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RFoG Introduction, Maintenance and Troubleshooting

Thursday, December 11, 2014

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Agenda

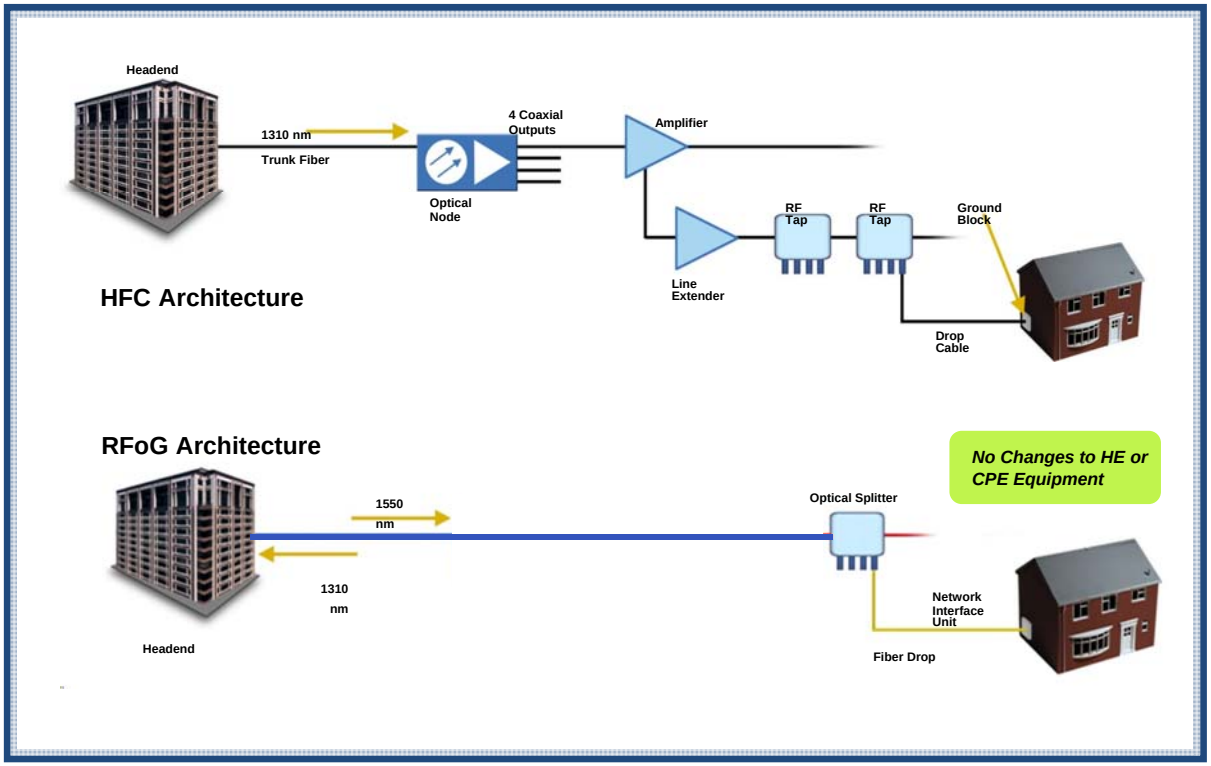
1. Introduction to RFoG
   a. What is it?
   b. How does it compare to HFC?
   c. Components and equipment.
   d. Benefits
2. Beyond RFoG
   a. GEPON and 10G
3. Challenges unique to RFoG
   a. Switching
   b. OBI

What is RFoG?

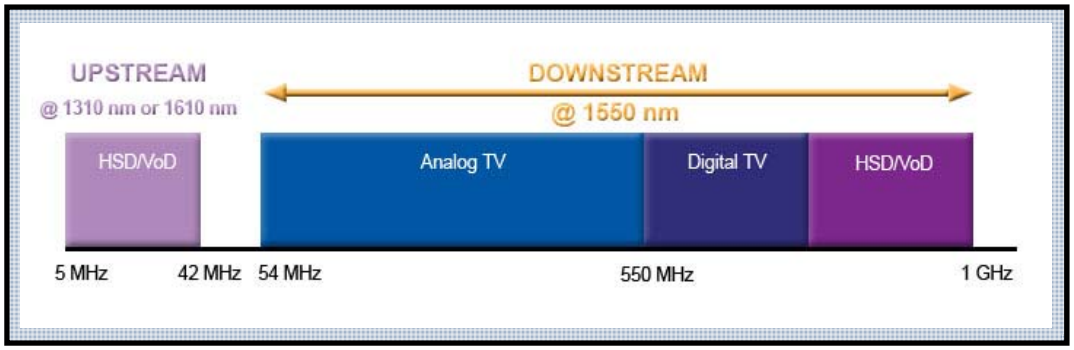
- RFoG = Radio Frequencies over Glass
  - FTTx: Fiber to the Home (FTTH) / Fiber to the Premises
  - Similar to what you're doing today! …just further into the network.
    - Ultimate Fiber deep network
  - Same back-office provisioning DOCSIS CMTS and CMs, VoIP, Analog and QAM video, VOD and RF settops.
  - Preserves in-home coax wiring
  - Use the ***existing skills and knowledge*** of your teams

  - SCTE - IPS SP 910 Phase 1 standard ratified (ANSI SCTE 174 2010)
    - Downstream wavelength 1550nm, upstream 1310nm or 1610nm, upstream RF input level and OMI, laser turn on threasholds and timing

