SCTE Golden Gate Chapter

Attempting to lift the Fog

RFoG Testing and Troubleshooting

December 11, 2014

Technical Session Overview

- RFoG Review
- Network Topography
- Tools of the Trade
- Testing and Troubleshooting
- Test Equipment Overview
- The Certified Installation

Advantages of RFoG and FTTH

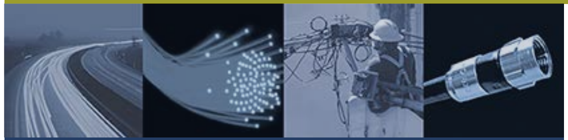
- No Return Path ingress concerns from the plant
- A reduced amount of actives in the network
  - Reduced utility bills
  - Reduced outages due to utility failures
- System Bandwidth capabilities increased
- Sweep and Balance not required
- Less of a chance for lightening damage, corrosion and electrolysis
- No CLI Flyovers, Ride Outs or POP needed
- Increased home and community value

Understanding the terms and Standards

- PON – Passive Optical Network
- APON – ATM PON (ITU-T G.983)
  - The first optical network standard
- BPON – Broadband PON (ITU-T G.983)
  - Is a standard based on APON with added support for WDM, dynamic and higher upstream bandwidth allocation.
- GPON – Gigabit PON (ITU-T G.984)
  - Supports higher rates, enhanced security and choice of Layer 2 protocol
- EPON – Ethernet PON (IEEE 802.3ah)
  - Is an IEEE/EFM standard for using Ethernet for packet data
- EDFA – Erbium Doped Fiber Amplifier
  - A device that boosts the signal in an optical fiber. An EDFA amplifies all the channels in a WDM signal simultaneously, whereas regenerators require optical to electrical conversion for each channel.

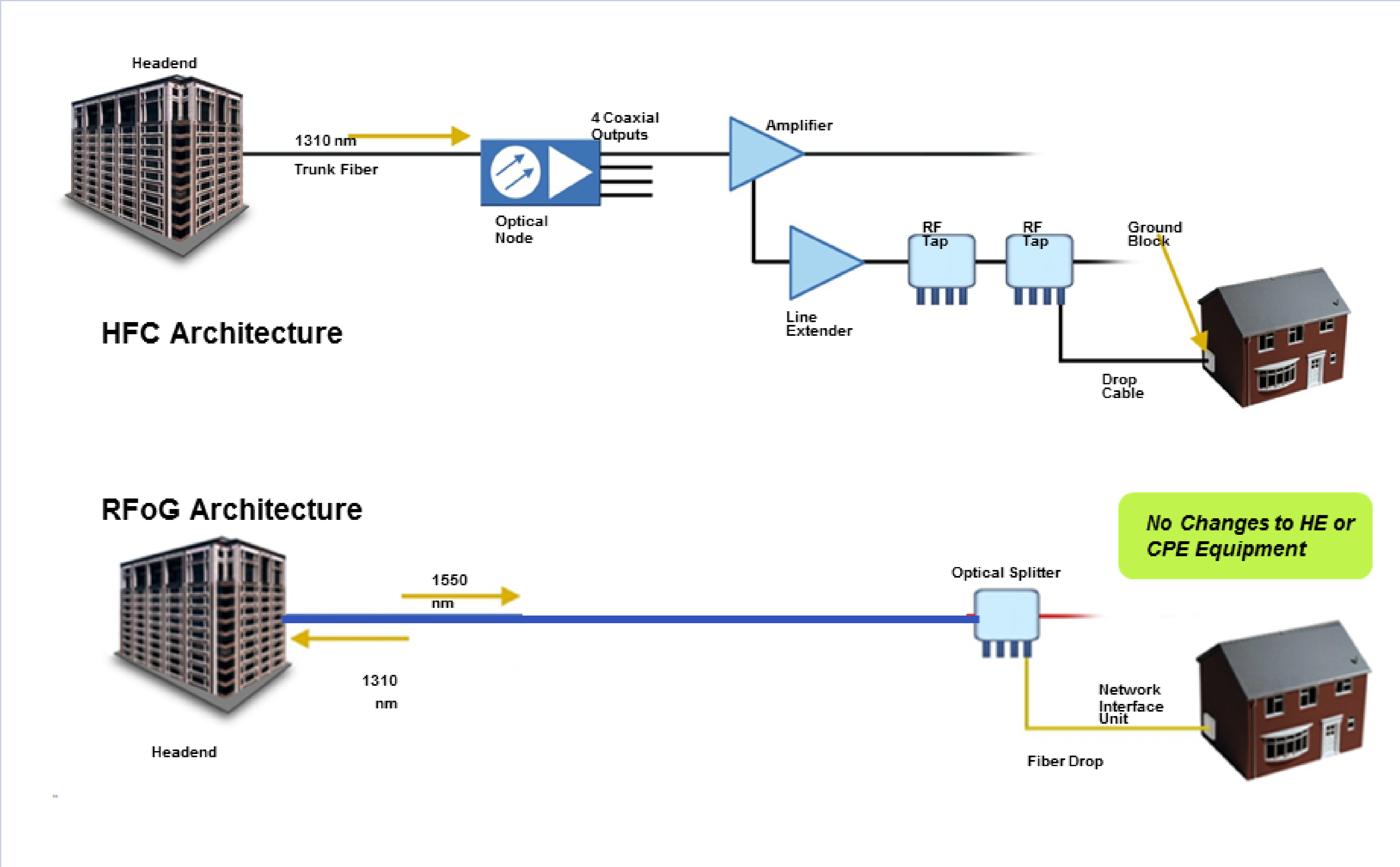
Understanding the terms and Standards

- RFoG – RF over Glass
  - Offers an FTTH PON like architecture for MSO's without having to select or deploy a PON technology
- FTTH – Fiber to the Home
- WDM – Wave Division Multiplexer
  - A technology which multiplexes a number of optical carrier signals onto a single optical fiber using different wavelengths. Conventional WDM systems provide up to 8 channels
- DWDM – Dense Wave Division Multiplexer
  - Uses the same transmission window but with denser channel spacing. a typical system would use 40 channels at 100 GHz spacing or 80 channels with 50 GHz spacing
- CWDM – Coarse Wave Division Multiplexer
  - Uses increased channel spacing to allow less sophisticated and thus cheaper transceiver designs.
- Virtual Hub
  - Fully operational hub in a standard node housing

