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Interface Practices Subcommittee

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**SCTE Test Procedures for Testing CWDM Systems in
Cable Telecommunications Access Networks**

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Table of Contents

Title	Page Number
NOTICE	2
Document Types and Tags	3
Document Release History	3
Table of Contents	4
1. Introduction	6
1.1. Scope	6
1.2. Benefits	6
2. Normative References	6
2.1. SCTE References	6
2.2. Standards from Other Organizations	7
2.3. Published Materials	7
3. Compliance Notation	7
4. Abbreviations and Definitions	7
4.1. Abbreviations	7
4.2. Definitions	7
5. OPTICAL TEST EQUIPMENT FOR CWDM-MOAN	8
5.1. OTDR Characteristics and Considerations	8
5.2. Test Meter Characteristics and Considerations	8
6. CWDM System Testing Basics	9
6.1. CWDM System Testing Considerations	9
6.1.1. Location and Types of Filters Used:	9
6.1.2. Location of Viable Test Connections	9
6.1.3. Wavelengths Present (at test points)	10
6.1.4. Signal Types at the Various Wavelengths	10
6.2. System Loss Budget Modeling	10
6.2.1. Fiber Loss	11
6.2.2. Connector Loss	11
6.2.3. Component Loss	11
6.2.4. Splice Loss:	11
6.2.5. Total Link Loss (TLL)	11
6.2.6. System Loss Budget	11
7. Testing Of CWDM Systems	12
7.1. Test Preparation	12
7.1.1. CWDM Systems with Hard Spliced Remote Filters (All Wavelengths)	12
7.1.2. Modular OSP Systems - Filtered 1310 nm Testing (if applicable)	13
7.1.3. 1550 nm Testing and Remaining Channels	14
7.1.4. Modular OSP Systems Special Case – OTDR Loop-back Test	15
7.1.5. CWDM Systems With Hard Spliced Remote Filters (All Wavelengths)	16
7.1.6. Modular OSP Systems - Filtered 1310 nm Testing:	16
7.1.7. Modular OSP Systems - Unfiltered Wavelength Testing	17
7.1.8. Modular OSP Systems Special Case – Loop-back Test – Filtered 1550	17
7.1.9. Modular OSP Systems Special Case - Dedicated Test Ports:	18
8. Test Documentation	19
8.1. End-to-End Attenuation Data	19
8.2. OTDR Signature Traces	19
8.3. Certificate of Compliance for Connector and Splice Loss	19

List of Figures

Title	Page Number
Figure 1 - CWDM Module with Test Port and Filter Test Box	10
Figure 2 - CWDM OTDR Test Signal Paths – 1310 and 1550 paths	12
Figure 3 - CWDM Test connections – Downstream - 1310	13
Figure 4 - CWDM Test Connections – Upstream- 1310	13
Figure 5 - CWDM Test Connections -Downstream Using 1550 nm port for 1570 nm Customer	14
Figure 6 - CWDM Test connections –Upstream Testing for 1570 nm customer	15
Figure 7 - CWDM Test connections – Replacing 1570 nm Drop cable	15
Figure 8 - OTDR Loop-back Test	16
Figure 9 - Power-Through Test – 1310 Filtered	17
Figure 10 - Power-through Test at Unfiltered Wavelength	17
Figure 11 - Power-through Test - Loop-Back Filtered 1550 nm	18
Figure 12 - Power Through Test with HE/Hub Test Port	18
Figure 13 - Power Through Test with OSP Terminal Test Port	19

1. Introduction

1.1. Scope

This document describes procedures to support the measurement and characterization of the system optical (loss) performance through the passive points and segments of a Coarse Wavelength Division Multiplexing (CWDM) based Multi-point Optical Access Network (CWDM-MOAN) fiber cable plant. The procedures contained herein are designed to be used in conjunction with the relevant industry test procedures for testing outside plant optical systems.

The term “optical fiber cable plant”, may consist of optical fiber cables, connectors, mounting panels, jumper cables, and other passive components, but may not include active components. For example, the cable plant can be a portion of a commercial services FTTX network, including optical switches or couplers, but would exclude gain elements in the optical path.

1.2. Benefits

Current industry standard optical fiber plant test methods are intended for point-to-point optical links, and are not optimized for point-to-multi-point CWDM systems with remote outside plant wavelength-specific filter devices. When used in conjunction with other relevant industry standardized test procedures, this document provides preferred measurement principles and practices to support valid and comprehensive evaluation of a CWDM-MOAN with remote outside plant CWDM filters in a point-to-multipoint configuration, which is critical to accurate testing and characterization of such systems.

This document does not cover all aspects of system testing and qualification and is not intended for the following purposes:

- Component testing or point to point links between elements of an optical system which can be accomplished via standard single-mode system testing. This includes systems with remote WDM filters co-located with end-electronics.
- Active components performance and qualification.
- Point-to-multipoint lengths with in-line optical power splitters
- Designing, specifying, ordering, installing, or maintaining CWDM-MOAN.
- CWDM-MOAN passive product specifications and qualifications.
- Detailed test equipment operation, including referencing procedures

2. Normative References

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

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- ANSI/TIA/-526-7 (February 2002) - OFSTP-7 - Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant (2003)

2.3. Published Materials

- No normative references are applicable.

3. Compliance Notation

<i>shall</i>	This word or the adjective “ <i>required</i> ” means that the item is an absolute requirement of this document.
<i>shall not</i>	This phrase means that the item is an absolute prohibition of this document.
<i>forbidden</i>	This word means the value specified shall never be used.
<i>should</i>	This word or the adjective “ <i>recommended</i> ” means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
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4. Abbreviations and Definitions

4.1. Abbreviations

DeMUX	De-multiplexer
COM	common port
EXP	express port
MUX	Multiplexer

4.2. Definitions

Multiplexer	Device used to combine two or more wavelengths over a single fiber.
De-Multiplexer	Device used to separate two or more wavelengths previously combined onto a single fiber to filtered wavelengths.
WDM Device	A means of increasing information carrying capacity by operating at multiple wavelengths over a single fiber.
Terminal	Optical enclosure that incorporates an optical connector to provide access at discrete locations in an optical network.

