Measuring OTDR Reflectance and ORL

Overview

Optical Return Loss (ORL) is the ratio between the light launched into a device and the light reflected by a defined length or region. ORL can be measured using two measurement techniques: optical continuous wave reflectometry (OCWR) or optical time domain reflectometry (OTDR). Both techniques are described in IEC 61300-3-6. This paper will briefly describe the OCWR method, but the emphasis will be on the OTDR method. While the OCWR method is more accurate, the time-domain method has become the more popular tool primarily due to its ease-of-use and ability to characterize total fiber spans results as well as individual event location, loss and reflectance.

OTDRs can measure reflectance and total ORL for a fiber span. Return Loss (RL) of individual events, i.e. the reflection above the fiber backscatter level, relative to the source pulse scatter, is called reflectance. Return Loss of a fiber span is referred to as ORL. Both reflectance and ORL are in units of dB but reflectance is always a negative value while ORL is a positive value. Larger reflections indicate bad reflectance or -14dB, or 4% Fresnel reflection indicating poor connection.

ORL and reflectance measurement results can be impacted by contaminated connectors so proper cleaning and inspection is critical prior to any measurement to ensure accurate and repeatable results. RL on a mated optical connector is ORL but when measured using OTDR, it is called reflectance. The ORL of a connector can change over time with repeated mating due to small changes to the surface.

OCWR

OCWR measures return loss of connectors or patchcords using a light source and power meter. This test is often used for terminated patch cords when the loss and reflectance values are required specifications. The OCWR method uses a coupler to send light from a source though a coupler out the common test port while measuring reflected light split into the power meter.

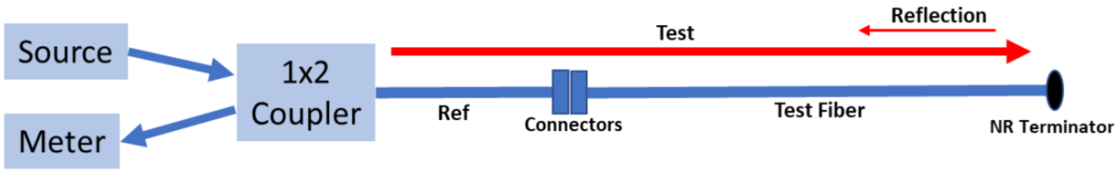

Figure 1: OCWR method of measuring return loss of connectors or patchcords

Just as it is required to obtain insertion loss (IL) referencing when measuring span loss, ORL referencing must also be established prior to making ORL measurements. This ORL reference process is a 3-step process:

1. Zero meter
2. IL reference
3. ORL reference using 1 or 2 reference cable(s)

The reference cable is used to connect to the fiber or connector under test. OCWR accuracy is about ±1% or 1 dB at best although most test sets have a readout to 0.01 dB which confuses people who think that the readout resolution of the instrument is the accuracy of the measurement. The image below shows the VeEX ORL meter measuring a fiber to be used in an optical network.