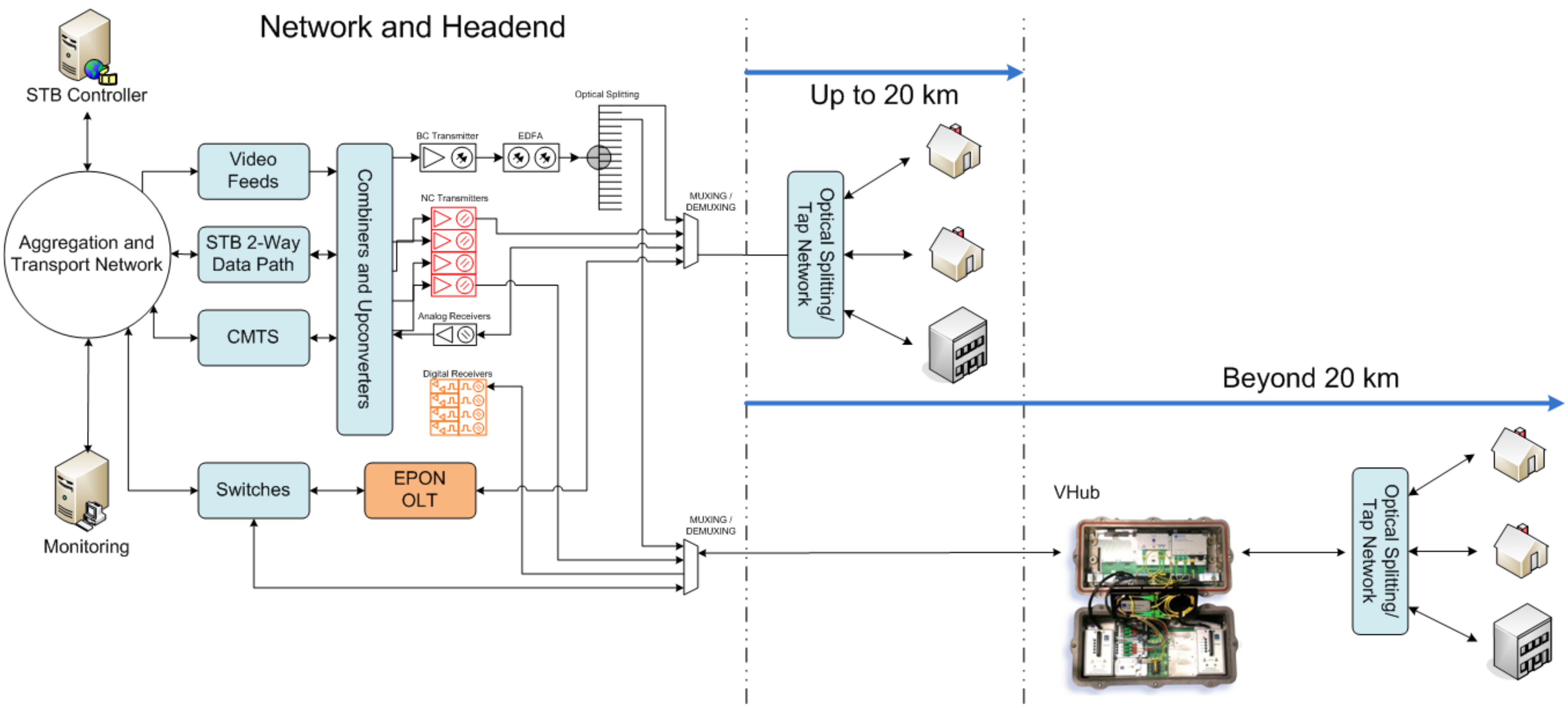


Network Topography

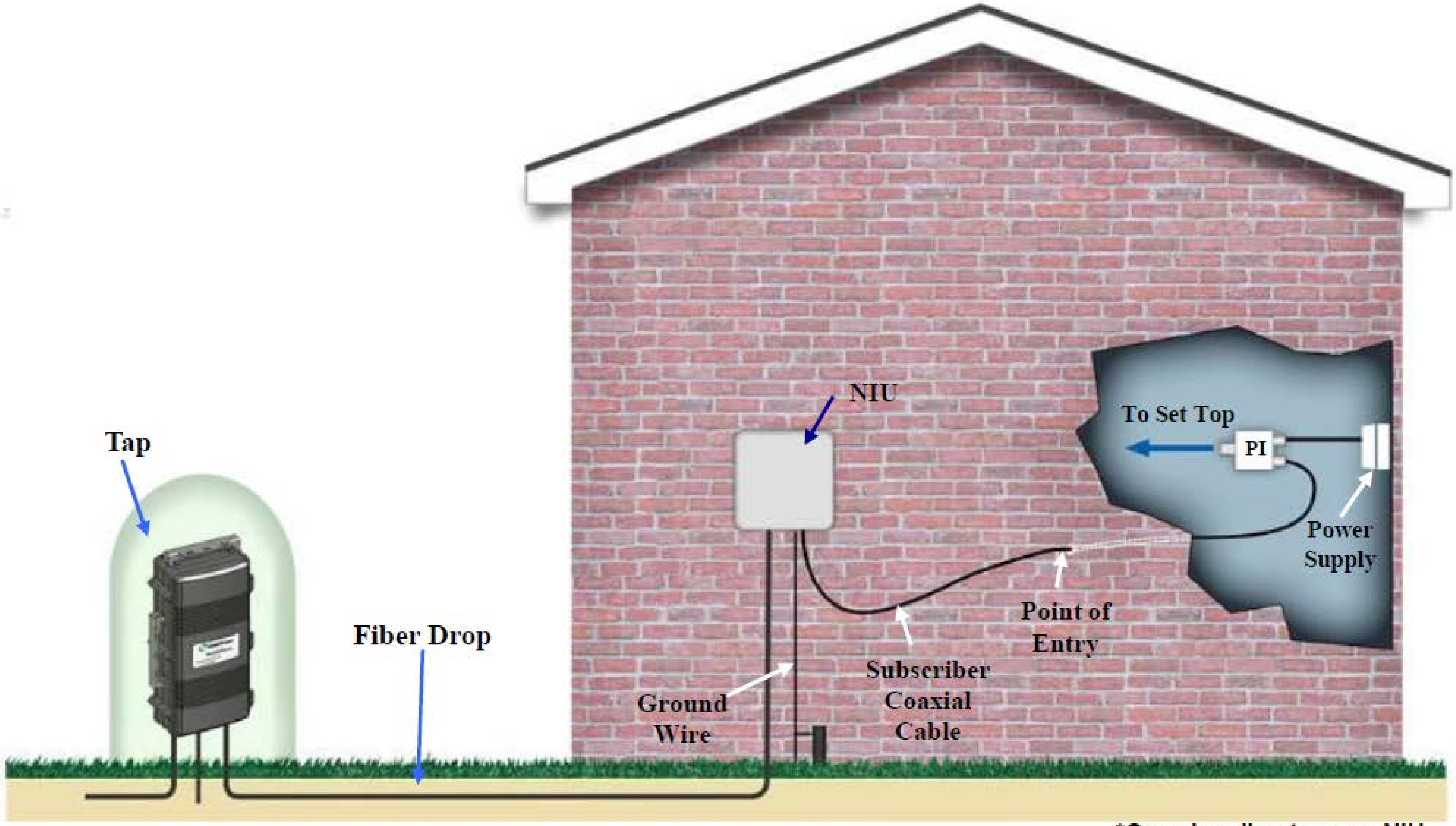
Comparing RFoG to HFC



RFoG Topology Passive and Active



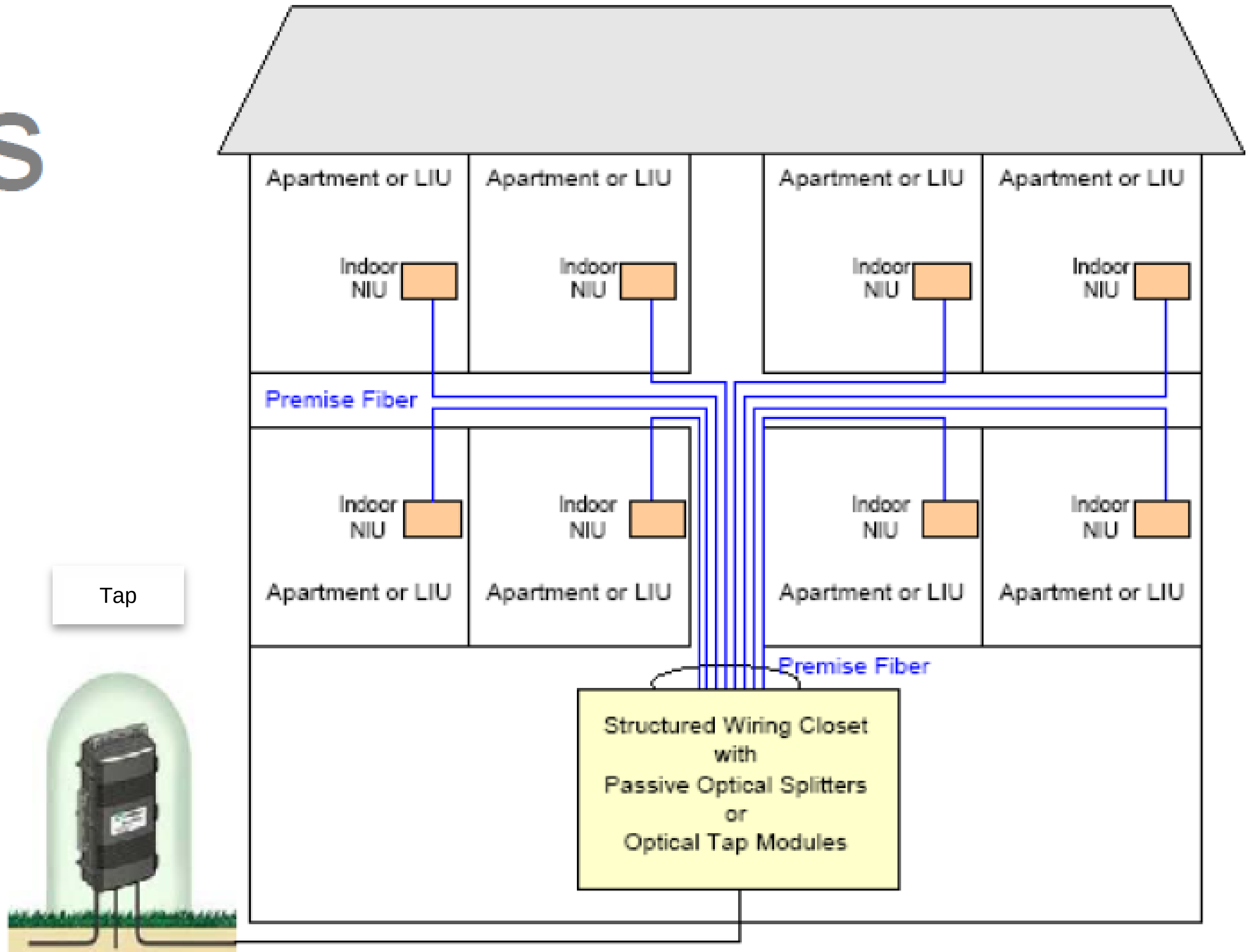
RFoG at the Premise



*Can also direct power NIU

MDUs

Taps May Be Placed
“Off Campus”



Tools of the Trade

RFoG Tools of the Trade

RF Testing

- Digital multi-meter
- CATV signal level meter
- Upstream RF signal generator
- Spectrum analyzer

Fiber Optic Testing

- Optical Power Meter (OPM)
- Optical Loss Test Set (OLTS)
- OTDR (In/Out of service)
- Fiberscope Inspection
- Fiber connector cleaner & jumper

Testing and Troubleshooting

Why is testing important???

- After the fiber optic cable is installed, it needs to be tested for four basic reasons
  - To ensure the fiber optic cable plant was properly installed to specified industry standards
  - To ensure the equipment intended for use on the cable plant will operate properly on the cabling
  - To ensure the communications equipment is working to specifications
  - To document the cable plant and network for reference in case of future problems

One of the Most Important Steps

- Connectors must be clean!!!
  - Whenever a connection is made, there is a chance that contaminants will be present
  - Dirty connections will cause high loss and reflectance
  - Protective caps on the connectors, are often called “dust caps” – some say that’s because they usually contain dust. It does not necessarily keep the connectors clean
  - Clean both sides of the connection
  - Only use cleaning supplies intended for cleaning fiber optic connectors

What Can Go Wrong???

- Fiber optic cables installed properly will give you years of error free performance
- It is important that time and care is taken during the installation/construction phase
- Some of the problems that are caused by installation practices include:
  - Damage to the cable during installation, caused by improper pulling techniques (not pulling by the strength member), excessive tension, tight bends under tension, kinking or too many bends
  - Damage to the fibers in the cable during cable preparation for splicing or termination. Fibers may be broken or cracked during cable jacket or buffer tube removal or fiber stripping
  - High loss splices caused by improper splicing procedures, especially poor cleaving on mechanical splices or improper programing of fusion splicers
  - High loss connectors may be caused by bad processes or damage after termination. Adhesive/polish connectors may have poor end finishes or cracks in the fiber at the end of the ferrule or internally.

Before the Construction/Installation