Test Port	An optical connection that has a percentage of power, typically 5%, split from the original transmission to enable the monitoring of an optical system with multiple wavelengths operating over a single fiber.
Common Port	An optical connection port where multiple wavelengths transmitted over a single fiber are present.
Express Port	An optical connection port that transmits the remaining wavelengths that have not been separated on a single fiber.
Filtered Wavelength	A specific wavelength that has been separated from all other wavelengths operating on a single fiber.
Add ports	An optical connection port where a wavelength can be combined to a network.
Drop ports	An optical connection port where a wavelength can be separated from a network.

5. OPTICAL TEST EQUIPMENT FOR CWDM-MOAN

The basic types of test equipment suitable for testing CWDM-MOAN are the OTDR, and power meter (and source). OTDR testing is generally considered the most useful for real-time testing and troubleshooting optical networks during installation. Although it is not a direct measurement of optical loss, OTDRs are able to detect and locate discrete anomalous attenuation events. Conversely, power through testing is primarily only used as a direct measurement of the passive link loss to ensure attenuation budgets are met, or that received power levels are adequate. The ability to perform any of these types of tests on a CWDM-MOAN depends on a number of factors. These factors are discussed in detail in the section on test considerations.

5.1. OTDR Characteristics and Considerations

Because of the ability of the OTDR to provide detailed analysis of individually installed components with access to only one end of the fiber, it is the most versatile installation and troubleshooting tool that can be used in a variety of scenarios including: Cable Acceptance; OTDR Signature Trace Documentation; Component, Connector and Splice Loss.

One key consideration for testing with an OTDR is the actual operating wavelength(s) of the device. Current OTDRs used in the industry transmit only 2 to 4 wavelengths (1310nm, 1550 nm, 1490 nm, and 1625 nm), while the wavelengths used in CWDM networks vary from 1270 to 1610 nm in 20 nm increments. Therefore most OTDRs are not generally capable of testing each individual channel (i.e., wavelength) in CWDM systems. Of the typically used OTDR wavelengths, only 1310 nm and 1550 nm are within the capability of most all OTDRs. Also, knowing the specific characteristics of the transmitted wavelength (e.g., center wavelength, spectral width, and side bands) are critical in understanding the measurement results.

5.2. Test Meter Characteristics and Considerations

Optical meters are the most common fiber optic tool, designed to measure optical power levels in dBm and losses in dB. Optical sources are important companions to optical meters for end-to-end attenuation testing, designed to launch a stabilized light of steady output power and known wavelength into the fiber. 1310, 1490, 1550, and/or 1625 nm lasers are commonly used for testing single-mode fiber systems.

End-to-end attenuation testing measures the total amount of loss between two endpoints. Direct end-to-end loss measurements require the use of a calibrated source and meter set. Most current test meters employ photo-detectors that can measure optical power across a wide spectral band. However, these detectors do not differentiate the wavelengths of light being received, and therefore will not be accurate when multiple wavelengths are present. A lesser effect is that these detectors are usually calibrated to a specific wavelength with a fixed gain, and therefore will be less accurate at other wavelengths. The capability of the test equipment selected should be evaluated considering both of these potential issues.

Note that when testing optical paths for wavelengths shorter than 1550 nm using a 1550 nm source, that actual loss values may be slightly higher due to the actual fiber attenuation coefficient at the actual operating wavelengths. The shorter the wavelength, the greater the degree of inaccuracy can be.

6. CWDM System Testing Basics

In addition to the specific test equipment used, the options available when testing a CWDM-MOAN depend significantly on the specific system being tested. This section discusses some of the key considerations and also addresses loss modeling of a CWDM-MOAN.

6.1. CWDM System Testing Considerations

The key system attributes that affect testing are related to the point-to-multi-point nature of these networks as well as the impact of CWDM wavelength specific bandpass filters. Specific key considerations include: 1) location and types of filters used, 2) the location of testable points, 3) the number of wavelengths present (active) and 4) the signal types carried at the various wavelengths.

6.1.1. Location and Types of Filters Used:

The configuration and specifics of the system filters determines much of what testing can be performed and how. The primary types of filter devices used in a CWDM-MOAN are discrete single channel filter elements (e.g., thin-film filters) used individually (e.g., spliced in trays) or devices which combine the function of multiples of such devices together in a modular form such as an add-drop (A-D) device or multichannel multiplexer (Mux) or Demultiplexer (DeMUX) devices. Also, filter devices that are hard-spliced in, will leave fewer accessible system testing and measurement points in the field than filter devices that are modular in nature (e.g., plug and play) and which are connected to the system via optical connectors.

6.1.2. Location of Viable Test Connections

6.1.2.1. Hub/Headend

Passive devices located in the hub or headend typically must have connector points provided to allow for connections to equipment (transmitters and receivers) and to the feeder fiber (common port). However, once a port is connected to active equipment, it becomes an issue to try and access for testing or monitoring. Another option is to have a dedicated test port, which consists of an in-line splitter device placed directly in line with the common port (COM) of the Mux or DeMUX device connected to the feeder fiber. The splitter device is used to pull off some portion of the optical power (typically 5%) to provide a test point where all active and test wavelengths can be accessed and measured. Figure 1 shows typical HE-Hub CWDM passive modules representative of most installations.

