Agilent Technologies

Optical Time Domain Reflectometers

Pocket Guide

Agilent Technologies

Notices

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1
Fiber Optic Basics

This section covers some basic information on fiber optics and the most commonly used fiber and connector types.

The intention is to mention the terms that you need to be familiar with in the later chapters and when working with an OTDR. This section is not suitable for learning the complete physics and technology behind fiber optics.

Fiber Optics Technology

The need for transporting data faster and over longer distances led to the development of new technologies. Using photons instead of electrons for signal transmission through cables allows much higher bandwidths at much lower costs.

Although the idea of transmitting information by light is not new, only the last decades brought up devices and materials that made the use of it affordable.

The advantages of fiber optic cables come from the fact, that glass is an isolator. No disturbing energy fields are emitted or absorbed. Glass has very little attenuation, which is independent of the modulation frequency. Compared to a copper cable of same transmission capability, the optic fiber is much smaller and lighter in weight. On top of that, it is much cheaper even when considering all necessary driving devices and installation costs.

Future developments will further reduce the costs for fiber optic networks. This applies for all areas, such as production, installation, maintenance and, of course, using the network.

To send data over a fiber optic cable, you need a source for modulated light. This typically is a laser diode that emits light pulses into the fiber. At the other end, you need a photo detector, usually a semiconductor device. It works similar to a solar cell by converting light into electrical current.

Todays fiber optic devices work with light at a wavelength of approximately 1 µm. This corresponds to a frequency of $3 \cdot 10^{14}$ Hz or 300.000 GHz. For technical reasons, most devices work with intensity modulation (AM), which yields a bandwidth of 5 to 10 GHz. Compared to the carrier frequency, this may seem very little, it is limited by the available technologies.

The attenuation of light in a glass fiber depends on the wavelength. There are minima in the attenuation curve around 1310 nm, and 1550 nm. Around these points are ranges of approximately 100 nm width that are called windows. These windows are the preferred frequencies used for transmitting data. Today’s fibers cover multiple windows (1300/1400/1500/1600 nm).

You can feed signals at different wavelengths in the same window into one fiber and separate them optically at the other end. This allows several channels per window with one single fiber and is called wavelength-division multiplexing (WDM).

Another technique is to send signals at different wavelengths in both directions through the same fiber. This is called bi-directional transmission and reduces the number of required cables by 50 %.

Time-division multiplexing (TDM) is a technique that is also used in telephony. Several slow signals can be sent concurrently in time slots of one fast serial signal. Synchronous sampling and demultiplexing separates the signals again at the end of the fiber.

Fiber Types

By far, most fiber cables used today are made of silica. Silica is a very pure and elastic material and resources are almost unlimited, as compared to copper, for example.

Some fibers, however, are made of polymers or other synthetic materials. But these can only be used for short distances because of their high attenuation. They usually have large diameters, into which a large amount of light can be emitted.

A fiber consists of a core, cladding, which provides insulation, and a buffer, which provides mechanical protection. Cables are labelled according to their core and cladding diameter. For example, a typical single-mode fiber cable is the 9/125 µm, which has a 9 µm core diameter and 125 µm cladding diameter. The buffer around a 9/125 µm fiber, would be typically around 250 µm.

Basically, the following fiber types are used:

- Step index fiber (single-mode)

Figure 1 Single-Mode Fiber

In step index fibers, the core and the cladding have a different index of refraction. Single-mode fibers have a very small core diameter (< 9 µm). This allows only one single mode (wave propagation) to pass through the fiber. Such fibers have very small attenuation and large bandwidth (> 10 GHz·km), no pulse broadening, no transit time differences.

Typically used: 9/125 µm fibers at 1300 nm for long distances.

- Step index fiber (multimode)

Figure 2 Multimode Fiber

Multimode fibers have a fairly large diameter (> 100 µm). This allows multiple modes to pass. Such fibers have higher attenuation and small bandwidth (< 100 MHz·km), strong pulse broadening and transit time differences.

Typically used for LAN applications (> 300 m).

- Graded index fiber (multimode)

Figure 3 Graded Index Fiber

In a graded index fiber, the index of refraction gradually changes from core to cladding. Such fibers have small transit time differences and small pulse broadening, small attenuation, and bandwidth < 1 GHz·km.

Typically used: 50/125 µm or 62.5/125 µm fibers for short distances (< 500 m).

Connector Types

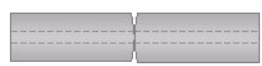
Connectors are used to link fibers together. Moreover, they must ensure a low loss even after a large number of plugging und unplugging procedures. Additionally the connection must cause as little reflection as possible. Finally, the connector should be cheap and easy to mount.

The materials, that are used for connectors are mainly ceramics, hard metals, some alloys and synthetics.

There are many different types of connectors available. Regarding the shape of the fiber end, you can distinguish between cylindric, biconic and lens coupling connectors.

Usually, the connectors are classified by how the fibers are mounted into them:

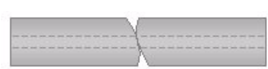
- Straight physical contact (PC)



The fiber ends are pressed together in the connector. There is no air gap left to cause reflections. The return loss is 30 – 55 dB.

This is the most common connector for single mode fibers (for example FC/PC, ST, SC/PC, DIN, HMS, E 2000 connectors).

- Slanted (angled) physical contact (APC)



In these connectors the ends of the fibers are slanted. Again no air gap is left. This gives the best return loss (60-80 dB).

These connectors are used for high-speed telecom and CATV links (for example FC/APC, SC/APC, E 2000-HRL connectors).

- Straight air gap

Inside these connectors there is a small air gap between the two fiber ends. Their return loss is less than 14 dB and the reflection is fairly high.

Straight air gap connectors, for example ST connectors, are used for multimode fibers.

2
Equipment for Measuring Fibers

In today’s world, the demand for optical networks is growing faster and faster. The networks are becoming bigger, more powerful and more reliable. This requires more operators, installers and maintenance contractors to provide information on the networks faster and with higher accuracy than ever before.

Optical Time Domain Reflectometer

The Optical Time Domain Reflectometer (OTDR) is the preferred instrument for characterizing optical fibers. With an OTDR you can evaluate the characteristic properties of a single fiber or a complete link. In particular, you can see losses, faults, and the distances between Events at a glance.

Agilent Technologies' OTDRs check the quality of fiberoptic links by measuring backscatter. Standards organizations, for example, the International Telecommunication Union (ITU), accept backscatter measurements as a valid means for analyzing a fiber's attenuation. Backscatter is also the only fiberoptic measurement method that detects splices within an installed link. It can also be used to measure the optical length of a fiber. Thus, the OTDR is a valuable tool for anyone who manufactures, installs, or maintains optical fibers.

The OTDR functions by looking for “Events” in a fiber, for example, irregularities or splices. This makes it an invaluable quality control tool for anyone who manufactures, installs, or maintains fiberoptic cables. The OTDR pinpoints these irregularities in the fiber, measures the distance to them, the attenuation between them, the loss due to them, and the homogeneity of the attenuation.

It is an especially valuable tool for the field. You can use it to regularly check if the link meets the specifications. In order to document the quality and to store it for maintenance purposes it is necessary to measure the optical length, the total loss, the losses of all splices and connectors—including their return losses.

Laser Safety

If you look into a laser beam then your eye may focus the light onto a very small spot on your retina. Depending on the energy absorbed by the retina, the eye may be damaged temporarily or permanently.

The wavelengths used in today's fiberoptic communication links are invisible. This makes even small optical powers more dangerous than bright visible light. Because you cannot see it, you may look much longer into a laser beam.

National and international organizations define standards for a safe operation of fiberoptic light sources.

All Agilent OTDRs meet the safety requirements of the most common standards. In the United States this is 21 CFR class 1, and in Europe it is IEC 825 class 3A. Products that are conform with these standards, are considered safe except if viewed with an optical tool (for example, a microscope). Nevertheless you should not look directly at the output or into any fiber end whenever a laser might be switched on.

WARNING Switch the OTDR off before you start to clean its connectors! Or at least disable the laser.

WARNING **INVISIBLE LASER RADIATION!**
DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.
CLASS 3A LASER PRODUCT

3
Events on Fibers

An Event on a fiber is anything that causes loss or reflections other than normal scattering of the fiber material itself. This applies to all kinds of connections as well as damages such as bendings, cracks or breaks.

An OTDR trace displays the result of a measurement graphically on the screen. The vertical axis is the power axis and the horizontal one is the distance axis. This section shows you drafts of typical traces for the most common Events.

Single Fibers

A single fiber yields the following trace. You see the slightly decreasing power level (attenuation) and strong reflections at the beginning and end of the fiber:

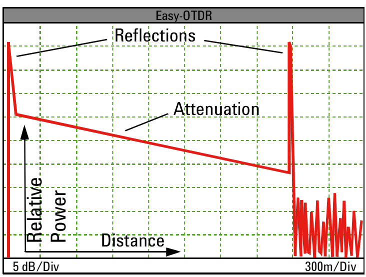


Figure 4 Single Fiber

Whole Links

The trace of a whole link, for example, between two cities, may look like this. Besides the normal attenuation you see Events and noise after the end of the link:

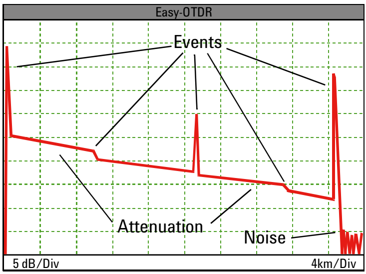


Figure 5 Whole Link

Beginning of a Fiber

If you are using a normal straight connector, the beginning of a fiber always shows a strong reflection at the front connector:

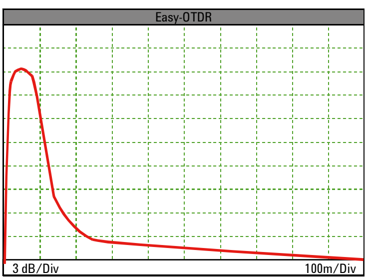


Figure 6 Beginning of a Fiber

Fiber End or Break

In most cases you see a strong reflection at the end of the fiber before the trace drops down to noise level:

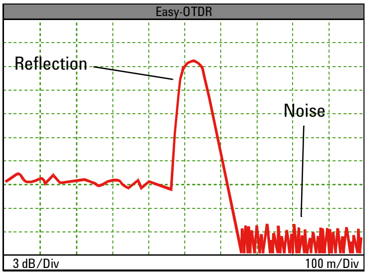


Figure 7 Fiber End

If the fiber is interrupted or broken, this is called a break. Breaks are non-reflective Events. The trace drops down to noise level:

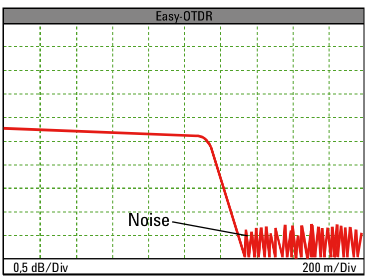


Figure 8 Break

Connector or Mechanical Splice

Connectors within a link cause both reflection and loss:

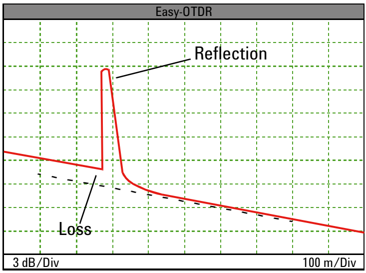


Figure 9 Connector

A mechanical splice has a similar signature to a connector. Usually it has lower loss and reflection values.