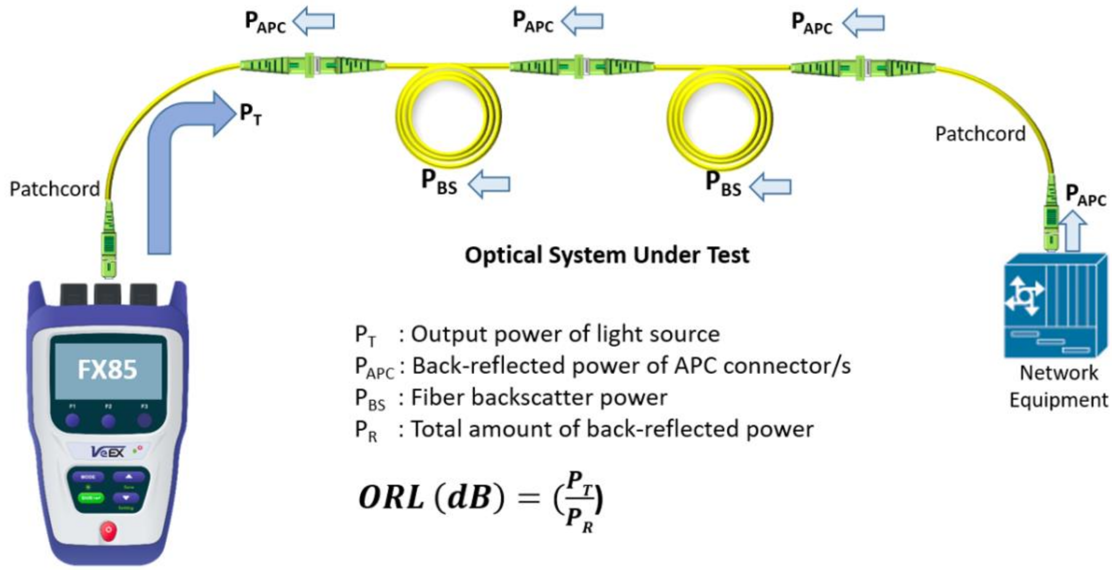

Figure 2: ORL meter measuring a fiber to be used in an optical network

OTDR

The OTDR, like the OCWR technique, identifies light that is returned from both Rayleigh backscatter and Fresnel reflection (reflectance) from a connector or splice. Unlike the OCWR technique, the OTDR can measure Rayleigh backscatter and Fresnel reflection separately, enabling the OTDR to report both total ORL for the fiber under test and/or individual event reflectance making it a perfect troubleshooting tool. Typically, reflectance measurements are limited to ~-70dB.

Optical Return Loss (ORL)

The OTDR generally tests ORL by calculating the total of all the light reflected from reflective events plus the total backscatter from the start to end of the fiber being tested. This ORL measurement is important on very high-speed systems as ORL can be a contributor to noise and bit error. OTDR ORL is not a reflectance test of an individual event and should not be confused with reflectance. In the trace below, the end connector is open with high reflection and should not be included in the link ORL measurement as it will result in erroneous failure of the span for ORL.

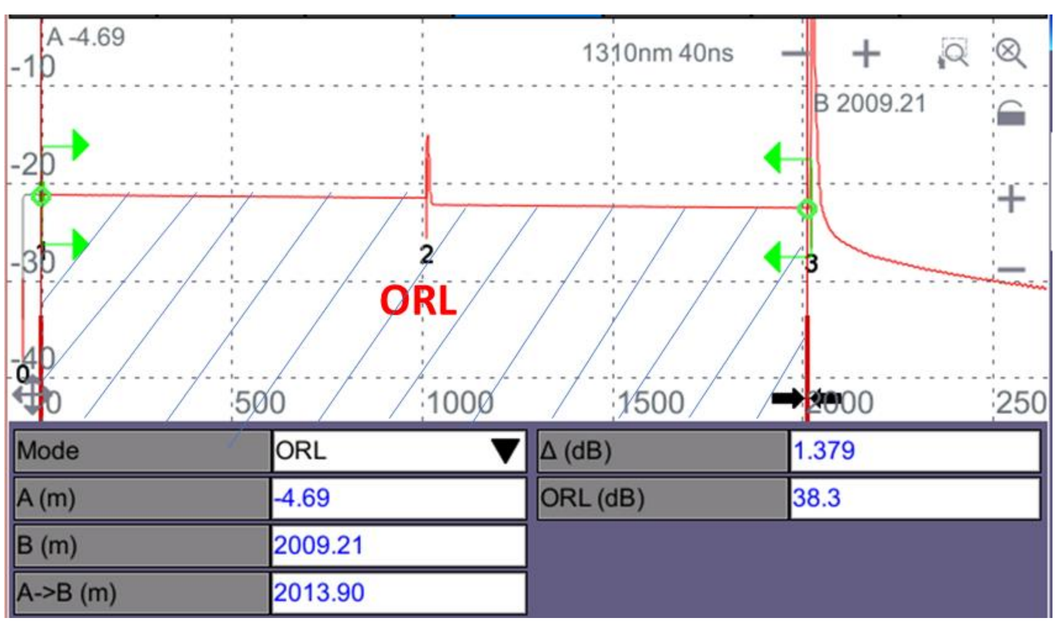

Figure 3: Trace graph showing an open end connector with high reflectance. This will result in erroneous failure of the ORL span if included in the link ORL measurement.

Scattering

Scattering occurs when light interacts with small discrete particles. These particles can be impurities, defects, or even regions of mechanical stress. There are many types of scattering, but the most common type in optical fiber is Rayleigh scattering. The important difference between Rayleigh scattering and Fresnel reflections is that Rayleigh scattering occurs along the total length of the fiber.