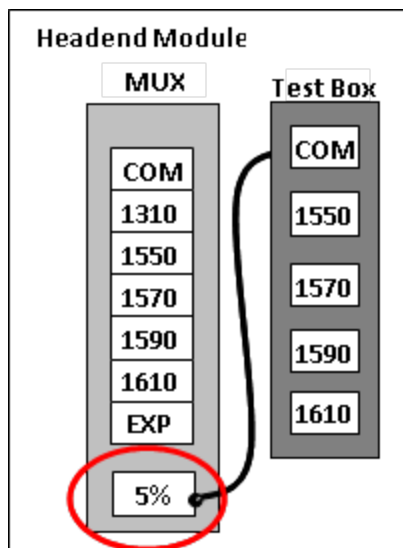


Figure 1 - CWDM Module with Test Port and Filter Test Box

6.1.2.2. OSP

For devices located in the OSP field terminal, many legacy systems simply have these devices hard-spliced into the feeder and drop fibers. That means that no test points are provided to allow for connections to equipment (transmitters and receivers) and to the feeder fiber (common port). For such systems the only accessible test points, other than at the HE/Hub, are therefore at the end-equipment (e.g., optical node or customer premises equipment (CPE)). For systems using hardened modular plug-and-play type modules, testable points are similar to those in the HE/Hub (Figure 1).

6.1.3. Wavelengths Present (at test points)

Multiple wavelengths may be present at any point in the system except at the following locations.

- Between HE/Hub transceivers and the add/drop ports of the HE/Hub CWDM devices.
- Between remote electronics and the add/drop ports of OSP or customer premises CWDM devices.

Optical test meters utilize broadband photo detectors that do not discriminate between different optical wavelengths received. Therefore, if more than one wavelength is present at a test point, individual wavelengths have to be isolated for testing. This can be accomplished with a CWDM filter test box (see Figure 1)

6.1.4. Signal Types at the Various Wavelengths

Test equipment commonly available today for single-mode fiber systems transmit only 2 to 4 wavelengths (1310 nm, 1550 nm, 1490 nm, and 1625 nm), while the wavelengths used in CWDM networks vary from 1270 to 1610 nm in 20 nm increments. Therefore, in order to test systems at other operational wavelengths, actual system transmitter equipment can be used to generate optical signals at the wavelength(s) being tested.

6.2. System Loss Budget Modeling

All passive fiber optic systems consist of the same basic components. A significant difference in calculating link loss values for CWDM systems is the impact of the passive CWDM filter component's

optical insertion loss on individual wavelengths. The following information is provided to assist operators in managing link budget values as part of the overall system design.

6.2.1. Fiber Loss

The attenuation coefficient of the cabled fiber is provided by the cable or fiber manufacturer, depending on the application.

$$FL \text{ (dB)} = \text{Cable Length (km)} \times \text{Fiber Attenuation Coeff. (dB/km)}$$

6.2.2. Connector Loss

The loss component associated with mated pairs including connections in the headend, but not including connections to equipment. Connector insertion loss values can be obtained from the manufacturer for budgetary planning.

$$CL \text{ (dB)} = \text{Ave. Insertion Loss (dB/conn)} \times \text{No. of Connector Pairs}$$

6.2.3. Component Loss

Insertion loss for discrete components, similar to connector insertion loss, associated with inserting certain devices such as a MUX/DeMUX filters, including losses from any fiber, filters, splitters, and the like used discretely or combined inside a device. It does not include component polarization dependent losses (PDL), which are treated separately.

$$CoL \text{ (dB)} = \text{Loss Component (1) (dB)} + \dots + \text{Loss Component (N) (dB)}$$

6.2.4. Splice Loss:

The sum of the loss values from any spliced connections, such as splicing together two feeder cables or splicing pigtail cables for connectivity.

$$SL \text{ (dB)} = \text{Ave. Splice Loss (dB/splice)} \times \text{No. of Splices}$$

6.2.5. Total Link Loss (TLL)

Adding all these components together, loss values are calculated as follows:

$$TLL \text{ (dB)} = FL + CL + SL + CoL$$

Accurate loss budget values for actual passive systems can be obtained by working with manufacturers and suppliers to model specific system attributes such as cable lengths, filter designs and locations, and the number and quantity of connector pairs and splices.

6.2.6. System Loss Budget

$$TLB \text{ (dB)} = Tpwr + Rsens - TLL \text{ (dB)}$$

Tpwr – transmitter power

Rsens – receive sensitivity

7. Testing Of CWDM Systems

7.1. Test Preparation

In preparation for actual field tests, the following guidelines are important for efficient and accurate test results:

- Ensure that the test jumpers (end-to-end attenuation) or test fiber box (OTDR) are of the same fiber type and connector type as the cable system.
- Ensure that optical sources are stabilized and have center wavelengths within ± 20 nm of 1310, 1490, 1550 and/or 1625 nm single-mode nominal wavelengths.
- Ensure that the power meter is calibrated at each of the nominal test wavelengths and traceable to the National Institute of Standards and Technology (NIST) calibration standard.
- Ensure that the power meter and the light source are set to the same wavelength.
- Ensure that all system connectors, adapters, and jumpers are properly cleaned prior to and during measurement.

OTDR Testing: For simplicity, the procedure herein is based on using an OTDR capable of testing at 1310 and 1550 nm. More capable devices, such as those having additional wavelength capability (e.g., 1625), allow for more flexibility in testing. It is recommended that ANSI/TIA/-526-7 be followed to conduct this procedure.

7.1.1. CWDM Systems with Hard Spliced Remote Filters (All Wavelengths)

For systems without accessible test connection points in the field, the testing options may be limited. This is especially true when one or more of the following conditions are present

1. Link under test includes filters not tuned to one of the OTDR wavelengths. In such instances, it is only possible to test from either end of the link towards the filters.
2. CWDM filters present for one or more OTDR wavelengths, even if those wavelengths not currently active.
3. One or more OTDR test wavelengths are already being utilized by system electronics (filters at those wavelengths present)

Figure 2 below, shows the optical paths for the primary OTDR single-mode test wavelengths in a typical CWDM system.

