 61000-4-5:2005)
• Safety: IEC/EN 61558
• Operating temperature: –10º to +40ºC (+14º to +104ºF)
• Storage temperature: –20º to +80ºC (–4º to +176ºF)
• Humidity: 5% to 95% non–condensing
• Dimensions: 2.3” W x 3.3” H x 2.0” D
(5.8 cm x 8.5 cm x 5.1 cm)
• Weight, typical: 1 lb (0.45 kg)

PS1913W-00 (Japan Voltage and & Connector)
100 VAC adapter with 12 VDC output on “F” connector,
with PSE Mark for Japan
• Output: 500 mA @ 12 VDC nom. (6 W)
• Operating input voltage: 90–110 V_{rms}
• Operating frequency: 47 to 63 Hz
• Input current, max: 150 mA
• AC input connector: JIS C8303, Class II
• DC output connector: F-female
• Surge protection: 1 kV min (per EN61000-4-5:2005)
• Safety: PSE IEC 61558
• Operating temperature: –10º to +40ºC (+14º to +104ºF)
• Storage temperature: –20º to +80ºC (–4º to +176ºF)
• Humidity: 5% to 95% non–condensing
• Dimensions: 2.3” W x 3.0” H x 2.0” D
(5.8 cm x 7.6 cm x 5.0 cm)
• Weight, typical: 1 lb (0.45 kg)

Uninterruptible Power Supplies

PS1811U-00 or PS1812U-00
• AC input voltage: 108–253 VAC
• Input frequency: 50/60 Hz
• AC Input connector: IEC C8
• Power cord
  PS1811U-00: IEC C8 to NEMA 1-15P (USA)
  PS1812U-00: no power cord provided
• Output voltage: 13.5 VDC nominal
• Operational output power: 6 W nom. (R-ONU load)
• Output connector: F-type coaxial
• Dimensions: 8.75” W x 7.75” H x 3.0” D
(22.2 cm x 19.7 cm x 7.6 cm)
• Weight: 1.3 lb (0.59 kg); battery: 5.7 lb (2.6 kg)
• Operating temperature: 0º to +40ºC (+32º to +104ºF)
• Storage temperature: –20º to +50ºC (–4º to +122ºF)
• Humidity: 5% to 95% non–condensing
• Safety: UL/CSA/EN 60950-1
• EMC: FCC Part 15 Class B, EN 55022, EN 55024
• CE, RoHS compliant
• Model identification: FlexPoint FPR1207-F

PS1801B-00 (Backup Battery for PS1811U-00 or PS1812U-00)
• 7.2 AH AGM battery
• Provides approximately 10 hrs of backup at 6W (or 20 hrs at 3W) to 25% reserve point shut-off, based on new, fully-charged battery
• Hot-swappable
• Recharge time 18 hours to 90%
• Uses maintenance-free sealed-lead acid
• Battery storage: –20º to +40ºC (–4º to 104ºF), six months max storage duration at +25ºC (+77ºF) without a recharge

Chapter 3 Installation, Test, and Software Setup

3.1 Installation

Actual physical installation instruction of the selected RFoG modules and equipment is outside of the scope of this document. Having determined the specific modules and components for the implementation, the installer should refer to the respective Technical Note (TN 87-*) or Technical Manual (TM 87-*) "Installation and Activation Guides" for physical installation and specific module setup instructions. See the tables in Chapter 4 which list the various Aurora RFoG products their respective technical notes or technical manual numbers. Go to www.aurora.com to obtain the specific Technical Note or Technical Manual of interest. Refer to Figure 2-3 in Section 2.3 for a reference diagram of SDU CPE equipment and connections.

NOTICE – Safety:

You should have read and be familiar with the respective Installation and Setup Guide for each of the modules being tested.

Observe all CAUTION and laser radiation notices in the respective user guides. Class 1M laser radiation **IS** present in various plug-in modules in the chassis.

INVISIBLE LASER RADIATION
DO NOT VIEW DIRECTLY WITH
OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT
101166

CAUTION! Laser Radiation – *Avoid any exposure to laser beams. Viewing the laser output with certain optical instruments (e.g. eye loupes, magnifiers and microscopes) may pose an eye hazard.*

CAUTION! Laser Radiation – *Use of controls or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.*

DANGER: Laser Radiation – ***All FA3500 series EDFA amplifiers emit laser light when:***

- ***power is applied or not applied****, a signal is present at the optical input port, and the Laser key switch is in the* ***Off*** *or* ***ON*** *position*
- ***power is applied****, no signal is present at the optical input port, and the Laser key switch is in the* ***Off*** *or* ***On*** *position. (The pump laser is on and will emit significant ASE optical noise).*

DANGER: Laser Radiation – ***All FA4500 series EDFA amplifiers emit laser light when:***

- ***power is applied or not applied****, and a signal is present at the optical input port*
- ***power is applied****, and no signal is present at the optical input port. (The pump laser is on and will emit significant ASE optical noise).*

Laser light, visible or invisible, can seriously injure eyes, or even cause blindness. ***Do not look directly into the optical ports of an EDFA unless all electrical power and optical inputs have been disconnected.***

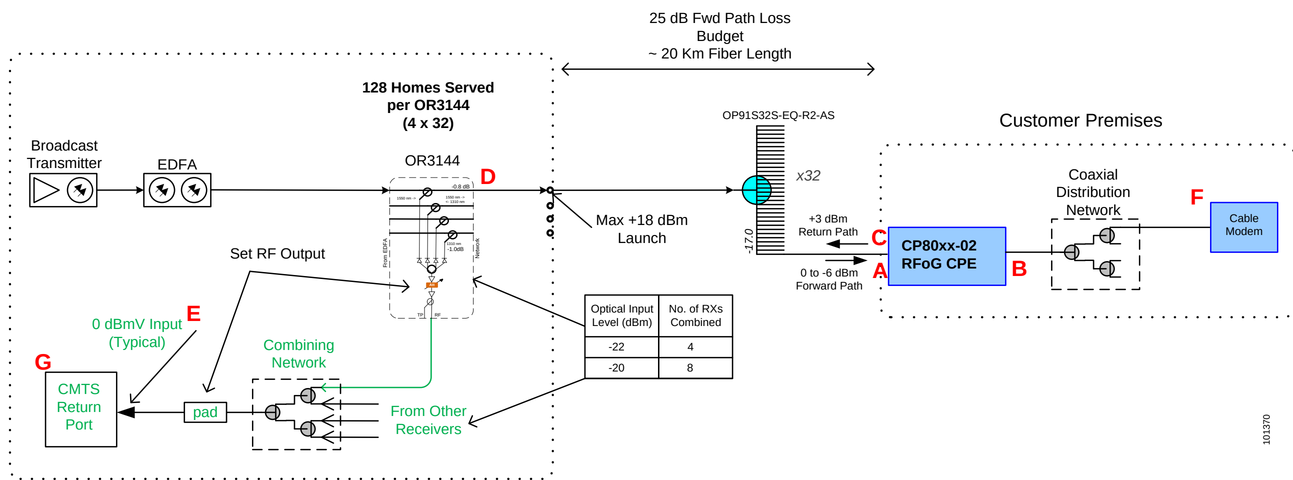
3.2 Test and Setup Considerations for Short Haul Implementation

Having installed the various selected modules for the target RFoG implementation, precise care must be used in tuning the network in order to achieve the desired performance levels needed to ensure optimal subscriber services. An RFoG implementation that delivers high quality services equal to what was achieved by HFC networks to the subscriber depends on a planned and not to exceed loss budget of 24 and 26 dB for 1550 and 1310 nm wavelengths respectively, for a 20 km fiber distance with a 32 split ratio, as shown in Figure 3-1.

The following is a detailed tutorial explaining the measurement and performance points for the simple short haul network overviewed in Section 2.1 and detailed in Figure 3-1. It is advised that the testing be performed on the longest fiber link, which typically is responsible for the greatest amount of loss.

Note *The implementations in Sections 3.2 and the diagram in Figure 3-1 is one of many possible hardware solutions that can be built using Aurora Networks hardware. Refer to Chapter 4 to view available hardware applicable for RFoG designs. Aurora is pleased to work with Cable Operators to design an optimal solution that meets all requirements including reach, performance, cost, and more.*

Figure 3-1 Short Haul implementation Test Points and Signal Levels



Forward Path Testing

1. At the subscriber end, in the 1550 nm forward path, measure the optical input power level that is being fed into the R-ONU CPE. It should be between 0 and -6 dBm. Refer to point **A** on the diagram.

2. At point **B**, the RF output level on the forward path at the CPE at 3.1% OMI (Optical Modulation Index) should be around 16.5 dBmV at 550 MHz. The CNR of analog channels and MER of digital channels should also be within the system design specifications.

Reverse Path Testing

3. Inject a CW (Continuous Wave) signal of 26.5 dBmV into the R-ONU CPE at point **B** and measure the optical output level of the R-ONU CPE at point **C**. It should be between +2 to +4 dBm. *See the note below (under step 8 CPE and System Testing) regarding the 26.5 dBmV signal level into the CPE.*

4. With the R-ONU CPE connected to one leg of the splitter, measure the optical power level at the input of the Headend OR3144H diplexer/RF receiver and make sure it is greater than -22 dBm. Refer to point **D** on the diagram. This can be observed using Opti-Trace OTS or EMS management software. Refer to Figure 3-2. The actual RF signal level can be measured using the test point on the front panel of the OR3144H.

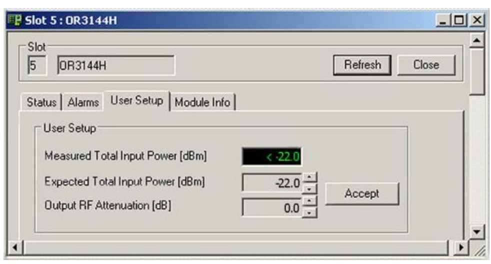
Note *Note that per the chart on Figure 3-1, if multiple OR3144H receivers are used in parallel feeding into a common combiner, the signal level coming into the receiver may need to be increased accordingly (through network design). From one to four OR3144 receivers, an optical return input level of -22 dBm is appropriate. If eight OR3144H receivers are used (to feed into the same combiner) the input level must be -20 dBm. The basic rule of thumb is, every time the number of OR3144H receivers is doubled, an additional 2 dB of input is required.*

Note *The receiver set point of -22 dBm noted in step 4 is appropriate for optical input levels from -22 to -16 dBm. The procedure outlined in steps 1 - 4 above should be performed at the input of the receiver that is serving the longest fiber link, which is typically the highest loss link.*

5. Using the software programmable RF attenuation on the OR3144H (via OTS or EMS), set the Expected Total input Power to -22 dBm. Refer to Figure 3-2.

6. Using external pad adjustments and/or the OTS/EMS gain setting capability of the OR3144H receiver, adjust the RF input level into the CMTS Return port. This level is typically set to 0 dBmV however this is governed by the CMTS and cable operator specifications. Refer to point **E** on the diagram and Figure 3-1. In a typical application, multiple RF return signals will be coming from other OR3144H receivers in the Headend and combined as shown in the diagram.

Figure 3-2 Opti-Trace OTS or CMS OR3144H Gain and RF Attenuation



CPE and System Testing

7. Connect the R-ONU CPE RF port at point **B** on the diagram to the inside premises coax distribution network to include the cable modem (point **F** on the diagram). The cable modem's visual indicators (Send, Receive, Link) should all turn green.

8. Using the CMTS Network Management System, (point **G** on the diagram) confirm that the upstream RF output of the cable modem is consistent with the loss of the coax distribution network. For example, if the RF input into the R-ONU CPE was set at 26.5 dBmV (Step 3), and the loss of the coax distribution network is 10 dB, then the cable modem should operate at approximately 36.5 dBmV.

Note *26.5dBmV into the CPE for the upstream signal is largely dictated by the ANSI SCTE 174 2010 RFoG standard and by the Bit Error Rate performance of 64QAM carriers. HFC deployments may require higher levels to overcome the higher ingress noise levels inherent in most HFC networks where a group of homes and associated distribution is RF combined to a single laser. This problem does not exist in RFoG SDU applications however since only a single home's RF network is served by its own RFoG CPE thus the cable modem can operate at lower levels due to lower noise floor of the network.*

At this point, the system should be operating correctly. Refer to section 3.5 for trouble shooting.

3.3 Test and Setup Considerations for Long Haul Implementation

Long haul implementation test requirements are very similar to short haul implementations in that:

1) The input to the R-ONU CPE coming from the Headend must be between 0 and -6 dBm

2) The output of the R-ONU CPE going towards the Headend must be between +2 to +4 dBm

3) The RF Return signal recovered from the optical link and fed into the CMTS at the Headend must (typically) be 0 dBmV

The big difference between the short haul and long haul obviously is the addition of the RFoG VHub which is necessary to provide the amplification in both downstream and upstream directions to support the longer link. Where the short haul implementation by definition provides services up to 20 km, a long haul implementation can serve distances to 100 km and longer.