RFoG Compared to HFC



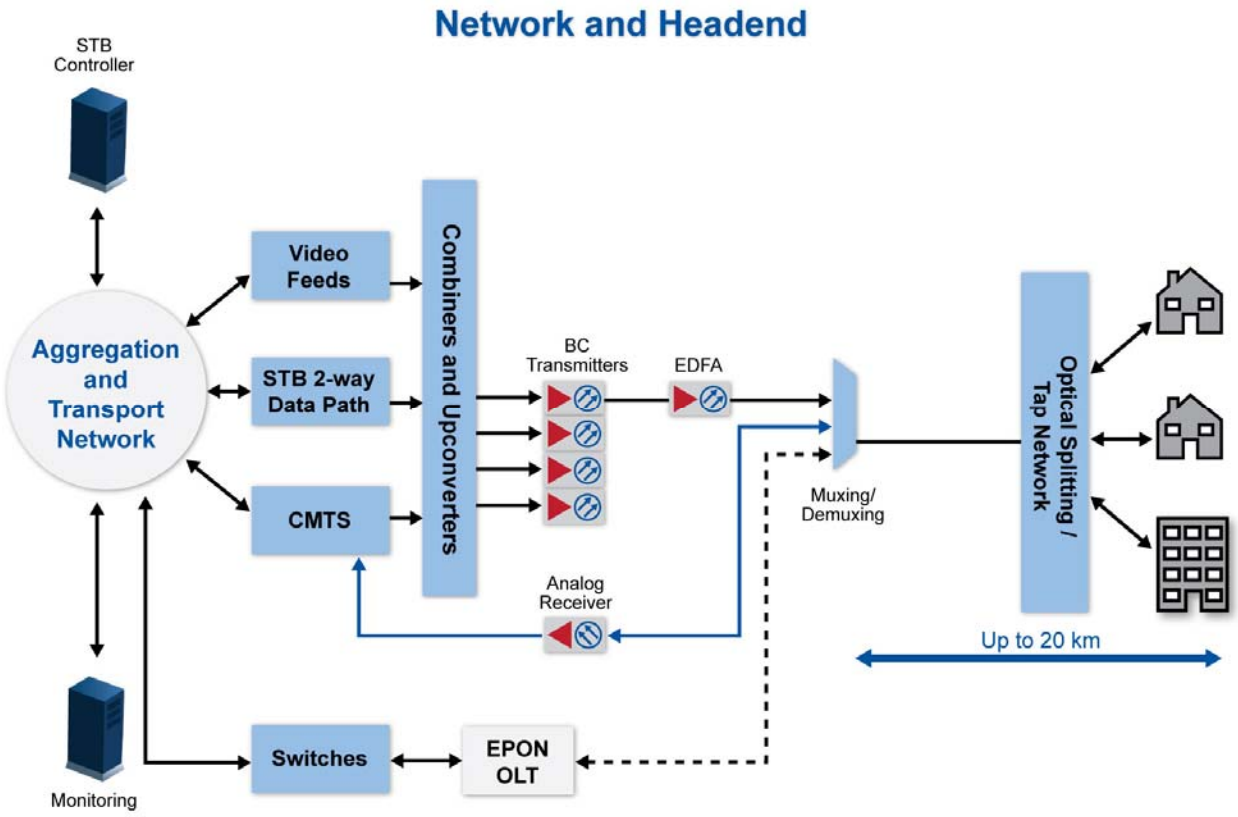
RFoG Spectrum



Return can be transmitted at 1310 or 1610 nm

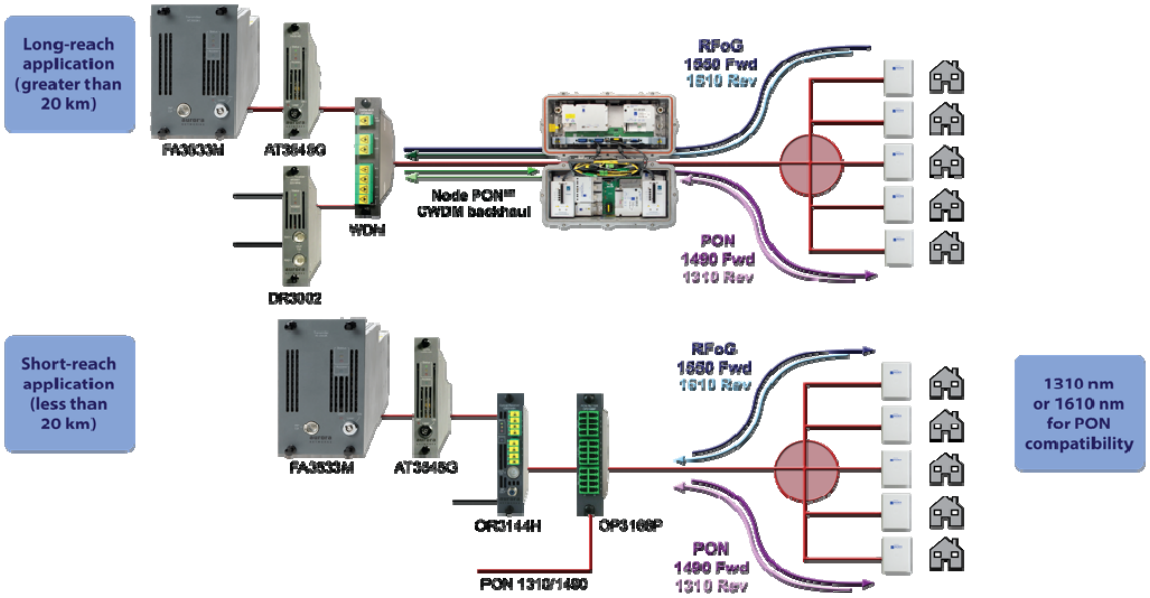
- 1310 nm is a lower-cost solution today
- 1610 nm is a future-proof solution
  - Compatible with current PON standards
    - 1490 nm downstream, 1310 nm upstream

Generic RFoG Network



RFoG Solutions

RFoG repeater application; long reach and fiber conservation



Short reach all passive RFoG application

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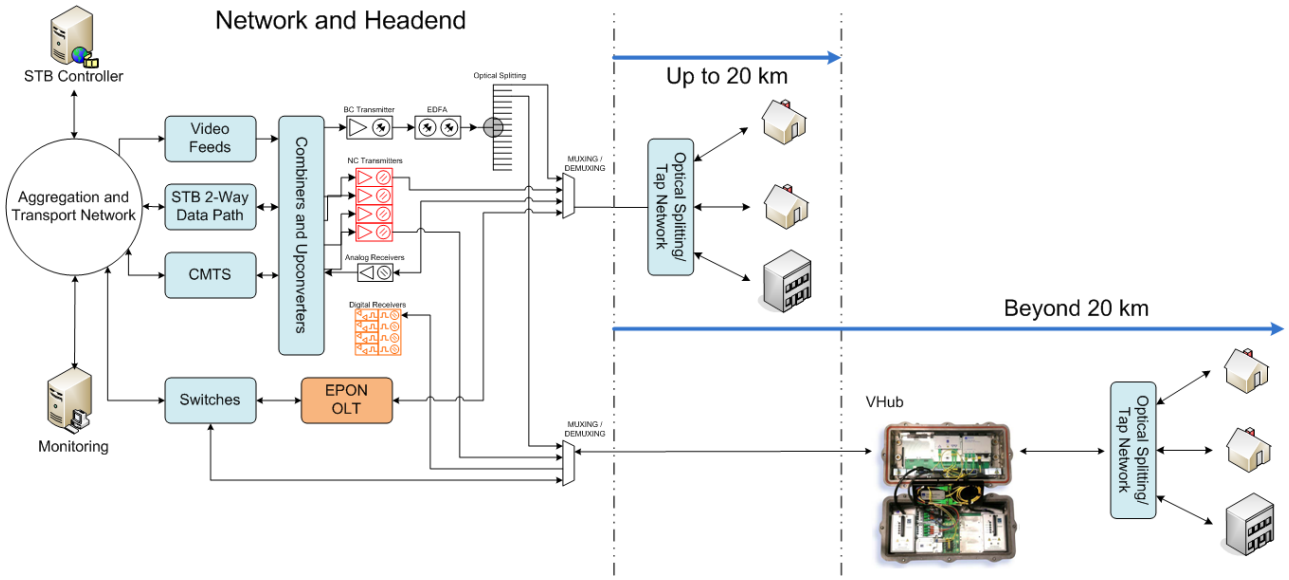
RFoG Topology – Passive & Active



SCTE 174 RFoG CPE Specifications

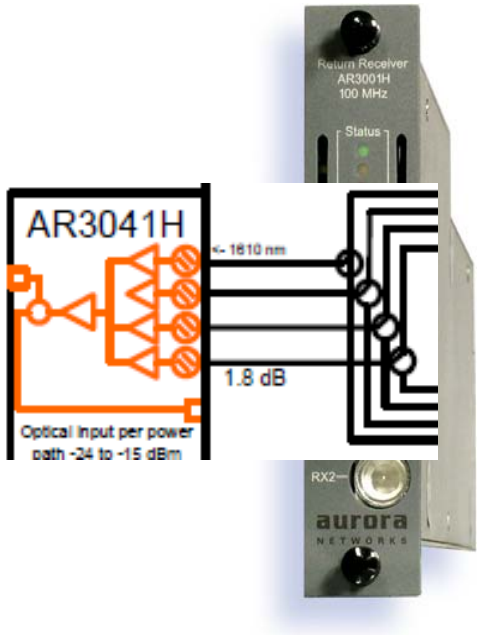
- Downstream
  - Optical input ranges 0 to -6dBm
  - RF out provides +17dBmv, tilted, to 1GHz, higher for MDU
- Upstream
  - Transmitter “Burst mode”
  - Typical 5-42 MHz, 5-65 MHz & 5-85 MHz
  - De Facto TDMA