Fusion Splice

A fusion splice is a non-reflective Event, only loss can be detected. Modern fusion splices are so good, they may be nearly invisible:

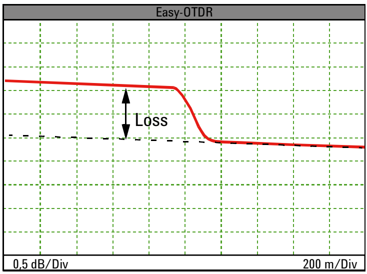


Figure 10 Fusion Splice

In the case of a bad splice, you may see some reflectance. Some splices appear as gainers as if the power level increases. This is due to different backscatter coefficients in the fiber before and after the splice:

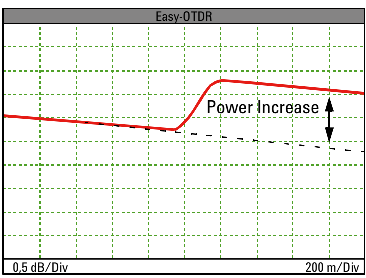


Figure 11 A Splice as a Gainer

If you see a gainer in a measurement taken in one direction, measure from the other end of the fiber. You will see a loss at this point in the fiber. The difference between the gainer and loss (the "averaged loss value") shows the real loss at this point. This is why we recommend that you take a 2-way averaging measurement of the fiber.

Bends and Macrobending

Bends in a fiber cause loss, but they are non-reflective Events:

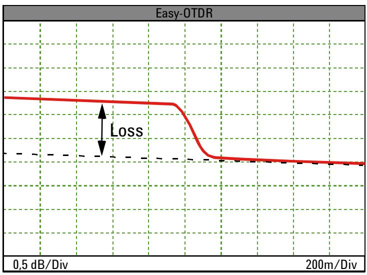


Figure 12 Bend or Macrobending

To distinguish bends from splices, look at the installation and maintenance records. In the case of macrobending, the loss is at an unknown location, Splices are at a documented, well-known distance.

If you measure at a higher wavelength, macrobendings show a higher loss. We therefore recommend that you make multi-wavelength measurements, so you can distinguish between bendings and splices.

Cracks

A crack refers to as a partially damaged fiber that causes relec-tion and loss:

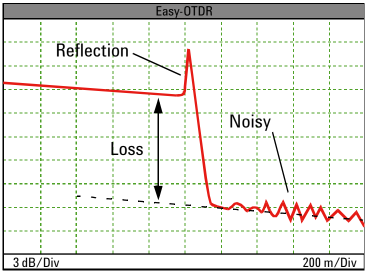


Figure 13 Crack

The reflectance and loss may change when the cable is moved.

Patchcords

Patchcords are used to connect the OTDR to the fiber under test. The initial reflection is not covering the beginning of the fiber. This allows better examination of the first connector:

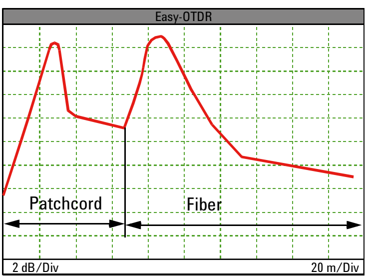


Figure 14 Short Patchcord

4
Important Parameters

This section covers the definitions of the most important parameters used when characterizing fibers.

Fiber Intrinsic Parameters

If you need more detailed information about your particular fiber, ask your fiber center.

The Refractive Index

An OTDR calculates the distances to Events by measuring the time elapsed between transmission of the light and reception of the reflection. This can be, for example, the rising edge of the reflection of the frontpanel connector, or the reflection from a connector. The distance displayed and the time measured are linked by the refractive index (sometimes called group index). This means that changing the refractive index causes a change of the computed distance.

How an OTDR measures a distance:

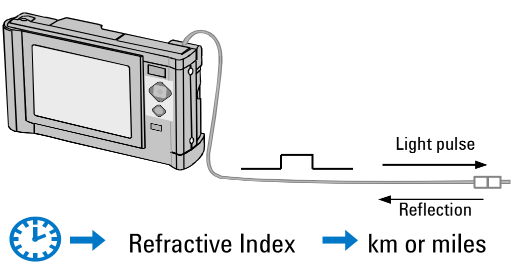


Figure 15 Refractive Index

Definition of the refractive index:

$$\textit{refractive index} = \frac{\textit{(speed of light in vacuum)}}{\textit{(speed of a light pulse in a fiber)}}$$

Displayed distance on the OTDR:

$$\textit{distance} = \frac{\textit{measured time} \times \textit{(speed of light in vacuum)}}{\textit{refractive index}}$$

The refractive index depends on the used fiber material and needs to be provided by the fiber or cable manufacturer.

It is important to understand the refractive index of the fiber you are measuring. The error due to this value not being known exactly is usually greater than any inaccuracies within the instrument.

The Scatter Coefficient

An OTDR receives not only signals from Events, but also from the fiber itself. As light travels along a fiber, it is attenuated by Rayleigh scattering. This is caused by small changes of the index of refraction of the glass. Some of the light is scattered directly back to the OTDR. This effect is called backscatter.

The scatter coefficient is a measure for how much light is scattered back in the fiber. This affects the value of return loss and reflectance measurements.

The scatter coefficient is calculated as the ratio of the optical pulse power (not energy) at the OTDR output to the backscatter power at the near end of the fiber. This ratio is expressed in dB and is inversely proportional to the pulse width, because the optical pulse power is independent of the pulse width.

A typical value is approximately 50 dB for 1 µs pulse width, depending on the wavelength and the type of fiber.

Measurement Parameters

The Pulse Width

One of the key parameters for good measurement results is the width of the light pulse emitted into the fiber. It determines the distance resolution, which is very important to separate Events clearly.

The shorter the pulse, the better the distance resolution. A short pulse, however, means that the dynamic range is smaller and the trace might be noisy.

If you want to measure long distances, you need a high dynamic range, so the pulse should be long. Longer pulses, however, average the fiber over a wider section, which means lower resolution.

Depending on the specific purpose of your measurement, you need a trade-off between high-resolution and high dynamic range. Thus, choose a short pulse width if you want to measure the loss of splices or connectors that are close together. But choose a long pulse width if you want to detect a break far away.

- **Short pulse width**
  High resolution but more noise. Decrease the pulse width in order to shorten the deadzones and to separate close Events clearly.

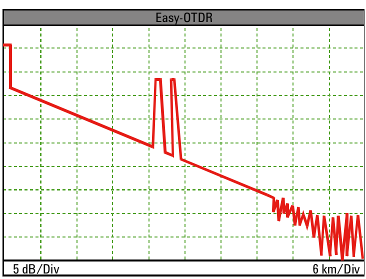


Figure 16 Short Pulses for Better Resolution

- **Long pulse width**
  High dynamic range but long deadzones. Increase the pulse width in order to reduce the noise and to detect Events far away.

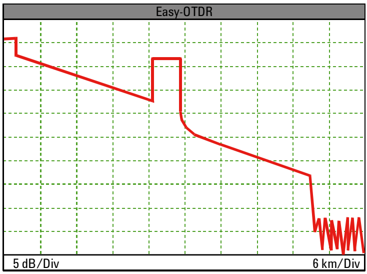


Figure 17 Long Pulses for Large Dynamic Range

- **Typical values**
  5 ns / 10 ns / 30 ns / 100 ns / 300 ns / 1 µs (short links), 100 ns / 300 ns / 1 µs / 3 µs / 10 µs (long fiber links)

The Optimization Mode

A normal OTDR makes a trade-off between resolution and noise. The better the resolution, the more the noise. This is because any hardware has a limited bandwidth. If the bandwidth is narrow, you have less noise but also a poor resolution and a long recovery time after a strong reflection. A wide bandwidth, however, can follow the received signal much faster—but the circuit also produces more noise.

Agilent OTDRs have three different receiver paths in each module. Besides the **Standard Mode**, one has narrower bandwidth and is optimized for the best **Dynamic Range**. The other has a wider bandwidth for a good **Resolution**. You select a path by selecting the **Optimization Mode** during the setup.

When optimizing for **Dynamic Range**, the OTDR uses long pulses and the trace has much less noise. Thus, you can measure the fiber even from great distances. But due to the narrower bandwidth the receiver rounds the edges more than when optimizing for **Resolution**. It also needs longer time to recover from connector reflections.

