INTRODUCTION TO FIBER LOSS TESTING FOR FIELD APPLICATIONS

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Introduction

This application note is a basic introduction to the equipment and methods commonly used to perform field loss testing of singlemode and multimode optical fibers. It is intended for those who already understand the basics of fiber optics but are in need of quick testing methods to get the job done.

The need for loss testing

When transmitting information from one point to another, the signal being sent from one point to the next must be strong enough to be "seen" at the receiving end to be of any value. In the case of optical fiber communications, we indicate the signal strength in terms of optical power and we "see" the signal with a photodector of some sort.

Consider an optical fiber to be a hose of sorts. At one end, a spigot supplies water to the hose and the hose sections are coupled together every so often until it reaches a pail at the far end. Obviously the goal is to deliver as much water as possible to the pail. In the ideal scenario all of the water from the spigot gets to the pail, however, in a real world situation, some water will leak from the hose and from every fitting on that hose. Any LOSS of water along that hose represents water that will never make it to the pail and a broken hose may keep the pail from being filled at all.

In the case of fiber, the spigot would be a transmitting LED or laser, the hose would be a fiber, the couplings would be connectors or splices and the bucket would be the receiving photodetector.

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The need for loss testing (cont.)

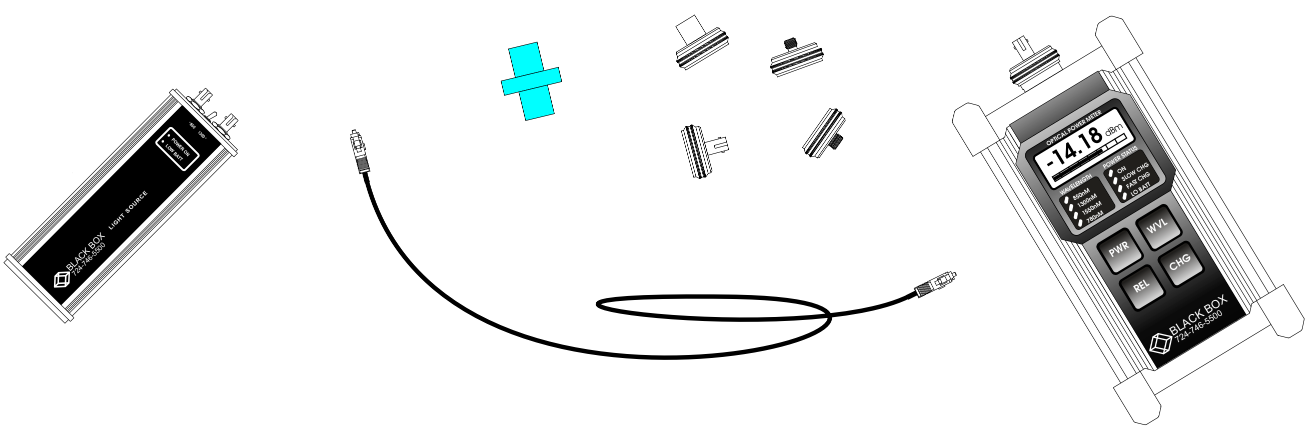
Light in an optical fiber is absorbed or scattered by the glass along its entire length and is leaked at every fiber joint. If too much light is lost, the system will fail.

Of course, one could use a flashlight to test for continuity on short runs or simply connect the communications gear and see if it works but this is asking for trouble in the long run. If the installed fiber link is losing so much light that the receiver at the far end is barely getting enough light to function, any component degradation over time will bring the entire link down. Loss testing tells the technician precisely how good or bad the fiber link actually is.

Remember, most fiber systems are digital in nature. They either work 100% or they work 0%, there is rarely a warning when a system is about to fail (much like a satellite television receiver). For this reason, those who have not physically loss tested a fiber before connecting their transmission gear simply have no clue when it comes to the true stability of their systems. Even a short patch cord can lose as much light as a 50km run if it has a fouled connector!