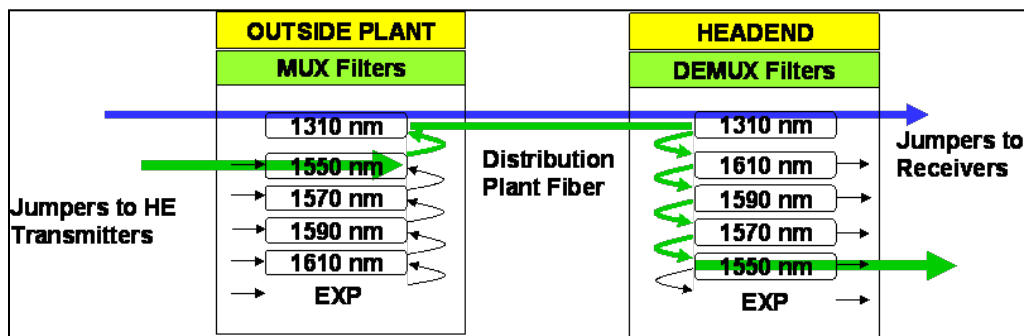


Figure 2 - CWDM OTDR Test Signal Paths – 1310 and 1550 paths

7.1.2. Modular OSP Systems - Filtered 1310 nm Testing (if applicable)

The first step is to test the downstream portion of a system at 1310 nm by connecting the OTDR to the 1310 nm input port on the CWDM located at the headend (see Figure 3). This OTDR trace provides the results for the downstream 1310 nm network.

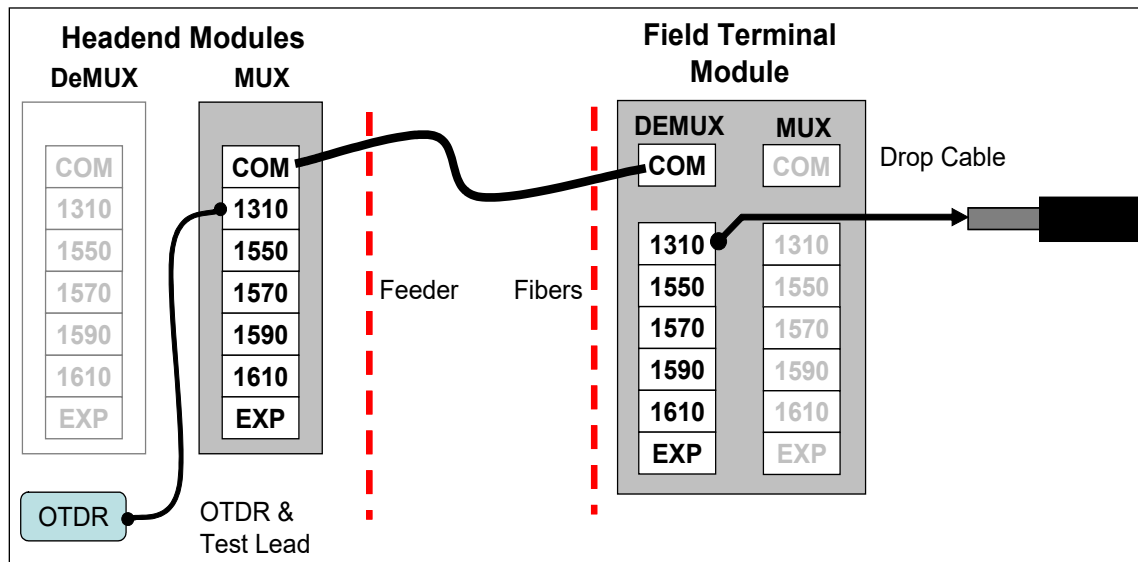


Figure 3 - CWDM Test connections – Downstream - 1310

Next, switch the test leads over to the upstream side and repeat (see Figure 4). Since the Mux and DeMUX filter sets are essentially the same, the test method is the same for both the downstream and upstream paths.

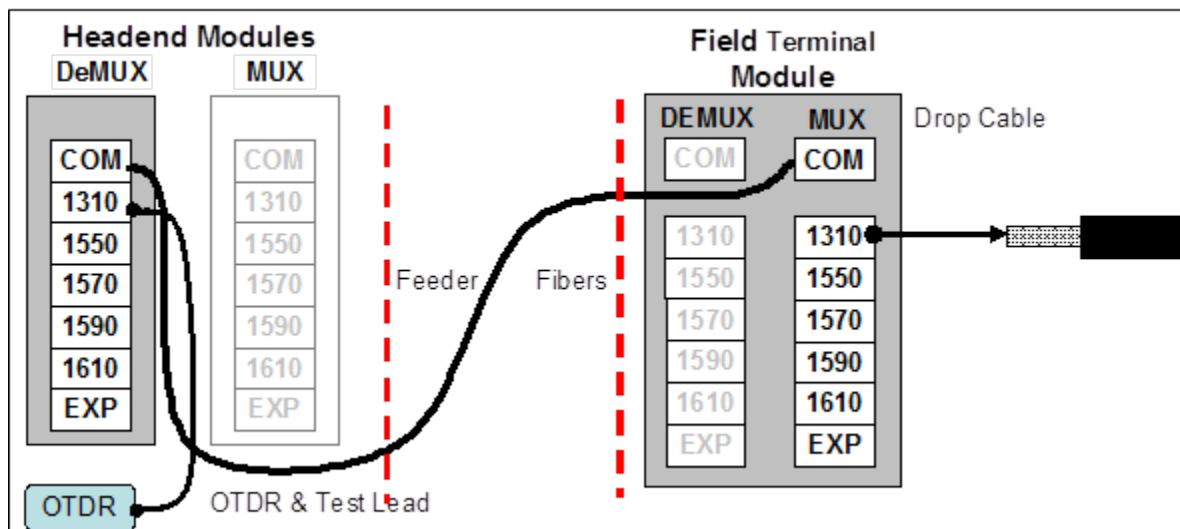


Figure 4 - CWDM Test Connections – Upstream- 1310

7.1.3. 1550 nm Testing and Remaining Channels

1550 nm testing is performed similarly by switching the test leads to the 1550 nm ports. However, if additional wavelengths are present (i.e., no 1310/1550 nm) follow the procedure below leaving the 1550 nm links last.