Forward transmission

- Transmitters
  - Direct modulated – Low cost, receivers have to be within distance ‘window’
  - Externally Modulated - Higher cost, no distance limits
- EDFA - always required to drive local distribution.
  - Power select on customers per segment and distance. Typically 17 to 21dBm
- Splitting
  - Typically 32 Homes per forward feed
  - 17dB passive loss plus fiber distance.
  - Limited to around 20km reach with no active field elements

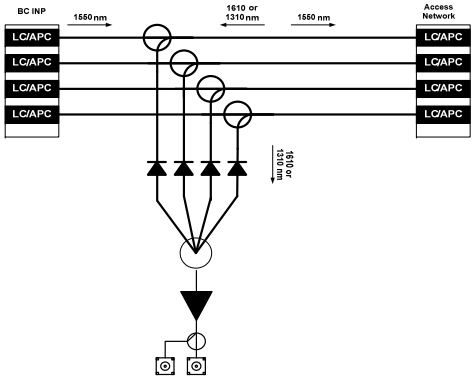
Analog Return Receivers

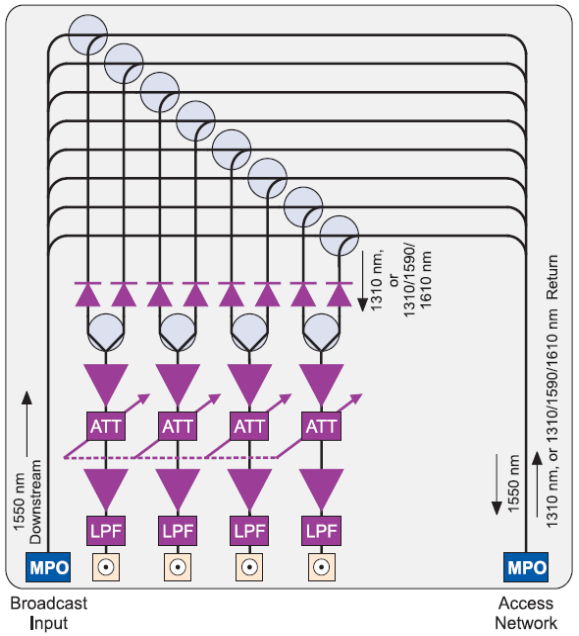
- Wavelength Agnostic
  - Require de-mux to separate returns
- Optical Receive Sensitivity
  - Low optical inputs -10 to -20dBm
  - Performance limitations
  - Link budget
- Noise/Ingress
  - Burst mode transmission - only active when cable modem is transmitting
  - Limits return noise
- Optical Return Unity Gain/Loss
  - Segments typically have common optical losses



Optical Muxes and Demuxes

- External Splitters for forward distribution
- Optical Wavelength Filters
  - Bi-Directional Operation
  - Integrated or Cascaded





RFoG CPE (R-ONU)

- Indoor/Outdoor
- SDU/MDU
- PON pass-through
- Powering options including battery backup

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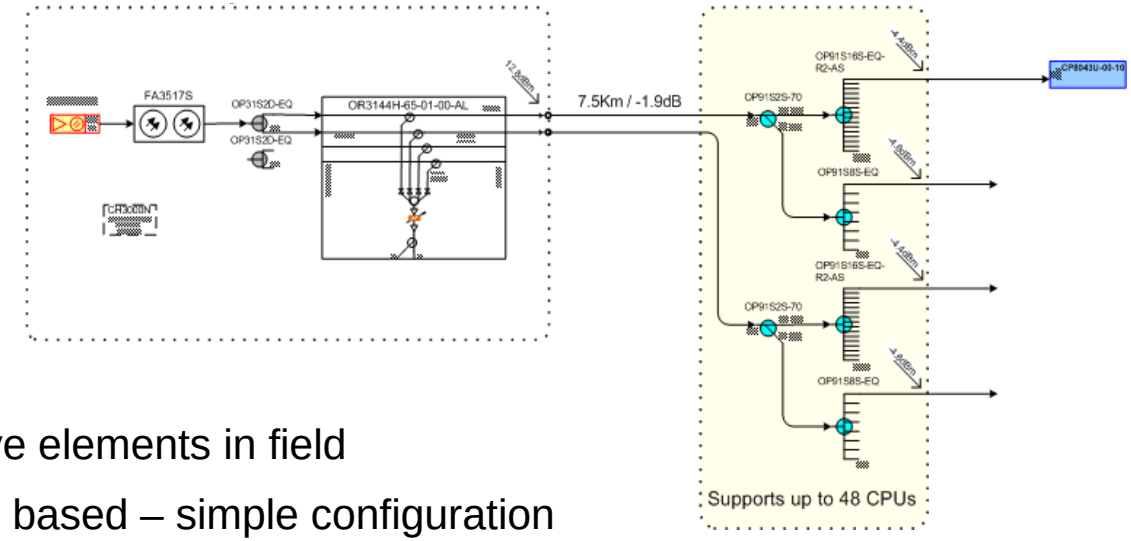
RFoG Benefits

- System Powering, Maintenance, Impairments
- Existing Headend and Customer Premise equipment
- Existing Back Office and Provisioning
- Uncomplicated
- Low Incremental Cost
- Competitive Positioning
- Return Noise limited to individual CPE
- Open platform
- Fiber all the way to the customer: “Future-proof” Network

RFoG Design 1 - Passive

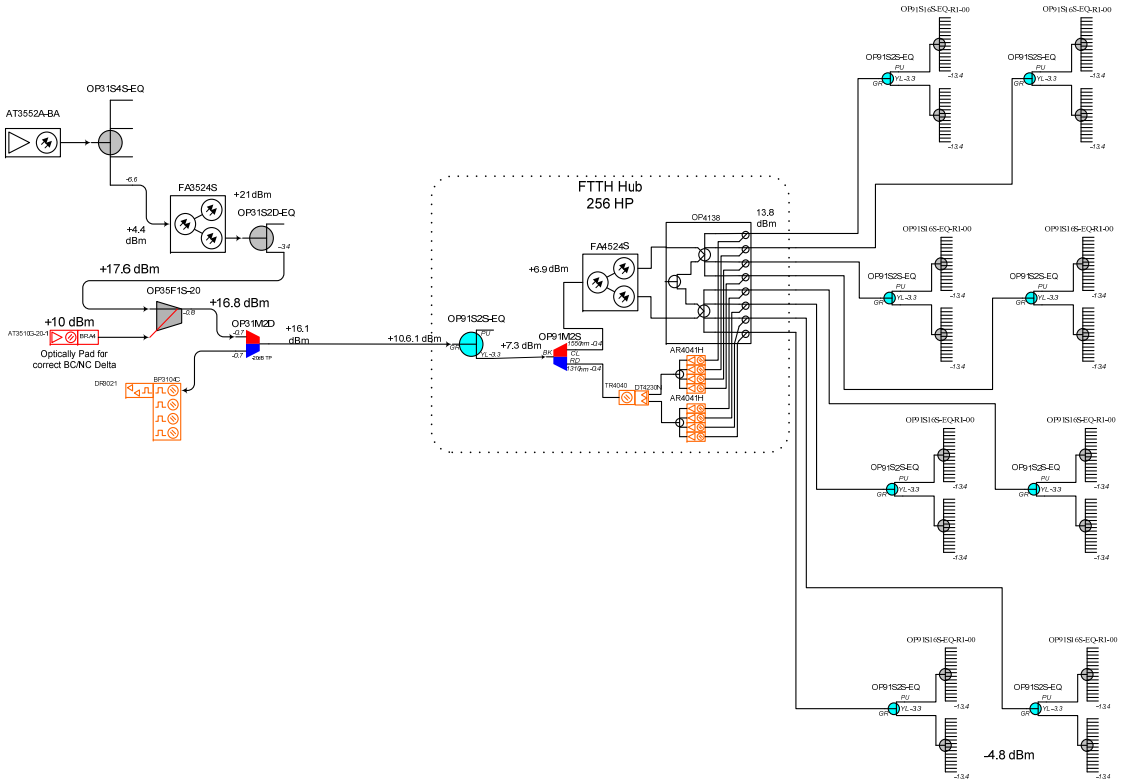


- No active elements in field
- Chassis based – simple configuration
- Single Transmitter
- Expansion by changing EDFA