Loss testing equipment

Fortunately, only a few instruments are required to perform field loss tests. These items are the optical power meter, the light source, patch cords, and mating adapters. The source emits light into a fiber, the meter will read how much of that light is passing through the fiber, and the cables/adapters are used to connect the test gear to the link being tested.



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Loss testing equipment (cont.)

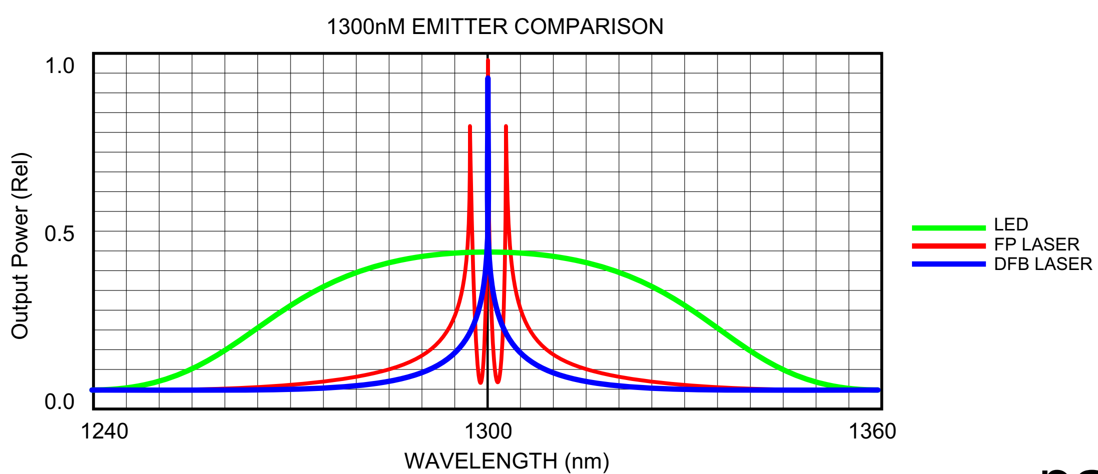
Optical power meters and light sources come in a variety of models and the proper type must be chosen for a given application. While some models will offer different features and vary widely in price, it is important to find meters and sources meant specifically for fiber optic cable testing. The patch cords and couplings which will be used during the testing process should be of a type similar to those used in the actual installation under test.

Choosing a light source

The technician should choose a light source which most closely matches the type of emitter which is in the transmission equipment of the final system. There are two fundamental types of light sources on the market for fiber testing, LED and LASER.

LED light sources utilize an light emitting diode (LED) as its internal transmitter. LED sources are relatively lower cost and best suited for use in multimode testing applications. LED sources generally have a wider bandwidth and less power output than their LASER counterparts. Typical center wavelengths of this type of source are 850nM and/or 1300nM.

LASER light sources are generally used in singlemode applications (with the notable exception of 850nM VCSEL lasers which are generally used with multimode fiber). Because they are meant to work with the tight physical tolerancing of singlemode fiber, they tend to be more sophisticated in construction. The output power of LASER sources is generally as much as 10 or more times greater than LED sources and the quality of the light is much more pure (narrow bandwidth). The vastly more sophisticated design of LASER sources does tend to make them more expensive. Typical center wavelengths of a LASER source are 850nM, 1310nM, or 1550nM.



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Choosing a light source (cont.)

