Test Guide - Fiber link and Network characterization

Fiber Link and Network characterization

Characterization is a comprehensive suite of point-to-point physical layer (including components) optical tests that measures and determines the quality and potential transmission capability of a given optical fiber.

Fiber Link Characterization is the Measurement of the fiber performance and the quality of any interconnections (splices, connectors…) between fiber sections, after the fiber link has been installed.

Network Characterization provides the network baseline measurements before turning the transmission system up. Network characterization includes measurements through the optical amplifiers, dispersion compensators, and any elements in line

Fiber Characterization is performed by a two technicians that utilize State-of-the-Art test equipment and analysis software.

The suite of Optical Tests

The recommended Fiber characterization test suite is described into the ITU-T G.650.3 standard

- ☑ **Connector Inspection and cleaning**
  Video Inspection Scope to inspect the connector surface of the link (front and end)
- ☑ **Insertion Loss**
  Optical Loss Test Set – Multiple wavelengths (1310/1550/1625nm) - Bi-directional
- ☑ **Distance (fiber length)**
  OTDR - single wavelength – Unidirectional
- ☑ **Connectors/splice loss**
  OTDR - Multiple wavelengths (1310/1550/1625nm) - Bi-directional
- ☑ **Connector Reflectance**
  OTDR - Multiple wavelengths (1310/1550/1625nm) - Unidirectional
- ☑ **Optical Return Loss (ORL)**
  Optical Loss Test Set with ORL meter – Multiple wavelengths (1310/1550/1625nm) - Bi-directional
- ☑ **Polarization Mode Dispersion (PMD)**
  PMD analyzer - unidirectional
- ☑ **Chromatic Dispersion (CD)**
  CD analyzer – DWDM bands – 1nm increment - unidirectional
- ☑ **Attenuation Profile (AP) measurements**
  Spectral analyzer - DWDM bands – 1nm increment – unidirectional

Measurement units

- Loss is measured in decibel (dB) or dB per kilometer (dB/km)
- Splice and connector losses are measured in dB.
- Reflectance is measured in – dB. The greater the number the higher the reflection.
- Chromatic Dispersion (CD) is measured in picoseconds per nanometer (ps/nm) and ps/nm/km when normalized to the distance.
- Polarization Mode Dispersion (PMD) is measured in picoseconds (ps) and picoseconds per square root kilometer.(ps/√km) when normalized to the distance.

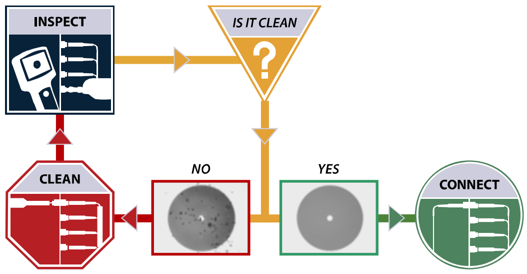
Connector Inspection

All connectors must be properly cleaned before use and cleanliness has to be verified.

Connectors are the only elements that can be easily disconnected and are subjected to dirt or scratches prior to reconnection, generating more than 80 % of the link/system failures.

Dirt is everywhere (Airborne, hands, bulkhead adapter, dust caps, etc.) and mating dirty connectors embeds the debris into the glass, damaging the fiber.

Inspection and cleaning procedure consist in verifying the connector surfaces (both sides of the connector), using a video inspection scope, and cleaning the connectors, with appropriate cleaning tools.



- ☑ **Contamination is the number one source of troubleshooting in optical networks.**
- ☑ **An average dust particle is 2–5 µm. A single particle mated into the 9 µm core of a SM fiber can cause significant back reflection, signal loss and even equipment damage.**
- ☑ **New connectors are not always clean. Dust caps protect the fiber end-face, but are often a source of contamination.**

Insertion Loss (IL)

The most important test to be performed, as each combination of transmitter/receiver has a power range limit.

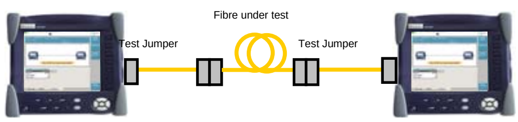
ILProvides the most accurate end-to-end loss measurement of fiber optic link including end connectors.

An IL measurement requires a calibrated source and a power meter. The source sends a signal at a given power level, and the power meter reads the remaining power level at the far end of the link.

It is a 2-step operation:

Step 1: Reference power level: Quantify the output power including the fiber jumpers. Connect source and power meter together with the jumpers.

Step2: Insert the fiber under test and the power measurement of the connected elements (jumpers + fiber under test).