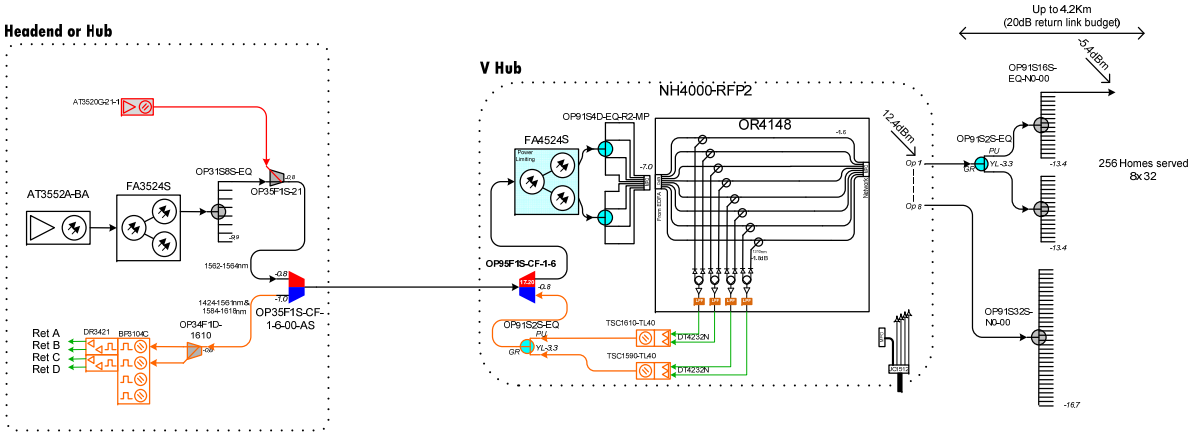
RFoG Active Distribution

- Move distribution EDFA to field
  - Pedestal/Cabinet with chassis modules
  - Virtual Hub – Hardened Enclosure
- Eliminates the 20km distance limitation
- Fiber count reduction
  - Single fiber can support more than 32 customers
  - Only build fiber where needed for local distribution
- Use standard return to bring back combined returns;
  - Digital or analog option now available
- Maintain overall performance

RFoG Long Reach with Repeater

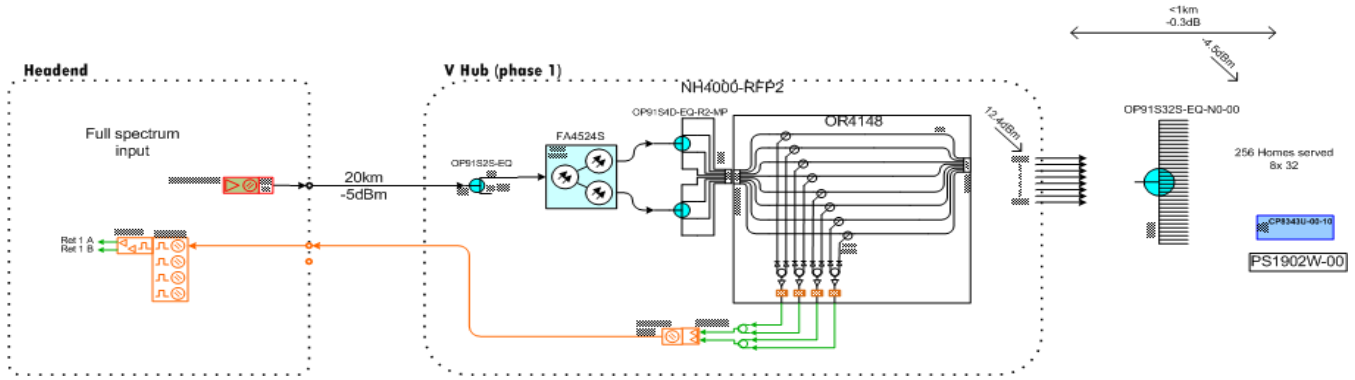


RFoG + BC with CWDM Returns



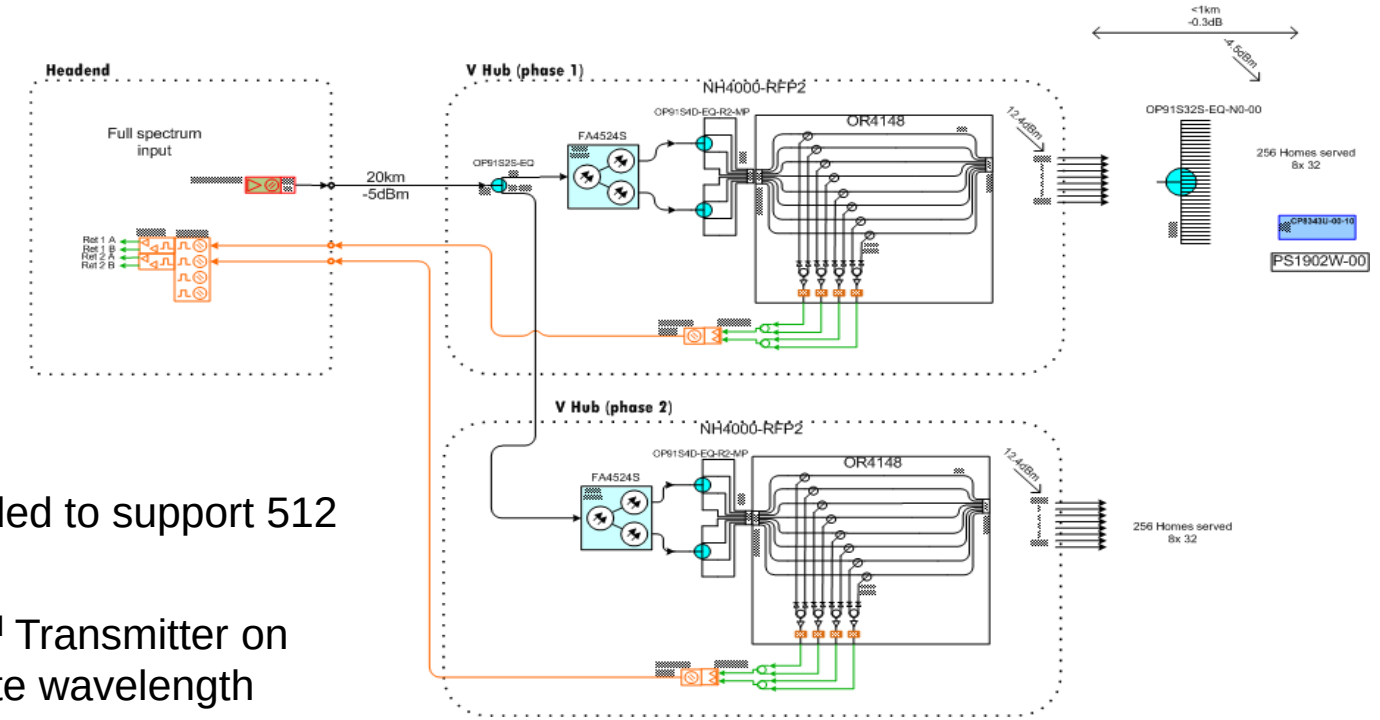
Single Fiber Operation

RFoG Long reach Active – Phase 1



- Full spectrum Transmitter
- 2 Fiber Operation
- 2x return
- 256 Homes passed Phase 1