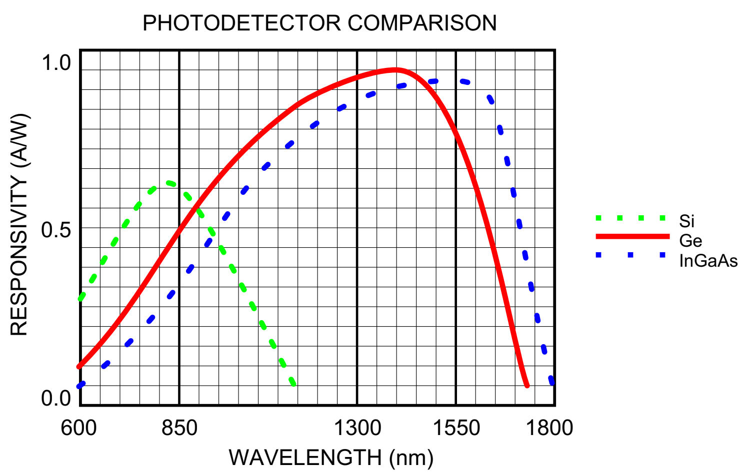
The connector style built into the equipment is generally a matter of convenience for the technician as a patch cord should be utilized when connecting to the system under test. This cord can be a hybrid type (differing connectors on either end). This allows the technician to test a variety of systems by simply changing patch cords. Common connector styles for the actual light source output tend to be ST type, SC, FC, or LC.

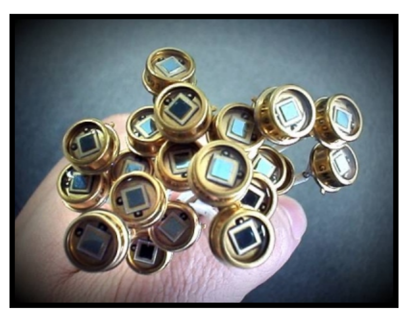
Black Box offers a variety of LED and LASER light sources which permit testing of most fiber networks currently being implemented.

Choosing an optical power meter

The choice of an optical power meter is a more simple matter. The technician should choose an optical power meter appropriate for use with the light source selected in the prior step. Fiber optic power meters usually come in a very few basic detector types: Si (silicon), Ge (germanium), and InGaAs (indium gallium arsenide).

All three types will work with 850nM light but only the Ge and InGaAs types will see 1310nM or 1550nM light. Cost is also a concern, Si based meters are the lowest cost units on the market and InGaAs are the highest.





2mm Ge Detectors

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Choosing an optical power meter (cont.)

If testing only 850nM systems, select a Si based power meter. For almost all other field applications, Ge based meters are the preference. InGaAs based units generally are considered overkill for field applications but offer performance similar to that of Ge.

Other than these considerations, it comes down to a matter of personal preferences with regard to features. For example, when testing for loss, a reference level is taken then a final end to end reading is taken. The difference between the two is a loss. Some meters offer a zero reference (or relative mode) feature to eliminate the need to perform this subtraction in the field, still other meters may offer readings in Watts vs the now conventional dBm. Other features may include interchangeable connector types, ruggedized construction, higher resolution, data storage, rechargable or AC power, or multiple wavelength operation.

Choosing test jumpers and mating adapters

The test jumpers and mating adapters are used to connect the power meter and light source to the system being evaluated. It is very important to use a fiber of the same core and cladding size as the cable being tested in order to produce valid results. The jumpers should be long enough to allow for easy connection to the system but not so long that they become awkward to handle. Generally a 1-3 meter length will work well.

The connectors on the patch cord should be microscope inspected to ensure that they are free of physical defects and should have a surface preparation (flat, PC, UPC, APC, etc.) matching the test equipment on one end and the system under test on the other. The defect inspection is critical and should not be overlooked. Any damage to a patch cord connector endface can and will transfer to everything it is connected to. Remember, when connectors are mated, the spring loaded endfaces produce forces of up to thousands of PSI over the very small contacting surfaces at the fiber core.

The mating adapters should be of good quality, preferably of zirconia ceramic constructed and inspected for damage. The split sleeve alignment mechanism inside the adapter is critical to the testing. This component will degrade with repeated matings and introduce additional losses. It is recommended that a mating adapter not be used for more than a hundred or two matings for the best results, fewer if practical.