- Test all cables as received on the reel for continuity using a visual tracer or fault locator
  - Cables showing signs of damage in shipment may need OTDR testing to determine if the cable itself is damaged
- Test the insertion loss after installation
  - All cables should be tested for insertion loss using a light source and meter or OLTS (optical loss test set)
  - Test cables individually (connector to connector for each terminated section of cable) Then the complete linked together cable plant is tested “end-to-end”, excluding the patch-cords that will be used to connect the instrument which are tested separately
  - It is the end-to-end test that is used to compare to the link power budget
  - Insertion loss testing should be done at the appropriate wavelength
  - Data on insertion loss of each fiber should be kept for future comparisons
  - Long cables with splices may be tested wit an OTDR to confirm splice quality and detect any problems caused during installation

Troubleshooting

- First determine if the problem is with one or all of the fibers in the cable
  - If all fibers are impacted there is a likelihood of a severe cable installation problem
  - If all of the fibers are broken or have a high than expected loss, an OTDR will show the location
  - If the problem is caused by kinking or too tight a bend, the cable will have to be repaired or replaced

Troubleshooting continued

- High loss fibers have several potential causes but bad splices or terminations are the most likely cause for field terminated cables
  - Test high loss fibers first with a microscope inspection of the terminations
  - If dirt appears to be the problem, clean the connectors and retest
  - If other damage is found on visual inspection, retermination will probably be necessary
  - Some connectors have a translucent backshell and can be tested with the VFL (Visual Fault Locator)
  - Fibers showing very high loss or no light transmission at all should be tested for obvious breaks in the pig tail fiber or cable, generally at the splice or connector, with a VFL or high resolution OTDR if the cable is of sufficient length

Troubleshooting continued

- Splice loss problems can be pinpointed during OTDR testing. Confirmation with a VFL should be done if the length from the end of the cable is short enough (~2-3km) where a VFL is useable.
- High loss links where the excessive loss is only a few dB can be tested like a patchcord with a single-ended test with a light source and power meter. When testing in this manner, a high loss connector will show high loss when connected to the launch cable connector but not when connected directly to the power meter