Using the 1550 nm test wavelength, switch the OTDR connection to the 1550 nm input port on the headend. Have a technician stationed at the field terminal connect the drop cable leg connectors for the 1570 nm customer to the 1550 nm port on the MUX/DeMUX device (see Figure 5). Test the downstream 1570 nm passive link at 1550 nm, and then repeat for the 1570 nm upstream side (see Figure 6). When testing is complete, have the technician switch the connections for the 1570 nm drop back to the 1570 nm ports on the field MUX/DeMUX device as shown in Figure 7. Repeat this process for the 1590 nm, 1610 nm drop cables and other wavelengths present. Finally, test the 1550 nm path normally with the

1550 nm drop cable connected to the 1550nm MUX/DeMUX ports.

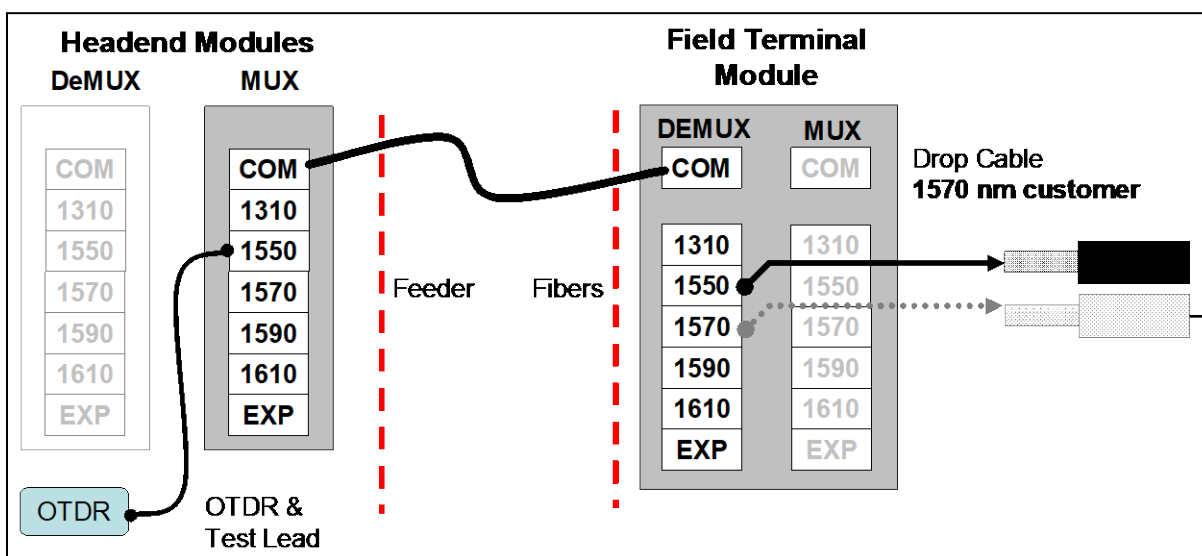


Figure 5 - CWDM Test Connections -Downstream Using 1550 nm port for 1570 nm Customer