The specific referenced long haul VHub test model shown in Figure 3-3 supports 256 SDU homes from a single fiber coming from the Headend, for a distance of 44 km. The VHub is located at a distance of 40 km from the Headend, and the R-ONU CPE SDU is located within 4 km of the VHub.

Note *Longer distances from the node to the CPE can be achieved by use of the FA4527 EDFA. The FA4527 EDFA is a higher power amplifier which can be used to increase reach, performance, or both.*

The specific distances achievable in a long haul implementation are dependent on:

1) The transmitter and EDFA power output levels, minus any loss. EDFAs with different output power levels are available. See the Table 15.

2) The EDFA, splitter, and RF receiver/diplexer minus any other loss in the VHub/node

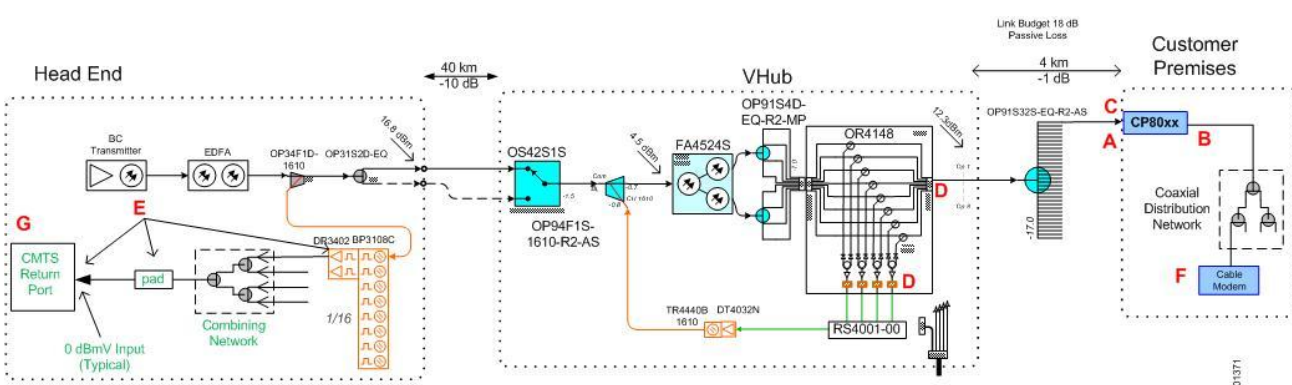
3) Loss in the splitter between the VHub and the R-ONU CPE, and the need for the R-ONU CPE to see 0 to -6 dBm coming from the downstream after a 1 x 32 split

4) The need for the OR4148H RF return receiver/diplexer in the VHub to see sufficient input optical power and provide corresponding return RF output level to drive the digital transmitter at the required level

5) The need for the DR3xx digital receiver at the Headend to see the appropriate signal level on the input (-3 to -19 dBm, with the newest generation down to below -30 dBm), and provide an appropriate RF output signal level as required by the CMTS (typically 0 dBmV).

Note *The implementations in Sections 3.3 and the diagram in Figure 3-3 is one of many possible hardware solutions that can be built using Aurora Networks hardware. Refer to Chapter 4 to view available hardware applicable for RFoG designs. Aurora is pleased to work with Cable Operators to design an optimal solution that meets all requirements including reach, performance, cost, and more.*

Figure 3-3 Long Haul implementation Test Points and Signal Levels



The following is a detailed tutorial explaining the measurement and performance points for the simple long haul network overviewed in section 2.2 and detailed in Figure 3-3. It is advised that the testing is performed on the longest fiber link, which typically is responsible for the greatest amount of loss.

Forward Path Testing

1. At the subscriber end, in the 1550 nm forward path, measure the optical input power level coming from the node that is being fed into the R-ONU CPE. It should be between 0 and -6 dBm. Refer to point **A** on the diagram.

2. At point **B**, the RF output level on the forward path coming out of the R-ONU CPE at 3.1% OMI (Optical Modulation Index) should be around 16.5 dBmV at 550 MHz. The CNR of analog channels and MER (Modulation Error Ratio) of digital channels should also be within the system design specifications.

Reverse Path Testing

3. Inject a CW (Continuous Wave) signal of 26.5 dBmV into the R-ONU CPE at point **B** and measure the upstream optical output level of the R-ONU CPE at point **C**. It should be between +2 to +4 dBm. *See the note below (under step 7 CPE and System Testing) regarding the 26.5 dBmV signal level into the CPE.*

4. With the R-ONU CPE connected to one leg of the splitter, measure the optical power level at the input of the OR4148H in the VHub/node according to Table 8. The goal is to set the input to the DT4032N transceiver to 10 dBmV. Refer to points **D** on the diagram above.

   There are two different ways by which the transceiver input levels can be measured:

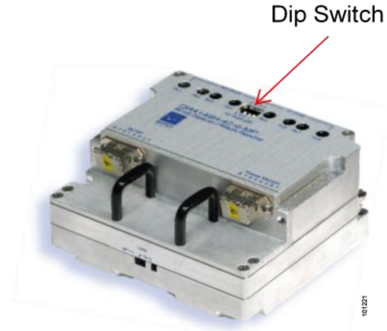
   a. Method 1
      i. Using a digital voltmeter, measure the DC voltage at any test point (Rx1 through Rx8) on the OR4148H. This voltage is proportional to the optical input level of the digital returns.
      ii. Set the DIP switches (Table 8, column 4) as indicated by the measured input level (Table 8, column 1). For example, if the input is 0.32 V, which equates to -15.0 dBm, set the attenuation to 4 dB by setting the dip switch to [0 1 0 0]. With the attenuation set correctly, the RF output from the OR4148H will provide the desired input to the respective DT4xxx transceiver. Check the specific DT4XXX transceiver for the required input level.

   b. Method 2
      i. Measure the RF level from the OR4148H to the DT4xxx return path at the applicable test points (TPA-1, TPA-2, TPF-1, and TPF-2) on the LM4005 motherboard within the VHub. The test points you choose will depend on the RS4xxx return path configuration module installed. The desired level at the -20 dB down test point is -10 dBmV, which is actually +10 dBmV into the DT4xxx transceiver.
      ii. Adjust the dipswitch attenuation as necessary to achieve -10 dBmV at the test point (+10 dBmV at the DT4xxx).

Table 8 OR4148H Attenuation Settings

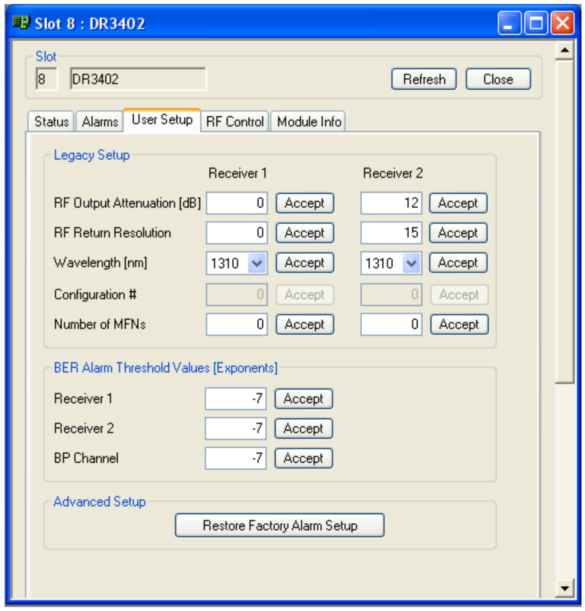
10V/mW Test Point	Input Power	Set Min Attenuation	DIP Switch
0.20 V	-17.0 dBm	0 dB	0 0 0 0
0.22 V	-16.5 dBm	1 dB	0 0 0 1
0.25 V	-16.0 dBm	2 dB	0 0 1 0
0.28 V	-15.5 dBm	3 dB	0 0 1 1
0.32 V	-15.0 dBm	4 dB	0 1 0 0
0.35 V	-14.5 dBm	5 dB	0 1 0 1
0.40 V	-14.0 dBm	6 dB	0 1 1 0
0.45 V	-13.5 dBm	7 dB	0 1 1 1
0.50 V	-13.0 dBm	8 dB	1 0 0 0
0.56 V	-12.5 dBm	9 dB	1 0 0 1
0.63 V	-12.0 dBm	10 dB	1 0 1 0
0.71 V	-11.5 dBm	11 dB	1 0 1 1
0.79 V	-11.0 dBm	12 dB	1 1 0 0
0.89 V	-10.5 dBm	13 dB	1 1 0 1
1.00 V	-10.0 dBm	14 dB	1 1 1 0
1.12 V	-9.5 dBm	15 dB	1 1 1 1

Set attenuation with DIP switch.



5. At the Headend, using an external attenuator pad or the Opti-Trace OTS or EMS software GUI attenuation capability of the DR3402 receiver, adjust the RF input level into the CMTS return port. Ultimately the input level is typically set to 0 dBmV however this parameter is governed by the CMTS and/or cable operator specifications. Refer to point **E** on the diagram and EMS screenshot in Figure 3-4. In a typical application, multiple RF return signals will be coming from other return path transceivers and OR4148H receivers in the node, and combined in the Headend as shown in the diagram.

Figure 3-4 DR3402 Receiver RF Output Attenuation



CPE and System Testing

6. Connect the R-ONU CPE RF port at point **B** on the diagram to the inside premises coax distribution network to include connection of the cable modem (point **F** on the diagram). The cable modem's visual indicators (Send, Receive, Link) should all turn green.

7. Using the CMTS Network Management System, (point **G** on the diagram) confirm that the upstream RF output of the cable modem is consistent with the loss of the coax distribution network. For example, if the RF input into the R-ONU CPE was set at 26.5 dBmV (Step 3), and the loss of the coax distribution network is 10 dB, then the cable modem should operate at approximately 36.5 dBmV.

Note *26.5dBmV into the CPE for the upstream signal is largely dictated by the ANSI SCTE 174 2010 RFoG standard and by the Bit Error Rate performance of 64QAM carriers. HFC deployments may require higher levels to overcome the higher ingress noise levels inherent in most HFC networks where a group of homes and associated distribution is RF combined to a single laser. This problem does not exist in RFoG however since only a single home's RF network is served by its own dedicated RFoG CPE thus the cable modem can operate at lower levels due to lower noise floor of the network.*

At this point, the system should be operating correctly. Refer to section 3.5 for trouble shooting.

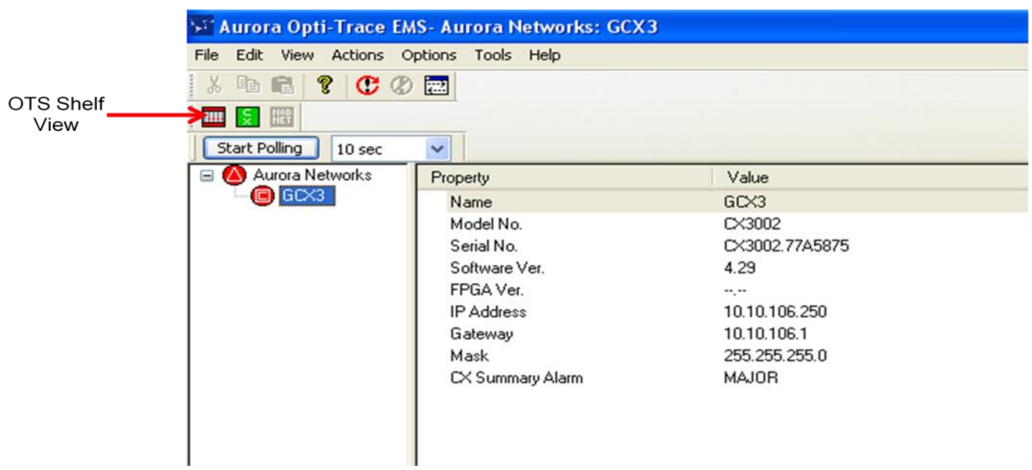
3.4 Management Software Configuration and Monitoring

Typically the Aurora Networks hardware modules for both Headend and VHub/node use can be monitored and in some cases software configured in order to meet system requirements, enable/disable features, set alarm thresholds and more. Aurora Networks Opti-Trace OTS or EMS software can be used for this purpose.