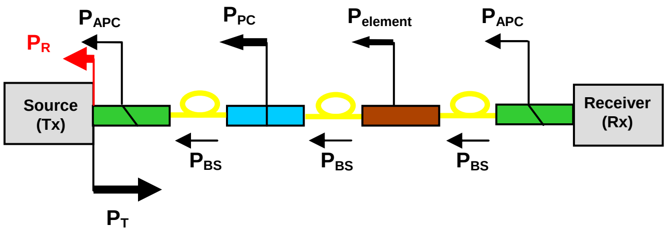
The difference between the two power readings gives the insertion loss of the fiber, provided in decibels (dB)

Loss (dB) = Power In – Power Out

- ☑ **The IL is most commonly measured at 1310, 1550 and 1625 nm singlemode wavelength.**
- ☑ **IL is a unidirectional measurement but will commonly be measured bi-directionally for operation efficiency.**

Optical return Loss (ORL)

The optical return loss (ORL) represents the portion of light reflected back to the transmitter by the link components (connectors…) and the fiber itself.



It is the ratio between the transmitted power and the received power at the fiber origin.

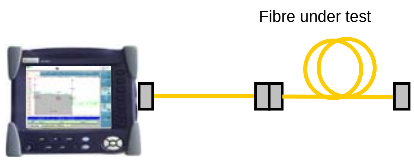
The Optical Continuous Wave Reflectometry (OCWR) is the reference method for ORL testing (OTDR is an alternative one): A laser source and a power meter using the same test port are connected to the fiber under test.

A 3-step operation:

Step1: ORL referencing: Measure the output power level at the fiber jumper using a separate power meter

Step2: Measure the ORL of the front connector (jumper to test equipment connection). Requires mandrel wrap or use of termination.

Step3: Connect to the fiber under test



☑ **ORL is measured in dB and is a positive value.**

☑ **The higher the number, the smaller the reflection - yielding the desired result.**

☑ **The ORL is most commonly measured at 1310, 1550 and 1625 nm singlemode wavelength.**

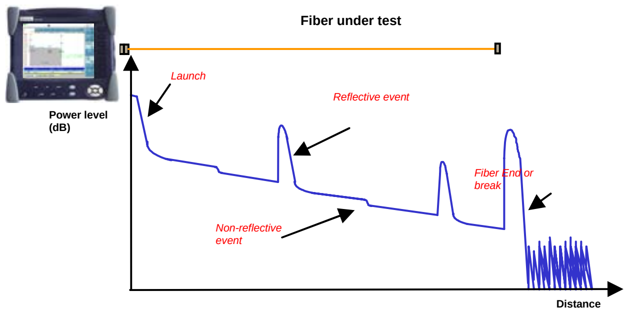
OTDR

An Optical Time Domain Reflectometer (OTDR) operates as one-dimensional radar allowing for complete scan of the fiber from only one end. It provides the following information:

- Distance of fiber span
- Total loss of fiber span
- Location and loss measurement of all fusion splices
- Location, loss, and reflectance measurement of all connector pairs and mechanical splices.
- Optical return loss of fiber span and total link.

The instrument sends out a laser light pulse and measures the round trip travel time of the laser to calculate distance. It also measures the power of the returned light (reflected or backscattered) to determine loss and reflectance. The loss and distance are then plotted on a graph known as a "trace". In addition an OTDR can accurately pinpoint any artifact or "event" on a fiber. The event can be characterized, measured and plotted.

In addition an OTDR can accurately pinpoint any artifact or "defect" on a fiber, such as macrobend or breaks.



For each section of fiber the OTDR provides:

- Section length
- Section loss in dB
- Section loss rate in dB/km
- ORL (Optical Return Loss) of the section

For each event the OTDR provides:

- Distance location
- Loss
- Reflectance

For the Complete link the OTDR provides:

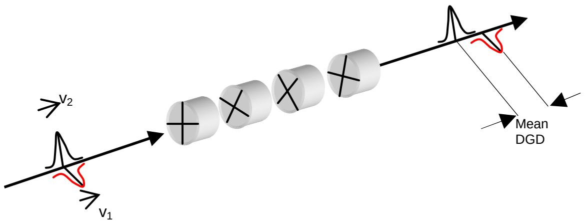
- Link Length
- Link loss in dB
- ORL of the link

☑ **OTDR tests are (almost) always performed in both directions and the results are averaged, resulting in bi-directional event loss analysis.**

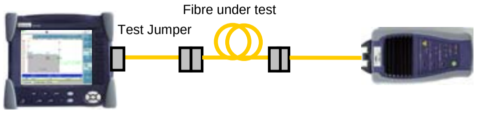
☑ **The OTDR most commonly operates at 1310, 1550 and 1625 nm singlemode wavelength.**

Polarization Mode Dispersion (PMD)

PMD introduces a differential time delay (mean Differential Group Delay) between signal components that are transmitted in two well-defined orthogonal polarization states which may cause severe distortion in the optical receiver at the end of the fiber.