RFoG Long reach Active – Phase 2



- Expanded to support 512 homes
- Use 2nd Transmitter on separate wavelength

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Optical distribution

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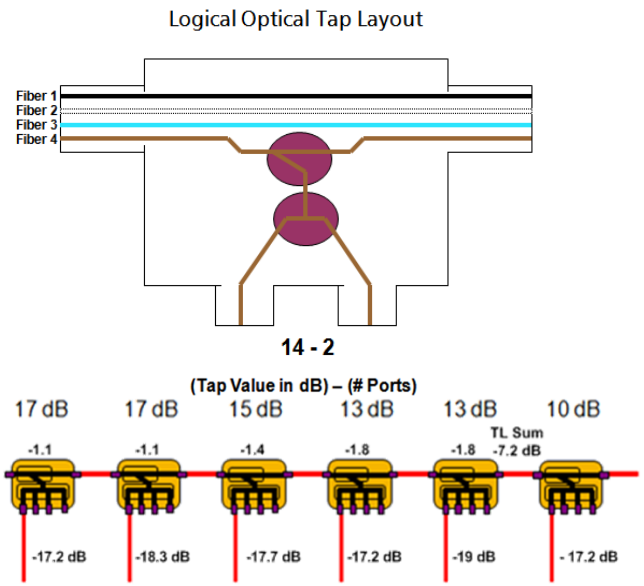
RFoG Field Split Topologies



24 Port Optical Taps have losses of 17.2 to 19 dB loss
Vs
1x32 PLC Splitter loss of 17.3 dB (OP91S32)

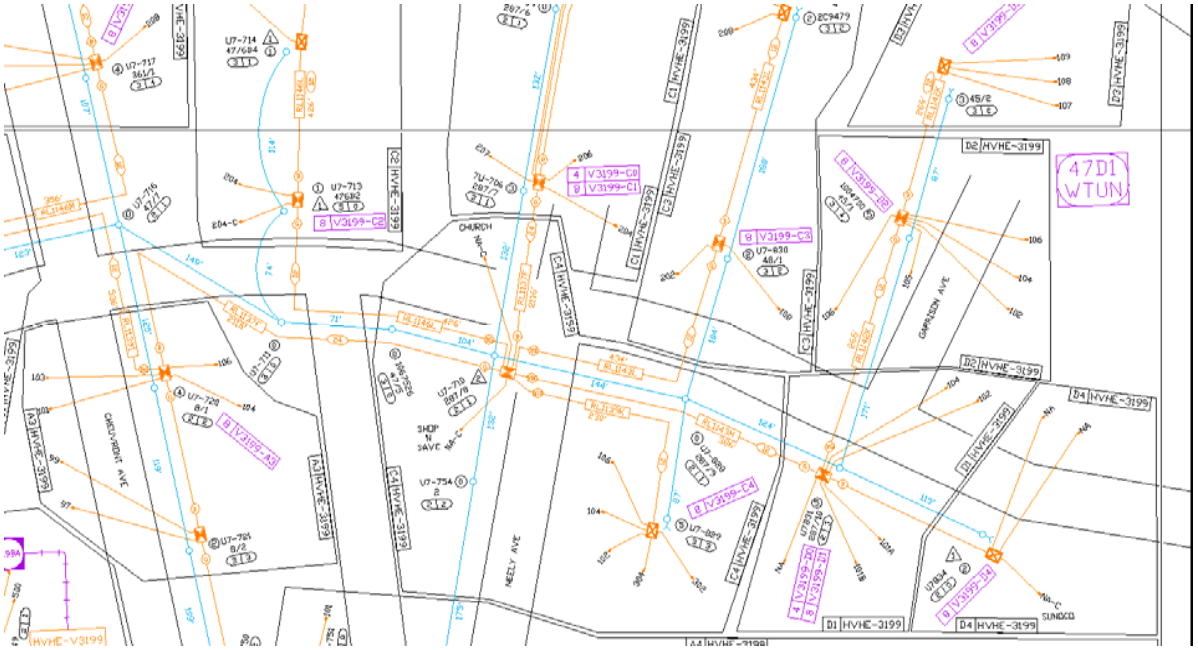
Tapped (Distributed) Topology

- Higher optical loss (Inefficient use of couplers), often not able to reach full 256 HP capacity
- Higher cost (material + labor + design)
- More sparing demand (21 different taps vs one PLC (planar light circuit splitter)
- Proprietary solution

Centralized Topology

- Lower loss = increased loss budget
- Fewer parts to spare
- Splitters consumed as penetration increases
- Standard solution for low cost 32-way PLC optical splitter
- Alternative options: 2x 16 way or 4x 8way

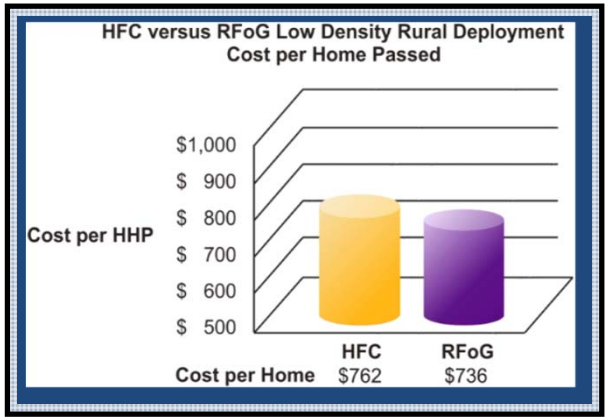
RFoG Optical Distribution



When to consider RFOG

- Deploy FTTH leveraging existing infrastructure, service offering and workforce as HFC network
  - Same headend, subscriber equipment, back office
  - No re-training required
  - Retain DOCSIS for HSD service delivery
- New build residential
  - Low density (<35 HP/mi) RFoG proves more cost effective due to reach of fiber
  - In case you must build FTTH (regulator, building society, market, competitive etc)
- Offloading MDU's with fiber
  - Sharing common RFoG ONU with multiple customers to off-set costs.

Cost Comparison (see Aurora whitepaper 20)



	HFC	RFoG
Headend/Hub/Field Optoelectronic Equipment	13%	19%
Coax/Fiber Cables in Serving Area (Construction, Material, Splicing, Labor)	41%	23%
Power Supplies/Active Elements (Amplifiers, Line Extenders)	11%	1%
Passive Elements	2%	5%
Aerial Strand Hardware	20%	25%
Drop and Installation (CPE included)	2%	19%
Project Management/Design Engineering/Turn Up and Test	10%	9%
	100%	100%