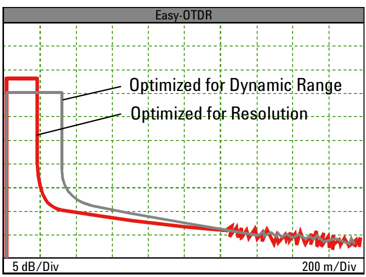


Figure 18 The Different Optimization Modes

The Measurement Span

An OTDR measures a specified number of sampling points (max 15710). The measurement span determines where these sampling points are distributed along the fiber. Hence, it defines both the distance of a measurement and the sampling resolution. This resolution is the distance between two adjacent measurement points.

Markers can only be set at sampling points. In order to place markers more accurately, you can try varying the measurement span to yield sampling points closer to an Event.

The table below shows how sampling point distance and the measurement span are related:

Measurement Span	Sampling Resolution
up to 1.2 km	0.080 m
up to 2.5 km	0.159 m
up to 5 km	0.318 m
up to 10 km	0.639 m
up to 20 km	1.27 m
up to 40 km	2.56 m
up to 80 km	5.09 m
up to 120 km	7.64 m
up to 160 km	10.18 m
up to 200 km	12.73 m
up to 240 km	15.36 m

Performance Parameters

Dynamic Range

The dynamic range is one of the most important characteristics of an OTDR. It specifies the maximum power loss between the beginning of the backscatter and the noise peaks.

If the device under test has a higher loss, the far end disappears in the noise. If it has less, the end appears clearly above the noise and you can detect the break.

Please keep in mind that a trace is disturbed close to the noise level. For example, you need the trace at least 6 dB above the noise in order to measure a 0.1 dB splice, and you need approximately 3 dB to detect a break. This is why the dynamic range of the OTDR should be at least 3 to 6 dB greater than your total system loss.

Like the deadzone, the dynamic range depends on the setup. The main influences are the pulse width, the optimization mode and the wavelength. So any specification of dynamic range must list the setup conditions.

The dynamic range can be given relative to the noise peaks or to the signal to noise ratio (SNR) = 1. Using the noise peaks here is more appropriate. If the dynamic range is given as SNR = 1, then subtract 2.2 dB to calculate the peak range.

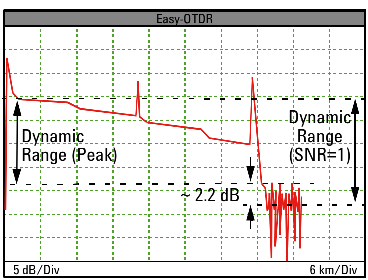


Figure 19 Dynamic Range

The Attenuation Deadzone

The deadzone is that part of an OTDR trace where a strong reflection covers measurement data. This happens because a strong signal saturates the receiver and it takes some time for it to recover. The attenuation deadzone describes the distance from the leading edge of a reflective Event until it returns to the fiber's backscatter level.

It is easy to determine the point where the leading edge starts but it is difficult to say when recovery ends. So many companies place a +/– 0.5 dB margin around the backscatter after the reflection. The deadzone ends at the point where the backscatter stays within this tolerance band.

In order to detect a splice or a break on the fiber, you need to examine the backscatter. Events in the deadzone might be undetected, because the backscatter cannot be displayed.

The size of the attenuation deadzone depends strongly on the instrument's setup.

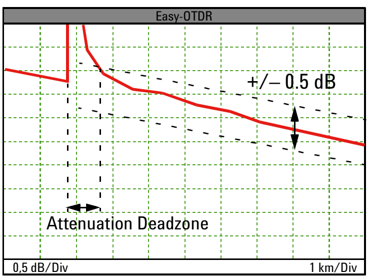


Figure 20 Attenuation Deadzone

The Event Deadzone

The Event deadzone is the minimum distance that you need between two Events of the same type in order to see them separately.

For example, if you have two connectors two meters apart, you see a reflection with two peaks and a drop between them. The drop indicates that there are really two reflections from two different Events. If the Events are too close, then you would not see a drop and you could not separate them.

The Event deadzone depends strongly on the instrument's setup.

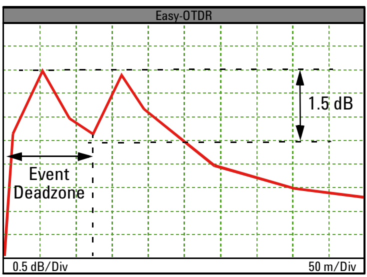


Figure 21 Event Deadzone

Averaging Time

The OTDR sends light pulses repetitively into the fiber. The results of each pulse are averaged. This reduces the random noise of the receiver:

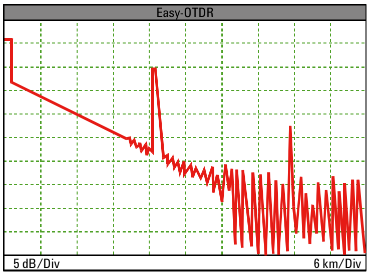


Figure 22 Trace After Ten Seconds Averaging Time

A longer averaging time increases the dynamic range by decreasing the noise floor of the OTDR. The best improvements for the trace are achieved within the first three minutes:

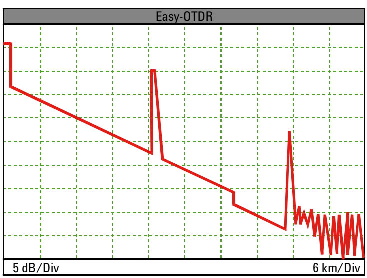


Figure 23 Trace After Three Minutes Averaging Time

5
Common Tasks

This section introduces the most common tasks that occur when measuring fibers and links. The exact procedures to perform the tasks are found in the manuals of your device or software.

Cleaning a Fiber

To achieve accurate and repeatable measurements, all the connectors in your setup must be clean. You can understand this requirement easily if you compare the diameter of a typical dust particle with that of the core of a fiber. The dust is 10 to 100 µm across while single-mode fibers have a 9 µm core. If you darken only 5% of the area where the light passes a connection, then your insertion loss increases by 0.22 dB.

If you have doubts that the measurement result is correct, or if the measurement cannot be repeated, then clean your connectors. In most cases a dirty adapter is the reason for such errors. Thus, remove the connector interface and clean the instrument's connector, clean the patchcord's connectors and clean the connectors on your fiber under test.

For cleaning the connectors, the following standard equipment is recommended:

- Dust and shutter caps

  All cables come with covers to protect the cable ends from damage or contamination. Keep the caps on the equipment at all times, except when your optical device is in use.

  Be careful when replacing dust caps after use. Do not press the bottom of the cap onto the fiber too hard, as any dust in the cap can scratch or pollute your fiber surface.

- Isopropyl alcohol

  Only apply alcohol used for medical purposes. Never use any other solvent or alcohol with additives, because they might damage your fiber.

  After solving dust and dirt, remove the alcohol and dust with a soft swab or tissue.

- Cotton swabs

  Use natural cotton swabs instead of foam swabs. Be careful when cleaning the fiber. Avoid too much pressure, because it may scratch the fiber's surface. Only use fresh clean swabs and do not reuse them.

- Soft tissues

  Cellulose tissues are very absorbent and softer than cotton tissues. Thus, they do not scratch the surface unless you press too hard. Use care when cleaning the fiber and do not reuse a tissue.

- Pipe cleaner

  Pipe cleaners can be used to clean connector interfaces. Again, make sure you use a new, fresh and soft cleaner and be careful to not scratch the device.

- Compressed air

  The compressed air must be dry and free of dust, water and oil.

  First spray into the air, as the initial stream of compressed air could contain some condensation or propellant. Always hold the air can upright to keep propellant from escaping and contaminating your device.

NOTE

Watch out for index-matching oil. Some types dissolve the adhesives inside connectors.

WARNING **Disable the laser or switch the instrument off before you start to clean connectors!**

For more information, please refer to your specific optical device manuals or guides. Additionally, you can consult the Agilent Technologies Pocket Guide *Cleaning Procedures for Lightwave Test and Measurement Equipment* (Agilent Part Number 5963-3538F).

Connecting the Instrument to a Fiber

Depending on the application, there are three major ways of connecting the fiber under test to the OTDR.

Direct Connection

Agilent offers user exchangeable connector interfaces. If your fiber or cable has one of these connectors, then you can plug it in directly:

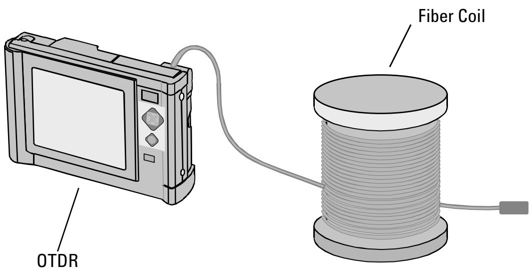


Figure 24 Direct Connection of the Fiber or Cable

Patchcord (Connector at Both Ends)

This is the recommended way if you want to measure a link in a system, especially if the terminal connector of the link is mounted in a rack:

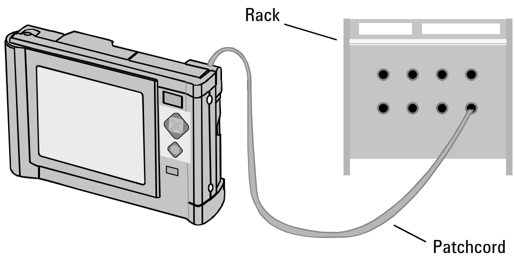


Figure 25 Connection with Patchcord

Pigtail with a Bare End

If the fiber under test has no connector at all, then use a bare fiber pigtail and an inexpensive mechanical splice. This provides a good connection and repeatable measurement results:

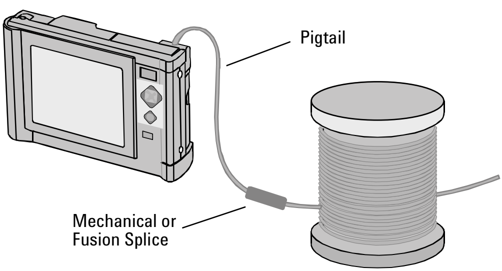


Figure 26 Patchcord with Bare End

The OTDR Display

All OTDRs display the measured fiber or link as a trace on the screen. The horizontal axis is the distance from the OTDR. The vertical axis is the relative power of the reflection of the emitted light pulse. The shape of the trace allows conclusions on the condition of the fiber and the included devices, such as connectors and splices.