A PMD test set consists of a polarized broadband light source (transmitter) and a spectrum analyzer (receiver). The broadband source sends a polarized light into the fiber under test, which is analyzed by the spectrum analyzer after passing through a polarizer.



☑ **PMD measurement is typically performed unidirectional.**

☑ **The results will be correlated to the transmission system limits according to the bit rate being implemented.**

Bit Rate per channel	Transmission		Max. Mean DGD(ps)
10 Gb/s	SDH - STM-64 (L-64.2)	SONET - OC-192 (LR-2)	10
40 Gb/s	SDH - STM-256 (VSR-2000-3L)	SONET - OC-768 (SR-2)	2.5
10 Gb/s	Ethernet		5

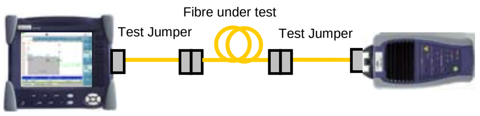
Chromatic Dispersion (CD)

Chromatic dispersion (CD) is the property that the effective Index of refraction of a medium (optical fiber) where propagates light, is color-dependant, or varies as a function of wavelength., each wavelength traveling at different speeds in the medium

The CD of a given fiber is measured in ps/nm and represents the relative arrival delay (in ps) of two wavelength components separated by one nanometer (nm).

- CD value is provided at a given wavelength
- CD coefficient—value normalized to the distance of typically one kilometer, expressed in ps/nm/km
- CD and its coefficient can be either positive or negative

A CD test set consists of a broadband light source (transmitter) and a phase meter (receiver) connected at each end of the fiber under test. The receiver measures the broadband signal light in user defined increments (such as10 nm increments). Approximation formula is then applied in order to calculate the dispersion over a given wavelength range.



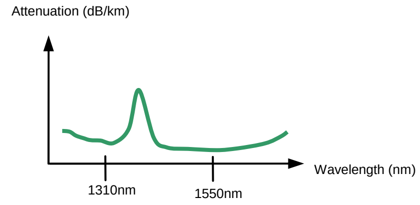
☑ **CD measurement is typically performed unidirectional.**

☑ **The results will be correlated to the transmission system limits according to the bit rate being implemented.**

Bit rate per channel	Transmission		chromatic dispersion @ 1550nm (ps/nm)
10 Gb/s	SDH - STM-64 (L-64.2)	SONET - OC-192 (LR-2)	1,176
40 Gb/s	SDH - STM-256 (VSR-2000-3L)	SONET - OC-768 (SR-2)	73.5
10Gb/s			738

Attenuation Profile (AP)

Every fiber presents varying levels of attenuation across the transmission spectrum. The purpose of the AP measurement is to represent the attenuation as a function of the wavelength.



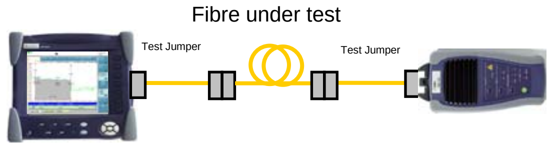
An AP test set consists of a broadband light source (transmitter) and a spectrum analyzer (receiver). The broadband source sends light, with a given wavelength range, into the fiber under test, which is analyzed by the spectrum analyzer at the far end.

A reference measurement of the source and fiber jumpers is required prior to performing the measurements.

A 2-step operation:

Step 1: Reference power level per wavelength: Quantify the output power including the fiber jumpers. Connect source and the spectrum analyzer together with the jumpers.

Step2: Insert the fiber under test and the power measurement of the connected elements (jumpers + fiber under test).

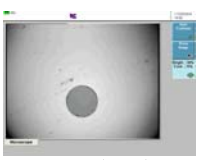


The receiver records the attenuation per wavelength of the source used for transmission.

☑ **This is used to determine amplifier locations and specifications, and could have an impact on channel equalization (bends).**

Measurement Report

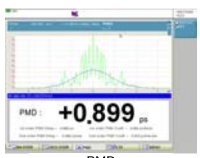
Once each individual test has been formed, the fiber link is considered as characterized. The resulting data have to be analyzed by the system engineers, measurement report has to be performed and archived in the database.


Connector inspection

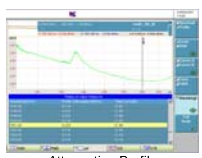

Insertion Loss & ORL


Bi-dir. OTDR


Chromatic Dispersion



PMD


Attenuation Profile