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Loss testing basics

To properly test for loss in a fiber system, it is necessary to launch not only the correct wavelength of light into a system (that which the end user will use in data transmission), but that light must also be conditioned to check the core glass only.

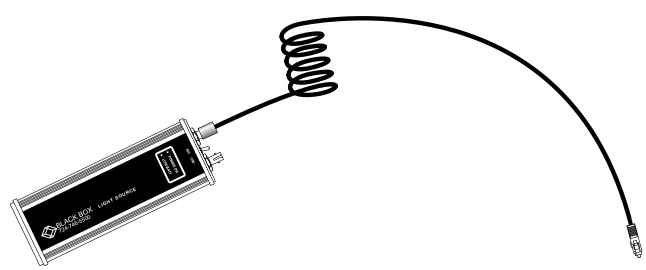
First, when light sources are powered up, they should be allowed to stabilize for a 10 minutes to allow accurate reference points to be taken. Next, a launch cable of similar fiber size and performance to the cable under test must be connected to the source. The launch cable will not only connect the source to the system under test but will also provide a fiber core source. Fiberoptic emitters generally fill both the core and cladding of a fiber. In loss tests, cladding light is not desired since it is not carried well by fiber. Also, in multimode fibers, an equilibrium mode distribution (EMD) must be established. EMD is the illumination of the entire fiber core in the same way it would be lit in a long run of fiber. Both the cladding mode strip and mode scrambling function can be realized through the use of a simple mandrel wrap in the launch cable.

A mandrel wrap is five wraps of fiber around a 1" rod under zero tension and is generally wound by hand in the field and held together with tape or a clamping device. Note: Some military specifications may prohibit the use of a mandrel wrap and instead use certified jumpers and specialized high CPR (coupled power ratio) versions of light sources.

Testing the fiber

The following is a step by step process for testing optical fibers with a Black Box TS1300A test set or any other test set with a zero referencing capability:.

STEP 1:
Attach launch cable with a 1/2", 5 turn mandrel wrap to source. Turn the source on and allow it to stabilize 10 min. *If testing two wavelengths, turn on both emitters and use two separate launch cables.*



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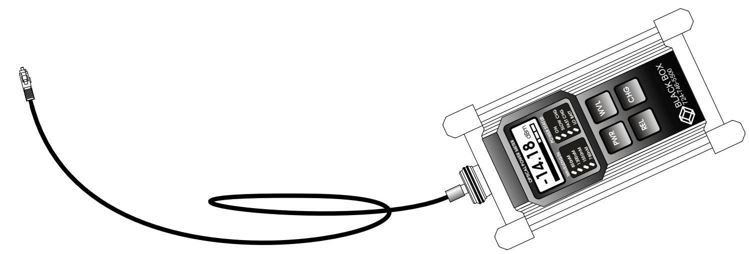
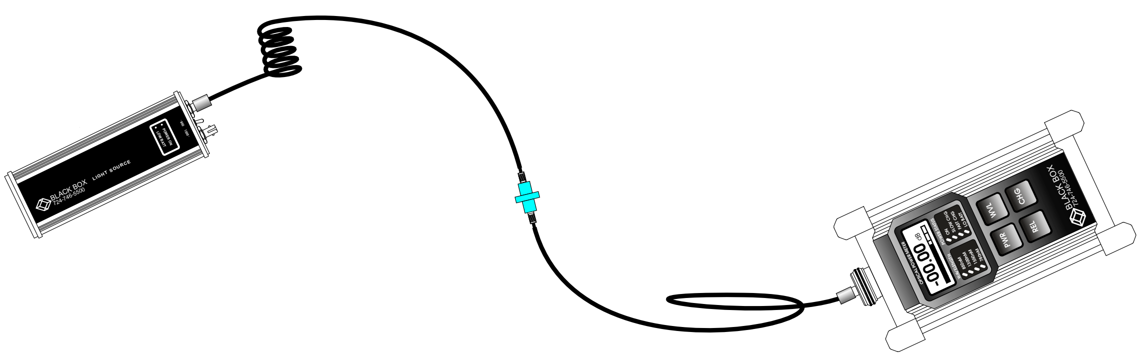
Testing the fiber (cont.)

