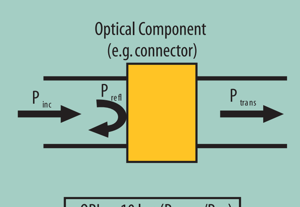
Understanding Fiber Characterization

Optical Return Loss

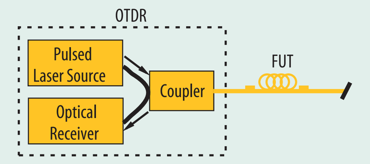
ORL is the ratio (expressed in dB) of reflected power to incident power from a fiber optic system or a link. The reflected power is due to Fresnel reflections or changes in the index of refraction.
The higher the ORL value, the lower the reflected power. An ORL value of 40 dB is better than 30 dB.



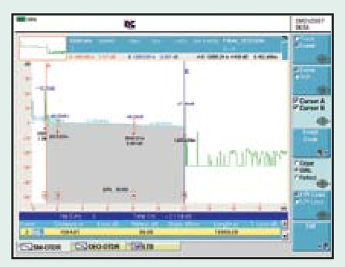
$ORL = 10 \log (P_{inc}/P_{refl})$

- IEC 61300-3-6 – Fiber optic interconnecting devices and passive components – Basic test and measurement – Part 3-6: Examinations and measurements – Return loss

OTDR Method

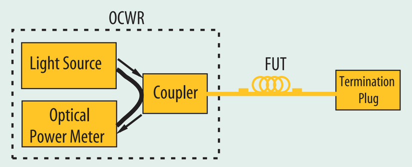


The OTDR launches light pulses into the device under test and collects backscatter information as well as Fresnel reflections.



Accuracy:	±2 dB
Typ. Appl.:	Spatial characterization of reflective events & estimation of sectional and total link ORL
Strength:	Reflective event localization
Weaknesses:	Accuracy Longer acquisition time

OCWR Method



The OCWR launches a stable, continuous wave signal into the optical fiber and measures the strength of the time-integrated return signal.

Accuracy:	± 0.5 dB
Typ. Appl.:	Total link ORL
Strengths:	Accurate Fast and real time information Possibility to measure short link
Weaknesses:	No reflective event localization

Why measure ORL?

It is essential to measure backreflection when installing and maintaining networks especially in DWDM or analog CATV transmission systems.
A high level of ORL will decrease the performance of this type of systems.

Typical Values

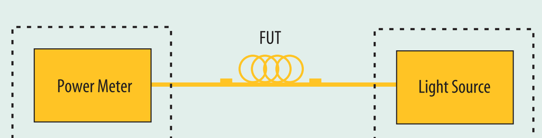
(defined by Telcordia GR-1312-CORE)

Requirement: 27 dB
Objective: 40 dB

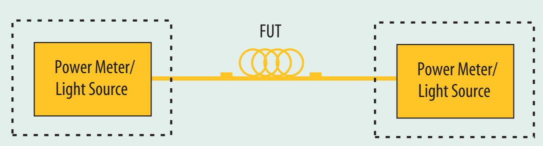
Insertion Loss/Bi-directional Insertion Loss

Insertion Loss is the loss in the power of a signal that results from inserting a passive component (connectors, splices. . .) into a continuous path.

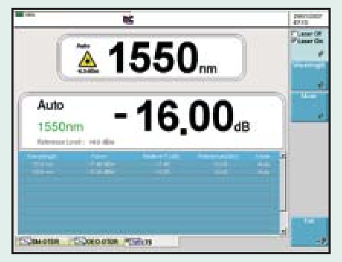
- IEC 60512-25-2 – Connectors for electronic equipment – Tests and measurements – Part 25-2: Test 25b- Attenuation (insertion loss)
- IEC 61300-3-34 – Fiber optic interconnecting devices and passive components– Basic test and measurement
- ITU-T G650.1 – Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable



Insertion Loss testing is typically performed with a power meter and a 2-lambda or a 3-lambda light source.



Automatic bi-directional Insertion Loss testing with a loss test set (combined light source and power meter).



Why measure IL?

Measuring insertion loss will give the attenuation across a fiber, a passive component or an optical link. The value obtained has to be taken into account in transmission system design (input power, receiver sensitivity).