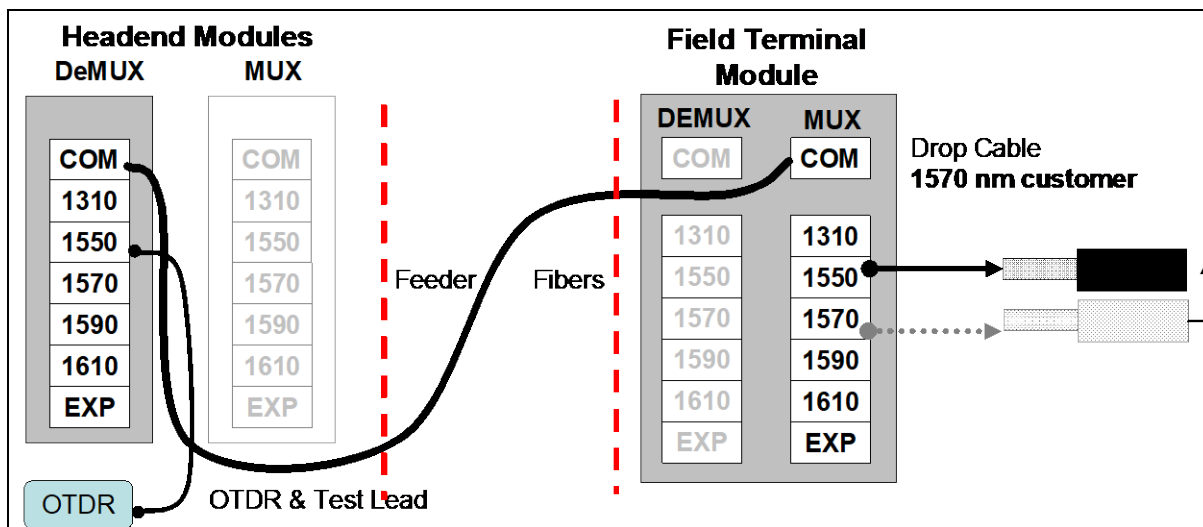


Figure 6 - CWDM Test connections –Upstream Testing for 1570 nm customer

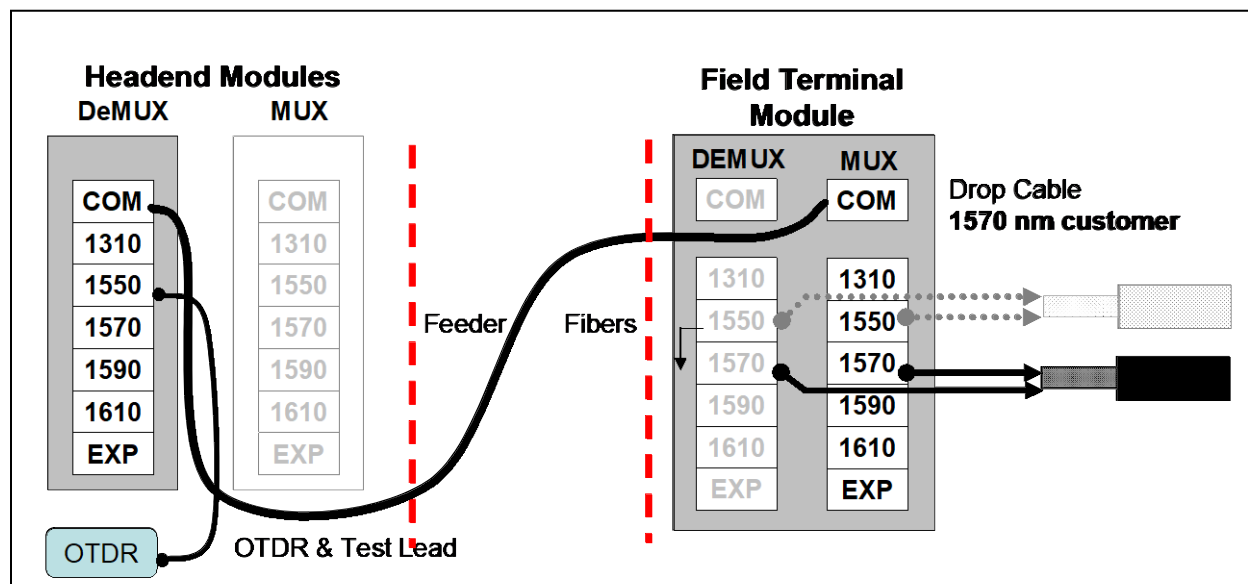


Figure 7 - CWDM Test connections – Replacing 1570 nm Drop cable

Note that with OTDRs capable of testing at 1625 nm, the drop cables under test could be connected to the output (i.e., express port) of the module and tested at 1625 nm, without having to connect each to the 1550 nm port. Otherwise the process is the same.

7.1.4. Modular OSP Systems Special Case – OTDR Loop-back Test

In certain modular systems it is possible to perform a complete bi-directional OTDR test from the HE/Hub. In pre-operational systems, for example, connections can be made to the filtered wavelength ports or COM and EXP (express port) of the MUX or DeMUX device to create a complete optical path (loop). Figure 8 below shows possible options for loop-back testing.

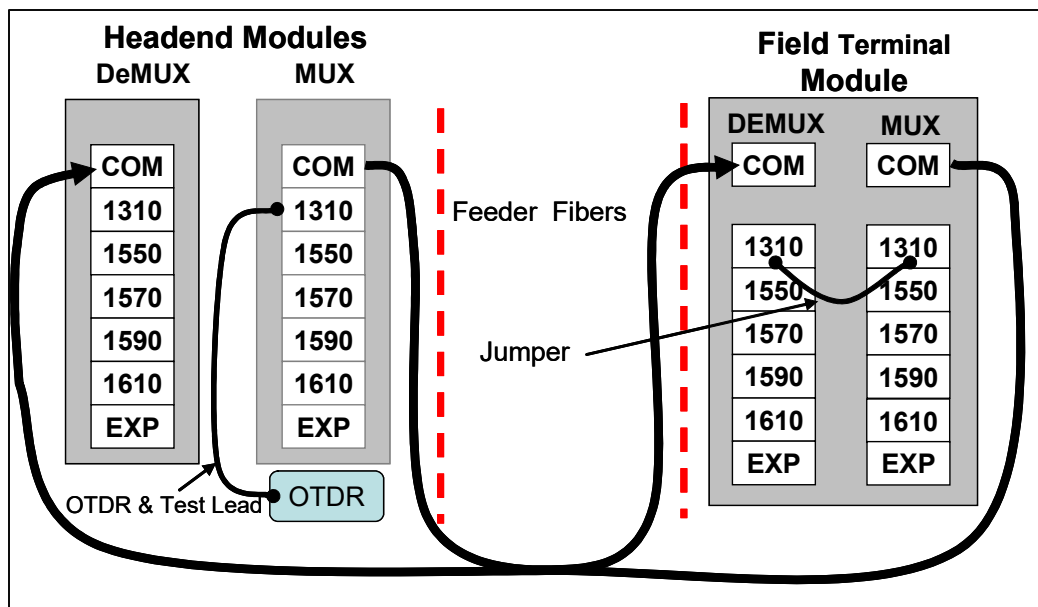


Figure 8 - OTDR Loop-back Test

To complete the bi-directional test, simply move the OTDR to the other lead in the headend representing the other end of the optical path loop.

Power-through (Optical Meter and Source) System Testing: End-to-end attenuation provides an accurate quantitative measure of the installed performance of the cable system and its components. This is a measure of the optical power loss between cable termination points. The end-to-end loss should always be less than the link loss budget calculated in the system design. The best way to verify that the cable meets the loss limit is to measure each segment after installation. It is recommended that ANSI/TIA/-526-7 be followed to conduct this procedure.

7.1.5. CWDM Systems With Hard Spliced Remote Filters (All Wavelengths)

Testing limited to optical length supporting one of the available test wavelengths. See section 7.1.1 and Figure 2.

7.1.6. Modular OSP Systems - Filtered 1310 nm Testing:

The first step is to test the downstream portion of a system at 1310 nm by connecting the test source to the 1310 nm input port on the CWDM MUX located at the headend (see Figure 9). Connect the power meter to the 1310 nm port on the OSP DeMUX port. The process can then be repeated for the other side (DeMUX). Other filtered wavelengths can be tested similarly.