In order to examine the trace in detail, you need to modify the trace view. The OTDR provides functions to change the scales of both axes, to zoom into parts of the trace, and to shift the trace along the axes.

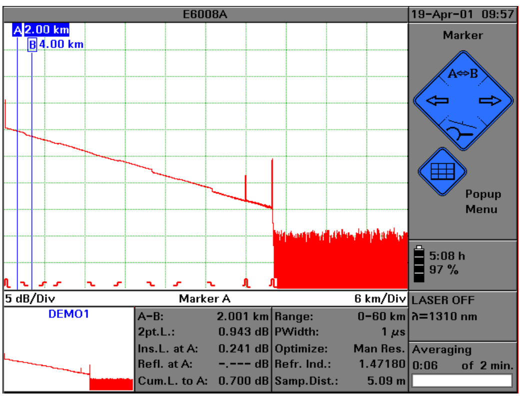


Figure 27 Screenshot from an Agilent OTDR

The ranges in which you can display the trace are, for example, vertically between 0.2 dB/Div and 5 dB/Div and horizontally from full measurement to roughly 100 times larger.

Furthermore, you can set two markers A and B anywhere into the trace and make use of the zoom functions **Around Marker A**, **Around Marker B**, and **Between Markers**.

You need to be familiar with these functions, because they are most commonly used when working with an OTDR. Most of the tasks in the following sections are based on them.

Zooming into Traces

After the measurement is finished, the OTDR display presents an overview of the complete measurement. The vertical scale and the vertical offset are fixed:

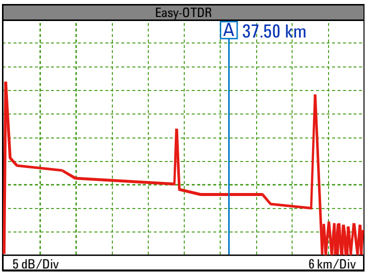


Figure 28 Complete Trace

Use the zoom functions around marker A or B to view particular regions in detail. The horizontal scale now is zoomed approximately to the factor of 10:

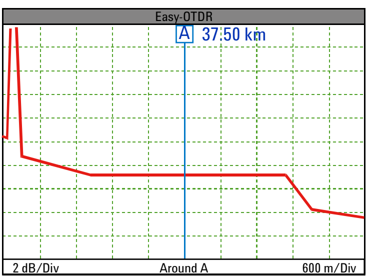


Figure 29 Zoom Around Marker A

You can now move the marker position in this view gradually. The display, however, will still show the marker in the center. As a result, the trace seems to move to the left or right:

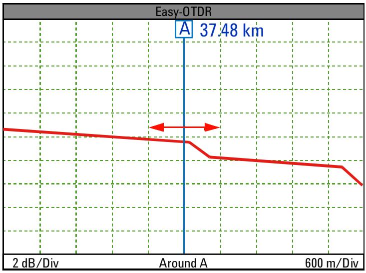


Figure 30 Moving the Marker Position

The scales for the complete trace of a 60 km link may be 6 km/Div and 5 dB/Div. This allows coarse positioning of a marker:

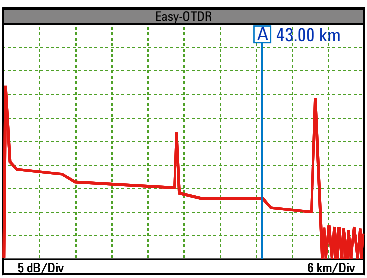


Figure 31 Complete Trace View for Coarse Positioning

In the zoomed view, the scales may be 200 m/Div and 0.2 dB/Div. This allows much finer positioning of a marker:

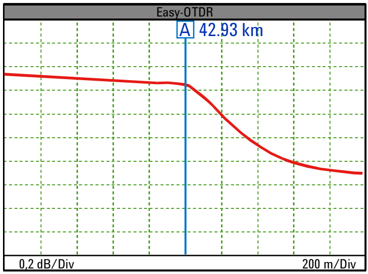


Figure 32 Zoomed View for Fine Positioning

In a fiber or cable production, you may need to test the uniformity of the attenuation. Position marker A at the beginning and marker B at least 500 to 2,000 m beyond marker A. Zoom the view between the markers to examine the attenuation. Additionally, you can move both markers parallel along the trace to view adjacent fiber parts:

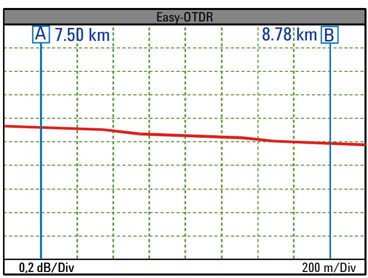


Figure 33 Moving the View between the Markers

Placing Markers Correctly

The position of an Event is always where the trace leaves the backscatter level. The exact locations of all Events are automatically determined and listed in the Event table.

For the position of a connector or another reflective Event, this is just at the beginning of the rising edge of the reflection:

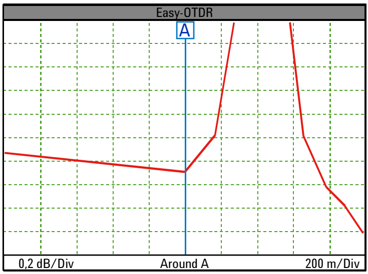


Figure 34 Measuring a Reflective Event

The position of a non-reflective Event is just at the last backscatter point before the trace bends downwards:

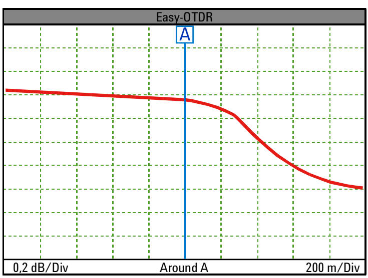


Figure 35 Measuring a Non-Reflective Event

The location of a break is found at the beginning of the falling edge:

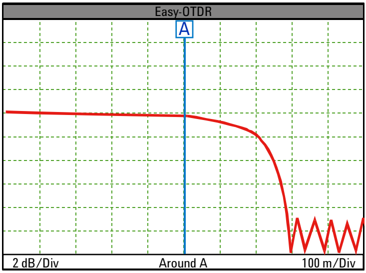


Figure 36 Measuring a Break

In order to measure the distance between two Events, place marker A before the first one and marker B before the second, as described on the previous page:

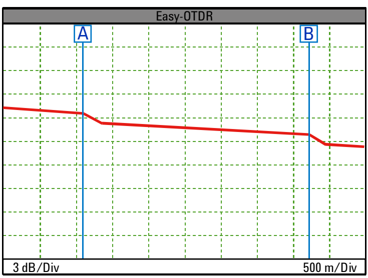


Figure 37 Distance between Events

In order to measure the fiber's attenuation between two Events, place marker A after the first Event, but place marker B before the second one:

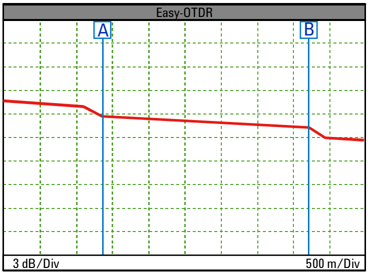


Figure 38 Attenuation between Events

Make sure that there are no Events between markers A and B, so the part of the trace between them is a straight line.

NOTE

Make sure that you use the correct refractive index in the setup, otherwise the distance values will be wrong!

Determining the Total Loss of a Link

Make a measurement of the whole link. Place marker A at the beginning and marker B at the end of the backscatter. Then zoom around marker A and position it precisely after the reflection of the first connector:

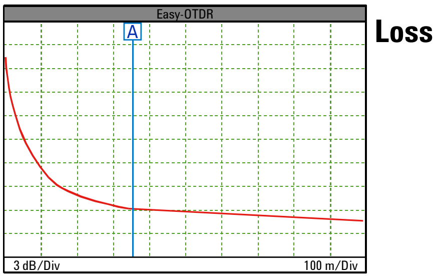


Figure 39 Marker A at End of First Connector

Now go to marker B and place it immediately before the end reflection:

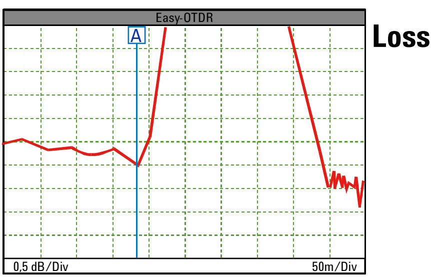


Figure 40 Marker B before End Reflection

Finally, go back to the full view and check whether or not the two markers are really placed correctly. Depending on your device, select the **Loss** function to display the total loss on the screen:

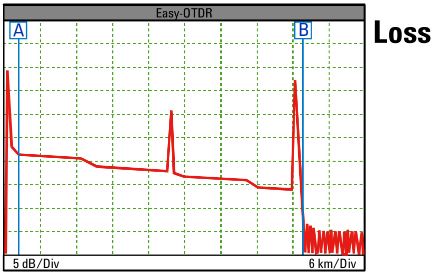


Figure 41 Total Loss of a Link

Determining the 2-Point Attenuation of a Fiber

Use the same procedure as for the measurement of the total loss (See “Determining the Total Loss of a Link” on page 44.). But instead of selecting the **Loss** function, choose **2-Point Attenuation**.

The 2-point attenuation is the loss between markers A and B divided by the distance between the markers:

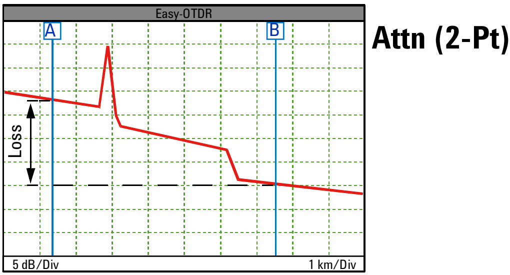


Figure 42 Calculating the 2-Point-Attenuation

Because this function is only a division of the power difference by the distance it always gives reasonable results, even if there are connectors or splices between the markers.