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Beyond RFoG

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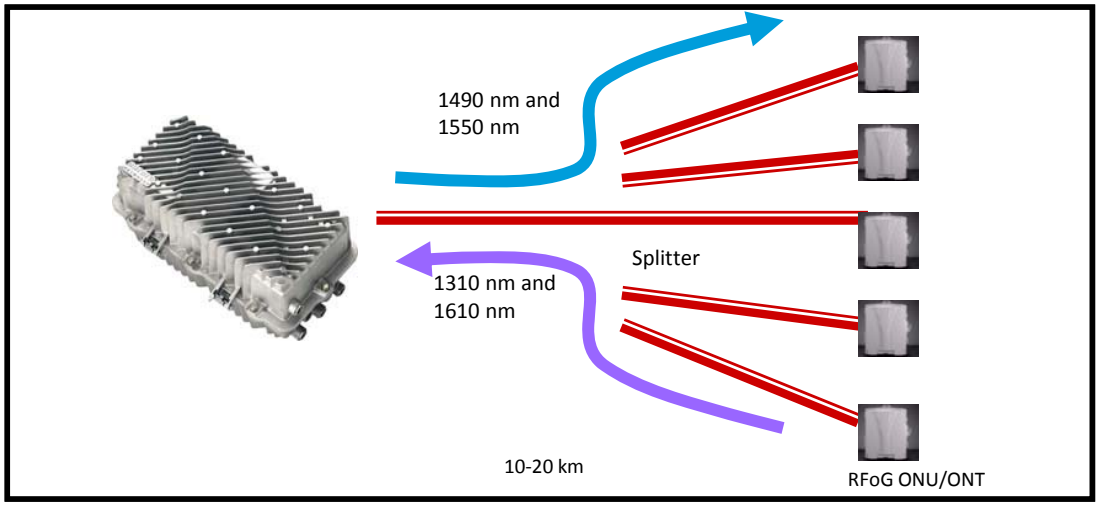
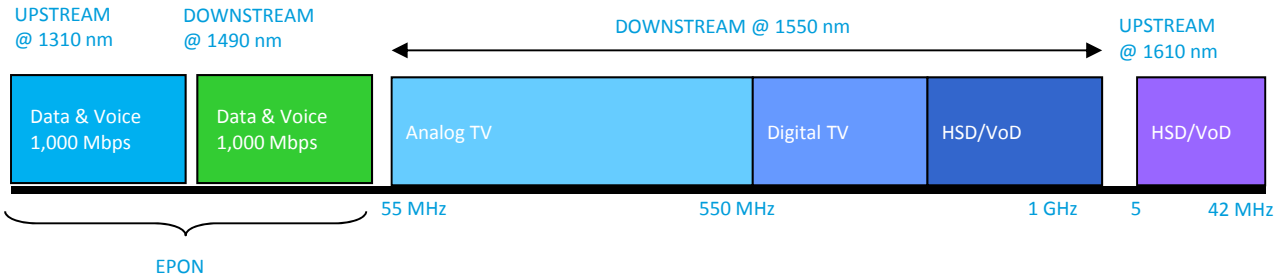
What is EPON?

- EPON can exist on the same fiber as RFoG.
  - Allows data pipe to be shared with multiple customers.
  - 1G was standard, new feature ‘Turbo mode’ offers 2G enhanced data rate when required to match GPON
  - Data can be provisioned with QoS and advanced features such as VLAN.
  - Offers DPOE; DOCSIS Provisioning of EPON
- EPON can be used for data services on top of RFoG triple-play, or its high data capacity can be used for all targeted services (VOD, HSI, telephony, etc.)
- Alternatively, EPON be deployed separately.
  - Example: RFoG for residential triple-play customers, GEPON for business-class services
  - Instead of a single fiber per customer, up to two could be used if both RFoG and GEPON services are used.
- 10G solution is on the way

RFoG & EPON





Same back-office provisioning systems as DOCSIS system

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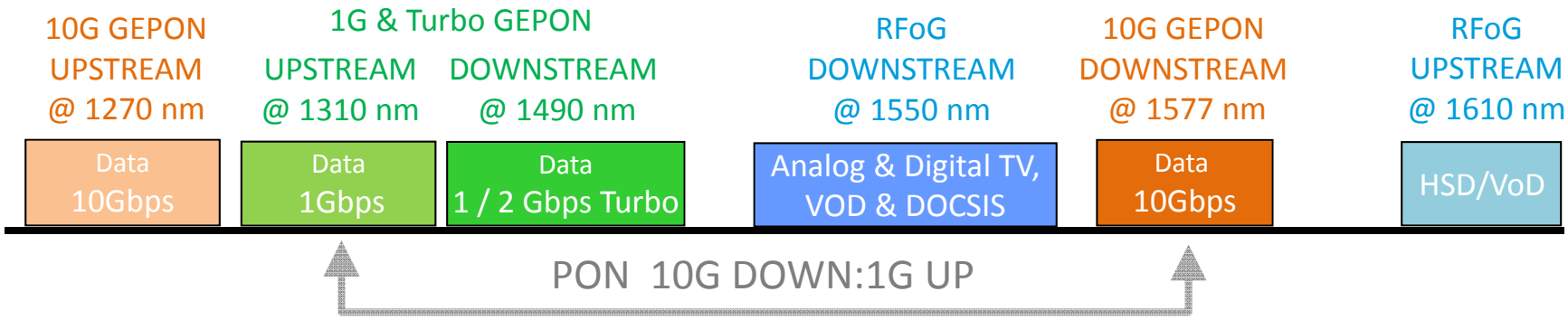
Optical Spectrum

Wavelengths pre-defined by ITU

- RFoG; 1550nm Downstream, 1610nm upstream
- PON 1 G for both standard and Turbo mode; 1490nm downstream, 1310nm upstream
- PON 10G down, 10G up; 1577nm downstream, 1270nm upstream
- PON 10G down, 1G up; 1577nm downstream, 1310nm upstream



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RFoG Switching & OBI

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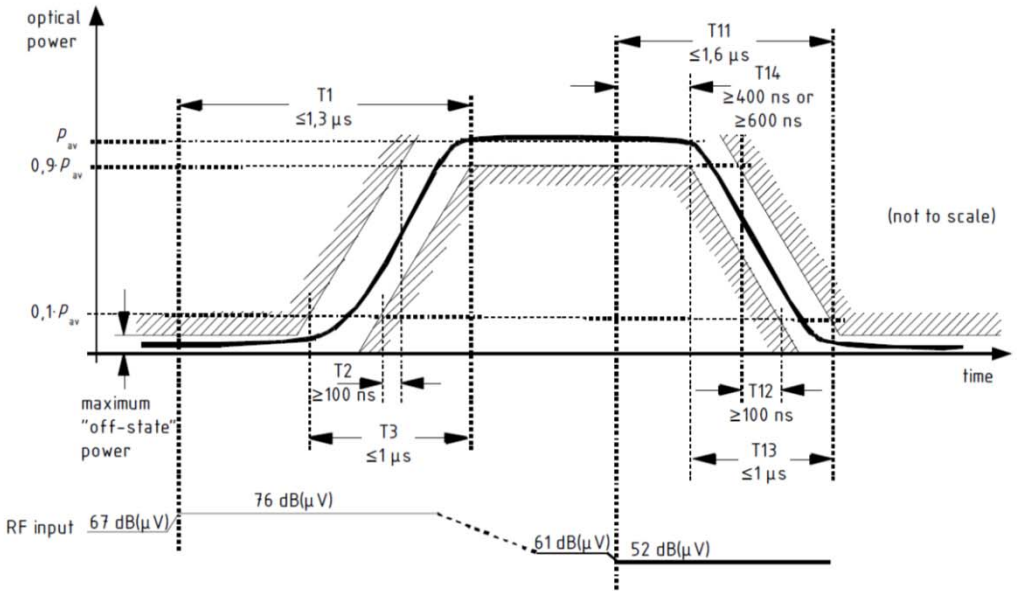
RFoG Switching noise

- RFoG standards define on-off ramp up of return transmitter when a signal is detected from the Cable Modem.
- Following slides illustrate this and why it is important for overall system performance.
  - Ramp up and down times must be controlled within SCTE specifications
  - Measured impact of different CPEs with different on-off return laser performance
  - Impact upon individual QAM carrier when this burst control is not properly managed