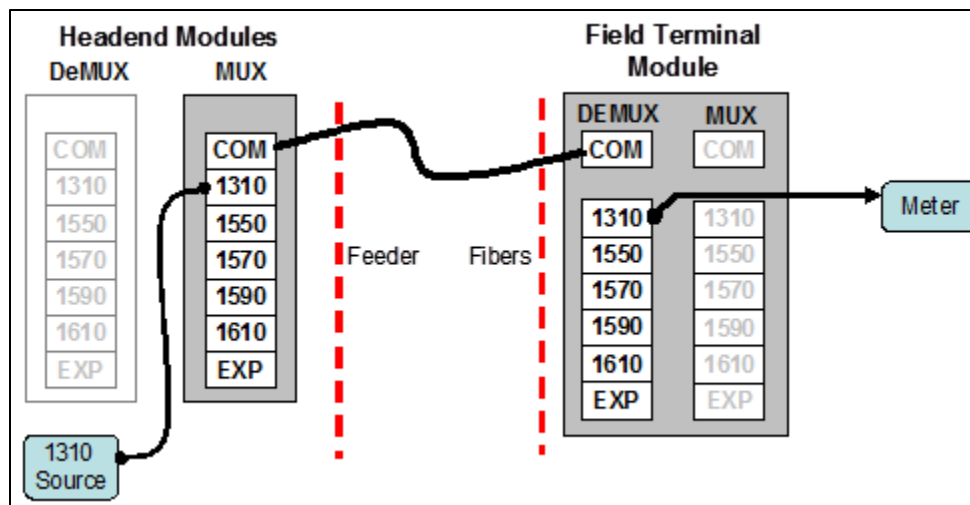


Figure 9 - Power-Through Test – 1310 Filtered

7.1.7. Modular OSP Systems - Unfiltered Wavelength Testing

Connect source to EXP on the headend MUX module. Connect power meter to EXP on the OSP DeMUX module. The upstream path can be measured similarly (See Figure 10)

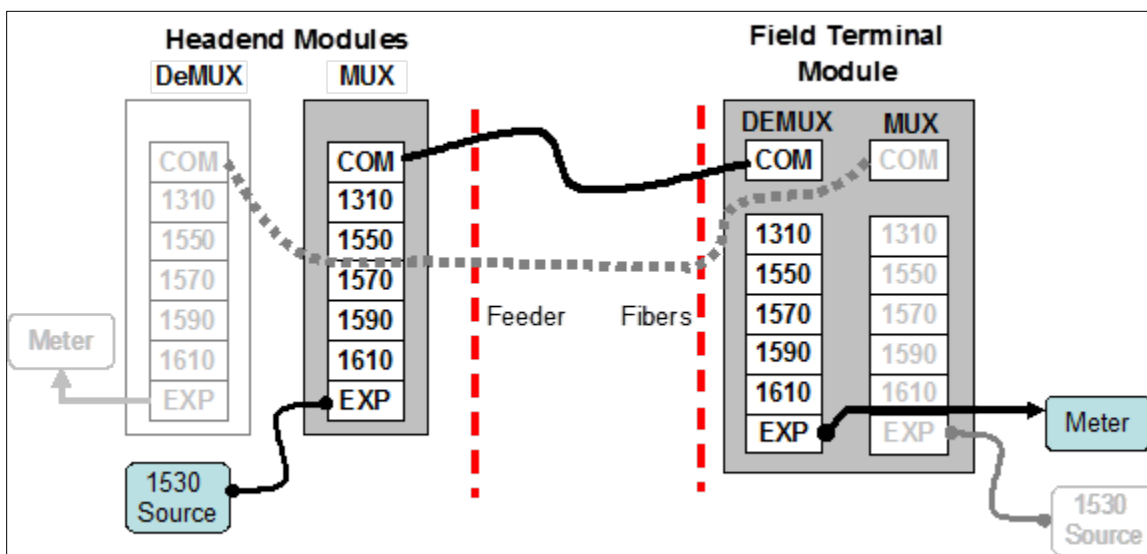


Figure 10 - Power-through Test at Unfiltered Wavelength

7.1.8. Modular OSP Systems Special Case – Loop-back Test – Filtered 1550

This is a variation of the “loop-back” test described in section 7.1.4. Connect a jumper between the MUX and DeMUX 1550 nm ports in the OSP terminal to complete the optical path. Test is shown graphically in Figure 11.

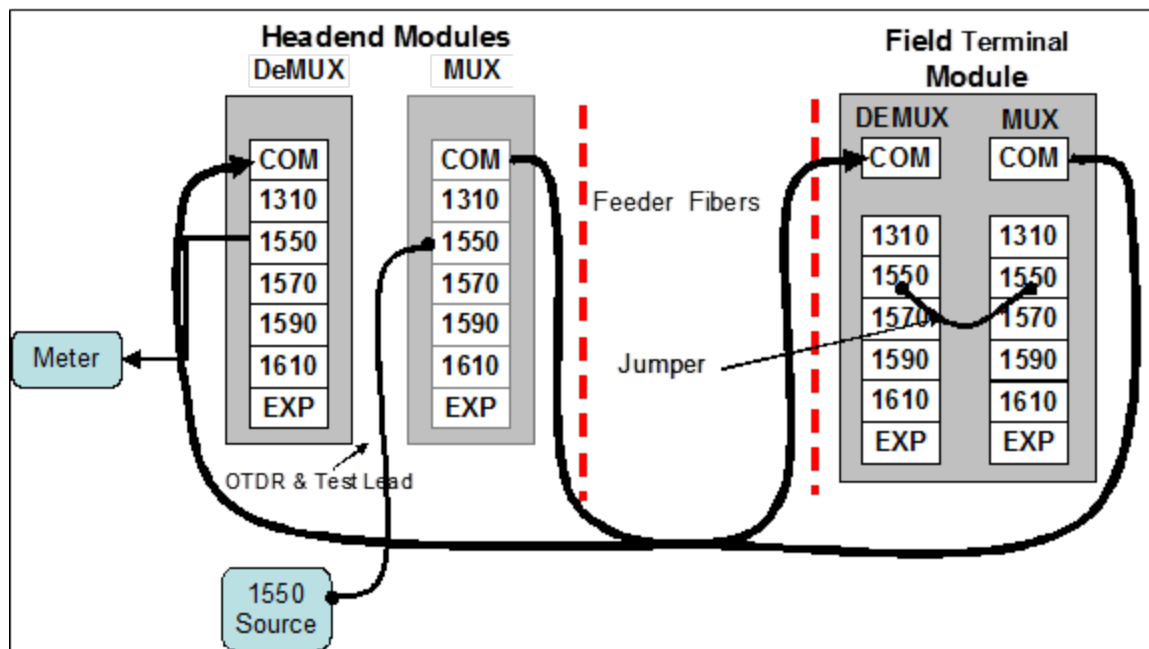


Figure 11 - Power-through Test - Loop-Back Filtered 1550 nm

7.1.9. Modular OSP Systems Special Case - Dedicated Test Ports:

Testing options for CWDM systems, especially when active signals are present, can be enhanced by employing test ports in the HE/Hub or OSP terminal. A portion of all active or test signals will be present at this port. Individual wavelengths can then be evaluated using a simple optical meter with a filter test box. Figure 12 represents testing with a test port in the HE/Hub. Figure 13 shows testing with a test port in the OSP terminal.

