

# FTTH NETWORK TESTING: REAL APPLICATIONS USING THE OLTS METHOD

# 157

## APPLICATION NOTE

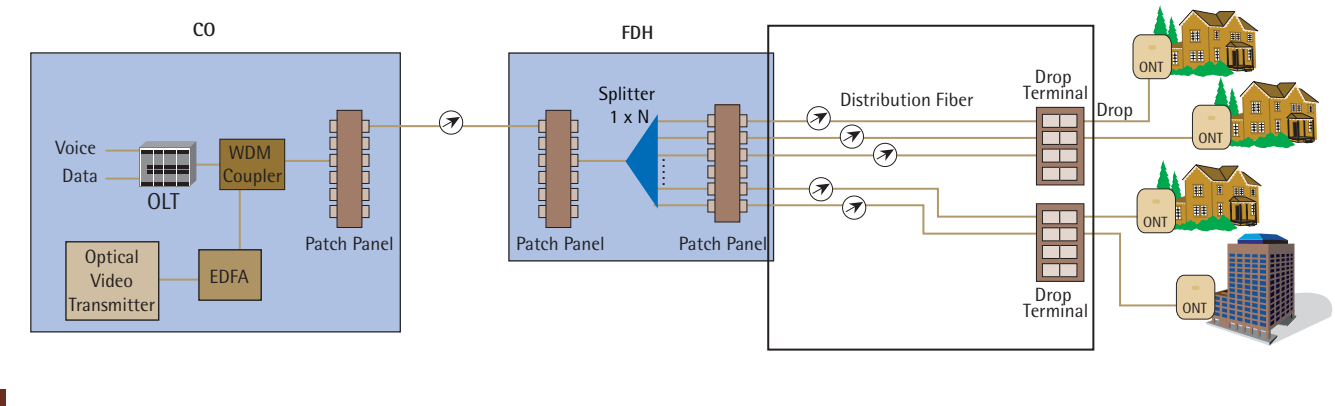
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The purpose of any fiber-optic network is to perform high-speed, error-free data transmission. Adequate testing during network installation minimizes costly and time-consuming troubleshooting efforts by locating faulty components before they disrupt service.

This article discusses the main aspects of FTTH PON construction testing through real case studies. The object of this paper is not only to introduce the theoretical principles behind the test method, but also to show real test results obtained from typical networks operating in different conditions and exhibiting both normal and problematic circumstances.

### Construction Testing: Two-OLTS Method

During the construction of an FTTH network, part of the testing occurs at the outside-plant level. This is when the distribution fibers need to be tested, as they are one of the last fiber links before the customer premises.



Although there are many ways of testing distribution fibers, the method described below uses two optical loss test sets (OLTSs). Here is an overview of its advantages and disadvantages:

Advantages	Disadvantages
Accurate IL and ORL measurement	Two technicians required
Transposed fiber identification	Communication required between technicians (when switching to another fiber)
Bidirectional IL and ORL values	One technician needs to move from drop terminal to drop terminal
Possible to test every distribution fiber	In case of a cut fiber or macrobend, an OTDR is required to locate the fault
Future-proof deployment	
Macrobend identification during testing is performed at 1550 and 1310 nm or at another combination of wavelengths, one of which is 1625 nm	

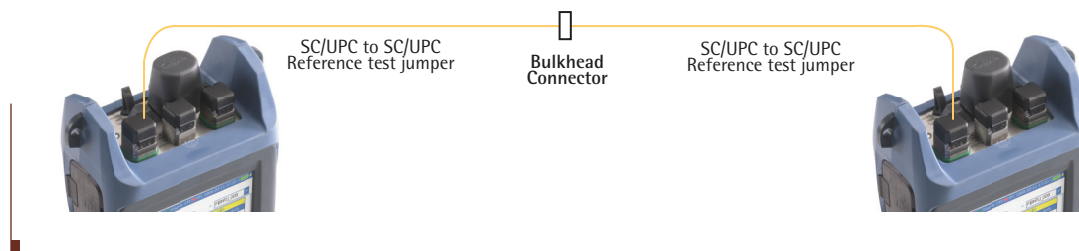
When using OLTS-based methods, it is important to follow the manufacturer's instructions to set the optical return loss (ORL) sensitivity of the test set and to reference the source and the power meter. Once this is done, testing can begin. The ORL measurement is crucial when dealing with high power such as analog video transmission. When the ORL is too high, it could have several undesired effects:

- Strong fluctuations in laser output power
- Potential permanent damage to the laser
- Interference at the receiver end
- Distortions in analog video signals
- Higher BER in digital systems

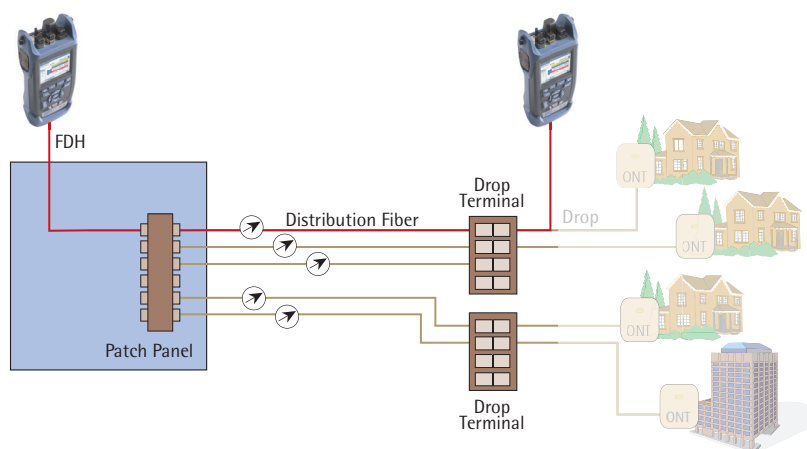
This basic method involves using an OLTS that can share data between two test sets to measure insertion loss (IL) and ORL. First, ORL sensitivity must be set by calibrating the minimum ORL that can be measured by the unit. The limitation comes from the weakest part of the test setup, which would most likely be the connector between the units and reference test jumper. ORL sensitivity should be set on both units.



Then, the two units should be referenced prior to measuring IL.



At this point, measurements can be performed on the distribution fibers between the fiber distribution hub and the drop terminal. The purpose of this test is to identify the transposed fiber and measure the IL and ORL to make sure that the loss budget is met and the ORL is at an acceptable level.

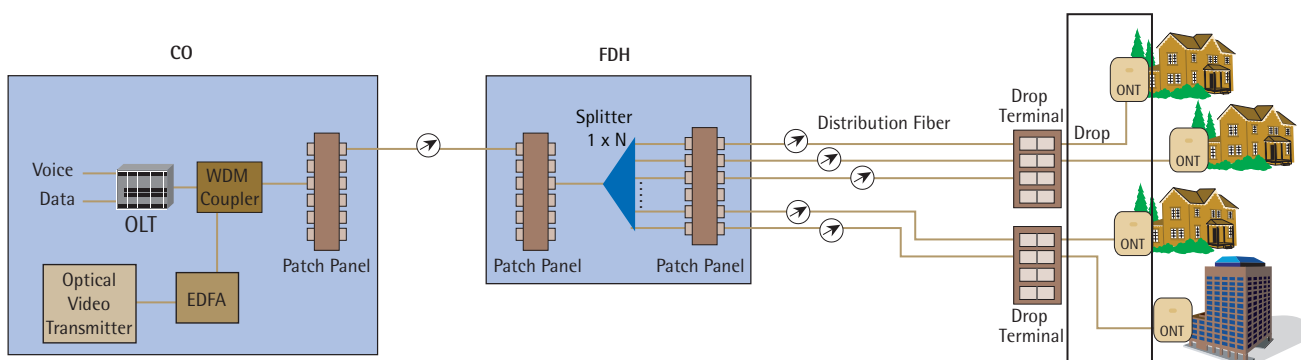


Measuring distribution fiber IL and ORL using a pair of OLTSs

When a fault is identified (other than a transposed fiber) the OLTS will be replaced by the OTDR to not only identify the fault but locate it as well.