STEP 2:
Attach a patch cable to the meter without a mandrel wrap. This will be called the receive cable. Make sure that the free ends of the receive and launch cables have the same connector style or can otherwise be directly mated. Also, make sure to select the proper wavelength on your meter.



STEP 3:
Connect the free cable ends together with a connector bushing and press REL on the meter. The meter should read 00.00 dB. *For dual wavelength testing, hook to the second launch cable, select the second wavelength on the meter, and zero the second wavelength also.*

Note that a newer alternative to steps 2 and 3 is to take a zero reference reading with the launch cable only then connect the receive cable prior to testing the entire link. More details on the differences between the techniques may be found in EIA/TIA-526-14A.



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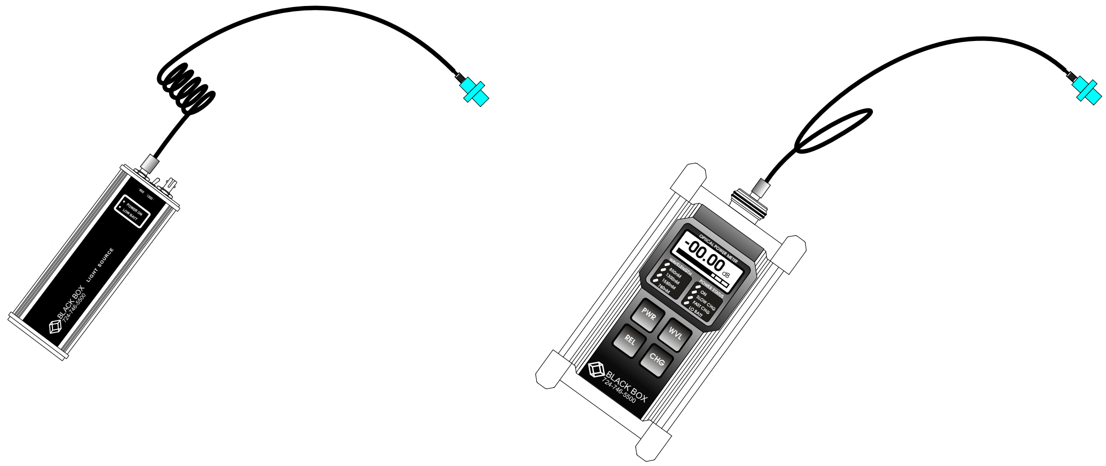
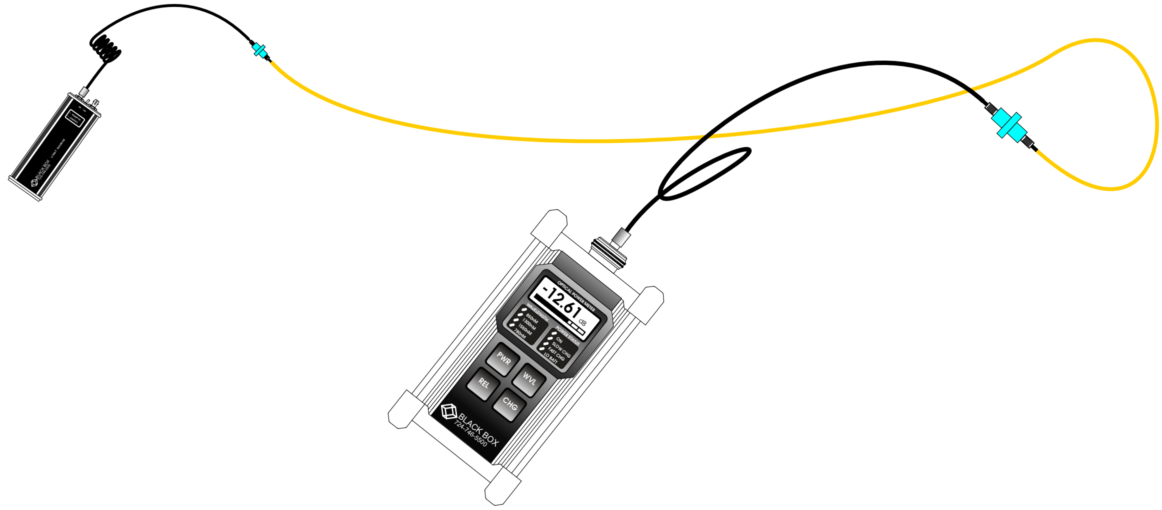
Testing the fiber (cont.)