- Having access to design specifications and installation documentation will greatly assist in troubleshooting

Testing and troubleshooting Patchcords

- Most patchcord problems are connector problems, caused by damage due to handling or numerous matings when used as a reference cable
  - All patch cables, especially those used as a reference cable should be tested for insertion loss
  - Patchcords should be tested with an optical loss test set or optical power meter and light source
  - After testing in one direction, reverse the patchcord and test the other end
  - Check in both directions, factory-made patchcords should have a loss of less than 0.5 or whatever performance was specified with the vendor

Testing and troubleshooting Communications equipment

- After the cable plant has been tested, the communications equipment should be properly connected using matching known-good patchcords
- If the cable plant loss is within the loss and within the loss budget of the equipment (including the loss of the patchcords), the communications link should work
- If the link does not work the most likely potential problem is from improper connections
- The system requires a transmitter be connected to a receiver, so it is important to verify this connection. Even if the cable plant is properly documented, fibers may have been crossed

Testing and troubleshooting Communications equipment

- Testing the communications equipment (node, virtual hub, etc.)
  - If it is connected to the cable plant but not operating properly, begin by checking the power at the receiver on one end of the link
  - Measure the power with an optical power meter. Make sure that the equipment is trying to transmit a signal. Some equipment has a testing mode to force transmission of a test signal
  - If the receiver power is within specifications, the receiver or electronics beyond the link may be the problem
  - If the receiver power is too high, it may be overloading the receiver and an optical attenuator should be inserted at the receiver end
  - If the receiver power is lower than required by operating specifications, the cause is either low transmitter power or too much loss on the cable plant

Testing and troubleshooting Communications equipment

- To test transmitter power, disconnect the patchcord connecting the transmitter to the cable plant and measure the optical power. If the power is low, there is a problem with the transmitter or patchcord
- To determine which is the problem try testing the transmitter with a known good patchcord. If the optical power is within spec, replace the bad patchcord and test again
- If the transmitter power is low with the known good patchcord, the equipment may need maintenance (cleaning) of the output port or replacement
- If the transmitter tests as good but receiver power is low, the problem is probably in the cable plant. First try to switch communications to a spare dark fiber to see if that solves the problem. Next test the loss of the suspect fibers in the cable plant with an OLTS to determine if the cable plant loss is excessive

Cable Plant Problems

- High loss in the cable plant can be caused by damage after installation and testing. Use a visual tracer or visual light source to confirm continuity and an OLTS to test loss.
- If the cable plant is long enough (>100m), it can be tested with an OTDR to pinpoint problems
- Singlemode links may suffer from problems caused by reflections at connectors or mechanical splices
- Reflections in singlemode terminations or splices near the source may cause nonlinearities in the laser transmitter which distort pulse shapes, causing high BER
- Reflections near the receiver or at both ends can cause multiple reflections in the cable that create optical noise that also causes BER
- Reflections can be tested if the cable is long enough (>100m) with an OTDR
- Highly reflective connectors or splices should be replaced

Test Equipment Overview

Fiber Connector Inspection

Fiber Scopes Applications

- Fiber Inspection Scopes provide a magnified image of fiber optics connectors' End Face, focusing on the contact areas (prone to loss or damage by mating)
  - End-face contamination is a leading cause of fiber failures in data centers, corporate networks, MSO and Telecom environments
  - Images, visual inspection and automated tools are used to grade the health and cleanliness of connectors, after polishing or cleaning and before being used

- Dirty or scratched connectors introduce loss, increase ORL and/or damage other connectors (Loss becomes more critical at higher data rates)
  - Dirt is even a bigger concern in applications that use high-power lasers
  - Male and Female connectors must be inspected before mating
- Test Gear Vulnerabilities
  - Opposed to permanent or semi-permanent connections found in network environments, “promiscuous” Test Equipment and their patch cords connect to multiple devices on a daily basis, increasing the chances to damage or get damaged
  - Extra care must be taken. Not only to avoid potentially expensive damage but to make sure that any tests and their results remain valid
  - Bad fiber or dirty/damaged connectors can result in false Anomalies, Defects or Errors

The Verification Experts

Visual Inspection Requirements

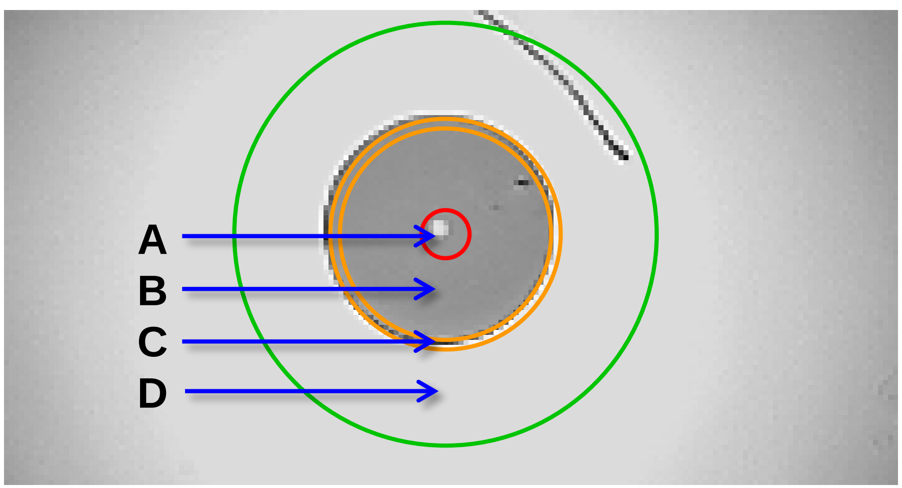
IEC 61300-3-35 Sect 5.4 (i)

- SMF (RL ≥ 45 dB)

ZONE	Scratches	Defects
A: Core	None	None
B: Cladding	None > 3 µm No limit ≤ 3 µm	None ≥ 5 µm 5 from 2 to 5 µm No limit < 2µm
C: Adhesive	No limit	No limit
D: Contact	No limit	None ≥ 10 µm

- MMF (RL ≥ 45 dB)

ZONE	Scratches	Defects
A: Core	None	4 if ≤ 3 µm
B: Cladding	None > 5 µm No limit ≤ 5 µm	None ≥ 5 µm 5 from 2 to 5 µm No limit < 2µm
C: Adhesive	No limit	No limit
D: Contact	No limit	None ≥ 10 µm



- It is critical that the Contact zones are free of particles and contaminants
  - Dirty connectors can contaminate and damage other connectors on contact
- In Practice
  - Inspectors may look beyond the contact zone (D) to evaluate overall cleanliness and workmanship

Visual Inspection Requirements

IEC 61300-3-35 Sect 5.4 (ii)

- Scratch requirements refer to their width
- Visible sub-surface scratches in core and cladding are NOT allowed
- All loose particles must be removed. Debris can cause significant back reflection, insertion loss and fiber damage
  - If defects are not removable, the defect must be within the criteria listed earlier, in order to be acceptable for use
  - Debris can come from: Mishandling, touching (oils), dust, lint, condensation or evaporation deposits, poor wiping technique, contaminated alcohol, contaminated caps, not using connector caps, etc.
  - Note: Connectors caps are often manufactured from materials that produce contaminants
- Hard debris can scratch connectors upon mating
- There are no requirements for the area outside of the contact zone since defects are in this area have no influence on the performance
  - However, cleaning loose debris beyond the contact region is a recommended good practice