### Testing the Feeder Fiber and Newly Activated Splitter Modules

The other part of the outside plant to be tested is the feeder fiber. This could be done with either an OTDR or an OLTS.

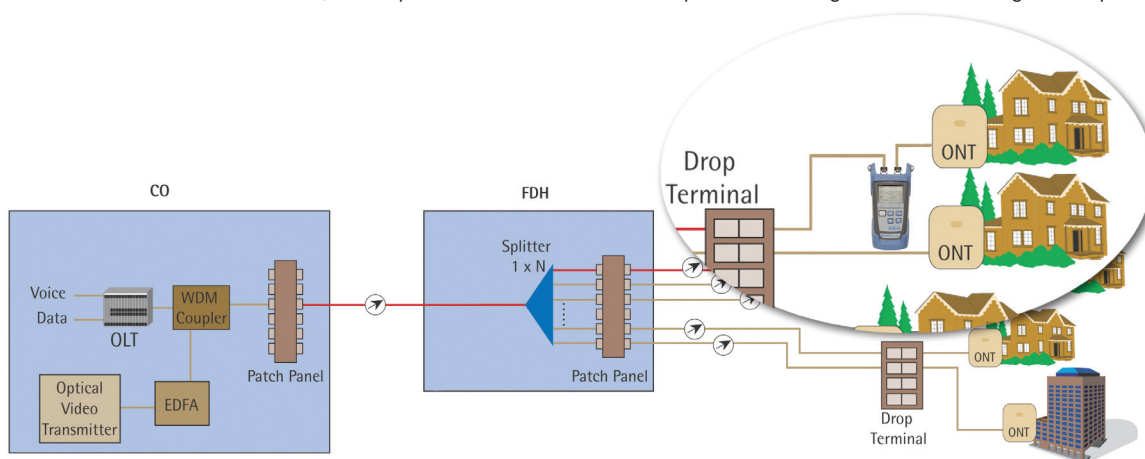


Testing the feeder fiber

Since the feeder fiber indeed consists of a single fiber, this is a basic test. Using an OTDR, a single technician can perform the test from the CO, measuring IL and ORL.

This test can also be performed by two technicians using a pair of OLTSs—one at the CO, and one at the FDH.

When it is time to connect the customer, the drop fiber is installed and a test is performed during the activation using a PON power meter.



Activation testing using a PON power meter

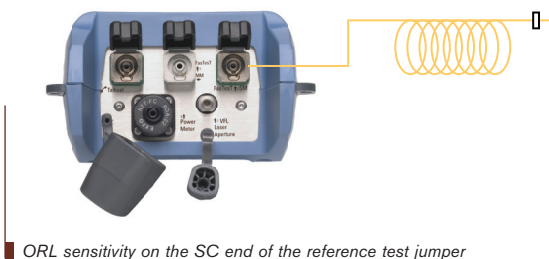
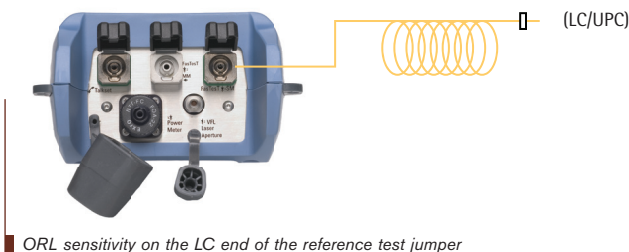
### Testing at the Central Office

At the central office (CO) itself, where all the fibers are installed, it is imperative to inspect all connectors with a probe to make sure that they are clean and in good condition. Damaged and dirty connectors can lead to very costly failures at the CO. A connector dirty with grease can appear to display acceptable IL, because the grease acts—for a short period of time—as an index-matching gel, minimizing the loss. But when the system is activated, this grease will have dried out, and with the high power involved (namely with video signals), it will carbonize on the endface of the connector.