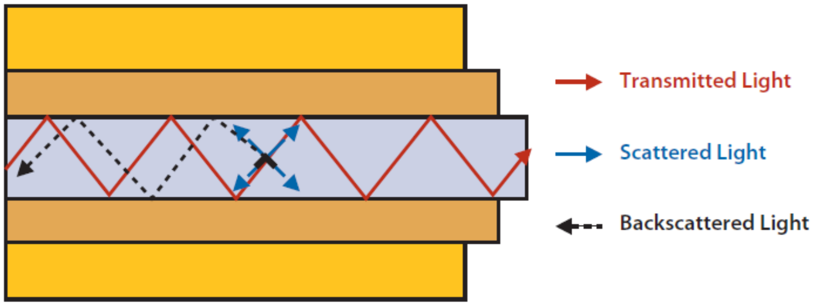

Figure 4: *Backscattering effects of light transmission*

Reflectance

Reflectance (sometimes called ORL) is the amount of light that is reflected back toward the OTDR from light reflections that occur whenever light travels across the interface of two material with different index of refraction (IOR) such as two fibers held together by some mechanical means. Reflections are a result of Fresnel reflection and is caused by the light going through the change in index of refraction at the interface between the fiber (n=~1.5) and air (n=~1). In modern fiber plants, reflectance is primarily a problem with connectors. However, in older fiber networks, mechanical splices that used index matching gel to prevent reflectance have been known to degrade over time also resulting in reflections. While mated connectors commonly show a reflective peak on OTDR traces, very high-quality APC connector mating may show little to no reflection. In addition, fusion splices typically will not show any reflection unless the splices are bad, and an air bubble or other impurity exist within the area where the cores are fused together.

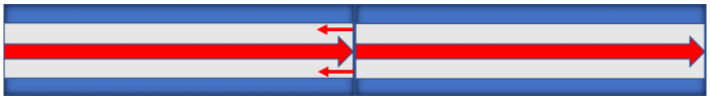

Figure 5*: Fresnel reflection*

Connector and patchcord manufacturers will specify the quality of their product by providing IL and ORL. OTDRs use the term reflectance which is the inverse of ORL, having the opposite sign, e.g. 45 dB ORL is -45 dB reflectance, when referring to connectors. ORL is the total of all reflective events and all backscatter of fiber under test. Connector ferrules can have different end polishes that can affect reflectance as well as loss. Higher bit rate networks need lower RL to get maximum performance and is typically more of an issue with singlemode networks. Therefore, manufacturers have concentrated on solving the RL problem for their singlemode components which have also led to improvement with multimode connectors. Two connector ferrule polish techniques are used to reduce reflectance. The convex physical contact (PC) polish has evolved over the years to reduce reflection from -14 dB (flat, no contact) to ~-45 to -55 dB ultra polish physical contact connector (UPC). The angled polished physical contact connector (APC) has an end face which has a slight 8^{o} angle and provides even lower reflectance (~-60 to -65 dB) than UPC polished connectors.

Reflectance is defined by the amount of light reflected compared to the power of the light being transmitted down the fiber. In an OTDR, the peak that identifies a reflective event is measured and reflectance calculated. Higher peaks indicate higher reflectance. To measure reflectance, the peak must not saturate the OTDR receiver, which is indicated by a flat-top reflection peak. When a peak has a flat top, the measured OTDR reflectance cannot be accurately reported as the reported value is less than actual reflectance. Calculating reflectance in an OTDR involves measuring the baseline noise of the OTDR, backscatter level and power in the reflected peak as shown in the diagram below. Since reflectance is defined as a fraction of the power in the test signal, the OTDR must calculate the test power from the backscatter level of the fiber, based on the typical backscatter coefficient of the fiber being tested.