Visual Inspection Requirements

IEC 61300-3-35 Sect 5.4 (iii)

Recommendations

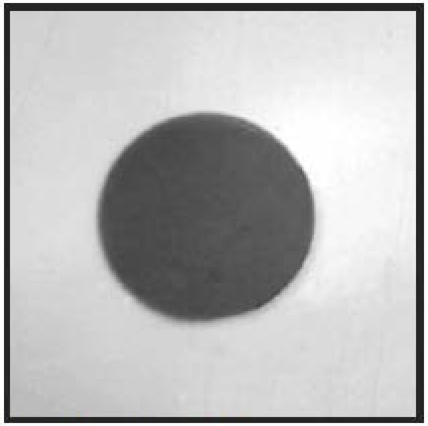
- Always inspect both connectors before mating
  - Patch cords can be easily replaced – Damaging equipment can be very expensive!
- Never assume that cables, connectors, bulkheads or pluggable optics are clean, just because they are brand new
- Learn and Master the cleaning techniques and tools adopted by your company
  - Know when to use each cleaning tool or method (the kit may include more than one)
- Clean and inspect again
- Carefully cap connectors and bulkheads before storing or moving test gear and cables

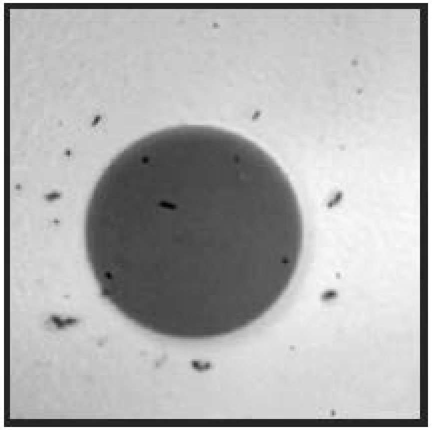
Digital Fiber Inspection Scope

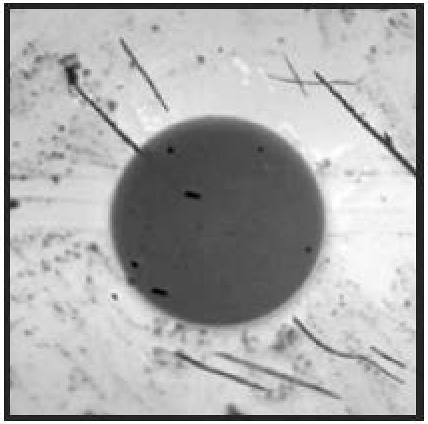
- Basic layout of a fiber scope
  - Focus Knob
  - Changeable Tips
  - Capture Button

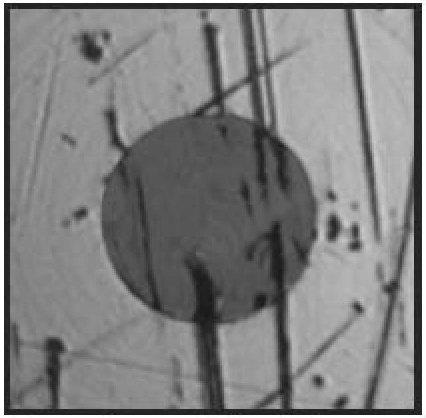
Viewing Fiber Ends

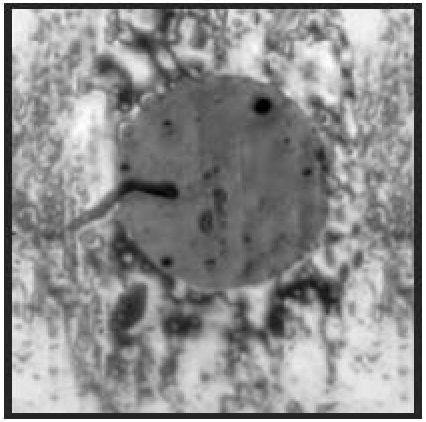
- After the focus is complete, the magnified view will reveal the condition of the core and cladding.


Excellent condition


Uncleaned, lint or dust


Scratches and dirt


Severely scratched face


Cleaning residue, water or alcohol

OTDR

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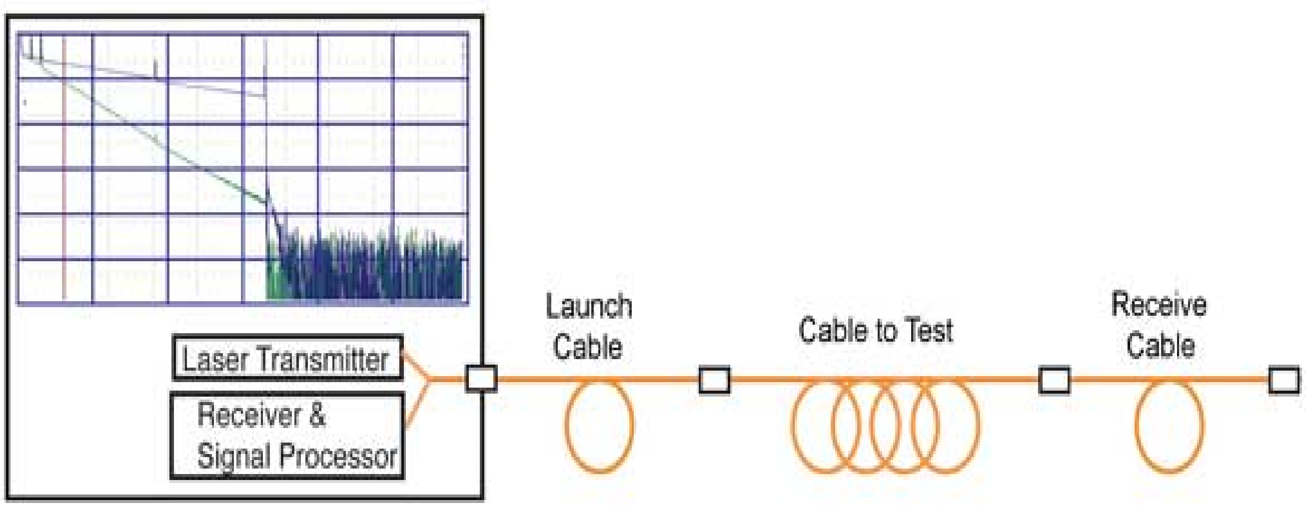
Testing a Fiber Optic Cable