Note *It is not the intent of this guide to provide a complete tutorial on use of Opti-Trace software tools, rather, to provide a brief snapshot of a few user configuration interfaces for a select set of applicable modules in the Headend and VHub/node.*

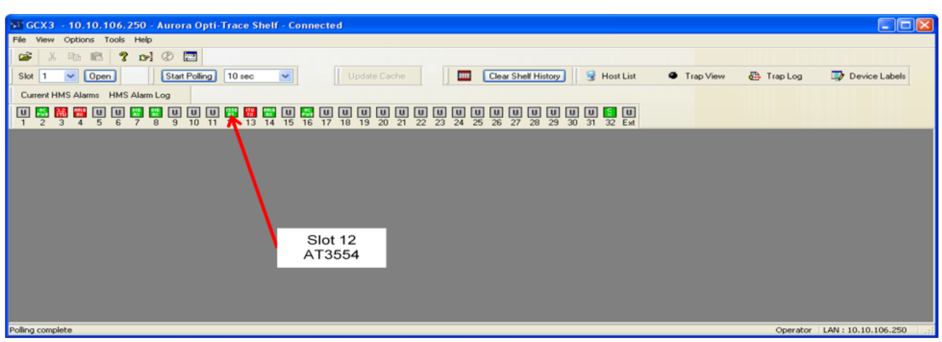
Opti-Trace Shelf (OTS) provides a view of and access to all modules mounted in the CH3000 rack (shelf) via SNMP using the IP address of the CX300X power supply module. If a digital receiver is installed in the chassis and it is connected to a digital transceiver (DT4xxx) in the VHub/node, the connection can be viewed in the receiver's user interface screen, and the user interface for modules installed within the VHub/node can be viewed. Some modules within a VHub/node can be configured from OTS. Opti-Trace Element Management Software (EMS), which includes the OTS shelf view and controls, provides a complete and hierarchical view of an entire network, to include all connected module elements. The Figure 3-5 shows access to a CX3002 power supply within a CH3000 chassis, using EMS.

Figure 3-5 Opti-Trace EMS View



Having clicked on the OTS shelf view on the EMS toolbar (above), the OTS user interface opens, exposing all 32 slots within the CH3000 chassis. Slots which are populated with modules can be highlighted in red, green, or blue colors, with abbreviated text which indicates the type of module.

Figure 3-6 OTS Shelf View and Module Selection



For purposes of this guide, slot 12 is selected, and the AT3554A transmitter user interface opens. The User Setup tab allows you to, from the EMS location, set the RF attenuation level, RF attenuation AGC, AGC Mode, and Alarm thresholds as shown in the following screenshot.

Figure 3-7 AT3554A Transmitter User Interfaces

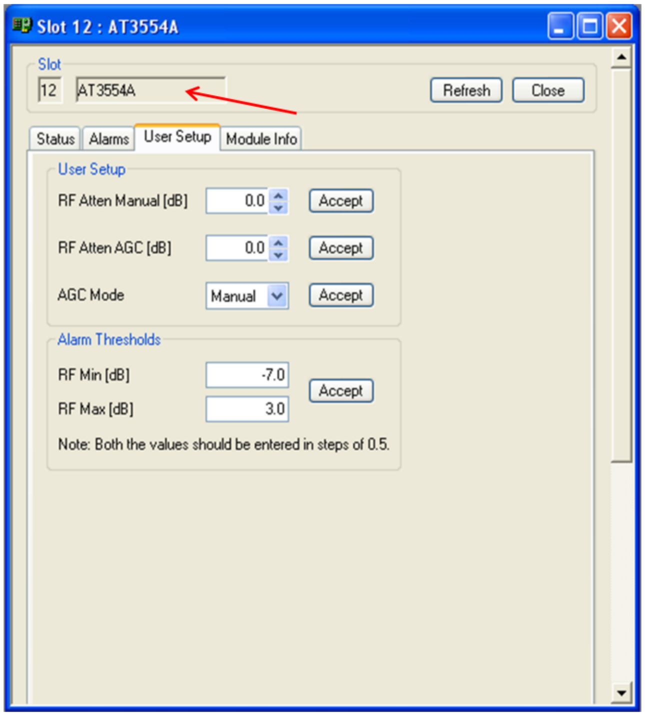


Figure 3-8 AT3554A Transmitter Status Tab

The AT3554 Status tab displays important read only status information as indicated below.

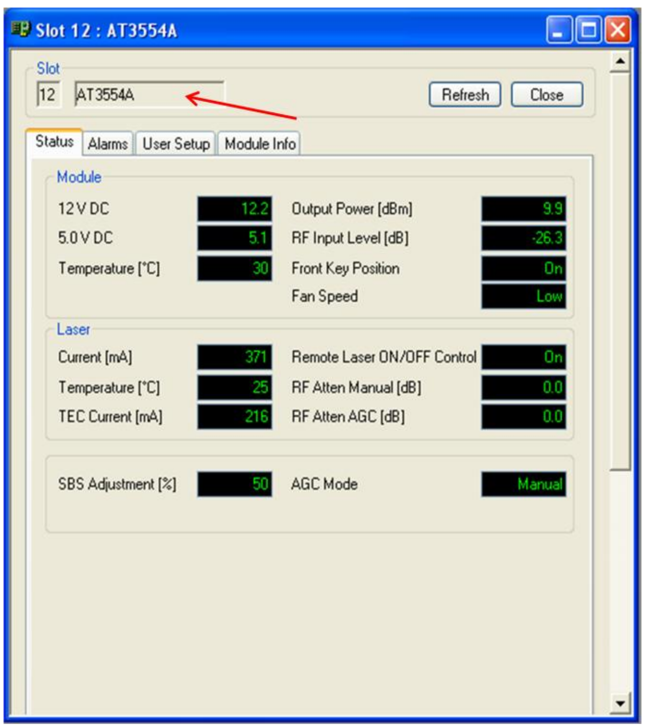
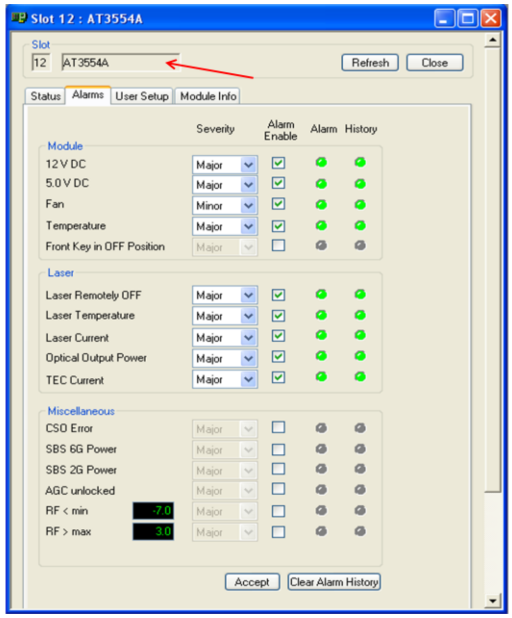


Figure 3-9 AT3554A Alarms Tab

Alarm thresholds can be enabled and severity levels (major/minor) selected. An alarm history is also maintained for each parameter.



Similar to Figure 3-4 in Section 3.3, the following is an example of EMS/OTS being used with the DR3021 Digital Receiver to

1. Set the output attenuation
2. Set the RF return resolution
3. Set the return path wavelength
4. Set Bit Error Rate thresholds

(The DR3021 is a similar OTS interface to the DR3402 used in the example in Figure 3-4.)

The DR3021 Digital Receiver resides in Slot 7 in the CH3000 chassis, as viewed from the OTS user interface.

Figure 3-10 DR3021 User Setup Tab

With the User Setup tab of the DR3021 user interface showing, you can set RF Output Attenuation, number of MFNs (Micro Fiber Nodes, i.e. NC2000, NC4000, VHub), Wavelength, and Bit Error Rate alarm thresholds.

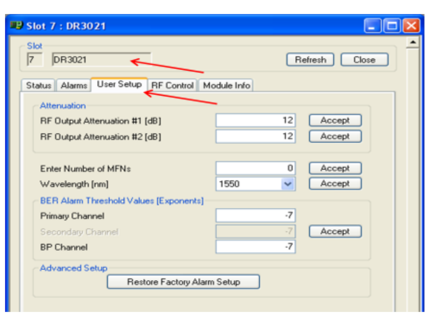


Figure 3-11 DR3021 RF Control Tab

While still on the DR3021 user interface, on the RF Control tab you can enable/disable Auto Squelching and set Optical Threshold levels, and select the desired algorithm. All other windows are read only.

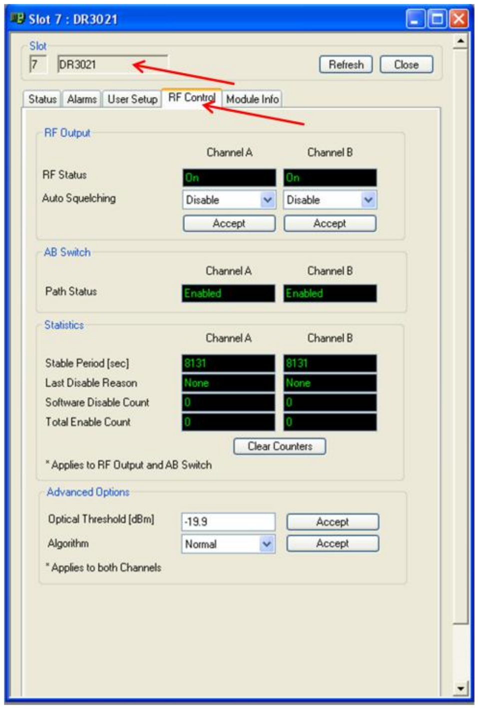


Figure 3-12 DR3021 Alarms Tab

For the same DR3021 digital receiver, EMS/OTS can also be used to set and monitor alarms, as shown below.

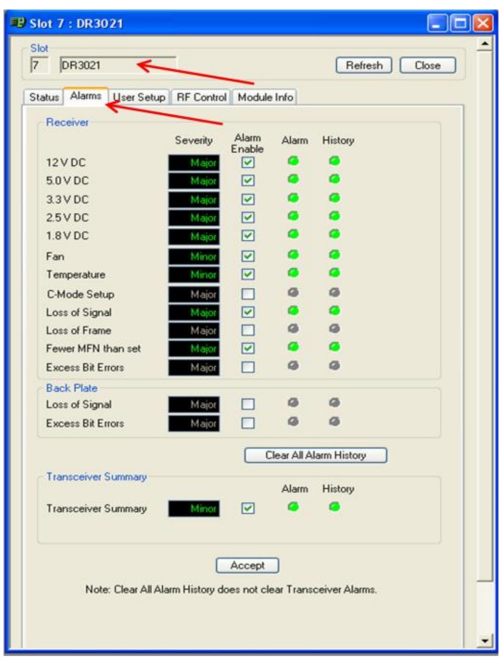
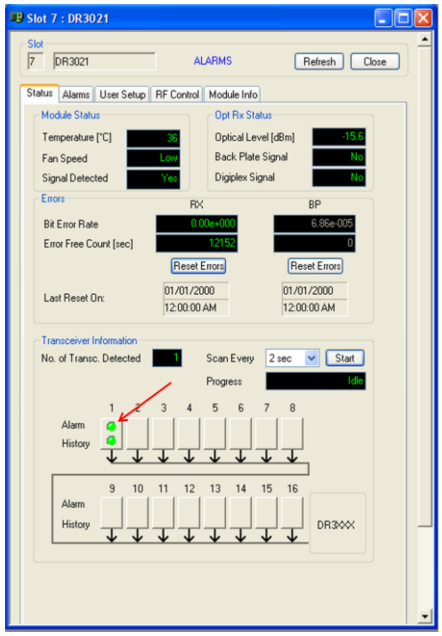


Figure 3-13 DR3021 Status Tab and Access to Node Modules

On the status screen of the DR3021 in EMS/OTS, various critical module status and error information is displayed. The DR3021 module, being a RF return path component, in a live implementation is connected to a digital transceiver (transmitter) in the VHub/node. In the screenshot below, in the lower half of the Status tab under "Transceiver Information", any digital transceivers that are connected to the DR3021 digital receiver will be indicated with green (or red, if an alarm has been set in the path) led-like indicators on the 1 – 16 buttons.



Clicking on any active RF return button will immediately allow you to "see through" the DR3021 (or equivalent) receiver to the user interface screen for the associated transceiver within the VHub/node, in this case the DT4230N transceiver. The DT4230N properties screen that is revealed provides various module information, status, and alarm information if the Enable Alarms feature has been selected.