STEP 4:
Disconnect the cable ends hooked together in STEP 3, then take source and meter to opposite ends of the cable to be tested. Do not remove the launch and receive cables from the instruments.



STEP 5:
Hook free ends of the launch and receive cables to the cable under test. The meter will display the loss of the cable under test. Repeat testing in the reverse direction. *For dual wavelength tests, test all fibers in the link at one wavelength. Next, switch launch cables at the source end, change to the second wavelength at the meter end,* and *repeat STEP 5.*



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Testing with a low cost meter (without relative mode)

If testing with a low cost power meter without a relative mode (zero reference button), step 3 of the prior procedure must be modified. Since low cost meters do not allow a zero reference to be taken, the test technician must write down the reference power level and subtract it from all subsequent readings.

For example, if the reference level with only launch and receive cables connected is -16.0dBm, -16.0 must be subtracted from all subsequent tests performed. This means that if the set is then connected to a communication cable and the display is reading -26.0dBm, power deviation = -26.0 -(-16) = -10dB. Since a negative power deviation indicates LOSS of power, this may also be termed a "10dB loss"

Remember, subtracting a negative number is the same as adding. This is why subtracting a negative 16 was the same as adding 16. Also note that power differences are termed dB since they are relative changes in power while power levels are termed dBm because they are fixed power levels being compared to 1 milliwatt of light.

Expected test results

Ultimately, test results are simply a collection of meaningless numbers without a standard to compare with. In most applications, the hard limits for system loss are simply the transmitter minimum output power and the receiver minimum sensitivity level. For example, if the transmitter power is specified at -16dBm and the minimum receiver sensitivity is -32dBm, you have a maximum tolerable loss of 16dB. Your cable plant must have less than a 16dB loss. Keep in mind that transmitters and receivers degradation, cable movement (wind, ice, temperature), tray stacking, and connector degradation may increase losses over time. For this reason, a buffer of 3dB or more may be desirable.

That being said, the performance of the fiber, connectors, and splices cannot be judged by the minimum system performance standards outlined above. To test connection quality, one must add the maximum expected cable loss (wavelength and length dependent), the maximum connector losses, and the maximum splice losses. These numbers are always available from the manufacturers of fiber optic components. For example, the loss of a 2km run of 62.5/125 fiber with 2 ST connectors and one mechanical splice tested at 1300nM would be estimated by adding the maximum losses of each component. A typical multimode loss at 1300nM is 1dB/km yielding 2dB for this application. Added to .5dB per connector and .5dB per splice, the cable should be giving loss results in the 3.5dB vicinity.

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Typical problems

As with any testing, there are any number of procedural problems which may be encountered. Although loss testing in fiber is a simple process, there are subtle effects unique to fiber which must be understood. A few of these items are listed below:

SOURCE STABILIZATION
Light sources almost always need a short period of time to reach thermal stability. A period of 10 minutes or so is generally a safe bet and will allow the Laser or LED component of a light source to become stable. If a reference is taken too quickly after turning a light source on, this startup drift will become an error of up to several tenths of a dB in the final test results.