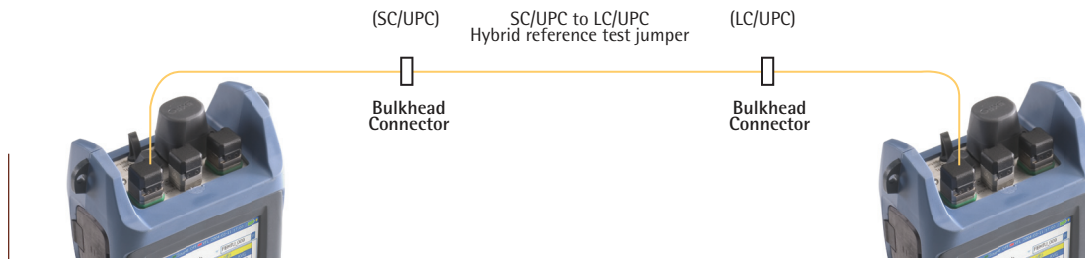
Ultimately, this problem can lead to the need to replace a connector on an expensive piece of equipment such as an EDFA. Not only can it generate considerable expenses in equipment replacement, but also in time and labor to find and fix the problem. Considering that a simple reflectance measurement could detect this problem during installation by displaying a high reflectance value for this specific connector, this major loss of time and money could easily be avoided.

IL and ORL testing can be performed during the installation using a pair of OLTs and the first distribution fiber testing method as described above. With different types of connectors at each end of the jumper (for example, LC, which is a small-form-factor connector with a smaller ferrule diameter than a standard SC connector), a different referencing method is needed. In this example, the test is on a combination of 20 ft jumpers with an SC/UPC connector and an LC/UPC connector at each end.

First, the ORL sensitivity test is conducted on each unit:



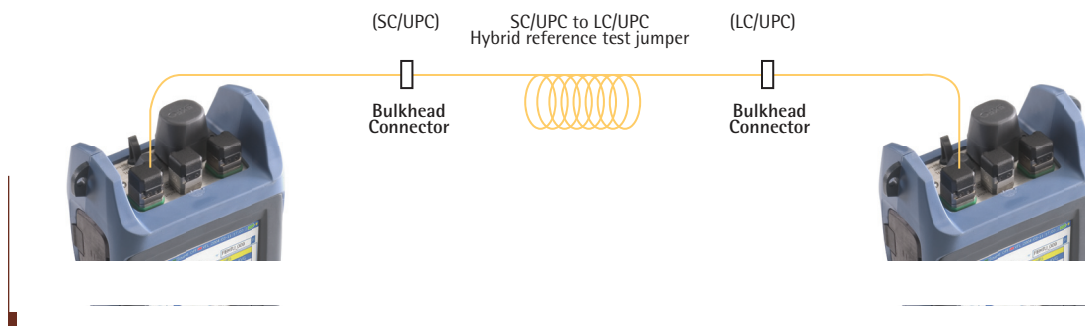
Next, the IL is referenced. This is where the technician has to decide between using an SC-to-LC bulkhead adapter in an effort to match the two different ferrule diameters (1.25 mm for the LC and 2.5 mm for the SC) or using a hybrid reference test jumper (LC to SC). In this case, the bulkhead adapters that were tested did not show good stability; it is very hard to align the two fiber cores correctly due to the different ferrule diameters. Therefore, we chose to work with the hybrid reference test jumper, which has no alignment problem as it allows an SC connector to be matched with another SC (the same for LCs) during the IL referencing.