Figure 3-14 DT4230N Properties Tab within the VHub

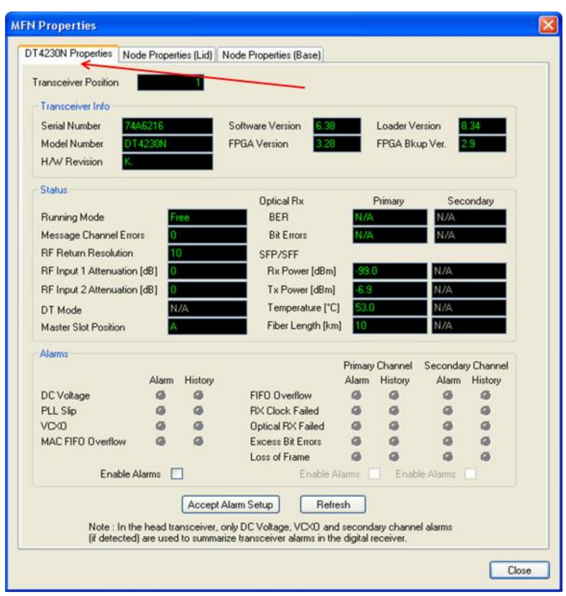
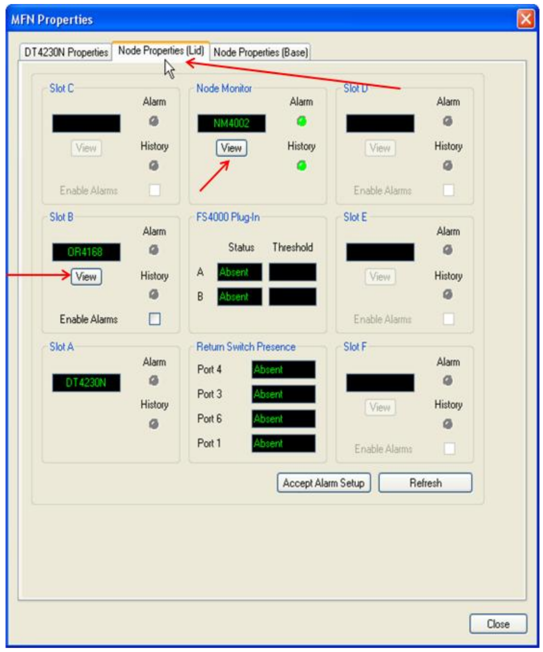


Figure 3-15 VHub Lid Properties and Node Module View

Other key elements within the VHub/node can also be viewed by clicking the VHub/node lid (Node Properties Lid) tab or base (Node Properties Base) tab. As noted in section 3.3, the VHub/node includes an OR4148H optical receiver that separates the upstream RF return from the downstream traffic, sending the resulting RF signal to the DR4230N transceiver. The OR4148H optical receiver is similar to the OR4168h which is shown in the screenshot below.



On the above screen clicking the "View" button for the OR4168 optical receiver provides an immediate view of the OR4168H module information (Figure 3-16) and signal levels on the respective (upstream) receiver inputs. Alarm level and alarms would also be showing in the event that alarms had been enabled on the node properties tab.

Figure 3-16 OR4168H Node Module Status

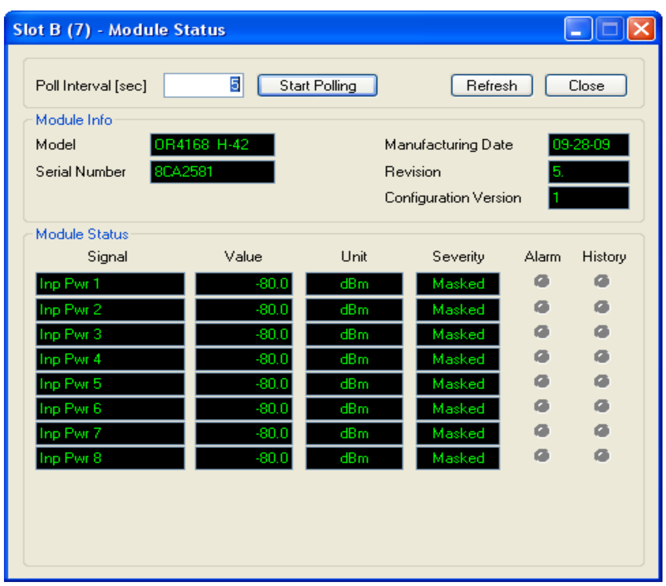


Figure 3-17 NM4002 Node Management Module User Interface

Selecting the NM4002 Node Management module within the VHub/node displays various information and status indication, and allows you to enable and set severity level of alarms, for both analog and digital signals.

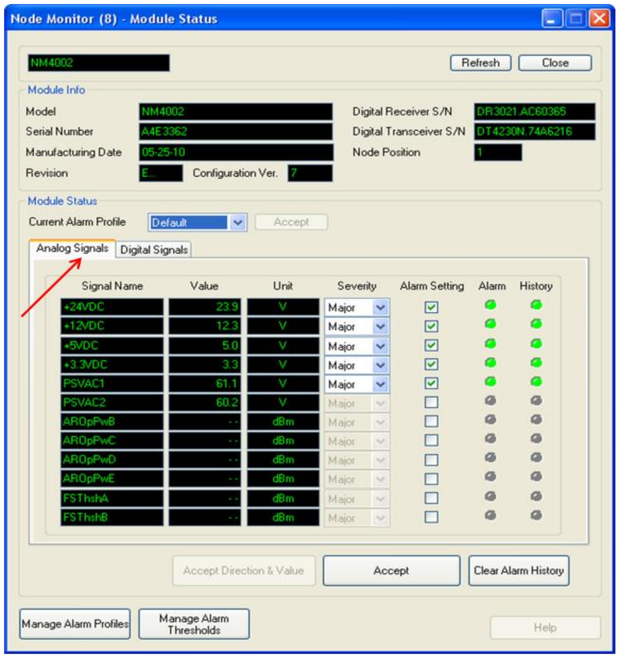


Figure 3-18 FA4524 Module Selection from Node Properties Base

Selecting the Node Properties (Base) tab displays the various modules installed in slots G, H, J, K, L, and M of the VHub/node. In this case, an FA4524 EDFA, FA4517 EDFA, and OP4528 optical splitter are installed. Click on the FA4524S View button to display the current characteristics of the FA4524S EDFA (Figure 3-19).

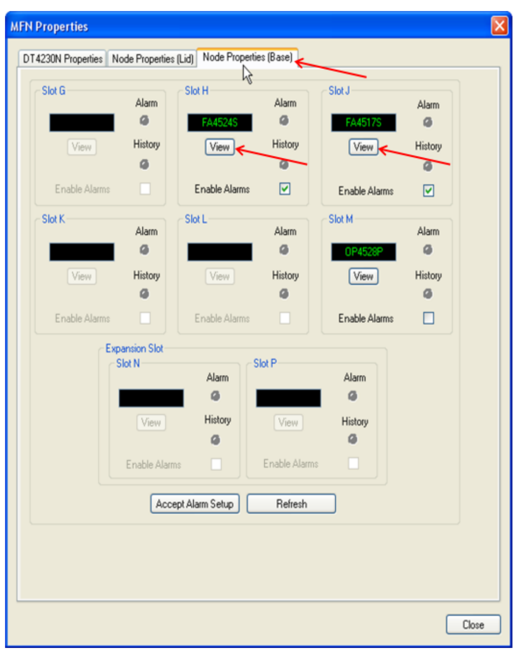


Figure 3-19 FA4524S View from Node Properties

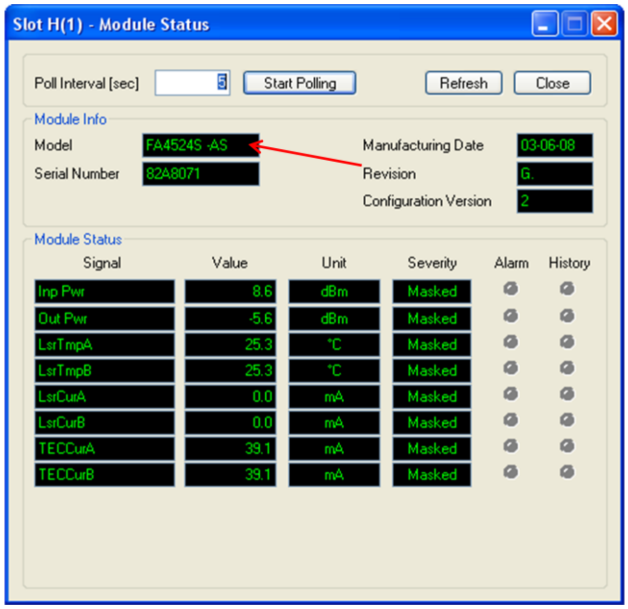
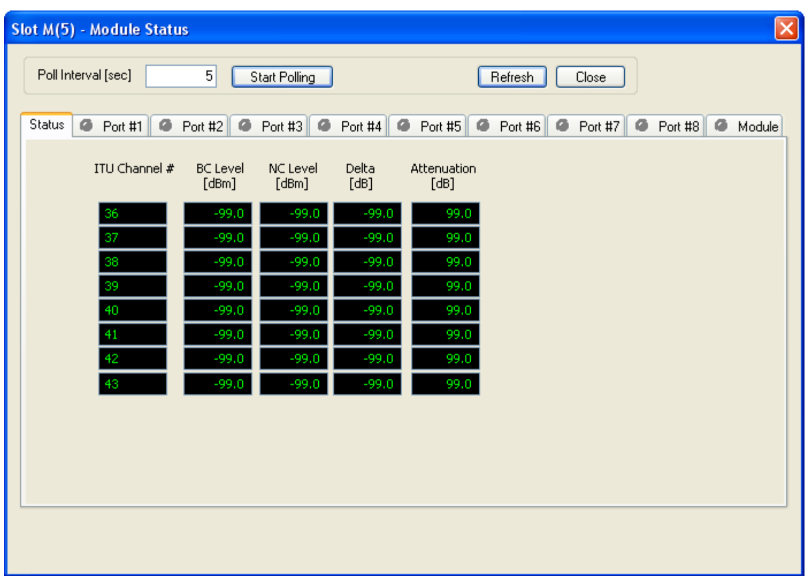
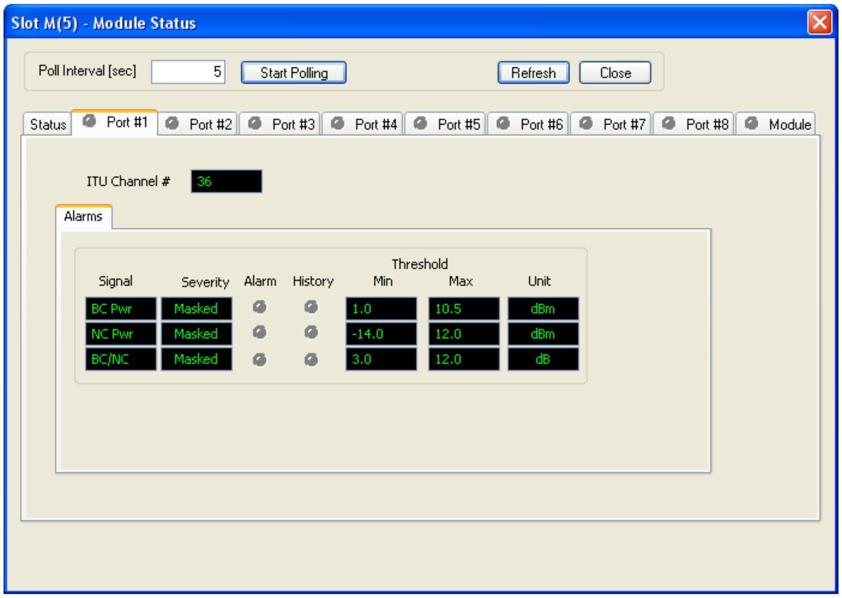


Figure 3-20 OP4528 View from Node Properties

Selecting the OP4528 View button displays (on the Node Properties Base tab) the current OP4528 configuration, both in terms of general status and per port. The OP4528M is a narrowcast demultiplexer with a broadcast/narrowcast combiner.

Note: the OP4528 is not included in the long haul implementation used in Figure 3-3.





Opti-Trace CMS/OTS/EMS monitoring and configuration of Aurora chassis and node module user interfaces are very much module dependent. For specific capabilities, please refer to the respective hardware module Installation and Activation guides as noted in the charts in Chapter 4.

It is recommended that you be familiar with the respective CMS, OTS, and EMS User Guides noted in the appendix of this guide.

3.5 Trouble Shooting the RFoG Installations

NOTICE – Safety: Please refer to section 3.1 regarding safety issues when troubleshooting fiber optic designs.

All Aurora Networks hardware modules have been pre-tested using factory default settings. Providing that all modules have properly been installed, power has been applied, and fiber/fiber connections between the Headend and R-ONU and connected CPE are intact and robust, downstream signals to the CPE from the Headend and upstream signals from the R-ONU CPE to the Headend should be available and providing acceptable service levels as expected. By following the setup instructions as outlined in sections 3.2 for short haul implementation or 3.3 for long haul implementations, signal levels as noted should be easily achievable at the respective test points shown.

Brand new HFC and RFoG distribution network installations typically are initiated at the Headend, built out towards the subscribers, and tested incrementally as the network is extended. This being the case, with Aurora Networks chassis, nodes, and modules being "plug-and-play", after final installation of the R-ONU and other CPE (cable modem etc.), it would be a rare occurrence if the appropriate signal levels providing acceptable functional performance is not achieved.