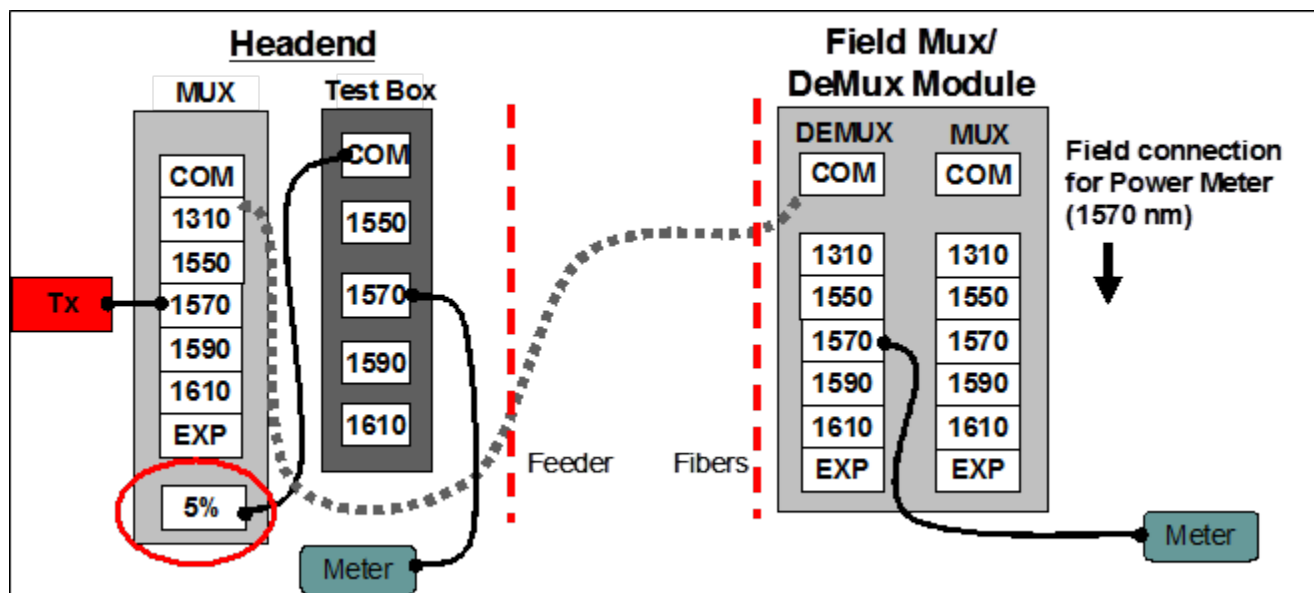


Figure 12 - Power Through Test with HE/Hub Test Port

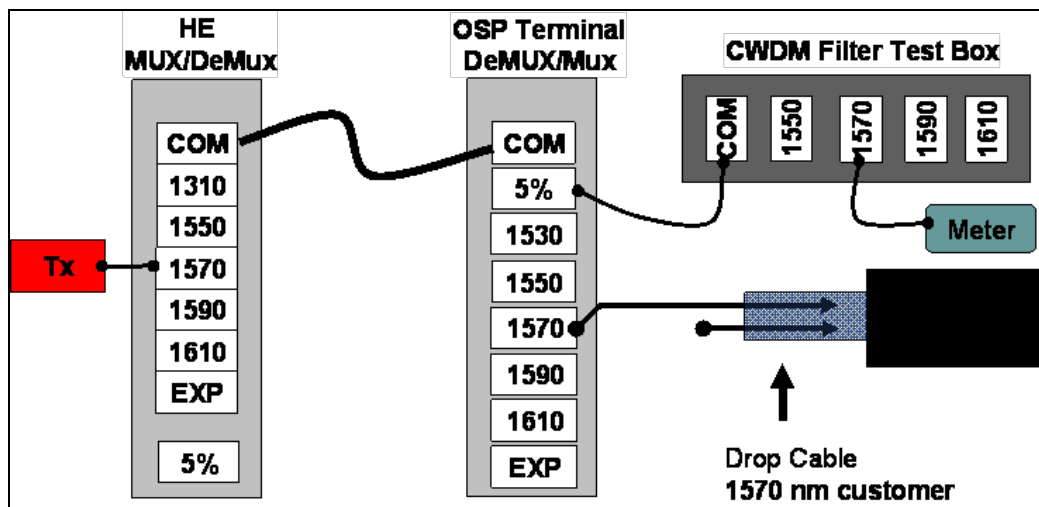


Figure 13 - Power Through Test with OSP Terminal Test Port

8. Test Documentation

Documentation plays a vital role in the long-term success of any cabling system with regard to system reconfiguration, upgrades, and maintenance. End-to-end test results establish the initial integrity and performance of a system. Documents of work performed on the fiber plant can be used for liability protection in the event that multiple vendors are involved. Equally important, these records establish “as-built drawings” and can be compared to current conditions when troubleshooting. The following are common test results and cable records.

8.1. End-to-End Attenuation Data

The end-to-end loss information is completed by the installer and usually considered the primary confirmation of the system performance.

8.2. OTDR Signature Traces

When provided by the installer, computer files or printouts of OTDR traces provide a graphical summary of the location and loss of each component in the middle of the cable system.

8.3. Certificate of Compliance for Connector and Splice Loss

The installer completes the certificate to confirm test performance, compliance with stated loss requirements, and applicable warranty coverage for all individual connector and splice losses in the backbone cable plant.