Typical Values

Mechanical splice: 0.5 dB
Fusion splice: 0.1 dB
PC connector: 0.3 dB
APC connector: 0.5 dB

Optical Connection Inspection

Fiber inspection must be utilized to ensure the optical connectors are operational and free from any contamination.
Particules (dust…) contamination is the first source of troubleshooting in optical networks causing back reflection, signal loss and equipment damage.
When contaminated connectors are mated, debris is embedded into the glass causing permanent damage.

Before cleaning

After cleaning

It is very important to clean connectors.
A dirty connector will dramatically increase the power loss!
Inspect your connector before and after cleaning using a videoscope.

Fiber connectors should always be visually inspected ***before mating!***

Fiber Characterization Test Requirements

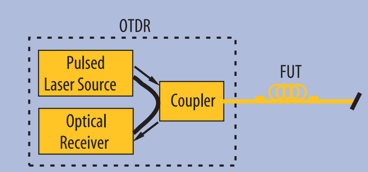
This table is greatly simplified and each user must review and modify it in accordance with their specific Network Element equipment and application.

Test	2.5 Gbps STM-16/OC-48 1550	2.5 Gpbs STM-16/OC-48 DWDM	10 Gbps STM-64/OC-192 1550	10 Gbps STM-64/OC-192 DWDM	40 Gbps STM-256/OC-768 DWDM	10 Gbps Ethernet	Equipment Required	Testing Recommended
Insertion Loss	1310/1550 nm	1550/1625 nm	1310/1550 nm	1550/1625 nm	1310/1550/1625 nm	1310/1550 nm	PM & LS, or LTS	Uni-directional
Return Loss	1550 nm	1550 nm	1550 nm	1550 nm	1550 nm	1550 nm	OTDR or ORL Meter	Uni-directional
Physical Plant Verification (Inc. Connector & Splice Loss/ Point Ref. / Distance)	1310/1550 nm	1550/1625 nm	1310/1550 nm	1550/1625 nm	1310/1550 nm	1310/1550 nm	2 or 3 wavelengths OTDR	Bi-directional
Polarization Mode Dispersion	<80 km not required unless pre-1993 fiber	<80 km not required unless pre-1993 fiber	Required	Required	Required	Required	BB Source, PMD Analyzer	Uni-directional
Chromatic Dispersion	Not required if less than150 km	Not required if less than 150 km	Recommended	Recommended	Recommended	Recommended	4 Lambda OTDR or Phase Shift Analyzer	Uni-directional
Attenuation Profile	No	1550 to 1625 nm	No	1550 to 1625 nm	No	1550 to 1625 nm	BB Source and OSA	Uni-directional

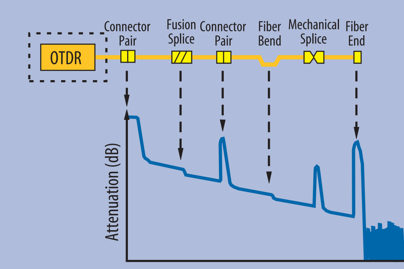
Optical Time Domain Reflectometry

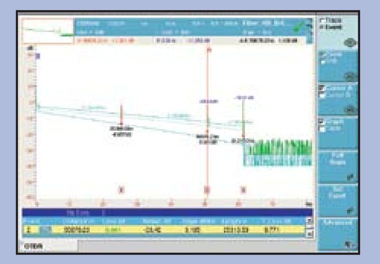
Fibers joined using splices and connectors provoke two types of attenuation: loss and reflectance. There are both due essentially to Fresnel reflections.

- IEC 61786 – Calibration of optical time-domain reflectometers (OTDR)
- GR-196 – Generic Requirements for Optical Time Domain Reflectometer (OTDR) Type Equipment
- ITU-T G650.1 – Definitions and test methods for linear, deterministic attributes of singlemode fibre and cable



The OTDR injects a short, intense laser pulse into the optical fiber and measures the backscatter and reflection of light as a function of time. It's then analyzed to determine the location of any fiber optic breaks or splice losses.





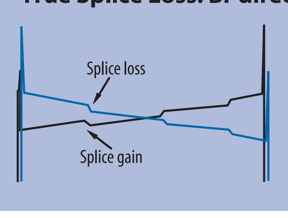
Why measure loss and reflectance?