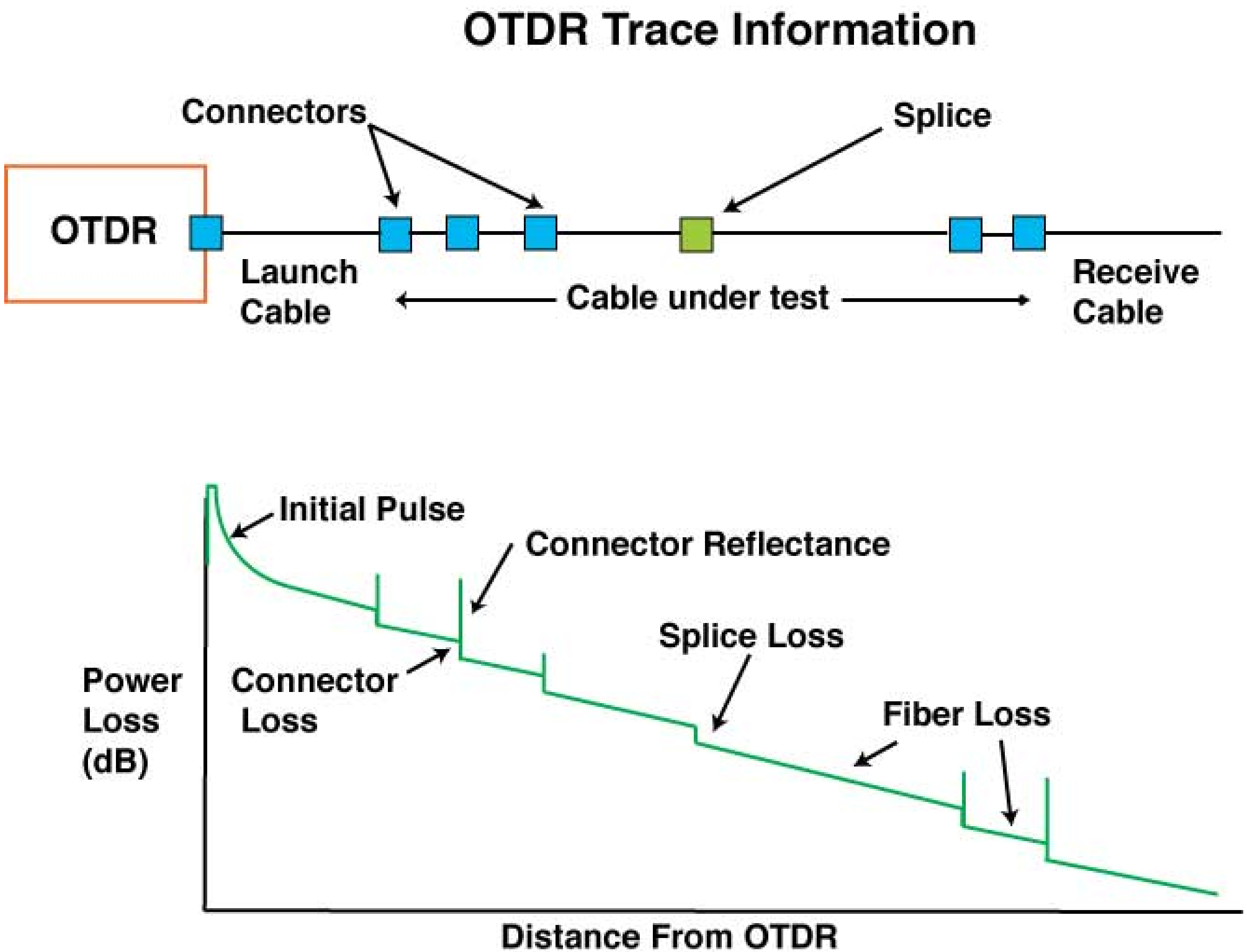
- Using an OTDR will acquire a trace of an installed fiber optic cable plant, single mode or multi mode, including the loss of all fiber, splices and connectors
- You will need the following equipment to perform this test
  - OTDR appropriate for the fiber being tested
  - Launch and receive cables (for testing the length, you only need the launch cable)
  - Mating adapters compatible to the connectors
  - Cleaning supplies



OTDR Test Procedures

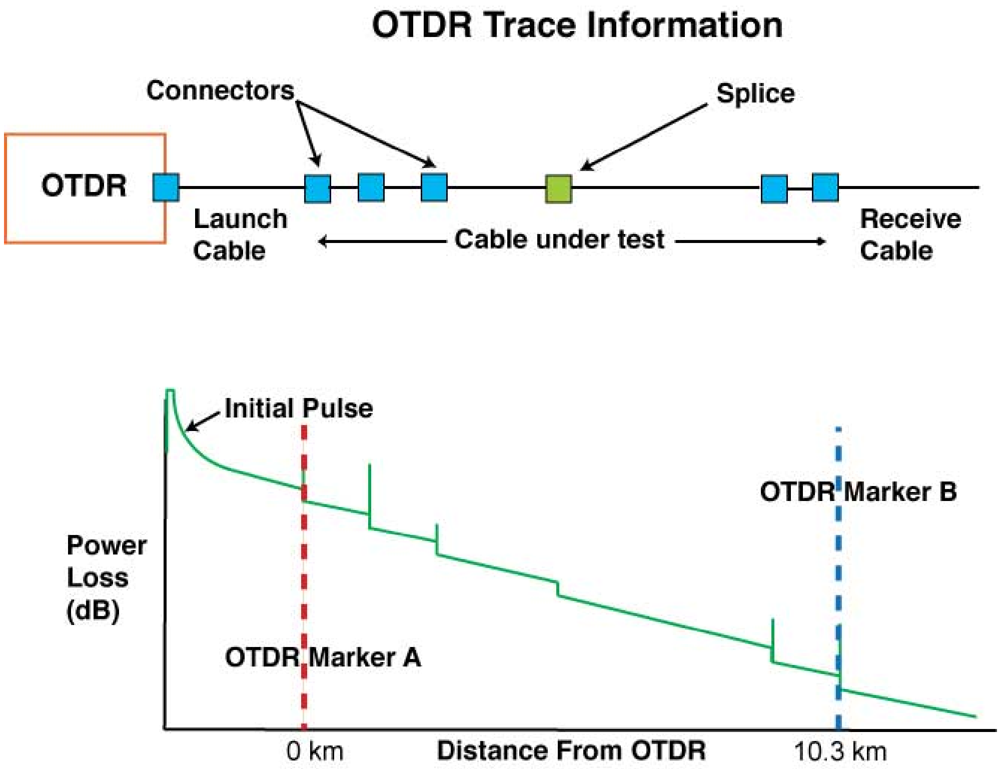
- Turn on the OTDR and allow time for warm-up
- Clean all connectors and mating adapters
- Setup test parameters on OTDR
- Attach cable to test end of launch cable and receive cable if used
- Acquire the trace
  - Most OTDRs have an “auto test” function, but these functions are not foolproof. Most problems with OTDR tests occur when an untrained user uses the auto test function without having an understanding of how the instrument works, what a good trace looks like and what are the characteristics of a cable plant (length, number and locations of splices and connectors)