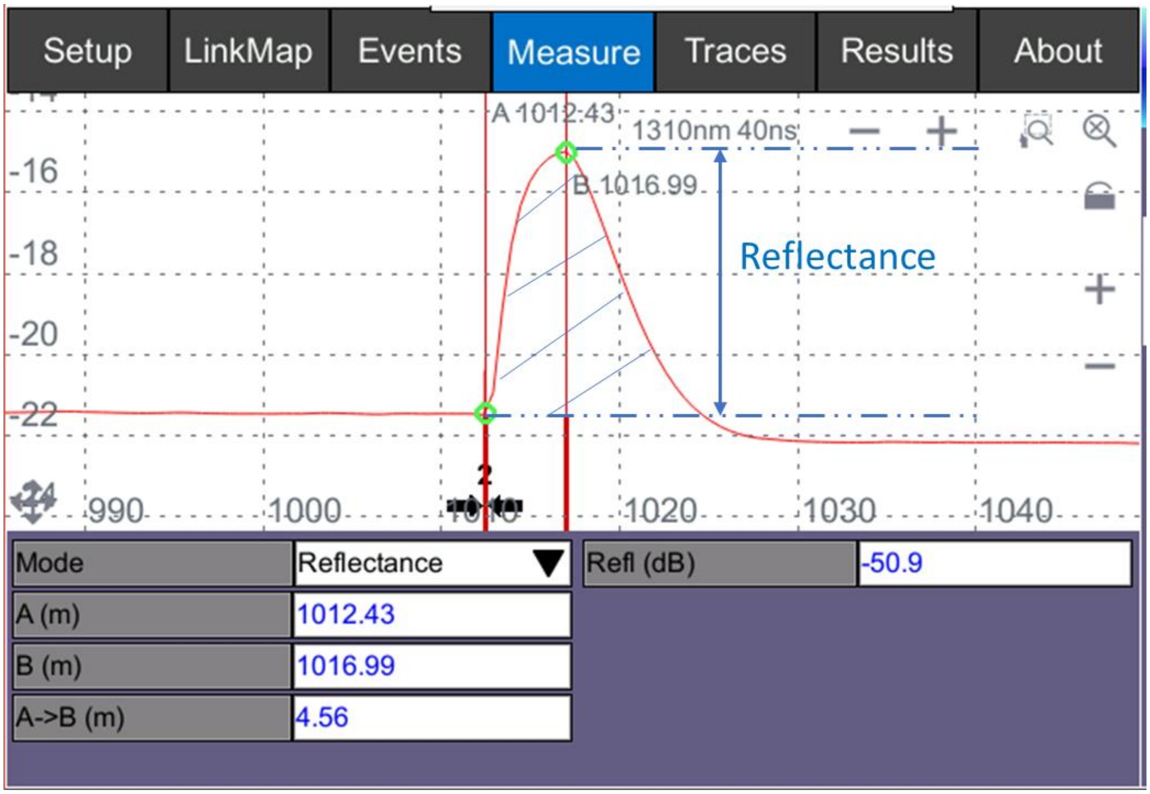

***Figure 6**: To find the OTDR's reflectance, measure the OTDR's baseline noise, backscatter level and power in the reflected peak.*

The OTDR measures the backscatter level just before the peak being measured, applies an adjustment to account for the OTDR test pulse width, and measures the power of the reflectance peak to calculate the reflectance. This measurement allows technicians the ability to show where high reflective events are located on a test fiber, so they can reduce ORL if needed. VeEX OTDRs will automatically measure reflectance when the A cursor is positioned on the backscatter just before the leading edge of the peak of a reflection, eliminating the need for the technician to also position cursor B at the top.

Typical Reflectance

Reflectance measurements can be limited by the OTDR dynamic range. The maximum optical reflectance is limited when a reflection has saturated the OTDR receiver which is seen as a reflection with a flat top. The minimum optical reflectance is limited by where the signal is too small relative to noise to be detected. Likewise, ORL is limited when any part of the return signal is saturated, or the entire trace span cannot be displayed (such as when there is insufficient dynamic range). The range for measuring optical reflectance and ORL depends on several factors: wavelength, pulse width, backscatter coefficient, attenuation, and OTDR dynamic range.

Modern singlemode networks are built with either UPC or APC connectors for minimal reflectance; however, legacy fiber networks may have connectors that were more reflective. The table below illustrates the different connector polishes that have been utilized historically. Multimode networks have benefited from improved polish techniques, but higher data networks typically use singlemode fiber so multimode connectors are typically -35 dBm.

Mated Connector Type	Typical Reflectance
Flat with air gap	-14 dB or 4%
Physical Contact	-25 to -35 dB
Super Physical Contact (SPC)	-35 to -45 dB
Ultra PC	-45 to -55 dB
APC (angled)	-60 dB or higher

Note 1: *Return Loss can be made worse by contaminated or damaged connectors. Before testing,* clean and inspect all connector end faces including the test port. Only pristine connectors can provide minimal reflectance. Connector damage can occur with repeated mating of improperly cleaned connectors and in this situation, cleaning will not help reflectance.

Note 2: Just as fiber types can have different IOR, it can also have different backscattering (BS) coefficients. Applying the wrong BS coefficient can result in erroneous ORL and reflectance values. Contact the cable manufacturers for their recommended IOR and BS coefficients for their cable.

About VeEX

VeEX Inc., a customer-oriented communications Test and Measurement company, develops innovative test and monitoring solutions for next generation telecommunication networks and services. With a blend of advanced technologies and vast technical expertise, VeEX products address all stages of network deployment, maintenance, field service turn-up, and integrate service verification features across Copper, Fiber Optics, CATV/DOCSIS, Mobile 4G/5G backhaul and fronthaul, next generation Transport Network, Fibre Channel, Carrier & Metro Ethernet technologies, WLAN and Synchronization.

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