In the event signals are not visible or signal levels are not achieved, follow these steps:

Short Haul Implementation, using the short haul example discussed in section 3.2 Figure 3-1 as reference:

1) Low/no downstream signal at the R-ONU input

   a. Verify signal levels at adjacent R-ONUs coming from the same 1 x 32 splitter

      i. If only one R-ONU fed from the splitter has a low/no signal, the problem is likely in the fiber link between the R-ONU under test and the splitter. Verify the physical link between the R-ONU and the splitter. This may not be possible without cutting the fiber, which is not desirable. It is possible that the one leg of the splitter is faulty. Replace the splitter if necessary.

      ii. If all R-ONUs fed from the same splitter have a low/no signal, the problem is either with the splitter or in the network upstream from the splitter. If possible, verify the signal level at the input (network side) of the 1 x 32 splitter. This may not be possible without cutting the fiber.

   b. If a low/no signal is observed going into the 1 x 32 splitter from the network/Headend side, at the Headend, check to see that all input and output ports of the OR3144H RF return/diplexer receiver are connected properly, i.e. network ports are connected to network fibers and transmitter/EDFA ports are connected to input ports.

   c. The OR3144H has 4 downstream/upstream ports (paths), each requiring its own Headend transmitter and EDFA feed, and each is connected to one splitter in the field. Taking care to find the OR3144H path that feeds the problematic splitter and R-ONUs, observe the signal level coming out of that specific connector port on the OR3144H. You can do this via unplugging the fiber link from the port and measuring the output downstream signal level. If an adequate signal is observed, the problem may be in the fiber connector or downstream fiber between the OR3144H port and the field splitter.

   d. If the observed port signal is low or missing, observe the 3 remaining OR3144H ports. If low or no signals are observed on other ports, the fault may be within the OR3144H itself, or with the transmitter/EDFA feed going into the OR3144H. Since the OR3144H will have 4 separate transmitters or transmitter or EDFA sets feeding it, it is unlikely that all 4 transmitters or transmitter/EDFA sets are not functioning, unless there is a chassis power supply or other problem in the feed network.

   e. If all other ports of the OR3144H are functioning, check the output of the upstream EDFA feeding into it. If a signal is observed, the problem is likely to be the specific path of the OR3144H is faulty.

   f. Continue this process upstream through the Headend transmitter to understand where the signal is visible and where it drops out. All components should be checked serially to include all fiber links, connectors, patch cords, and the like. Replace or repair the faulty component as needed.

g. In the downstream direction, with connectivity and signal levels achieved, television/broadband reception should be as expected.

1) Reverse (upstream) direction: CMTS/set top box/modem non-operation. Visible television reception at the subscriber premise does not ensure upstream CMTS signal control or connectivity. Given the downstream functionality meets requirements and performance levels are as expected, end-to-end fiber connectivity is consequently verified. The problem remains that upstream signals from the set top box/modem are not reaching or not adequately reaching the CMTS at the head end. If the CMTS at the Headend is not able to see or handshake with the subscriber set top box or modem, or if the signal levels noted in section 3.2 steps 3 – 8 are not realized, follow these steps. All steps are with reference to Section 3.2 Figure 3-1 short haul implementation. The assumptions are 1) the downstream signals and service are operating properly (therefore end to end connectivity is verified and 2) the CMTS at the headend is operating properly for other subscribers that it services.

a. The first step is to determine if all other subscriber R-ONUs sharing the same splitter are having the same RF return problem. If other R-ONUs on the same splitter are not experiencing the same lack of service, try a different R-ONU CPE. If replacing the R-ONU CPE does not resolve the problem, the likely source of the problem is in the fiber connecter to the R-ONU or the fiber link to the upstream splitter. *Keep in mind however that since downstream service has already been verified on that fiber link, this is an unlikely suspect scenario. The problem is likely upstream above the 1 x 32 splitter feeding the R-ONUs, which means that all R-ONUs connected to that same 1 x 32 splitter would likely have the same problem.*

b. In a short haul implementation where nothing but the fiber link exists between the head end and the subscriber R-ONU CPE, CMTS control is heavily dependent on the OR3144H RF receiver/diplexer extracting the return signals from the upstream dataflow and converting them into a single RF signal which is finally read by the CMTS.

Since a single OR3144H supports 4 separate downstream/upstream paths and each path supports up to 32 subscriber R-ONUs, it is unlikely that only one subscriber R-ONU which resides of one leg of a 1 x 32 splitter would have a problem without all R-ONUs on that splitter having a problem.

Since four 1 x 32 splitters are dependent on one single OR3144H RF receiver, it is unlikely that one group of 32 R-ONUs would be non functional if the other three groups of 32 R-ONUs are functional, however it is possible.

c. To test the OR3144H, as noted in 3.2 step 3, disconnect all CPE equipment from the problematic R-ONU path and inject a 26.5 dBmV CW signal into the TV coax connection of the PS1000 power inserter that connects to the R-ONU RF/Power connector, or directly into the RF IN/OUT port if not using the PS1000.

Note *Injecting this signal will override all other signals going to/coming from all other subscriber R-ONU/CPEs connected to the same splitter.*

d. Measure the upstream output of the R-ONU (point C on Figure 3-1). It should be between +2 and +4 dBm. If the signal level is sufficient the R-ONU is working correctly in the upstream direction.

e. Any suspected non functioning OR3144H path can be tested by disconnecting the network downstream/upstream connections for the 3 other paths and measuring the RF output on the RF output test point on the front of the OR3144H.

Note *Removing a fiber link connection from the OR3144H will affect (disconnect) service to all subscribers fed from that link.*

If the OR3144H return receiver path is working, the CW signal injected at the R-ONU input will be measurable on the RF output test point on the front of the OR3144H. With the other (3) parallel path network fibers being removed from the OR3144H, there is no risk that any measured RF signal observed on the OR3144H test point would be coming from any other source. If no signal or low signal is observed, open the EMS/OTS software OR3144H User Setup tab and try adjusting the Output RF Attenuation via software. Increasing the RF output should have impact on the actual measurement observed at the RF Output test point. With reference to the 26.5 dBmV CW signal injected at the upstream input of the R-ONU, if no RF Signal can be measured on the OR3144H RF test point, the OR3144H is suspect and should be replaced.

f. For one leg of each 1 x 32 splitter, it is recommended that the same steps above be followed for independent verification of the 4 return paths within the OR3144H.

g. If it is determined that all (4) OR3144H return paths are adequately passing upstream signals providing the appropriate RF level and a CMTS – R-ONU path is still not functioning properly, the suspect area lies within the combiner network between the OR3144H RF output and the CMTS input. Note that any problem in this network however would most likely cause CMTS service for all subscribers to be affected.

Long Haul Implementation, using the long haul example discussed in Section 3.3 Figure 3-3 as reference, the process of troubleshooting a non functional long haul RFoG implementation is essentially the same as for short haul, however complicated with the addition of the VHub/VHub internal components, and the longer distance for which it serves.

For a new HFC or RFoG installation, as with the short haul implementation, the build-out generally begins at the Headend and extends towards the subscriber population. Typically the network is incrementally tested simultaneous with the build-out, such that by the time the customer premise R-ONU and other CPE is connected, the expected signals, signal levels, and functionality is in place.

For a long haul implementation, just as in a short haul implementation, if signals are not as expected at the SDU CPE, gradually work upstream to discover where the fault is.

2) <u>Low/no downstream signal at the R-ONU input</u>. Note that in addition to providing amplification to drive long distances, a VHub is also a point to multipoint distribution hub, typically being fed by a single fiber coming from the Headend. The typical VHub has eight subscriber-side ports, each serving a 1 x 32 splitter. Therefore, given there is no specific R-ONU CPE or respective network fiber link problem:

   a. It is unlikely that only one subscriber on a given leg of a 1 x 32 splitter would be having a problem without all subscribers on that splitter having a problem.

      i. If there is such a problem, if possible, check each leg of the 1 x 32 splitter. However not desirable, you may have to cut the fiber to do this.

   b. It is unlikely that only one 1 x 32 splitters (and respective subscribers) would be having a problem without all 8 splitters (and respective subscribers) having a problem. It is possible however that the multi-channel OR4148H RF receiver/optical diplexer that serves the 8 downstream/upstream ports is problematic.

   c. By attaching an MPO pigtail connector to the subscriber side of the OR4148H, each downstream path can be observed. A signal level of 12.3 dBm on each path should be measured on each path.

   d. If any of the 8 OR4148H paths are low or no signal is observed, by the same method as in (a) above, observe the 8 signals coming out of the MPO connector of OP91S4D-EQ-R2-MP dual 1 x 4 optical splitter. The output of the OP91S4D dual splitter is the first point at which 8 independent downstream signals are available and therefore the point at which any single path could be non functional where all adjacent parallel paths are functioning. If all 8 signals coming out of the OP91S4D dual splitter are visible, and the same signals are not seen at the output of the OR4148H, then the OR4148H is suspect.

   e. The FA4524S EDFA in front of the OP91S4D dual splitter is providing 2 parallel optical paths. If the downstream signals coming out of the dual FA4524S EDFA in front of the OP91S4D dual splitter are as expected, then the dual splitter is suspect.

   f. The FA4524S EDFA within the VHub in Figure 3-3 is driven by a single fiber coming from the Headend. In this example, the VHub also uses a switchable parallel fiber link to the Headend, for redundancy purposes, however at any given time only one fiber link is used. The fiber coming into the

VHub FA4524S EDFA is also shared with an OP94F1S-1610-R2-AS combiner, which combines the upstream 1610 nm return signal onto the common feeder fiber. Any issue with the Headend-VHub fiber link, optical switch, or return combiner would most likely affect the entire distribution network of the VHub, and consequently all subscribers would be without service, both downstream and upstream.

g. From this point it is suggested, just as in the case of the short haul troubleshooting, to incrementally test the connecting fibers, RF return filter, EDFA, and transmitter(s) feeding the problematic VHub distribution link. As per Figure 3-3, the output signal strength of the Headend driving towards the VHub should be around 16.8 dBm. Attenuation on the Headend transmitter and or EDFA should be adjusted to achieve this level.

3) Reverse direction: CMTS/set top box/modem non-operation. Troubleshooting in the reverse direction follows the same procedure as for the short haul, however consideration for the addition of the VHub must be followed. Again, as in the procedure for the short haul (above), the assumptions are 1) the downstream signals and service are operating properly (therefore end to end connectivity is verified and 2), the CMTS at the Headend is operating properly for other subscribers that it services.

a. The first step is to determine if all other all subscriber R-ONUs sharing the same splitter and coming from the VHub are having the same RF return problem. If other R-ONUs on the same splitter are not experiencing the same lack of service, try a different R-ONU. If replacing the R-ONU does not resolve the problem, the likely source of the problem is in the fiber connecter to the R-ONU or the fiber link to/from the upstream splitter. *Keep in mind however that since downstream service has already been verified, this is an unlikely suspect scenario. The problem is likely upstream above the 1 x 32 splitter feeding the R-ONUs, which means that all R-ONUs connected to the same 1 x 32 splitter would likely have the same problem.*

b. Given that the R-ONU reverse optical signal, splitter, and VHub connecting fiber links are robust, in a long haul implementation, CMTS control is heavily dependent on

i. the OR4148H RF receiver/diplexer that extracts the return signals coming from the R-ONU

ii. the DT4032N (or equivalent) digital transceiver that receives the signals from the RF return receiver

iii. the optical combiner that merges the return signal from the DT4032N transceiver onto the common downstream feeder fiber coming from the Headend

iv. the optical switches (if used) in the VHub and Headend

v. the optical filter at the Headend that extracts the 1610 nm signal from the downstream feeder fiber and routes it to the Headend DR3402 digital receiver

vi. the combiner network between the DR3402 digital receiver and CMTS.

The troubleshooting process is to work your way upstream from the R-ONU to understand where the upstream signal coming from the R-ONU drops out.

Since a single OR4148H in the VHub supports 8 separate downstream/upstream paths and each path supports up to 32 subscriber R-ONUs, it is unlikely that only one subscriber R-ONU which resides of one leg of a 1 x 32 splitter would have a problem without all R-ONUs on that splitter having a problem.

Since eight 1 x 32 splitters are dependent on one single OR4148H RF receiver/diplexer, it is unlikely that one group of 32 R-ONUs would be non functional if the other three groups of 32 R-ONUs are functional.

h. To test the OR4148H, as noted in 3.3 step 3, disconnect all CPE equipment from the problematic R-ONU path and inject a 26.5 dBmV CW signal into the TV coax connection of the PS1000 power inserter that connects to the R-ONU RF/Power connector, or directly into the RF IN/OUT port if not using the PS1000.

Note *Injecting this signal will override all other signals going to/coming from all other subscriber R-ONU/CPEs connected to the same splitter.*

c. Measure the upstream output of the R-ONU (point C on Figure 3-3). It should be between +2 and +4 dBm. If the signal level is sufficient the R-ONU is working correctly in the upstream direction.

d. Any suspected non functioning OR4148H path can be tested by measuring the return path signal on the respective optical test point (Rx1 – Rx8) on the top of the OR4148H. The CW signal injected at the R-ONU should be measureable at this point.