Reading OTDR traces



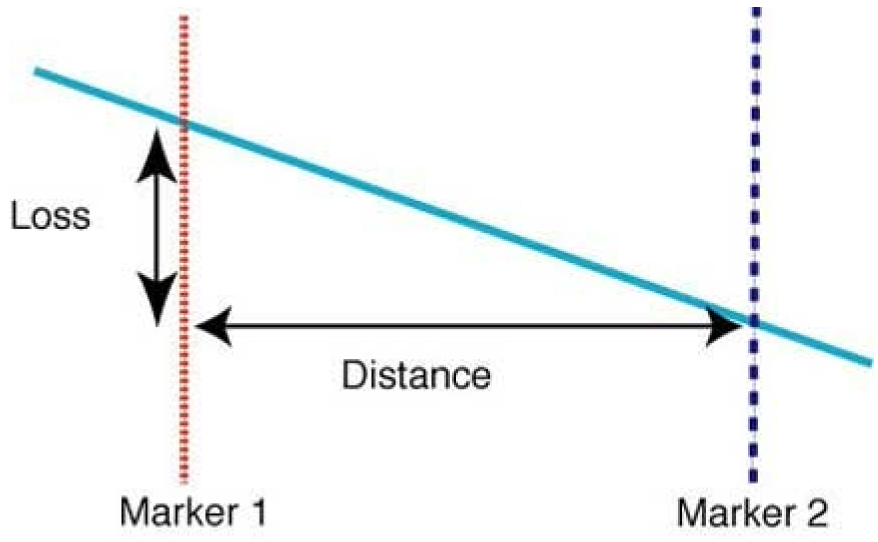
Measuring distance with the OTDR

- Place one of the markers just before the reflectance peak from the connection between the launch cable and the cable under test
- Place second marker just before the reflectance peak from the connection between the cable under test and receive cable
- The OTDR will calculate the length of the segment between the markers



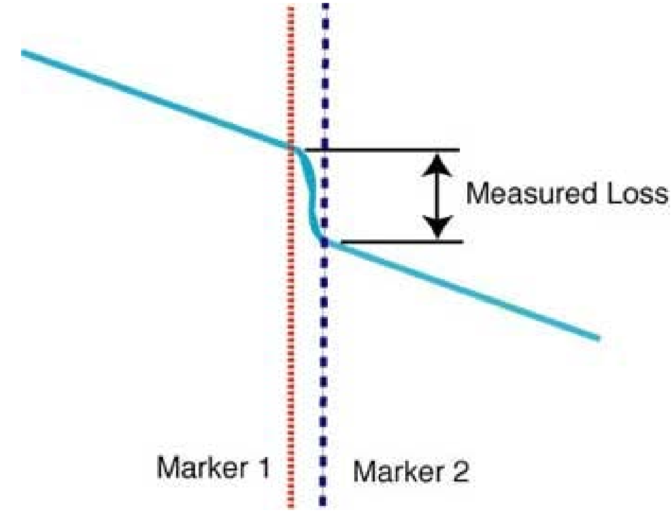
Measuring Fiber Attenuation Coefficient

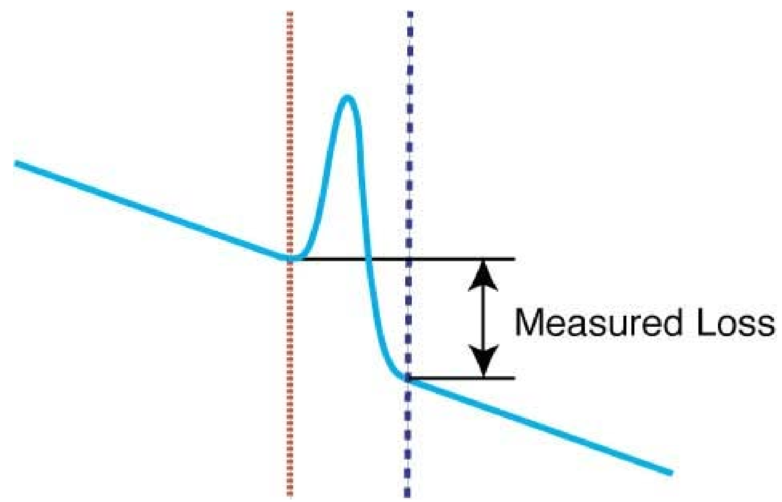
- Place one of the markers on the fiber segment to be tested away from any splice or connection in the cable under test
- Place the second marker further away on the same segment
- The OTDR will calculate the loss between the markers



Measuring Splice or Connector Loss

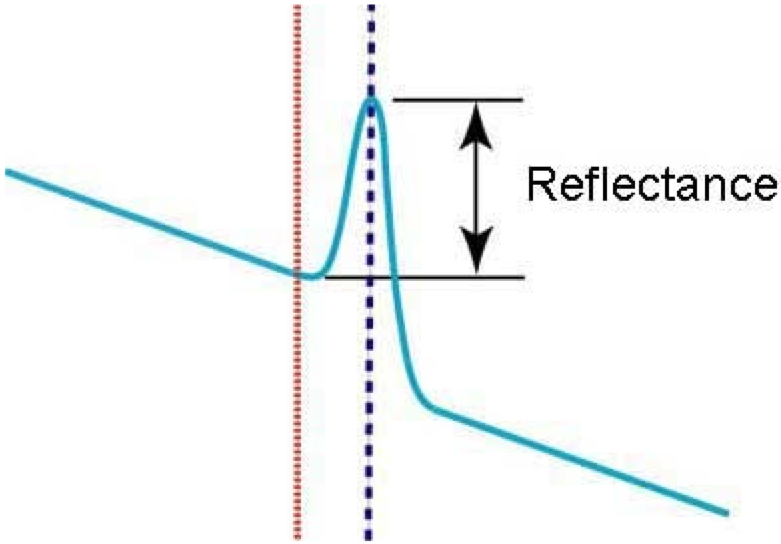
- Ensure that markers are not placed on curved parts of the trace which will cause erroneous readings
- Place one of the markers just before the splice or reflectance peak from the connection in the cable under test
- Place the second marker just after the splice or the reflectance peak from the connection in the cable under test
- The OTDR will calculate the loss of the segment between the markers





Measuring Reflectance

- Place one of the markers just before the reflectance peak from the connection in the cable under test
- Place the second marker at the top of the reflectance peak from the connection in the cable under test
- The OTDR will calculate the reflectance of the peak chosen by the markers



Power Meter

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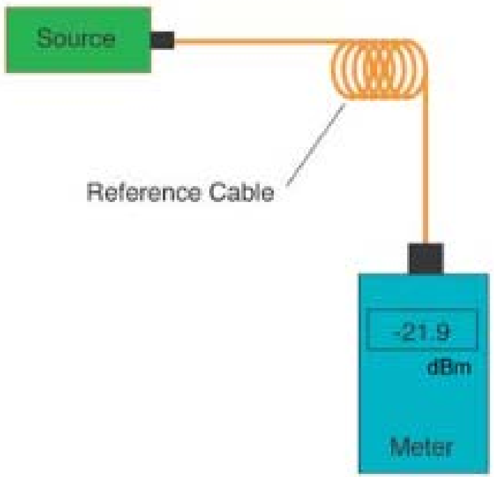
Optical Power Meter

- The most basic fiber optic measurement is optical power from the end of the fiber
- This measurement is the basis for loss measurement as well as the power from a source presented at a receiver
- Measuring the power of a transmitter is done by attaching a test cable to the source and measuring the power at the other end