BENDING EFFECTS
It is very important to realize that bending of a fiber can and will induce losses which will manifest themselves as either loss or gain in a test. A bend placed in a fiber after a reference has been taken will leak light out of a fiber thereby making loss numbers higher than expected. On the other hand, a bend in a fiber while a reference is being taken will cause problems if that bend is later released. What happens is that the reference level is deceptively low and after release of the bend, light is added to the equation. This effect is most apparent when testing low loss links such as patch cords where the test technician may even observe positive rather than negative power deviations (implying a gain).

PORT STRESS
Similar to bending stress, port stress is pressure being placed upon a connector mated to the actual test gear. Never allow tension to pull the connectors in any direction as this will induce power deviations as well. This effect is most apparent on the light source because of the precise lensing or fiber coupling at this location. Meters often have a wide light capture zone which make them less susceptible to the problem. It is recommended that when zero references are taken during testing, this should be performed at one end of the cable being tested then the METER should be transported to the far end. This leaves the source relatively stationaryand tends to yield better results.

MATING ADAPTER (COUPLING) QUALITY
One of the greatest sources of test problems is poor mating adapter quality. Become familiar with the appearance of the metal or ceramic alignment sleeve inside a mating adapter. They do become damaged either by chipping, losing tension, or contamination. Keep in mind that these devices are only designed for dozens or at most a few hundred cycles. CHANGE YOUR MATING ADAPTERS OFTEN. This cannot be stressed enough. The mating adapter provides much of the mechanical variability in a mated connector pair.

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Loss test analysis for fault location

Aside from simply determining a loss number for a link, it is sometimes useful to analyze loss test data to gather even more information than is at first apparent.

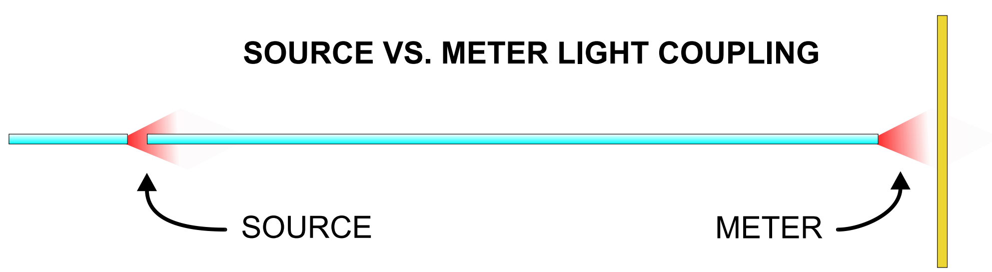
Whenever a link does appear to have a loss problem, a diagnosis is often required. Often the initial solution is to re-clean, re-mate, or check for kinks in the cable but once this is done, the solution is either to fully re-terminate or use an OTDR or fault locator. What many technicians do not realize is that sometimes, the loss test can help give some clues to the problem.

Often times, link failures are due to a connector fault at one end or the other and the question then becomes "Which connector is it?" If the loss test is again performed in both directions, but WITHOUT a receive cable, and if there is a difference between the readings, this can sometimes indicate the bad connector due to a surface defect such as a chip, rough polish, or crack. When connecting the source and meter this way, the bad connector is more likely to be on the METER side of the link when the equipment is connected in the direction indicating the lowest loss.

In other words, perform the loss test in both directions. Hook the gear up in the direction that gives the best performance. The bad connector is probably connected to the meter.

The reason why this assumption is often true has to do with the way light coupling takes place in fiber test equipment. By connecting directly into the meter without a receive cable, we allow the core of the fiber under test to illuminate relatively large detector surface which may be a thousand times larger. Any surface defects on this connector will have a difficult time refracting light enough to fully escape the detector. On the other hand, the connector on the source end has to have a near perfect fit with the launch cord core in order to pass light. This makes it more sensitive to surface defects therefore creating higher losses when a poor connector is at the source.

SOURCE VS. METER LIGHT COUPLING



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