Determining the Attenuation of a Fiber

The straight line between splices and connectors is the back-scatter of the fiber. In order to measure the attenuation of it precisely, place marker A after the first Event (to the left) and marker B before the second Event (to the right). Then select the **Attenuation (LSA)** function:

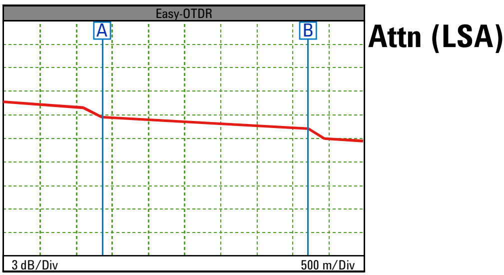


Figure 43 Fiber Attenuation

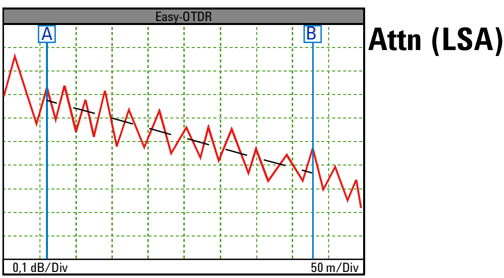


Figure 44 Attenuation of Noisy Backscatter

The LSA line causes severe errors if you include Events between the markers. So avoid this when using LSA.

Also, do not use the 2-point attenuation to measure a noisy fiber. The noise peaks may decrease the accuracy.

Determining the Loss of a Splice (Analyze Insertion Loss)

Place Marker A at the splice and zoom the view around it. Select the **Analyze Insertion Loss** function. Four additional markers appear, that you can move on the trace. Place all four level-markers at the backscatter on the left-hand and on the right-hand side in order to approximate the fiber as closely as possible:

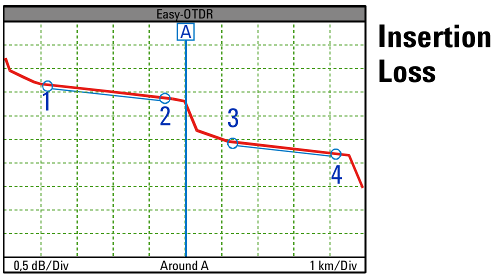
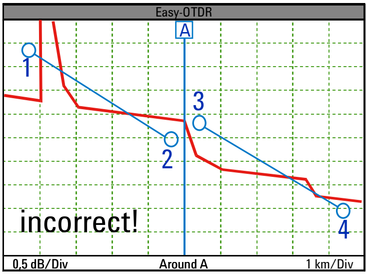


Figure 45 Analyzing the Insertion Loss of a Splice

Keep the level-markers 2 and 3 close to the splice as shown above, and make the line segments between 1 and 2 and between 3 and 4 as long as possible. However, keep the lines strictly on the backscatter, even if it is noisy.

Make sure that the lines between the level-markers (the LSA line) follow a straight part of the trace. The LSA should not cover any part of the trace containing an Event:



Insertion Loss

Figure 46 Incorrect Approximation due to Wrong Marker Positions

Determining the Loss of a Connector

This measurement is very similar to the splice loss measurement, so it uses the same loss function. Place marker A at the connector and zoom around it. Start the **Insertion Loss** function. Four level-markers appear. Place all four level-markers at the backscatter at the left and at the right of the connector:

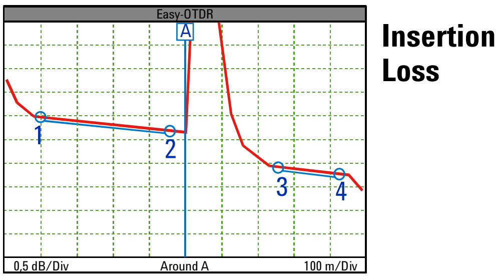


Figure 47 Approximating the Trace Around a Connector

The same rules as for the splice measurement also apply to the level-markers here. Keep the lines strictly on the backscatter, even if it is noisy. In any case, avoid the region where the trace is rounded. This causes incorrect results:

Figure 48 Incorrect Results due to Wrong Marker Positions

Determining the Reflectance of a Connector

Place marker A at the beginning of the connector reflection and zoom around it. Make sure you can see both the backscatter and the top of the peak. If necessary, adjust the vertical zooming and the offset.

Activate the **Reflectance** function. Three level-markers appear. Move the first two markers to an average backscatter level (not on a noise peak) in front of the reflection. Confirm the position and then move level-marker 3 to the peak of the reflection. The OTDR computes and displays the result in the readout field:

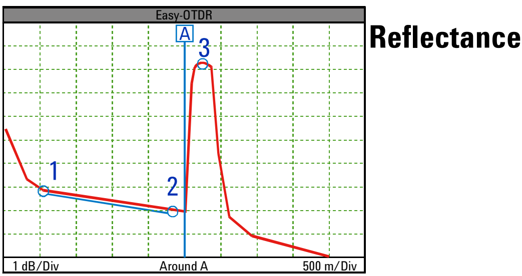


Figure 49 Calculating the Reflectance of a Connector

6
Practical Hints from OTDR Experts

This section contains practical hints and tricks collected from experienced people who use OTDRs in factories, during installation and for maintaining telecommunication networks.

Know the Link to be Tested

Before you start to characterize a fiberoptic link, look at the installation plan. Make sure you have the right module and accessories. Determine the wavelength to be used.

Determine whether you are measuring this link for the first time, or whether you are comparing the measurement with an older one.

If you are comparing with an older measurement, you only need to load the previous trace as the reference in the compare mode. The OTDR will do the setup automatically and you only have to start the new measurement.

Clean the Connectors

A dirty connector makes measurements unreliable, very noisy, or even impossible. It may also damage the OTDR. Furthermore, watch out for index–matching oil. Some types dissolve the adhesives inside connectors.

Is the Connector or the Patch Cord Damaged?

Be sure that the connector is clean. And check whether the patch cord, the module, and the fiber under test are single-mode or multimode. To test the patch cord, activate the laser in the CW mode and measure the power at the end of the patch cord with a power meter, for example, an Agilent E6006A. This should display between 0 and - 4 dBm for most single-mode modules and wavelengths.

Instrument Settings

If you use the OTDR regularly for similar links, then optimize the setup for these applications and store it in one of the four user definable settings. Use a meaningful name for it (for example, INTER STATE, CITY LINK, FEEDER, TRUNK, and so on).

Recommended Setup Parameters

Set the measurement span slightly longer than the length of the link. For example, if your link is 56.3 km long, choose 60 km. For distances greater than approximately 15 km, make your first measurement in longhaul mode, otherwise use shorthaul. Begin with a 1 ms pulse for spans greater than 10 km, and 100 ns below that span. Set the refractive index according to your information about the link. If the index is not known, use 1.4580 as this is a typical value.

Noisy Traces

If the trace is very noisy, increase the number of averages. If you already averaged more than 100 times, then increase the pulsewidth. Try to average over a longer time.

Realtime Mode

Activate the instrument’s **Realtime Mode**, if you want to adjust the settings during a measurement. In this mode the instrument averages for 0.3 seconds only, thus, you get three display updates per second. This mode allows to change any setup parameter without the need to stop the measurement.

This is in contrast to the continuous average mode with one update per second. In this mode, it is required to stop a measurement explicitly before you can modify parameters. This avoids that you erase a trace averaged over a long time by accident.

You use Realtime mode to check your connection, the quality of splices, and whether a fiber is connected. Start in Automatic mode, then switch to Realtime mode and select the most suitable parameters.

Very Long Deadzone

If the deadzone is too long to separate the Events of interest, reduce the pulsewidth. If you are in Optimize Dynamic mode, first try repeating the measurement in Optimize Resolution mode, before you reduce the pulsewidth.

What to Do if No Trace is Visible

In case you lost the trace when zooming into it, return to the full view.

If you see only noise instead of a trace, then either the measurement span is far too long, or the start position is beyond the end of the fiber. Check both values in the setup. Also check the connection to the fiber.

Adjust the Refractive Index

You can measure the refractive index if you know the exact physical length of the fiber under test. Start the measurement with refractive index 1.5000. Place a marker at the end of the fiber. Then select the **Refractive Index** function and adjust it until the displayed marker position is equal to the known fiber length. Now the effective refractive index is displayed.

The Exact One-Way Loss

The OTDR's loss measurements are based on the backscatter effect in the fiber. Because this effect changes in different fibers, the loss accuracy may not meet your requirements. In order to measure the link's loss more precisely, the single-mode modules provide a CW mode. This mode simply switches the laser on.

Measure the power (given in dBm) with a power meter (for example, the Agilent E6006A) at the end of a short patchcord. The absolute value of the power varies from one source module to another but the power for a particular module remains very stable over hours. Then connect the link to the patchcord and measure the power at the far end. The difference between the two results is the one-way loss of the fiber.

Bending Loss

In 1550 nm single-mode, fibers are very sensitive to macrobending as for example, a tight bend or local pressure on the cable. It happens sometimes that you see a bending loss clearly at this wavelength but not at all at 1310 nm. Hence, characterize your link at both wavelengths.

Before You Save a Trace

After your measurement is completed you should enter identification data before you save a trace on a disk or memory card. For this purpose, the OTDRs provide the **Trace Information** window, accessible from the File menu.

Use this feature to store the cable ID, the fiber ID, the origin and the termination location, and the fiber operator. The used OTDR and modules as well as the date and time of the measurement are saved automatically with the file.

This will help a lot if you need the trace later for comparison purposes or for further analysis on a personal computer.

7
Automatic Trace Analysis

Many links consist of several sections which are connected or spliced together. A good quality control after installation is the measurement of all losses on the link in order to verify that the splices, connectors, etc. meet their specification. However, doing this manually is a time consuming process.

Seeking Events Above a Threshold

The Agilent OTDRs accelerate this task with a built-in trace analysis function: **Scan Trace** seeks Events on the trace from the beginning to the end. If an Event exceeds a given threshold (for example, 0.05 dB) then the OTDR lists it in a table. The table contains the Event’s position, its loss and return loss (if it is reflective), and the fiber attenuation between the Events.