   If the OR4148H return receiver path is working, the CW signal injected at the R-ONU input will be also be measurable on its respective RF output test point (TPA-1, TPA-2, TPA-3, TPA-4) on the LM4005 motherboard of the VHub.

   The desired level at the -20 dB down test point is -10dBmV, which is actually +10 dBmV into the DT4032N Transceiver.

e. If it is determined that all (8) OR4148H return paths are adequately passing upstream signals providing the appropriate RF level at the DT4032N transceiver input, any problem in any link or hardware component upstream will affect service to all subscriber R-ONUs being serviced by the VHub being tested.

f. If service is affected for all R-ONUs fed from the VHub, it is suggested to incrementally work your way upstream by testing and verifying serial links, connectors, and modules in the path (combiners, filters, digital receivers, etc).

Also Refer to:

Aurora Networks TN-08-001 Cleaning Fiber Optic Connectors

Fiber Optic Association "Guidelines for Testing and Troubleshooting Fiber Optic Installations".

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Chapter 4 Aurora Networks RFoG Equipment

While Figure 2-1 and Figure 2-2 portray simplified reference diagrams for RFoG installations, Aurora Networks offers a variety of transmitters, transceivers, amplifiers, diplexers, splitters, multiplexer/demultiplexers, and R-ONU CPE modules that can be combined to provide a complete and very sophisticated RFoG system. The following charts outline the various modules available in each category along with their respective key features. It is up to the MSO/Cable Operator to determine the specific product needs based on the required network functionality. Aurora Networks Field Services, Technical Support, and Product Marketing are available to provide assistance for network and system planning. Please refer to each product data sheet for the complete features list and specifications.

CH3000 Chassis Based Head End Equipment

Table 9 Headend Forward Path Transmitters

Function	Part Number	Key Features	Installation and Deployment Guides
Analog Externally Modulated Full Spectrum Transmitter	AT3552A AT3552D	• Externally modulated 1563 nm broadcast • Full spectrum transmitter on the DWDM ITU grid • Narrowcast input port • 46 – 1002 MHz RF bandwidth • 79 Channel NTSC channel loading • Manual or AGC level controls • AT3552A: 8 dBm minimum optical output power • AT3552D: 12 dBm minimum optical output power • Single width full depth chassis slot	Check www.aurora.com
Analog Broadcast Transmitter	AT3553 AT3554	• 1550 nm • 65 km (AT3553) or 100 km (AT3554) distance • 9.5 dBm minimum optical power output • 1545 nm, 1563 nm, or DWDM ITU grid channel selections • 1GHz RF bandwidth • Externally modulated • Triple-slot width full depth chassis module	TM 87-10265
Full Spectrum Direct Modulated DWDM Transmitter	AT3545 Series	• 1550 nm • 30, 40, and 60 km distance • 40 DWDM wavelengths • 1 GHz passband • Switchable RF input gain stage • All QAM loading up to 1002 MHz • Light analog loading up to 258 MHz plus QAM loading up to 1002 MHz • Full analog loading up to 552 MHz plus QAM loading up to 1002 MHz • Single width full depth chassis slot	TM 87-10535

Table 10 Headend RF Return/Diplexer Receivers

Function	Part Number	Key Features	Installation and Deployment Guides
Diplexer/Return Path Receiver-separator	OR3144H	• 1550 nm downstream and 1610 or 1310 nm upstream • Serves 4 downstream and 4 upstream optical channels • Combines 4 upstream channels onto a single RF out • Low optical insertion loss • Low noise • 5 -85 MHz passband • Software RF Attenuator	Check www.aurora.com

Table 11 Headend Amplifiers (EDFAs)

Function	Part Number	Key Features	Installation and Deployment Guides
EDFA	FA3500 Series	• 1550 nm • 14 to 21 dBm output power level • Single and dual amplifier configurations • Gain flattened versions • Output power alignment • Constant current and constant gain modes	TM 87-10037
High Performance Multiport EDFA	FA3527M FA3533M	• 1550 nm • FA3527M: 8 ports (at 18 dBm per port) serve up to 256 subscribers (with splitters) • FA3533M: 16 ports (at 21 dBm per port) serve over to 1000 subscribers (with splitters)	Check www.aurora.com

Table 12 Headend Optical Splitters / Combiners

Function	Part Number	Key Features	Installation and Deployment Guides
Optical Splitters, Combiners, Multiplexers, Demultiplexers	OP31/35Dxx OP31/35Mxx OP31/32/34/38Sxx OP33/35xx	• Demultiplexers • Multiplexers • Splitters • Combiners	• TM 87-10043 Check www.aurora.com and individual datasheets for key features and details

Table 13 Headend Digital Receivers

Function	Part Number	Key Features	Installation and Deployment Guides
Dual Digital Receivers (Two independent receivers in a single wide module: 2 optical inputs and 2 RF outputs)	DR3002-AS	• 5 – 45 MHz passband • High RF output (-32 dBmV/Hz typical) • 8 to 12 bit dynamic range for digital return	TM 87-10040
	DR3102-AS	• 5 – 50 MHz passband • High RF output (-32 dBmV/Hz typical) • 8 to 12 bit dynamic range for digital return	
	DR3402-AS	• 5 – 65 MHz passband • Hi RF output (-32 dBmV/Hz typical) • RF output level independent of optical input power	
Dual Return Channel Digital Receivers (Single optical input and 2 RF outputs)	DR3021-AS	• 5 – 42 MHz passband • High RF output (-32 dBmV/Hz typical) • RF output level independent of optical input power • Use with DT4230N or DT3500 Digital Transmitters	
	DR3121-AS	• 5 – 50 MHz passband • High RF output (-33dBmV/Hz typical) • RF output level independent of optical input power • Use with DT4230N or DT3500 Digital Transmitters	
	DR3421-AS	• 5 – 65 MHz passband • High RF output (-33dBmV/Hz typical) • Use with DT4232N or DT3515C Digital Transceivers	

Note *All digital receivers above can be used with the BP3108C-AS (8 optical input) receiver back plate. DR3021AS, DR3121AS, and DR3421AS digital receivers can be used with the BP3104C-AS (4 optical input) receiver back plate. Each BP3104C-AS and BP3108C-AS Back Plate accommodates up to four DR3xxx Digital Receivers, and convert optical signals (up to 3.1875 Gbps from the network fiber channels) to electrical signals, then passing them through high speed connectors to the dual channel receivers. Refer to the BP3104C or BP3108C data sheets for more information.*

Field/Node Components

The tables below present a list of various optical splitters, combiners, and multiplexers that are applicable for RFoG implementations. All units include the following features:

- -40° to +85° C operating range
- Low insertion loss
- Small footprint form factor
- GR-1209 and GR-1221 qualified

Table 14 Field Splitters / Combiners

Function	Part Number	Key Features	Installation and Deployment Guides
Optical Splitter / Combiner	OP91S8S OP91S16S OP91S32S	• 1263 – 1619 nm operating wavelength window • 1x8 (OP91S8S), 1x16 (OP91S16S), and 1x32 (OP91S32S) splitter options	Check www.aurora.com
Dual Wavelength Splitter/Combiner	OP91S2S OP92S2S	• 1310 nm and 1550 nm wavelengths • 1x2 (OP91S2S) and 2x2 (OP92S2S) splitter options	Check www.aurora.com
Dual Wavelength Splitter/Combiner	OP91S3S OP91S4S	• 1310 nm and 1550 nm wavelengths • 1x3 and 1x4 splitter options	Check www.aurora.com
Dual Wavelength Splitter/Combiner	OP91S2Q OP91S4D	• 1310 nm and 1550 nm wavelengths • Quad 1x2 (OP91S2Q) • Dual 1x4 (OP91S4D)	Check www.aurora.com
Optical Multiplexer	OP91MsS	• Multiplex 1310 nm and 1550 nm wavelength onto a common fiber	Check www.aurora.com

VHub/Node Components

Table 15 VHub/Node Amplifiers

Function	Part Number	Key Features	Installation and Deployment Guides
High Output EDFA	FA4512 FA4514 FA4517	• 12 dBm output power • 14 dBm output power • 17 dBm output power	TM 87-10165 pages 18-20 VH4000 Virtual Hub Installation and Activation Guide
	FA4521S	• 21 dBm output power • Selectable constant gain or constant current	
Dual Output EDFA	FA4522S	• Dual outputs • 19 dBm output power per output • ASE muting function	Check www.aurora.com
	FA4524S	• Dual output • 21 dBm output power per output • ASE muting option	Check www.aurora.com
Octal Output EDFA (Requires a JC1443-R patch connector to the OR4148H)	FA4527S	• Eight outputs • 18 dBm output power per output • ASE muting	TN-10-009

Table 16 VHub/Node Diplexer/RF Return Receivers

Function	Part Number	Key Features	Installation and Deployment Guide
Diplexer/Return Path Receiver	OR4148H	• 1550 nm downstream and 1310 or 1610 nm upstream • Serves 8 downstream and 8 upstream channels • Combines 8 upstream channels onto 4 RF outputs • Low optical insertion loss • Low noise • 5-42 MHz passband (OR4148H-42-0-MP) • 5-65 MHz passband (OR4148H-65-0-MP) • RF Attenuation	TN-10-002

Table 17 VHub/Node Digital (RF) Transceivers (Transmitters)

Aurora transceivers for the VHub or NC2000/4000 nodes are actually digital transmitters that perform the functions of receiving the upstream analog signal from the OR4148H diplexer, reconverting the signal back into digital optical, and then transmitting the optical signal back to the Headend via a single fiber link.

Various offerings of either single or dual transceivers are available, each with respective features for wavelength and RF return frequencies.

Read the respective part number data sheets for specific details, specifications, and other information. Refer to Table 18 to learn about specifications and capabilities of the various plug-in transceivers available for the return transmitter SFP ports.

Function	Part Number	Key Features	Installation and Deployment Guide
Single Transceiver Single RF and single fiber ports	DT4030N-01	• Manages the conversion and upstream transmission for a single RF return onto a single fiber operating at 2.125 Gbps • 5 – 50 MHz RF return • 1310 nm, 1550 nm • 1 of 15 CWDM, or 1 of 40 DWDM wavelengths	Refer to 87-10382 (NC4000HG Node Guide)
Dual Transceiver Dual RF and single fiber ports	DT4230N-01	• Manages the conversion and upstream transmission for two RF returns onto a single fiber operating at 2.125 Gbps • 5 – 50 MHz RF return • 1310 nm, 1550 nm • 1 of 15 CWDM, or 1 of 40 DWDM wavelengths	
Single Transceiver Single RF and single fiber ports	DT4032N-01	• Manages conversion and upstream transmission for a single RF return onto a single fiber operating at 2.125 Gbps • 5 – 65 MHz RF return • 1310 nm, 1550 nm • 1 of 15 CWDM, or 1 of 40 DWDM wavelengths	
Dual Transceiver Dual RF and single fiber ports	DT4232N-01	• Manages the conversion and upstream transmission for two RF returns onto a single fiber operating at 3.2 Gbps • 5 – 65 MHz RF return • 1310 nm, 1550 nm • 1 of 15 CWDM, or 1 of 40 DWDM wavelengths	

Aurora optical pluggable SFP transceivers can be used to populate designated ports on products in the chassis at the Headend and plug-in modules within the outdoor optical node platforms.

Table 18 provides a list of the specific SFP modules by part number, their transmit wavelengths, link budget, distance capability, and applicable chassis, node, and CPE equipment where they can be used.

All connectors are duplex LC/IPC except where stated otherwise in their respective notes. Please refer to the data sheets for specific SFP descriptions, specifications, and other information. SFP modules listed can be used in any equipment noted in the above tables, where SFP ports are provided.

Table 18 Portable Small Form Pluggable SFP Modules

					Ports of Products Using SFP Transceivers									
		SFP Model Number	Tx Wavelength	Link Budget	BP-4104C	BP-3108C	DT3032S-Network Port	DT4030N-00/4032N-00 - Network Port	DT4030N-01 - Network Port	DT4230N-00 - Network Port	DT4230N-01 - Network Port	DT4232N-00 - Network Port	NI3030x - Network Port	OE4130S - Network Port
Max Tx Rate	2.125 Bbps	TR4000-PI	1310 nm	10 km	√	√	√	√	√	√	√	√	√	√
		TR4020-PI	1310 nm	20 km	√	√	√	√	√	√	√	√	√	√
		TR4040-PI	1310 nm	40 km	√	√	√	√	√	√	√	√	√	√
		TR4540-0000-PI	1550 nm	40 km	√	√	√	√	√	√	√	√	√	√
		TR4440B-xxxx-PI	CWDM xxxx	60 km	√	√	√	√	√	√	√	√	√	√
		TR4580-xx-PI	DWDM xx	>80[1] km	-	-	-	-	√	-	√	-	-	-
	3.1875 Mbps	TSA1310-TL10	1310 nm	10 km	√	√	-	-	-	-	-	√	-	-
		TSA1310-TL40	1310nm	40 km	√	√	-	-	-	-	-	√	-	-
		TSA1550-TL40	1550 nm	40 km	√	√	-	-	-	-	-	√	-	-
		TSC-xxxx-TL40	CWDM xxxx	40 km	√	√	-	-	-	-	-	√	-	-

[1] Application dependent; please refer to the product data sheets for individual products for further information about supported link lengths.