IL reference using a hybrid reference test jumper

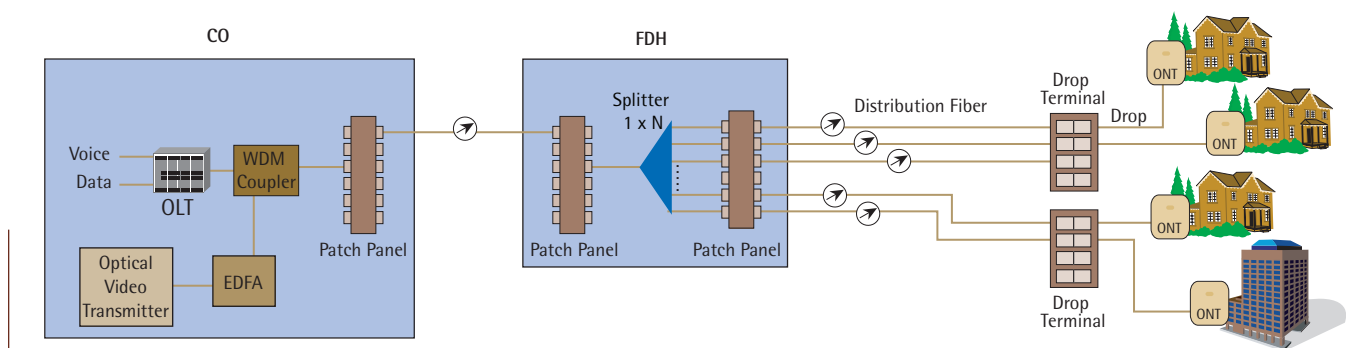
There is also a way to verify if the connection is good between the two SCs and LCs by measuring the ORL. In our example, the ORL should be at a minimum of 50 dB and close to 55 dB, as it is specified for UPC connectors.

The same procedure can be used to test other hybrid jumpers (SC/APC to LC/APC, APC to UPC, etc). The uncertainty increases by  $\pm 0.08$  dB for a UPC connector and by  $\pm 0.12$  dB for an APC connector.



## Case Studies

In this section, we will examine four actual test cases. In all cases, end-to-end testing refers to tests performed with an OLTS. Feeder fibers were tested from the CO to the FDH, and the distribution fibers were tested from the FDH to the drop terminals.



**Situation #1**

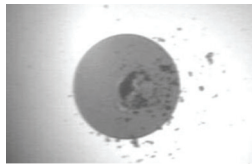
Construction activity was complete and end-to-end loss tests had been conducted from the serving terminal back to the CO. The installation technician had successfully activated broadband and telecom services at the customer's home. At that point, the customer requested that video services be added to the package, which prompted the installation technician to return and carry out this new task.

First, using a PON power meter, the technician measured the 1550 nm signal level at the customer premises and found it to be almost 14 dB too low. During the same set of tests, the 1490 nm signal was determined to be well within the expected level range.

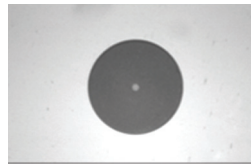
The installation technician referred the problem back to the construction technician, who checked levels from the serving terminal back to the demarcation point at the CO. They discovered that the 1550 nm signal level was low all the way back to the WDM equipment at the CO.

The problem was then passed on to the CO technician, who used a standard optical power meter and found that the 1550 nm signal was low going back to the EDFA but normal at the EDFA optical port. The CO technician replaced an optical jumper between the EDFA and the WDM equipment and cleared the problem (i.e., the problem was not corrected until the EDFA and jumper were replaced).

Inspection of the optical jumper revealed that it was dirty and had been damaged by the higher power levels transmitted by the EDFA. The debris had been carbonized by the optical signal and had created a hot spot on the jumper endface. The hot spot resulted in pitting of the jumper endface.



Burnt connector



Clean connector

**Summary**

1. Cleaning optical jumpers is imperative!
2. The presence of a normal 1490 nm signal coupled with an abnormal 1550 nm signal can only be determined by using a PON power meter.
3. Assessing problems with the appropriate instruments leads to fast resolution. Once it was determined that the 1490 nm signal was normal and the 1550 nm was abnormal, it was easy to conclude that the problem could be traced back to the central office.

**Situation #2**

Construction activity was complete and end-to-end loss tests had been conducted from the serving terminal back to the CO. Installation technicians were unable to successfully provision broadband services. Using a PON power meter, they determined that both the 1490 nm and 1550 nm optical signals did not reach the customer location. They referred the problem to the construction technicians.