After a trace has been scanned automatically, the OTDR keeps the Event table together with the trace and the setup. This means that the table is also saved when you store the trace in a binary or in an ASCII file. By reading the ASCII file into a PC you can use this information to compute statistics.

For noisy sections of the fiber the OTDRs increase the threshold in order to reduce the sensitivity to noise peaks. However, it is still often very hard to decide whether something is a real Event or a distortion due to the noise. So it is important to look at the Events closely. If necessary, remove any reported Event that is just a noise peak. Or add any Event that was assumed to be noise.

Looking at a Selected Event

Let us assume that the reported Event table contains several non-reflective Events at 12.689, 15.632 and 20.091 km:

NO	TYPE	LOCATION	LOSS dB	ATT dB/km
4:	NONREFL	12.689 km	0.192	0.220
5:	NONREFL	15.632 km	0.172	0.220
6:	NONREFL	20.091 km	0.380	0.215

Your installation plan lists a splice at 12.7 km and at 20.1 km but nothing between them. Therefore, you want to look at the trace at 15.6 km. To do this, select the unknown Event in the table. Use the **Snap to Event** function. This zooms in on the Event and places marker A and all the level-markers for the splice loss measurement exactly at the position where **Scan Trace** found the Event.

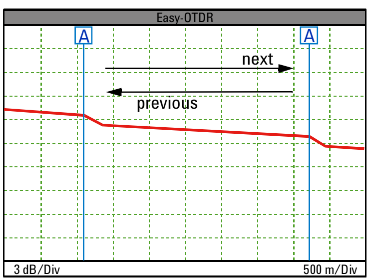


Figure 50 Switching between Selected Events

With the **Next Event** function you can quickly check all events found on the trace.

8
Agilent Technologies' OTDRs

Agilent Technologies provides all necessary equipment to test your optical network quickly and easily. The Agilent family of OTDRs provides technicians highly reliable instruments for the installation and maintenance of optical fibers. All models in the family are very easy to use and have comprehensive analysis features. Importantly, the file formats used are Bellcore certified and can, thus, be exchanged with any other standardized device.

This section introduces the different OTDR devices, modules, software, and accessories.

Additional information on Agilent's OTDR products can be found on the Web at www.agilent.com/comms/otdr.

For Analysis and Documentation: The OTDR Toolkit II*plus*

The Agilent E6091A OTDR Toolkit II*plus* is the indispensable Windows-based PC software to complement the other OTDR devices.

It collects, analyzes, organizes and stores the traces for fast creation of acceptance documentation. Batch processing and printing let users fulfill their documentation requirements when and where they want.

If your PC is connected to an OTDR, you can even set up and start a measurement directly from the Toolkit II*plus* software.

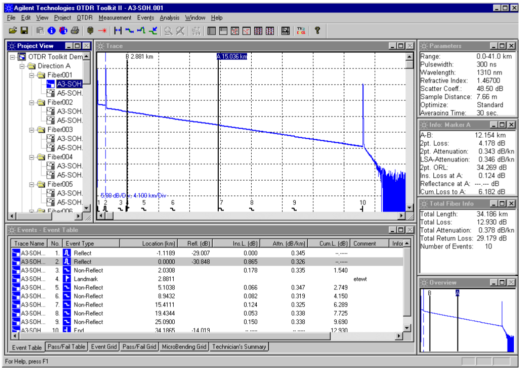


Figure 51 Screenshot from the ODTR Toolkit II*plus*

The key features of the Toolkit II*plus* are:

- Advanced batch processing
- Desktop viewing and post-processing of OTDR trace data
- Remote control of OTDR Instruments
- High-speed multiple trace transfer between the OTDR and PC.
- Analysis of splices, connectors and attenuations
- Simultaneous comparison of as many traces as you want
- Two-way averaging for accurate loss calculations
- Comprehensive context sensitive online help
- Extensive Events window with Event tables, pass/fail tables, Event grid, microbending grid, etc.
- Quick and simple report generation ("Technician's Summary")
- Export Function to Microsoft Excel
- Trace Browser
- Available in five languages

For Locating Breaks and Maintenance: The Fiber Break Locator

Agilent Technologies specifically addresses the needs of maintenance technicians with the E6020A Fiber Break Locator. It can find faults in the network up to 150 km away, accurate within one meter. It offers guided operation and online help to help inexperienced users learn to use the equipment faster.

The Fiber Break Locator is designed for both inside and outside plant environments and features a powerful display, a rugged carrying case, and is lightweight and portable. A full range of connectors and accessories is also available.

Figure 52 Fiber Break Locator

The key features of the Fiber Break Locator are:

- Step-by-step procedures with Fiber Break Assistant
- Easy error messages to help resolve problems quickly
- Data traffic detection protects your equipment
- Fiber vendor selection table for easy setup
- Crisp and clear display of fiber break location
- Easy save mode of test results
- Available in four languages

For Installation and Commissioning and for Detecting Events: The Mini-OTDR

The Agilent E6000C Mini-OTDR is designed to provide its users with the fastest tool available for installing and commissioning multiple fiber links and locating faults for fiber maintenance. This is accomplished through high measurement performance and an award-winning simple user interface.

Figure 53 Mini OTDR

The key features of the Mini OTDR are:

- High dynamic range of - 45dB
- Fiber Break Locator to quickly find breaks and bends
- Location and characterization of splice and connector losses
- Multifiber testing for fast high-count cable qualification
- Power and loss measurements with the built-in light source and the power meter module
- Graphical representation of measurement results in Event tables, showing loss and reflection, and pass/fail results

- Visual Fault Finder to check patch cords for light leakage
- Available in 14 languages

The Mini-OTDR can be equipped with different modules and submodules for different purposes. The modules are simply plugged in on the back of the OTDR and the submodules into the modules.

E6006A Power Meter Submodule

The E6006A Power Meter Submodule is used to measure the power of light at the end of a fiber when a light source is supplied at the beginning.

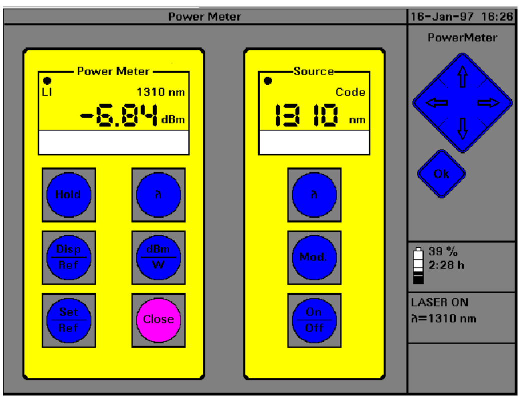


Figure 54 Power Meter Submodule

You can display the absolute light power as well as the power relative to a reference value. Also, you can toggle the display between different units (dBm, dB, and W). Furthermore, you can measure at different wavelengths.

E6007A Visual Fault Finder

With the E6007A Visual Fault Finder Submodule and an optical connector interface you can see strong bendings and stresses in fibers, patchcords, and so on. The Visual Fault Finder uses a visible red laser as light source. This light can be modulated either as constant light or flashing at 1 Hz.

At points where the fiber is broken or otherwise faulty, the light is refracted through the coating—if it is less than 3 mm thick. Thus, you can see exactly where the fault is.

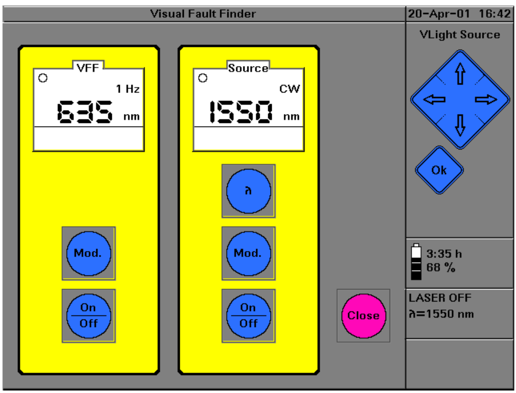


Figure 55 Visual Fault Finder

Patchcords

Every OTDR measurement has a strong reflection at the front connector. The deadzone after this reflection can cause Events in the first part of the fiber to remain undetected. To avoid this, patchcords are plugged between the OTDR and the fiber under test.

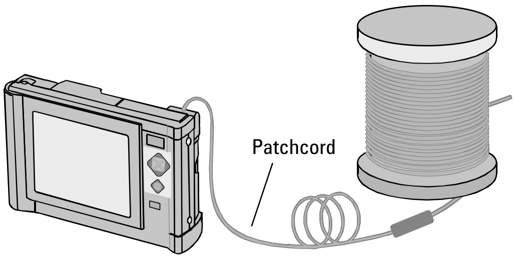


Figure 56 OTDR with patchcord

Patchcords must be of the same type as the fiber under test. For example, if you characterize a 50/125 µm fiber, you need a 50/125 µm multimode module for the OTDR and a patchcord of the same type.

If you have to measure many fibers in a cable or in a terminal station, then you can connect the patchcord once to the OTDR and then leave it connected. If you damage the other end of the patchcord with one of the fibers then you have to replace the patchcord only.

Use a 300 m to 1000 m patchcord if you need to measure the insertion loss of the first connectors of the link. With one of these patchcords at each end you can characterize both the first and the last connector.

In fiber or cable production, a 300 m patchcord and a mechanical splice drastically reduce the deadzone and insertion loss difficulties of bare fiber adapters or micrometer adjustment tools.

9
Tables

Typical Results

The tables in this section contain typical values for the different fiber parameters.

Fiber Attenuation	Multimode Fiber	Single-Mode Fiber
850 nm	<= 3.5 dB/km	not used
1300/1310 nm	<= 1.5 dB/km	< 0.4 dB/km
1550 nm	not used	< 0.3 dB/km
Insertion Loss		
Fusion splice	<= 0.10 dB	<= 0.15 dB
Mechanical splice	<= 0.15 dB	<= 0.20 dB
Connector with physical contact	<= 0.5 dB	<= 0.5 dB

Return Loss	
Connectors without physical contact (for example, the FC connector)	11 to 15 dB (two glass/air interfaces)
Physical contact connectors (for example, HMS-10, FC/PC, ST, DIN 47256)	30 to 50dB (clean, good polishing)
Angled connectors with physical contact (such as HMS-10/HRL, APC)	60 dB and more

Conversion of Units

This section covers some useful tables for the conversion of the different units.