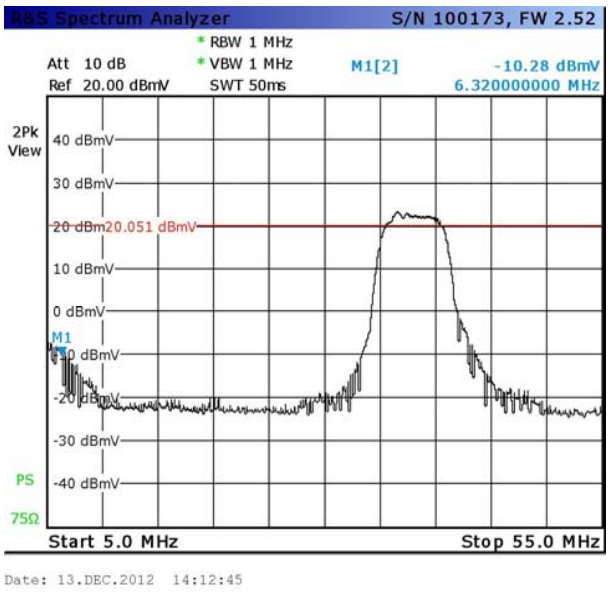
Reverse On/Off Specifications

Tightly controlled burst mode circuit and laser on/off parameters, including environmental variations

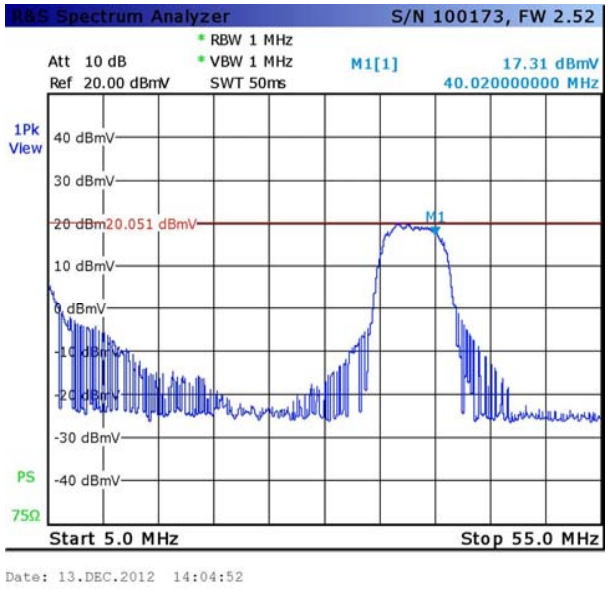


RF noise caused by laser turn on/off

CPE x



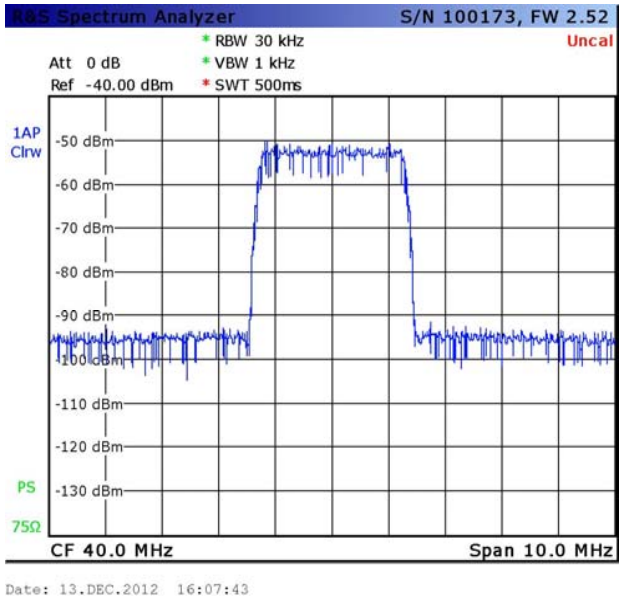
CPE y



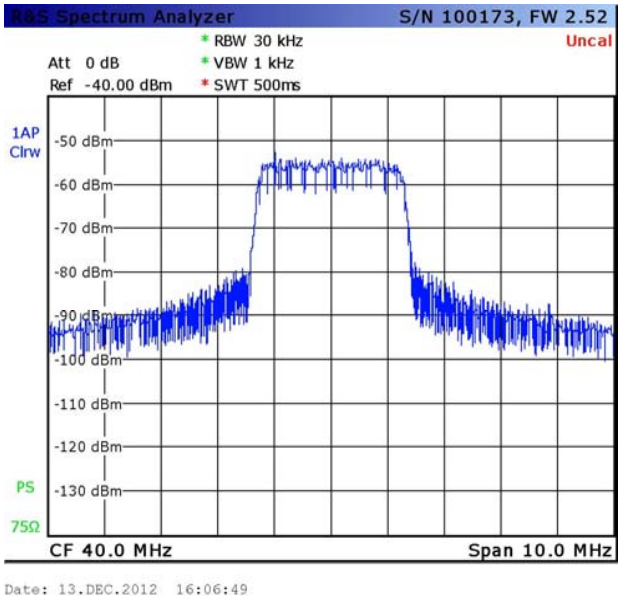
RF noise at Receiver output as result of poorly controlled Laser turn on/off

Side Band Spikes during Transmission

CPE x (Tightly controlled)



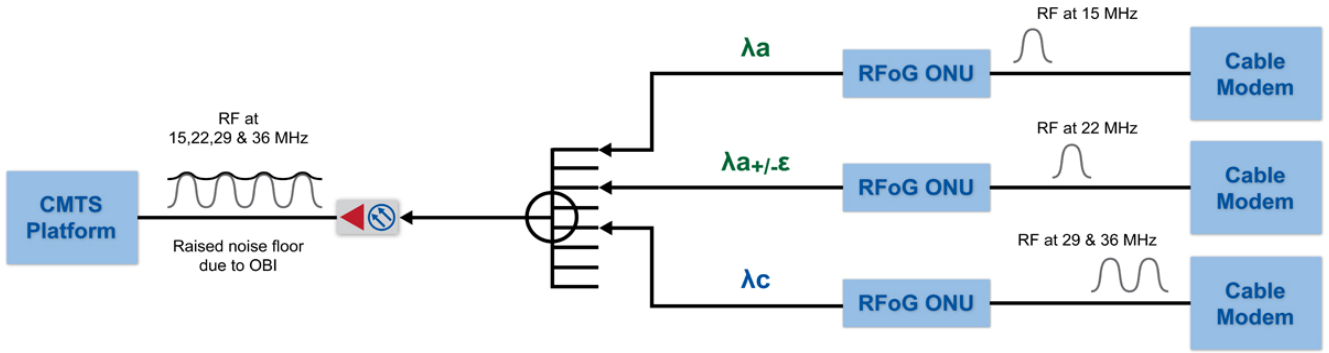
CPE y (Poorly controlled)



RF noise at Receiver output as result of power intensity variation in QAM carrier when the burst mode is not properly controlled

Optical Beat Interference: Cause and Effect

- OBI is caused when two transmitters with the same or very similar optical wavelengths transmit to the same optical receiver at the same time
- Occurs when two or more upstreams are used: multiple MAC domains, DOCSIS 2.0 and 3.0, separate VoIP and data links or other return systems
- It is a statistical probability event:
  - Occurrence increases with number of upstreams used, number of customers active and amount of data transmitted
  - Occurrence decreases with increased receiver count per upstream CMTS port