CPE Equipment

Table 19 R-ONU and Other CPE Components for SDU Applications

<table>
<tr><th>Function</th><th>Part Number</th><th>Key Features</th><th>Installation and Deployment Guides</th></tr>
<tr><td rowspan="2">SDU R-ONU</td><td>CP8013U-02
CP8043U-02
CP8063U-02</td><td>• 1310 nm, 54-1002 MHz FWD, 5-42 MHz RTN
• 1310 nm, 85-1002 MHz FWD, 5-65 MHz RTN
• 1310 nm, 72-1002 MHz FWD, 5-60 MHz RTN</td><td rowspan="2">TN 11-014</td></tr>
<tr><td>CP8015U-02
CP8045U-02
CP8065U-02</td><td>• 1610nm, 54-1002 MHz FWD, 5-42 MHz RTN
• 1610 nm, 85-1002 MHz FWD, 5-65 MHz RTN
• 1610 nm, 72-1002 MHz FWD, 5-60 MHz RTN</td></tr>
<tr><td rowspan="3">AC Wall Adapter</td><td>PS1911W-00</td><td>• 120 VAC adapter with 12 VDC output on an “F” connector
• 500 mA @ 12 VDC nominal, (6 W)
• AC Input connector NEMA 1-15P (USA)</td><td rowspan="5">87-10592</td></tr>
<tr><td>PS1912W-00</td><td>• 230 VAC EU type adapter with 12 VDC output on “F” connector
• 500 mA @ 12 VDC nominal, (6 W)
• AC input connector CEE 7/16 (Europe/Latin America)</td></tr>
<tr><td>PS1913W-00</td><td>• 100 VAC adapter with 12 VDC output on an “F” connector
• 500 mA @ 12 VDC nominal, (6 W)
• AC input connector JIS C8303, Class II (Japan)</td></tr>
<tr><td>Uninterruptible Power Supply</td><td>PS1811U-00
PS1812U-00</td><td>• AC input voltage: 108 – 253 VAC
• AC input connector IEC C8
• Output voltage 13.5 VDC nominal
• Output connector “F” type coaxial
• PS1811U-00 includes power cord</td></tr>
<tr><td>Back up battery for PS1811U-00 or PS1812U-00</td><td>PS1801B-00</td><td>• 7.2AH AGM battery
• Provides approximately 10 hours of backup at 6 Watts to 25% reserve point shut-off
• Recharge time 18 hours to 90%</td></tr>
<tr><td>R-ONU Enclosure Housing</td><td>CE8300H
CE8302H
CC8300H</td><td>• Outdoor Enclosure
• Indoor wall mounting bracket
• Cover for CE8302H wall mounting bracket</td><td>87-10611</td></tr>
</table>

Chapter 5 Reference RFoG Designs

This chapter portrays and discusses typical Aurora Networks RFoG SDU implementations denoting specific Aurora part numbers and feature capabilities.

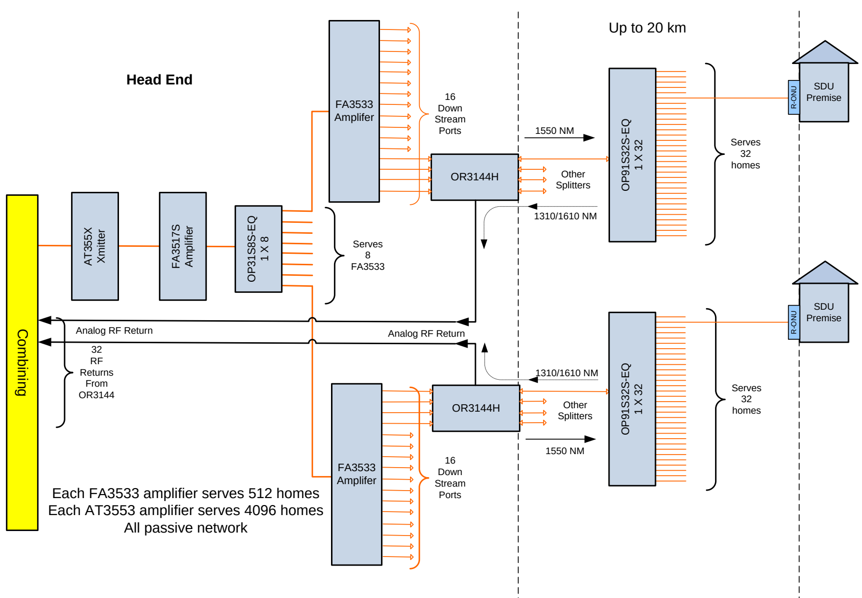
Short haul Implementation for 4096 Homes

Figure 5-1 provides a block diagram of a short haul implementation that services to 4096 SDU homes.

Starting from the Headend, service is provided using:

1) an AT3545 (or AT3552, AT3553, AT3554) 1550 nm broadcast transmitter provides an optical input to a FA3517S EDFA
2) following the FA3517S, an OP31S8S-EQ 1x8 splitter divides the signal into 8 individual/parallel paths, each feeding a 16 port (output) FA3533 EDFA.
3) each 16 port FA3533 EDFA takes a single leg from the OP31S8S splitter and divides (and amplifies) it into sixteen parallel paths. Eight FA3533 EDFAs are fed from the single OP31S8S. With each FA3533 EDFA providing 16 output ports, a total of 128 paths emanate from the Headend (8 x 16).
4) each group of 4 paths coming from the FA3533 EDFA feeds a single OR3144H RFoG Diplexer/Return Path Receiver. The OR3144H passes the 1550 nm downstream signal for 4 paths. It also accepts the 1310 (or 1610) upstream return path signals and combines them into a single RF signal which is fed back into the CMTS. Four OR3144H units are used with each FA3533 EDFA, therefore a total of 32 OR3144H modules (4 x 8 = 32) are needed for this implementation.
5) in the field an OP91S32S 1 to 32 optical splitter is used, where each leg of the 32 splits services one SDU R-ONU CPE. Each leg of an FA3533 EDFA and OR3144Hs support one OP91S32S, therefore 128 OP91S32S splitters are needed. With each of the 128 splitters providing 32 splits, 4096 SDUs are supported.

Figure 5-1 Short Haul RFoG Implementation for 4096 Homes



Long Haul RFoG Implementation for 2048 Homes

Figure 5-2 provides a block diagram of a long haul implementation that services 2048 SDU homes.

Starting from the Headend, service is provided using:

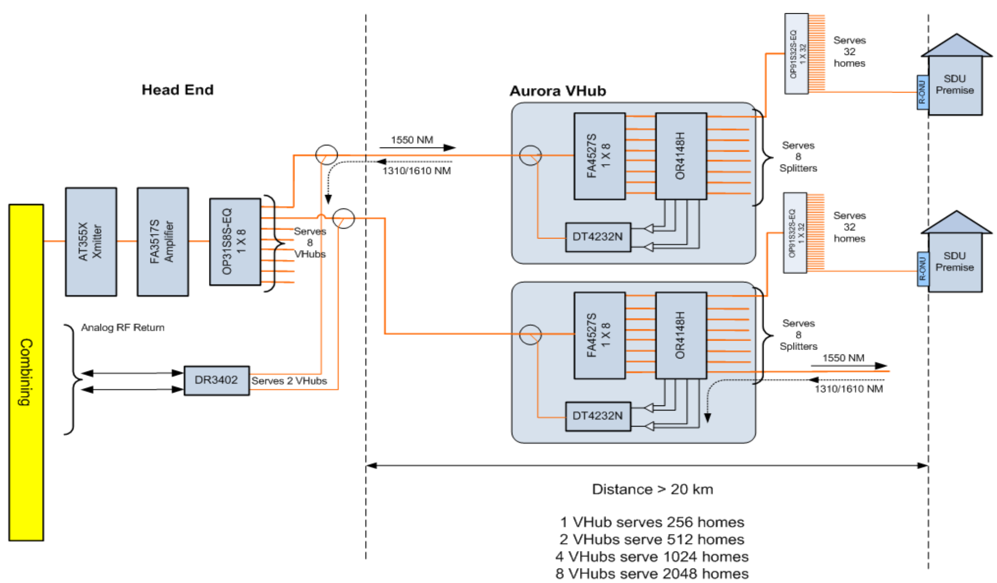
1) An AT3545 (or AT3552, AT3553, AT3554) 1550 nm broadcast transmitter provides an optical input to an FA3517S EDFA
2) A 1 by 8 OP31S8S-EQ optical splitter splits the downstream signal into 8 individual parallel paths
3) OP31S2D-EQ-00-AS dual 1 by 2 splitters (4 required) separate the 1310 (or 1610) nm upstream return signal, and passes it to the DR3402 digital receiver(s)
4) DR3402 dual digital receivers (4 required) receive the upstream return signal and convert it back to an RF signal where it is then passed to the CMTS

Each in-field path from the Headend includes a VHub or NC4000 Node that include:

1) An OP1S2S-EQ 1 by 2 splitter/combiner that combines the upstream signals onto the same fiber as the downstream
2) An FA4527S 1 to 8 channel EDFA that amplifies and splits the 1550 nm downstream signal into 8 parallel paths. *The FA4527S provides the highest power EDFA option to increase signal reach or performance, or both.*
3) An OR4148H 8 channel diplexer/return receiver that passes the 8 parallel 1550 nm downstream signals and also filters and extracts the 1310 (or 1610) nm upstream return signals from each upstream path. The filtered upstream signal is then converted into an RF signal and passed to the DT4232N dual digital transmitter.
4) Each leg of the FA4527S/OR4148H is fed to a single OP91S32S 1 by 32 optical splitter. Each of the 32 splits provides service to a single SDU R-ONU CPE.
5) The 5-65 MHz DT4232N (or 5-50 MHz or 5-85 MHz versions) dual digital transmitter accepts the upstream RF return signals from the OR4148H and re-digitizes them, and then passes them on to the OP1S2S-EQ where they are combined on to the downstream fiber, and transmitted to the Headend.

With the Figure 5-2 implementation, a single VHub supports 256 SDUs. With the OP31S8S splitter implemented at the Headend, 8 VHubs are supported, consequently service for 2048 SDUs is provided.

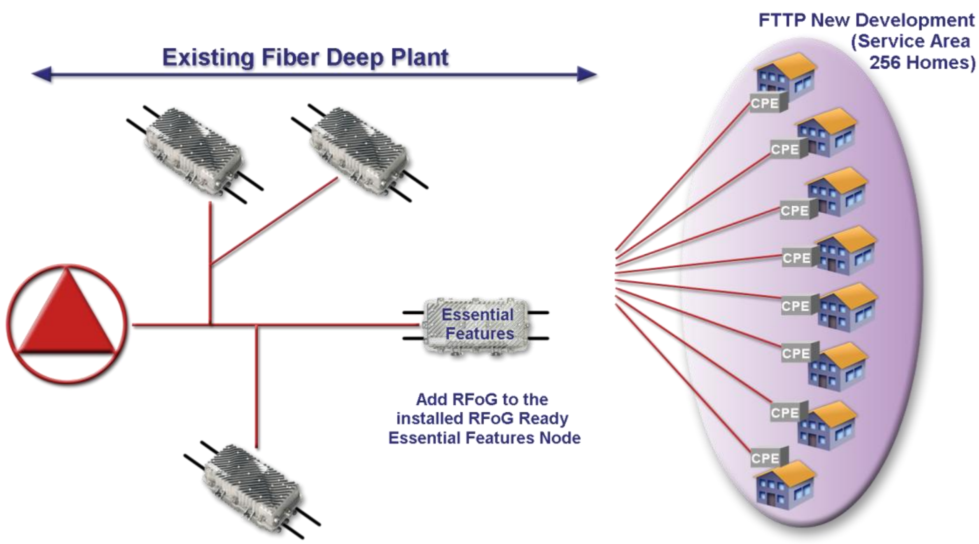
Figure 5-2 Long Haul RFoG Implementation for 2048 Homes



NC4000EG Essential Features RFoG Ready Premium Node

The basic Aurora Networks NC4000EG series is a turn-key fiber deep node platform solution that has been optimized to provide all necessary features and hardware required by today's Fiber Deep (HFC Node+0) architectures that typically serve 50 to 200 homes passed per node. In addition, the NC4000EG also accommodates up to 6 additional Aurora plug in modules that can instantly provision and provide RFoG services for up to 256 customers from within the same node housing. (Figures 5-4 and 5-5)

Figure 5-3 Addition of Essential Features RFoG Node to Existing Fiber Deep Plant



These "Essential Features" nodes enable fiber deep architectures to be cost-effective (equal or less than traditional HFC costs), and extremely reliable due to the elimination 75% less actives and requiring minimal maintenance. The NC4000EG series fiber deep node platform maintains the industry's highest RF output capability with its 4-output design, its one forward and one or two return segmentation capability, its status monitoring and control, and its digital return technology with daisy-chain ability.