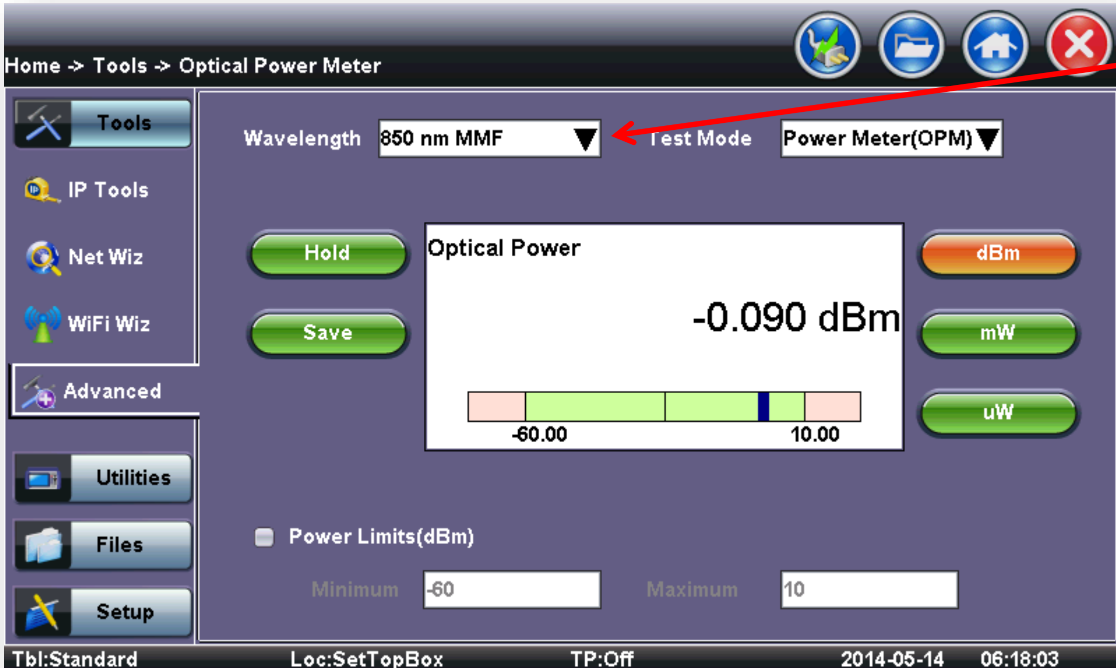
- Below are typical optical power levels

Network Type	Wavelength, nm	Power Range, dBm	Power Range, W
Telecom	1310, 1550	+3 to -45 dBm	50 nW to 2mW
Datacom	650, 850, 1300	0 to -30 dBm	1 to 100uW
CATV, DWDM	1310,1550	+20 to -6 dBm	250 uW to 10mW

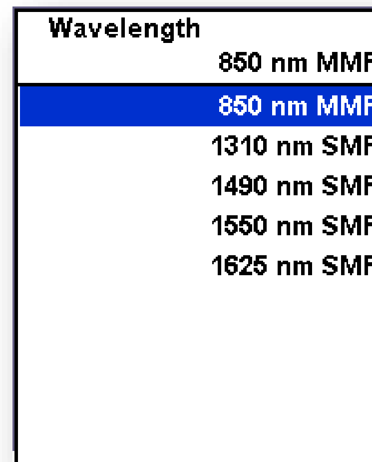
Measurement Units dB or dBm

- Whenever test are performed on fiber optic networks, the results are displayed in dB.
  - Optical loss is measured in dB
  - Optical Power is measured in dBm
- When we make fiber optic measurements, we are measuring the power in the light we measure
- Optical loss is a ratio of two power levels, one of which is considered the reference value
  - dB is a logarithmic scale
  - When we have loss in a fiber optic system, the measured power is less than the reference, so the ratio of measured power is less than 1 and the log is negative, making dB a negative number
- Measurements of optical power is expressed in units of dBm
  - The “m” in dBm refers to the reference power which is 1 milliwatt
  - A source with a power level of 0dBm has a power of 1milliwatt. Likewise, -10dBm is 0.1 milliwatt and +10dBm is 10 milliwats

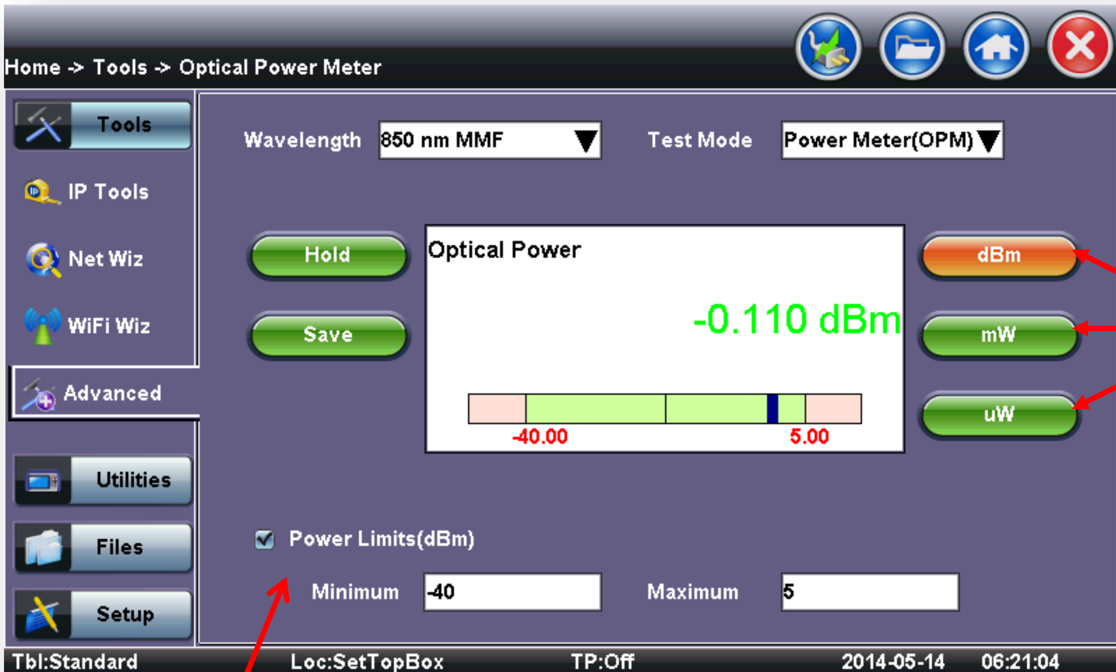
Optical Power Meter Measurement



- **Wavelength**: Choose per your system:



Optical Power Meter
Other Setup Items



- Change measurement units

- **Power Limits**: define a visual pass range. Set the Minimum and Maximum values

Optical Power Meter
Loss Meter

- Change **Test Mode** to Loss Meter

Certified Installation

Benefits of a Certified Installation

- Maintain High Performance of Signals
- Provide High Level of Signals Reliability
- Preserve the Integrity of Drop & Cabling
- Reduce Repeated Truck Rolls
- Reduce Service Calls
- Creating Workforce Database
- Enhancing Customer Satisfaction

Subjective & Objective Procedures

- Drop must be properly bonded
- Proper identification tagging on the drop near tap
- Pedestal must be locked
- Routing and attachments follow industry installation guidelines
- Fiber optic connectors must be clean

Subjective & Objective Procedures

- Drops must be free of splices
- All digital STB must be checked to make sure they are responding
- Inspect the in home network wiring, tighten connectors
- All external drop splitters must be sheltered with a SDU house box
- Home Certification measurements must be in compliance with company’s procedures and standards

The Verification Experts

Questions???

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