Splices and connectors are important components to be tested as their losses and reflectances have a strong impact on the link quality. Tests can be performed during installation or for commissioning. An OTDR enables to detect, localize, and measure events along a fiber link.

Typical Values

Mechanical splice: 0.5 dB
Fusion splice: 0.1 dB
UPC connector: Loss: 0.3 dB, Reflectance: -55 dB
APC connector: Loss: 0.5 dB, Reflectance: -65 dB

True Splice Loss: Bi-directional OTDR Measurement

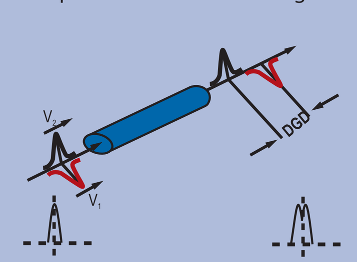


Due to fiber backscatter coefficient mismatches, a splice can appear as a gain or as a loss depending on the test direction. Bi-directional analysis is used to minimize this possible mismatch by measuring the splice loss in both directions and averaging the result to obtain the true splice loss.

Polarization Mode Dispersion

PMD (or average DGD) is caused by the differential arrival time of the different polarization modes (horizontal and vertical) transmitted into a fiber caused by its birefringence. PMD broadens transmission pulse and is critical for high bit rate transmission.

- IEC 60793-1-48 – Optical fibers - Part 1-48: Measurement methods and test procedures – Polarization mode dispersion
- ITU-T G650.2 – Definitions and test methods for statistical and non-linear attributes of single-mode fibre and cable
- TIA/EIA-455-FOP113



The second order PMD gives the delay created by the PMD variation linked to the wavelength, and therefore is interesting to know for DWDM systems. Second order PMD has to be added to chromatic dispersion figures, and therefore is limiting the link distance.

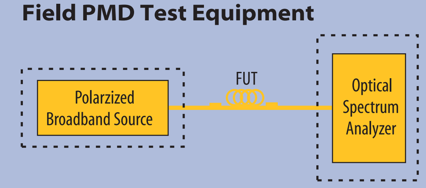
PMD Limits According to Bit Rate

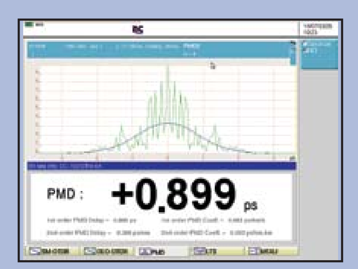
Bit Rate Per Channel	SDH	SONET	PMD Delay Limit
2.5 Gbps	STM-16	OC-48	40 ps
10 Gbps	STM-64	OC-192	10 ps
40 Gbps	STM-256	OC-768	2.5 ps
10 Gbps	Ethernet	-	5 ps

Why measure PMD?

PMD measurement shall be at least performed when the bit rate is equal or higher than 10 Gbps. However, for some applications, such as analog cable TV applications, lower transmission bit rates can be affected by PMD.

Field PMD Test Equipment





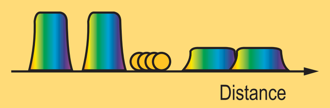
A polarized light is sent over the FUT and the transmitted spectrum is analyzed through a polarizer. The analysis of the fixed-analyzer response is shifted to the time domain by taking the Fourier transform. The mean DGD is calculated from the Gaussian distribution.

Typical Values

For a new fiber - Max PMD: 0.2 ps/$\sqrt{\text{km}}$ITU-T G.652D

Chromatic Dispersion

The different wavelengths (colors or spectral component of light) travel at different speed in a fiber due to the variation of index of re-fraction. It induces a pulse width variation.



- IEC 60793-1-42 – Optical fibres - Part 1-42: Measurement methods and test procedures – Chromatic dispersion
- ITU-T G650.1 – Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable

CD Limits According to Bit Rate

Bit Rate	SDH	SONET	Total Allowable Dispersion Coefficient at 1550 nm for a Given Link
2.5 Gbps	STM-16	OC-48	12000 to 16000 ps/nm
10 Gbps	STM-64	OC-192	800 to 1000 ps/nm
40 Gbps	STM-256	OC-768	60 to 100 ps/nm
10 Gbps	Ethernet	–	738 ps/nm

Why measure CD?