Construction technicians used an OTDR at the serving terminal and determined that the F2 fiber (distribution fiber) was intact all the way back to the hub. They then moved to the ONT, at the customer premises, and found that the drop fiber (the fiber between the serving terminal and the ONT) was shorter than expected. They replaced the drop fiber and successfully activated services. As it turns out, on the previous day, a contractor had installed a sprinkler system for the homeowner and had damaged the drop fiber.

**Summary**

1. Proper use of a PON power meter lead the technicians to the next logical step—troubleshooting the physical layer (fiber).
2. Proper use of an OTDR revealed the location of the problem and enabled a quick repair.

**Situation #3**

During the construction phase, it was found that an F2 fiber did not meet the end-to-end loss specifications for the 1550 nm wavelength, while the 1310 and 1490 nm wavelengths were within acceptable limits. Construction crews inspected the fiber with an OTDR and determined that there was a macrobend near the fiber distribution hub (FDH).

A macrobend normally exhibits a greater loss at a longer wavelength. Using a dual-wavelength OTDR is a great way of pinpointing a macrobend. Performing a trace comparison at 1310 nm and 1550 nm enables you to locate the macrobend.

Physical inspection revealed a pinched fiber behind the cross-connect panel of the FDH. After rearranging the fiber to eliminate the sharp bend, all test results were within limits.

#### Summary

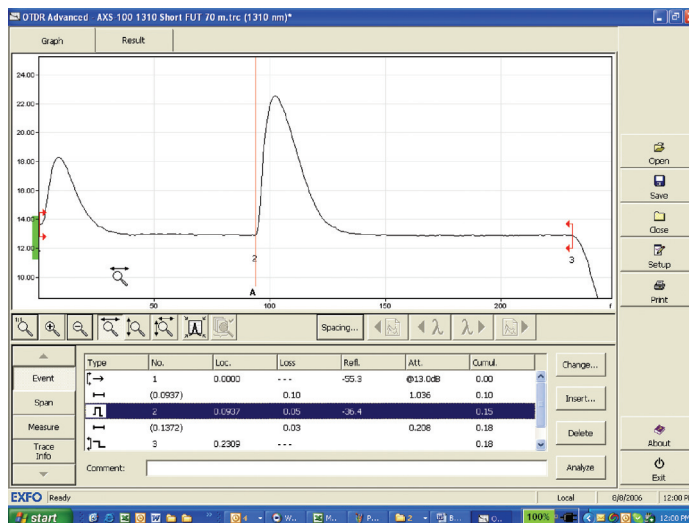
1. Thorough testing reveals problems before the customer experiences them.
2. Proper use of a dual-wavelength OTDR helped identify a problem that had no impact on broadband and telecom services but would have caused problems with video services.
3. End-to-end loss testing resulted in early detection of the problem and benchmarked the optical circuit for engineering records.

#### Situation #4

End-to-end loss testing showed that the attenuation at all three wavelengths exceeded limits on an F2 fiber. Testing the F2 fiber with an OTDR did not allow technicians to detect any problems. The technician performed the end-to-end loss test again and found that the problem was still there.

At this point, he inserted a 94 ft patchcord between the OTDR and F2 fiber and performed the test once more, which showed that the connector's reflectance value was very high.

The technician then inspected the angled connector's endface with a video inspection probe to see that epoxy resin covered the core area—very likely a manufacturing defect. Replacing the connector effectively solved the problem.



#### Summary

1. Testing from the beginning reveals problems before the customer experiences them.
2. When using an OTDR, always connect a launch fiber to fully characterize the link including the first connector.

#### Conclusion

Although it may seem to be an obvious conclusion, testing is essential; most importantly, it must be done right from the very start. Several testing methods exist, and selecting the most appropriate one depends mainly upon your specific constraints, whether they be economical or related to human resources or time. One constant remains, though: dirty connectors are your worst enemy. That's why each connector should be inspected prior to performing a test or a final connection to a network element. As far as test equipment, the OLTS and OTDR are the instruments that can help prevent, identify and address problems before transmission equipment is activated.

Each segment of the network is important, as the network is only as strong as its weakest link.

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