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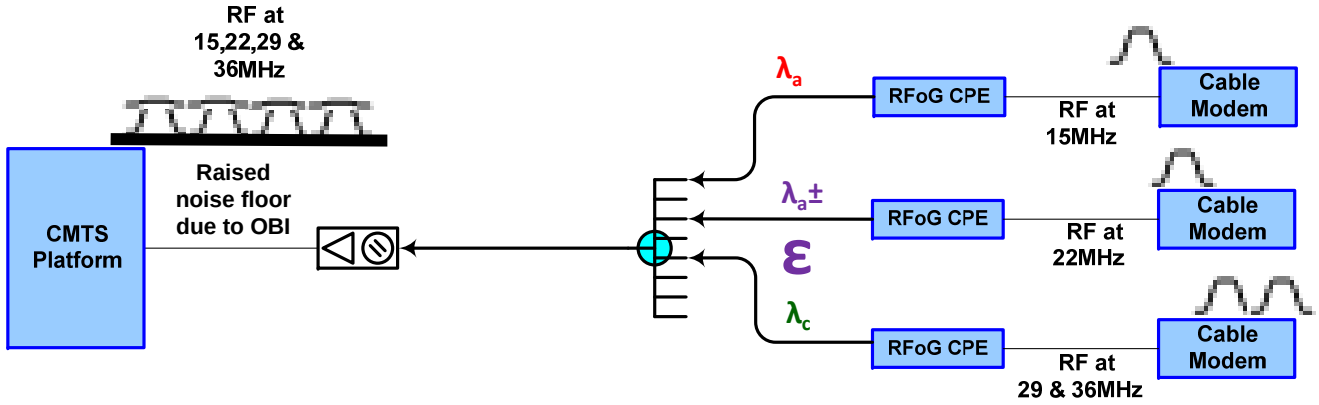
Optical Beating Interference (OBI)



Possible to have multiple ONUs transmit at same time…

- Disparate protocols or MAC domains in same receiver group
- Multiple DOCSIS MACs
- Set-top return
- Non-TDMA MAC protocols

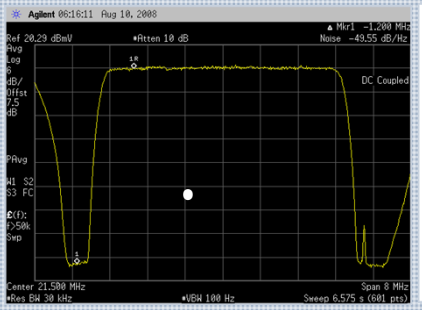
OBI – What is the impact?

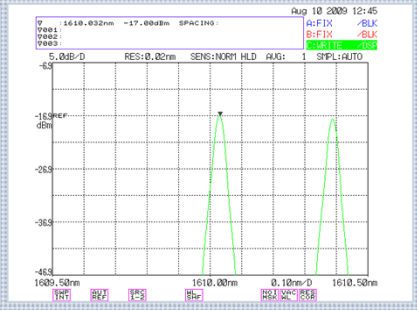
- When OBI occurs a full spectrum flat level noise signal is generated across the entire return bandwidth, the amplitude of the noise is a function of how close the optical wavelengths are together.
- It will completely block all the CMTS upstream ports connected to that receiver.
- Short duration effect, only occurs when the second transmitter is on.
- Will also cause code word errors in the CMTS upstream traffic. For efficient network performance these should be <1%
- Network Maintenance and fault response is critical.
  - A faulty CPU which is Always On can also cause it.
  - In extreme instances high levels of ingress noise can also cause it if of sufficient level to trigger return transmitter.

Optical Beating Interference (OBI)

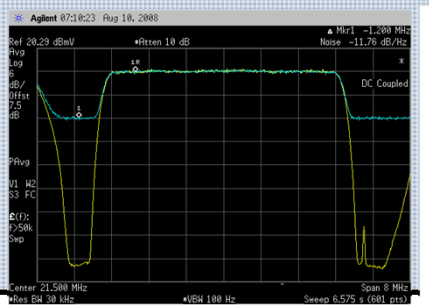
OBI induced with 2 optical transmitters

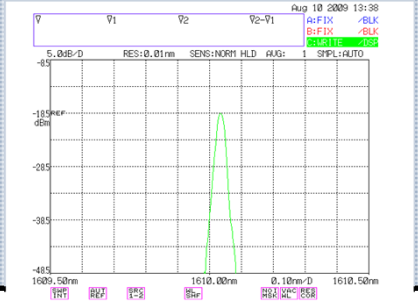
Performance not affected at >10 GHz separation between wavelengths





- Loss of synchronization at separations <1 GHz





Aurora incorporates temp stable DFB lasers without side modes to reduce probability of OBI

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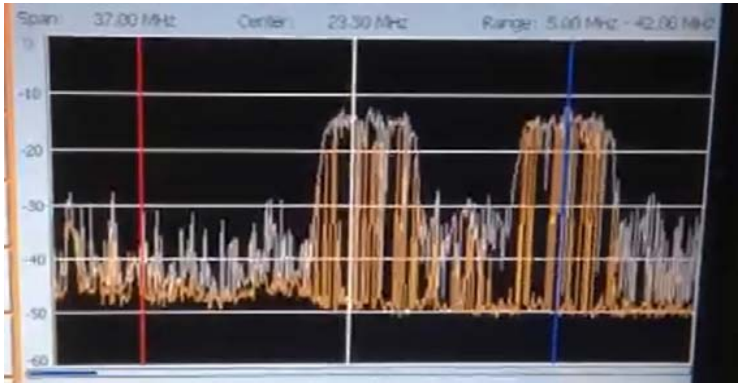
OBI – What does it look like?

5-42 MHz Span

Noise spectrum

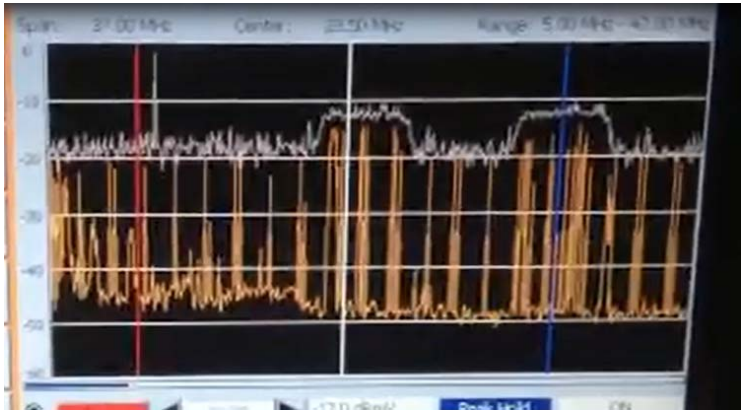
- No OBI
- Peak Hold

10dB / div



Noise spectrum

- With OBI
- Peak Hold
- Full spectrum distribution
- (One CPE on full time due to noise)



OBI in MDU Deployments

In MDU (multiple dwelling units) or fiber to the building (FTTB) applications a single device supports multiple customers.

- To maintain network segmentation size a reduced number of ONU devices deployed, each supporting multiple customers
- Each optical receiver in the Headend has lower number of ONUs connected.
- Upstream transmitters now active for extended periods to support multiple customers.
- When OBI occurs, its duration is longer and hence its impact upon data transfer is greater.

OBI-free

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Test Equipment, Tools and Optical Cleaners

- Optical power meter
- Digital multi-meter
- CATV signal level meter
- Portable upstream RF signal generator or combination SLM with upstream generator
- Spectrum analyzer or combination SLM
- TP4000 Test probe (adapter, GFA to F)
- Fiber optic connector cleaner
- Fiber optic connector scope
- Fiber test jumper
- Various hand tools

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