NC4000EG series Fiber Deep Nodes utilize the NC4000H housing as its 1.5 GHz foundation to accommodate a collection of modules. All essential node functions have been maintained and designed into a single integrated node module, the NM4114EG-xx, which includes a forward optical receiver, RF amplification for four ultra high level RF outputs and one return segment digital transceiver. A second basic module configuration is available to support two return segments using Aurora's patented "2-fer" technology. Return path transmission is supported with pluggable SFP transceivers. Three return/forward passband versions are enabled using plug-in filter designs for frequency splits of 5–45 MHz/54–1002 MHz, 5–60 MHz/72–1002 MHz, and 5–65 MHz/85–1002 MHz.

The Essentials Features Node provides space in the lid for a variety of other service modules, including modules intended for RFoG and PON applications.

Figure 5-4 portrays the schematic diagram for a typical RFoG equipped NC4000EG Essential Features node. The upper portion of the schematic (inside the dotted line, i.e. the node) reveals the forward and reverse path circuitry that is integrated into the base mother board of the node that supports a classical Fiber Deep implementation for four subscriber paths. All functionality in both directions is completely integrated within the base mother board.

The lower portion of the schematic presents the installation of an FA4524S dual output EDFA fiber amplifier, an OP91S4D-EQ-RS-MP 2x4 splitter, an OR4148 RF return receiver/diplexer for 8 paths, and two DT4230N digital return transmitters having their outputs combined using an OP94F1S-R2-AS. The higher power FA4527S EDFA could also be used to serve greater distances from the node to the SDU.

Figure 5-4 NC4000EG RFoG Ready Essential Features Node Schematic

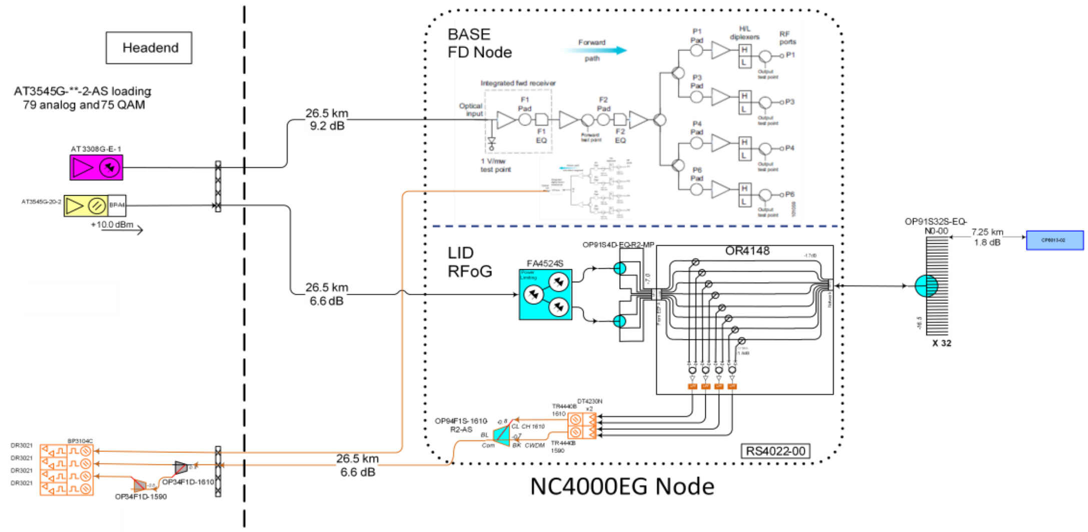
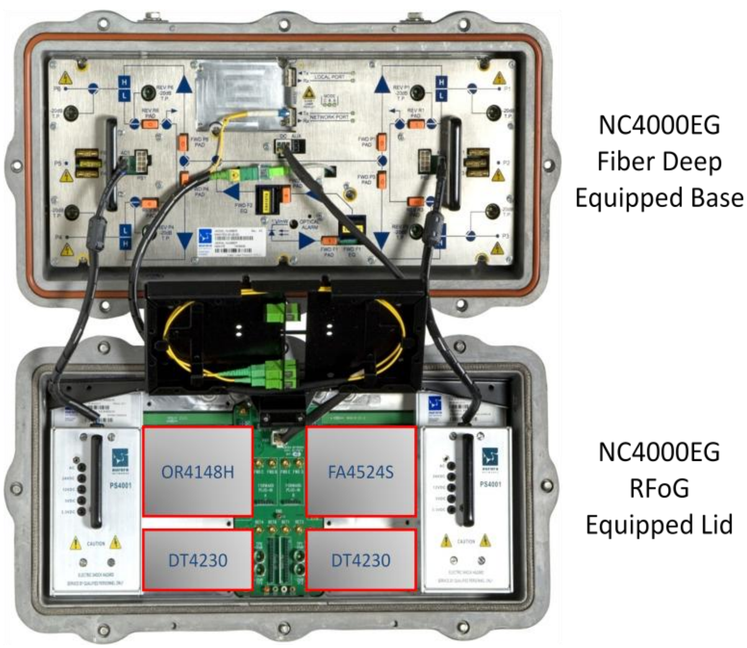


Figure 5-5 is a photograph of the NC4000EG base and lid, with the location and positioning of the RFoG specific add-in modules installed to accomplish the functionality of the schematic noted in Figure 5-4. Not shown are the necessary OP91S4D-EQ-R2-MP and OP94F1S-R2-AS combiners.

Figure 5-5 NC4000EG RFoG Ready Essential Features Node



Other NC4000 Fiber Nodes with space for 4 module slots can serve as an RFoG VHub as well, with 1 slot for the EDFA, 2 slots for the OR4148 and 1 slot for the digital transmitter.

NC2000 Mini VHub Node

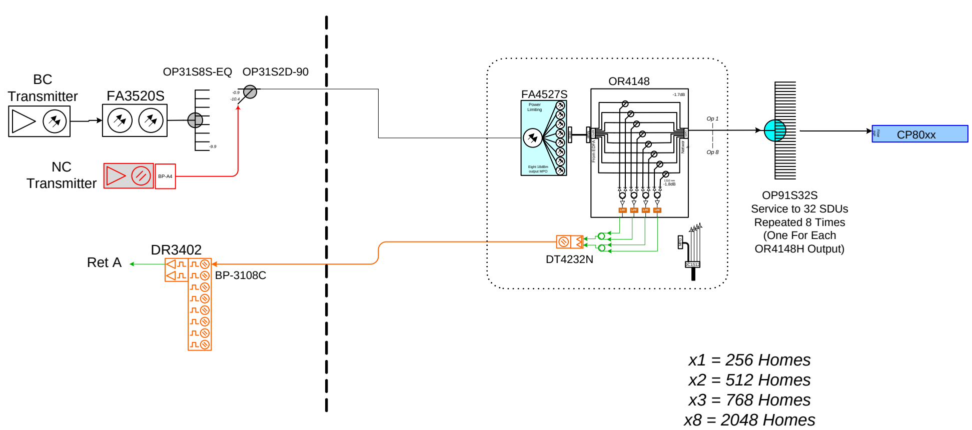
The NC2000 Scalable Optical Node Platform is designed for various applications for HFC, Fiber Deep, and RFoG architectures. The node's small physical size and modular design can be wall or pedestal mounted.

The NC2000 includes six flexible module slots that can be populated according to network architecture and service requirements. Two of these slots are most commonly used for a forward receiver and a single or "2-fer' digital return transceiver. The node can also be populated with other single or dual slot Aurora node modules such as optical switches, EDFAs, or DWDM transponders, optimizing performance and reliability for a wide range of applications.

Similar to the NC4000EG Lid installation for RFoG shown above, Figure 5-6 portrays an NC2000 node with an FA4527S octal output EDFA fiber amplifier, OR4148 RF return receiver/diplexer for 8 paths, and a 5-65 MHz DT4232N "2-fer" digital return transmitter.(Alternately, a 5-50 MHz or 5-85 MHz transmitter could be used). The necessary splitters and fiber connections are not shown. Figure 5-7 portrays the network schematic using an RFoG outfitted NC2000 node that supports 256 homes.

Figure 5-6 NC2000SG Scalable Node with RFoG Modules Installed for 256 Homes

Figure 5-7 NC2000SG Scalable Node 2048 Home Network Design



F

Appendix

Other Related RFoG Documentation

- Brochures
    - RFoG and RFPON Solutions: Breaking Access Barriers
        - M09-001 7/10 Rev C
    - Forward Path 1GHz Transmitters
        - M06-003 9/10 Rev D
    - RFoG-Ready Essential Features Premium Node
        - M11-001 01/11 Rev A
- White Papers
    - RFoG: How to Make it Work and How To Expand It
        - White Paper #13, April 2009
    - RFPON: The Next-generation RFoG Solution
        - White Paper #14, June 2009
    - RFoG Return on Investment in Rural Environments
        - White Paper, October 2009
    - RFoG: Promise to Support High Reverse Bandwidth
        - White Paper #22, March 2010
    - RFPON: Fiber Technology Supporting an Emerging SMB Opportunity for Cable
        - White Paper #26, December 2010
    - RFoG: Matching and Exceeding HFC and PON Performance and Capacity
        - White Paper #27, March 2011
    - RFPON: RFoG plus PON
        - White Paper #30, May 2011
    - RFoG: Overcoming Forward and Reverse Capacity Constraints
        - White Paper #32, June 2011
    - DOCSIS 3.0 Solving the Upstream Challenge
        - White Paper, September 2009
    - Reverse Optical Links from Nodes in DOCSIS 3.0 Environment
        - White Paper #21, March 2010
- Technical Manuals
    - Opti-Trace CMS Craft Management Software V7.09.15 Installation/User Guide
        - TM 87-10664
    - Opti-Trace OTS Shelf Management Software V7.09.13 Installation/User Guide
        - TM 87-10663
    - Opti-Trace EMS Element Management Software V7.06.18 Installation/User Guide
        - TM 87-10662
    - CH3000 Chassis Installation and Activation Guide
        - TM 87-10029
    - VH4000 Virtual Hub
        - TM 87-10605
    - Cleaning Fiber Optic Connectors
        - TN-08-001

Terms/Acronyms Used in this Document

Term	Definition
ASE	Amplified Spontaneous Emission
CMS	Aurora Networks Opti-Trace Craft Management Software
CMTS	Cable Modem Termination Service
CNR	Carrier Noise Ratio, or C/N Carrier/Noise Ration
CW Signal	Carrier Wave Signal
DFB	Distributed Feedback (Laser)
DOCSIS	Data Over Cable Service Integration Specification
DWDM	Dense Wavelength Division Multiplexing
EDFA	Erbium-Doped Fiber Amplifier
EMS	Aurora Networks Opti-Trace Element Management Software
EMTA	Embedded Multimedia Terminal Adapter
FP	Fabry-Perot (Laser)
FTTH/FTTP	Fiber to the Home, Fiber to the Premise
GEPON	Gigabit Ethernet Passive Optical Network
GPON	Gigabit Passive Optical Network
HFC	Hybrid-Fiber Coax
MDU	Multi (family) Dwelling Unit. Typically a large physical building housing multiple families or office suites, therefore housing multiple subscribers. Typical examples are townhouses, condominiums, apartment buildings, and office suites. Incoming CATV services need to provide connection services to hundreds if not thousands of potential subscribers within the structure.
MER	Modulation Error Ratio
MFN	Micro Fiber Node, i.e. NC2000, NC4000, VHub
MSO	Multiple System Operator
NPR	Noise Performance Level
OMI	Optical Modulation Index
OTS	Aurora Networks Opti-Trace Shelf Management Software
PON	Passive Optical Network
RF	Radio Frequency
RFoG	RF over Glass. Transmission of analog RF (Radio Frequency) signals over fiber, replacing or outdating traditional coaxial cable.
R-ONU	RFoG Optical Network Unit
SDU	Single (family) Dwelling Unit. A physical home or small stand alone office where only a single subscriber resides. The physical building is stand-alone as in a typical residential home, and is not attached or a part of a larger structure such as a townhouse, condominium, or apartment building. Incoming CATV services typically only need to provide a single connection service to the structure.
SNMP	Simple Network Management Protocol
UPS	Uninterruptable Power Supply
Two-fer	An Aurora Networks node transceiver module that integrates 2 fiber paths into the same single-slot module
WDM	Wavelength Division Multiplexing

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