Conversion Table	
+ 30 dBm	1W (watt)
+ 20 dBm	100 mW (milliwatts)
+ 10 dBm	10 mW
+ 7 dBm	5 mW
+ 3 dBm	2 mW
0 dBm	1 mW = 0.001 W
– 3 dBm	500 µW (microwatts)
– 7 dBm	200 µW
– 10 dBm	100 µW
– 20 dBm	10 µW
– 30 dBm	1 µW = 0.001 mW
– 40 dBm	100 nW (nanowatts)
– 50 dBm	10 nW
– 60 dBm	1 nW = 0.001 µW
– 70 dBm	100 pW (picowatts)
– 80 dBm	10 pW
– 90 dBm	1 pW = 0.001 nW

Useful Relations			
+ 3 dB	* 2	– 3 dB	1 / 2
+ 6 dB	* 4	– 6 dB	1 / 4
+ 10 dB	* 10	– 10 dB	1 / 10
+ 20 dB	* 100	– 20 dB	1 / 100
+ 30 dB	* 1,000	– 30 dB	1 / 1000
+ 40 dB	* 10,000	– 40 dB	1 / 10,000
+ 50 dB	* 100,000	– 50 dB	1 / 100,000
+ 60 dB	* 1,000,000	– 60 dB	1 / 1,000,000

Conversion of Length Units			
1 nm	(nanometer)	0.001	µm
1 µm	(micrometer)	0.001	mm
1 in (1")	(inch)	25.4	mm
1 kft	(1,000 feet)	304.8	m
1 mile		1.6093	km

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Service and Support

Any adjustment, maintenance, or repair of this product must be performed by qualified personnel. Contact your customer engineer through your local Agilent Technologies Service Center. You can find a list of local service representatives on the Web at:

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Or contact the test and measurement experts at Agilent Technologies (during normal business hours).

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11
Glossary of Terms

This glossary explains fiber optic terms and terms specific to OTDR technology and devices.

A

Absorption A physical mechanism in fibers that attenuates light by converting it into heat—thereby raising the fiber's temperature. In practice, the temperature increase is slight and difficult to measure. Absorption arises from tails of the ultraviolet and infrared absorption bands, from impurities such as the OH ion, and from defects in the glass structure.

Amplifier An electrical device used to strengthen audio or video signals or radio frequency (RF) energy. The same service is provided by a repeater for digital signals.

Attenuation The decrease in magnitude of power of a signal in transmission between points. A term used for expressing the total loss of an optical system, normally measured in decibels (dB) at a specific wavelength.

Attenuation Coefficient The rate of optical power loss with respect to distance along the fiber, usually measured in decibels per kilometer (dB/km) at a specific wavelength. The lower the number, the better the fiber's attenuation. Typical multimode wavelengths are 850 and 1300 nanometers (nm); single-mode wavelengths are 1310 and 1550 nm. Note: When specifying attenuation, it is important to note whether the value is average or nominal.

B

Backscattering The scattering of light in a direction opposite the original one.

Bandwidth The lowest frequency at which the magnitude of the waveguide transfer function decreases to 3 dB (optical power) below its zero frequency value. The bandwidth will be a function of the length of the waveguide, but may not be directly proportional to the length.

Buffer Material used to protect optical fiber from physical damage, providing mechanical isolation and/or protection. Fabrication techniques include tight or loose tube buffering as well as multiple buffer layers

Buffering (1) A protective material extruded directly on the fiber coating to protect it from the environment (tight-buffered); (2) extruding a tube around the coated fiber to allow isolation of the fiber from stresses in the cable (buffer tubes).

Buffer Tubes Extruded cylindrical tubes covering optical Fibers used for protection and isolation. (See Loose Tube.)

Bundle Many individual fibers contained within a single jacket or buffer tube. Also a group of buffered fibers distinguished in some fashion from another group in the same cable core.

C

Cable An assembly of optical fibers and other material providing mechanical and environmental protection.

Cable Assembly Optical Fiber Cable that has connectors installed on one or both ends. General use of these cable assemblies includes the interconnection of optical Fiber Cable systems and opto-electronic equipment. If connectors are attached to only one end of a cable, it is known as a pigtail. If connectors are attached to both ends, it is known as a jumper or patch cord.

Cable Bend Radius Cable bend radius during installation implies that the cable is experiencing a tensile load. Free bend infers a smaller allowable bend radius since it is at a condition of no load.

Celsius Temperature scale in which zero is the freezing point of water and one hundred is the boiling point. Unit: °C(elsius).

Centralized Cabling A cabling topology used with centralized electronics connecting the optical horizontal cabling with intra-building backbone cabling passively in the telecommunications closet.

Chromatic Dispersion (CD) Spreading of a light pulse caused by the difference in refractive indices at different wavelengths.

Cladding The dielectric material surrounding the core of an optical fiber.

Coating A material put on a fiber during the drawing process to protect if from the environment and handling.

Conduit Pipe or tubing through which cables can be pulled or housed.

Connecting Hardware A device used to terminate an optical fiber cable with connectors and adapters that provide an administration point for cross-connecting between cabling segments or interconnecting to electronic equipment.

Connector A mechanical device used to align and join two fibers together to provide a means for attaching to and decoupling from a transmitter, receiver, or another fiber (patch panel).

Connector Panel A panel designed for use with patch panels; it contains either 6, 8, or 12 adapters pre-installed for use when field-connectorizing Fibers.

Connector Panel Module A module designed for use with patch panels, it contains either 6 or 12 connectorized fibers that are spliced to backbone cable fibers.

Core The central region of an optical fiber through which light is transmitted.

Core Eccentricity A measure of the displacement of the center of the core relative to the cladding center.

Core Ellipticity (non-circularity) A measure of the departure of the core from roundness.

Coupling See Adapter.

Critical Angle The smallest angle from the fiber axis at which a ray may be totally reflected at the core/cladding interface.

D

Dark Fiber Monitoring Dark fiber monitoring requires only one spare Fiber in an N-core Cable to be connected to the test equipment. This Fiber will not carry live communications traffic. Over 80% of all Fiber problems can be detected by dark fiber monitoring, as they affect the whole Cable.

Data Rate The maximum number of bits of information which can be transmitted per second, as in a data transmission link. Typically expressed as megabits per second (Mbps).

Decibel (dB) The standard unit used to express gain or loss of optical power.

Detector A transducer that provides an electrical output signal in response to an incident optical signal. The current is dependent on the amount of light received and the type of device.

Dielectric Non-metallic and, therefore, non-conductive. Glass fibers are considered dielectric. A dielectric cable contains no metallic components.

E

Equipment Telecommunication equipment.

Equipment Room A centralized space for telecommunications equipment that serves the occupants of a building. An equipment room is considered distinct from a telecommunications closet because of the nature or complexity of the equipment.

Event A status change of a network object. For example, if a Link is damaged, this causes an Event.

F

Fahrenheit Standard scale used to measure temperature in the United States; in which the freezing point of water is thirty-two degrees and the boiling point is two hundred and twelve degrees. Unit: °F(ahrenheit).

Fan-Out Multifiber cable constructed in the tight- buffered design. Designed for ease of connectorization and rugged applications for intra- or interbuilding requirements.

Fiber Any filament or fiber, made of dielectric materials, that guides light.

Fiber Bend Radius Radius a fiber can bend before the risk of breakage or increase in attenuation.

Fiber Distributed Data Interface (FDDI) A standard for a 100 Mbit/s fiber optic area network

Fiber Optic Cable An optical fiber, multiple fiber, or fiber bundle which includes a cable jacket and strength members, fabricated to meet optical, mechanical, and environmental specifications.

Fiber Optic Link Any optical fiber transmission channel designed to connect two end terminals or to be connected in series with other channels.

Fiber Optics The branch of optical technology concerned with the transmission of radiant power through fibers made of transparent materials such as glass, fused silica, or plastic.

Fusion Splice A permanent joint produced by the application of localized heat sufficient to fuse or melt the ends of the optical fiber, forming a continuous single fiber.

G

Geomark Geographical symbol that represents a building, site, bridge, or other geographical landmark.

Gigahertz (GHz) A unit of frequency that is equal to one billion cycles per second, 109 Hertz.

H

Horizontal Cabling That portion of the telecommunications cabling that provides connectivity between the horizontal cross-connect and the work-area telecommunications outlet. The horizontal cabling consists of transmission media, the outlet, the terminations of the horizontal cables, and horizontal cross-connect.

Horizontal Cross-Connect (HC) A cross-connect of horizontal cabling to other cabling, e.g., horizontal, backbone, equipment.

Hybrid Cable A fiber optic cable containing two or more different types of fiber, such as 62.5 µm multimode and single-mode.

I

Index of Refraction The ratio of light velocity in a vacuum to its velocity in a given transmission medium.

Index Profile Curve of the refractive index over the cross section of an optical waveguide.

Insertion Loss The attenuation caused by the insertion of an optical component; in other words, a connector or coupler in an optical transmission system.

Inside-Plant Equipment and connections inside a building, for example, patchcords and plugins.

Interbuilding Backbone The portion of the backbone cabling between buildings. (See Backbone Cabling.)

Intrabuilding Backbone The portion of the backbone cabling within a building. (See Backbone Cabling.)

IP Address Used to identify a node on a network and to specify routing information. Each node on the network must be assigned a unique IP address, which is made up of the network ID, plus a unique host ID assigned by the network administrator. This address is typically represented in dotted-decimal notation, with the decimal value of each octet separated by a period (for example, 138.57.7.27).

Irradiance Power density at a surface through which radiation passes at the radiating surface of a light source or at the cross section of an optical waveguide. The normal unit is Watts per centimeters squared, or W/cm^2.