CD must be measured to insure the compatibility of the fiber link with the high bit rate transmission and the network equipment manufacturing constraints. It has to be performed during manu-facturing process, fiber installation and system upgrade.

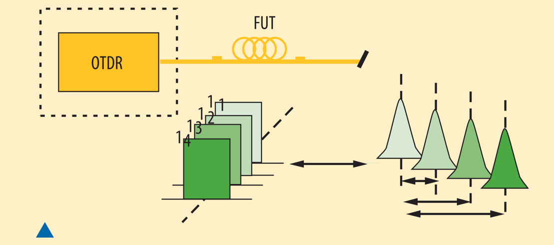
Fiber Types

Typical Values

ITU-T G.652: ~ 17 ps/(nm.km) at 1550 nm
ITU-T G.653: 0 ps/(nm.km) at 1550 nm
ITU-T G.655: ~4 ps/(nm.km) at 1550 nm

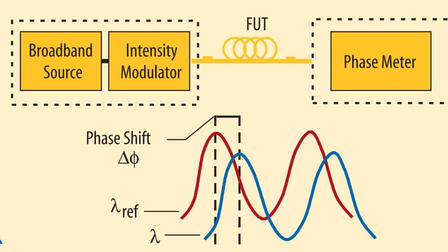
Field CD Test Equipment

Propagation Time Method (pulse delay)



The OTDR sends four (or more) wavelengths over the FUT. The time delay between the different wavelengths at the end of the link is measured. The chromatic dispersion of the tested fiber is then calculated using the right nonlinear regression.

Phase Shift Method

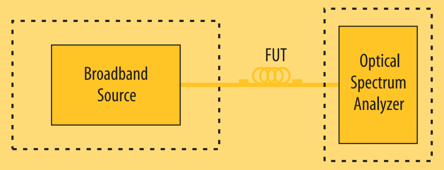


The modulated light is sent over the FUT. The phase of the test signal is compared to the phase of the reference signal used to modulate the input signal. The phase measurement is performed over the entire wavelength range of the broadband source.

Attenuation Profile

Attenuation Profile is the loss of signal power normalized to 1 km caused by material absorption, impurities, waveguide geometry and scattering.

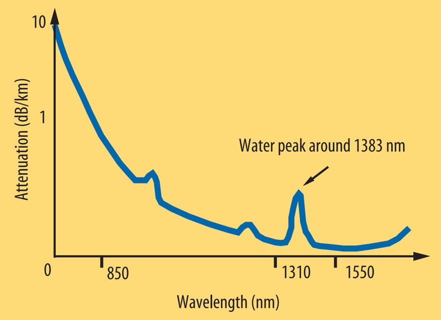
- IEC 60793-1-40 – Measurement methods and test procedures

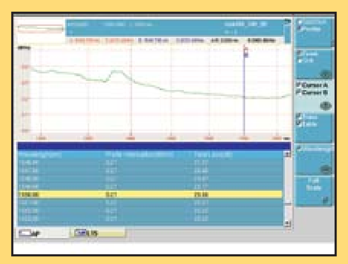


Spectral Attenuation testing is performed using a broadband source and optical spectrum analyzer. The OSA is like a wavelength-selective power meter. It records the source spectrum (taken as reference) and compares it with the spectrum of the source at the link output.

Why measure attenuation?

For DWDM systems, it is important to obtain the attenuation profile of the band used for transmission, as this will have an impact on channel equalization as well as amplifier specifications if they are implemented in the network. For CWDM systems which cover the band from 1261 nm to 1611 nm, the fiber suitability in this entire range, especially within the "water peak" region around 1383 nm, must be checked.





Typical Values

1260 nm – 1360 nm: 0.35 dB/km
1530 nm – 1565 nm: 0.22 dB/km
1565 nm – 1625 nm: 0.25 dB/km

Fiber Test Products

T-BERD® 8000/ MTS-8000

Scalable Optical Test Platform

T-BERD® 6000/ MTS-6000

Compact Optical Test Platform

SMART

Optical Handheld Meters

OVIP-250/ OVIP-400

Optical Video Inspection Probes

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