K

Kelvin Standard scale used to measure temperature; in which the freezing point of water is 271 degrees. Unit: °K(elvin).

kpsi A unit of force per area expressed in thousands of pounds per square inch. Usually used as the specification for Fiber prooftest. e.g., 100 kpsi.

Kilometer (km) One thousand meters, or approximately 3,281 feet. The kilometer is a standard unit of length measurement in fiber optics. Conversion is 1 ft. = 0.3048 m

L

Lambda Channel Special wavelength of a Fiber. Different Lambda Channels can be used to transfer different data.

LAN See Local Area Network.

Landmark Characteristic point on a geographical map.

Laser Diode (LD) Light Amplification by Stimulated Emission of Radiation. An electro-optic device that produces coherent light with a narrow range of wavelengths, typically centered around 780 nm, 1320 nm, or 1550 nm. Lasers with wavelengths centered around 780 nm are commonly referred to as CD Lasers.

Leaky Modes In the boundary region between the guided modes of an optical waveguide and the lightwaves which are not capable of propagation, there are so-called leaky modes which are not guided but are capable of limited propagation with increased attenuation. Leaky modes are a possible source of errors in the measurement of fiber loss, but their effect can be reduced by mode strippers.

Light In the laser and optical communication fields, the portion of the electromagnetic spectrum that can be handled by the basic optical techniques used for the visible spectrum extending from the near ultraviolet region of approximately 0.3 micron, through the visible region and into the mid- infrared region of about 30 microns.

Light Emitting Diode (LED) A semiconductor device which emits incoherent light from a p-n junction when biased with an electrical current in the forward direction.

Light may exit from the junction strip edge or from its surface, depending on the device‘s structure.

Lightwaves Electromagnetic waves in the region of optical frequencies. The term „light“ was originally restricted to radiation visible to the human eye, with wavelengths between 400 and 700 nanometers (nm). However, it has become customary to refer to radiation in the spectral regions adjacent to visible light (in the near infrared from 700 to about 2000 nm) as „light“ to emphasize the physical and technical characteristics they have in common with visible light.

Link A telecommunications circuit between any two telecommunications devices, not including the equipment connector.

Local Area Network (LAN) A LAN is a data communications system that enables users to access common data processing (PCs, minicomputers, and mainframe computers) and peripheral equipment (printers and fax machines). LANs are created by using workstations with adapter cards and connecting them to file servers (where the operating system/software resides) and printers.

Gateways are used to connect LANs to other LANs or operating systems like large mainframes where there is a need to share departmental or corporate computing systems. A LAN can be as simple as a few workstations working off a file server or as complex as putting hundreds of workstations on a network that runs between floors of a building or between a number of buildings in a campus environment.

LANs, which were originally designed so that users could share and access a few expensive printers or controllers, have expanded into essential telecommunications networks. Today, LANs are used for file and printer sharing, electronic mail, shared databases, point-of-sale, and order entry systems.

M

Macrobending Macroscopic axial deviations of a fiber from a straight line.

Main Cross-Connect (MC) The centralized portion of the backbone cabling used to mechanically terminate and administer the backbone cabling, providing connectivity between equipment rooms, entrance facilities, horizontal cross-connects, and intermediate cross-connects.

Material Dispersion The dispersion associated with a non-monochromatic light source due to the wavelength dependence of the refractive index of a material or of the light velocity in this material.

Mechanical Splicing Joining two fibers together by permanent or temporary mechanical means (vs. fusion splicing or connectors) to enable a continuous signal. The CamSplice is a good example of a mechanical splice.

Megahertz (MHz) A unit of frequency that is equal to one million cycles per second.

Micrometer (µm) One millionth of a meter; 10-6 meter. Typically used to express the geometric dimension of fibers, for example, 62.5 µm.

Modal Dispersion Pulse spreading due to multiple light rays traveling different distances and speeds through an optical fiber.

Mode A term used to describe an independent light path through a fiber, as in multimode or single-mode.

Mode Mixing The numerous modes of a multimode fiber differ in their propagation velocities. As long as they propagate independently of each other, the fiber bandwidth varies inversely with the fiber length due to multimode distortion. As a result of inhomogeneities of the fiber geometry and of the index profile, a gradual energy exchange occurs between modes with differing velocities. Due to this mode mixing, the bandwidth of long multimode fibers is greater than the value obtained by linear extrapolation from measurements on short fibers.

Modes Discrete optical waves that can propagate in optical waveguides. They are eigenvalue solutions to the differential equations which characterize the waveguide. In a single-mode fiber, only one mode, the fundamental mode, can propagate. There are several hundred modes in a multimode fiber which differ in field pattern and propagation velocity. The upper limit to the number of modes is determined by the core diameter and the numerical aperture of the waveguide.

Modulation Coding of information onto the carrier frequency. This includes amplitude, frequency, or phase modulation techniques.

Monochromatic Consisting of a single wavelength. In practice, radiation is never perfectly monochromatic but, at best, displays a narrow band of wavelengths.

Multifiber Cable An optical fiber cable that contains two or more fibers.

Multimode Distortion The signal distortion in an optical waveguide resulting from the superposition of modes with differing delays.

Multimode Fiber An optical waveguide in which light travels in multiple modes. Typical core/cladding size (measured in micrometers) is 62.5/125.

Multiplexer Device that combines two or more signals into a single bit stream that can be individually recovered.

Multi-User Outlet A telecommunications outlet used to serve more that one work area, typically in open-systems furniture applications.

N

Nanometer (nm) A unit of measurement equal to one billionth of a meter; 10-9 meters. Typically used to express the wavelength of light, for example, 1300 nm.

Node Splice point.

Numerical Aperture A measure of the range of angles of incident light transmitted through a fiber. Depends on the differences in index of refraction between the core and the cladding (the number that expresses the light gathering ability of a fiber; related to acceptance angle).

O

Optical Fiber See Fiber.

Optical Time Domain Reflectometer (OTDR) A device for characterizing a fiber wherein an optical pulse is transmitted through the fiber and the resulting backscatter and reflections to the input are measured as a function of time. Useful in estimating attenuation coefficient as a function of distance and identifying defects and other localized losses.

Optical Waveguide Dielectric waveguide with a core consisting of optically transparent material of low attenuation (usually silica glass) and with cladding consisting of optically transparent material of lower refractive index than that of the core. It is used for the transmission of signals with lightwaves and is frequently referred to as fiber. In addition, there are planar dielectric waveguide structures in some optical components, such as laser diodes, which are also referred to as optical waveguides.

Optoelectronic Pertaining to a device that responds to optical power, emits or modifies optical radiation, or utilizes optical radiation for its internal operation. Any device that functions as an electrical-to-optical or optical-to-electrical transducer.

OTDR Optical Time Domain Reflectometer. Sends pulses into a fiber to measure the backscatter. From the analyzed trace Events can be identified.

Outside-Plant All network equipment outside, for example, cables, fibers, or nodes.

P

Patch Cord Inside-Plant connection between two plugins.

Peak Wavelength The wavelength at which the optical power of a source is at a maximum.

Photodiode A diode designed to produce photocurrent by absorbing light. Photodiodes are used for the detection of optical power and for the conversion of optical power into electrical power.

Photon A quantum of electromagnetic energy.

Plugin Network equipment inside a cardcage, for example, OTDRs, or switches.

Port At the ports of a Plugin the patch cords or fibers are connected.

R

Rack Where a cardcage is installed.

Reference Measurement Measurement taken after a line is taken into operation to compare later measurements with the original and healthy condition of the line.

Ray A geometric representation of a light path through an optical medium; a line normal to the wave front indicating the direction of radiant energy flow.

Receiver A detector and electronic circuitry to change optical signals into electrical signals.

Receiver Sensitivity The optical power required by a receiver for low error signal transmission. In the case of digital signal transmission, the mean optical power is usually quoted in Watts or dBm (decibels referred to 1 milliwatt).

Reflection The abrupt change in direction of a light beam at an interface between two dissimilar media so that the light beam returns into the media from which it originated.

Refraction The bending of a beam of light at an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position (graded index medium).

Refractive Index The ratio of the velocity of light in vacuum to that in an optically dense medium.

Repeater In a lightwave system, an optoelectronic device or module that receives an optical signal, converts it to electrical form, amplifies or reconstructs it, and retransmits it in optical form.

RTU **R**emote **T**est **U**nit.

S

Scatter Coefficient Determination of the light loss of the transmitted beam (angle = 0°), i.e. the quantity of light withdrawn from the incident beam as a result of scatter.

The variable measured by this method is the scatter coefficient s.

Scattering A property of glass that causes light to deflect from the fiber and contributes to optical attenuation.

Single-Mode Fiber Optical fiber with a small core diameter (typically 9 µm) in which only a single-mode, the fundamental mode, is capable of propagation. This type of fiber is particularly suitable for wideband transmission over large distances, since its bandwidth is limited only by chromatic dispersion.

SNMP Simple Network Communication Protocol. SNMP agents are accessed by remote network management stations. To allow network management stations to send inquiries to the SNMP agent, you must define a list of community names and IP addresses that can use these community names.

Splice A permanent joint between two optical waveguides.

Switch Module Optical Multiplexer.

T

Telecommunications Closet (TC) An enclosed space for housing telecommunications equipment, cable terminations, and cross-connects. The closet is the recognized cross-connect between the backbone and horizontal cabling.

Threshold Current The driving current above which the amplification of the lightwave in a laser diode becomes greater than the optical losses, so that stimulated emission commences. The threshold current is strongly temperature- dependent.

Total Internal Reflection The total reflection that occurs when light strikes an interface at angles of incidence greater than the critical angle.

Trace Run of a measurement curve.

Transmission Loss Total loss encountered in transmission through a system.

Transmitter A driver and a source used to change electrical signals into optical signals.

W

Wavelength Division Multiplexing (WDM) Simultaneous transmission of several signals in an optical waveguide at differing wavelengths.

Z

Zero-Dispersion Wavelength Wavelength at which the chromatic dispersion of an optical fiber is zero. Occurs when waveguide dispersion cancels out material dispersion.

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Your Notes

Your Notes

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