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Four Ways To Test Installed Fiber Optic Cables

And How The Results Will Differ With Each Method

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***Abstract**: We often are asked questions about testing installed fiber optic cables that indicate the industry standards are often confusing, have little information on measurement uncertainty and no guidelines for troubleshooting. This paper is an attempt to clear up some of this confusion. Further useful information is available from Lennie Lightwave's Guide To Fiber Optics (http://www.lennielightwave.com/) and the FOA Tech Topics (http://www.thefoa.org/tech/index.html), especially the Tech Bulletins.*

There are four ways listed in various international standards from the EIA/TIA and ISO/IEC to test installed cable plants. Three of them use test sources and power meters to make the measurement, while the fourth uses an OTDR. The best way to understand them is to look at the diagrams below.

The source/power meter method, generally called "insertion loss," approximates the way the actual network uses the cable plant, so one would expect the loss to be similar to the actual loss seen by the network, which is preferable. The OTDR is an indirect method, using backscattered light to imply the loss in the cable plant, which can have large deviations from insertion loss tests.

The differences in the three insertion loss tests are in how we define "0 dB" or no loss. All three tests end up with the same test setup (Figure 1), but the reference power can be set with one, two or three cables as shown in the three setups below.

All four methods have measurement uncertainty. After we explain the methodology, we will examine the measurement uncertainty.

For convenience in comparing methods, each is on a separate page. We suggest you print them out and place next to each other on a table to compare the differences.
We also suggest you read the FOA Tech Topics pages on testing, calculating link loss budgets, etc. and read Lennie Lightwave's Guide to Fiber Optics on Testing and the virtual hands-on Testing and OTDR tutorials.

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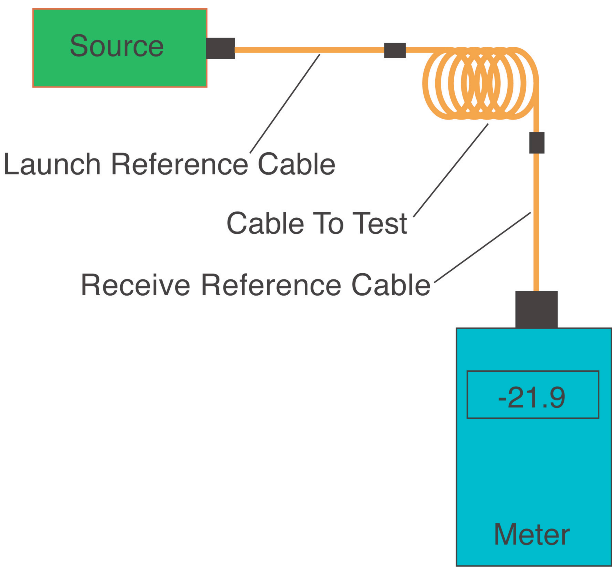
Test Methodology, OFSTP-14

Figure 1. OFSTP-14 Insertion Loss Test of Installed Fiber Optic Cable



1. All insertion loss tests using a test source and fiber optic power meter use this same test setup.
2. Requires both launch and receive cables.
3. Cable loss measurement includes losses of mated connectors from reference cables to both connectors on the cable under test plus the loss of the fiber in the cable under test.
4. Variations in how the “0 dB loss” reference is set causes the differences.

Note: The uncertainty of the measurement is directly related to the quality of the reference jumpers. Bad connectors on reference cables will give consistently high loss readings.
Note 2: Some standards call for specific ways of modifying the modal power distribution; see below.

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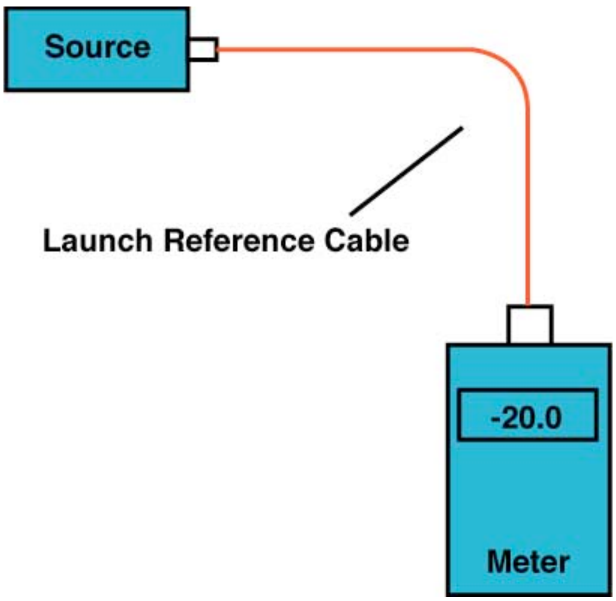
Setting "0 dB Loss" Reference, Method B

Figure 2. 1 Cable Reference (Method B)



1. No connectors are included in the reference setting.
2. Measures cable plant loss including connectors at both ends.
3. This method is specified by all network test specifications and EIA/TIA 568 Appendix H.

Note: this method connects directly to the FO Power Meter. The connection to the meter effectively has no loss, so the reference is the actual output of the reference cable.

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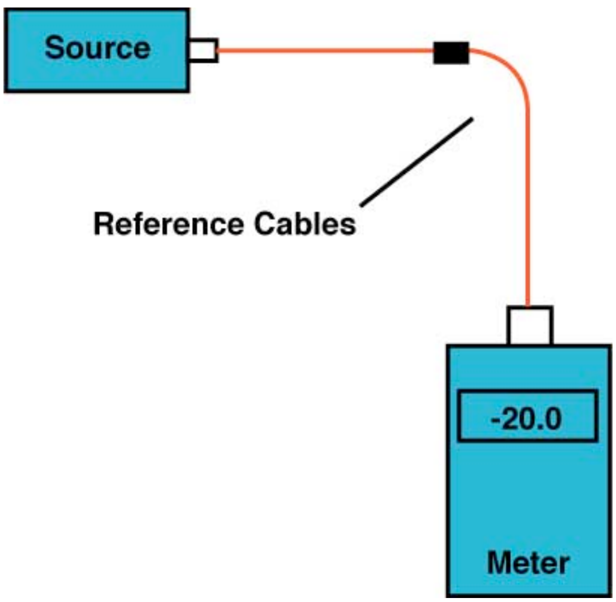
Setting “0 dB Loss” Reference, Method A

Figure 3. 2 Cable Reference (Method A)



1. Sets reference with both launch and receive cables while connected to each other.
2. Has one unknown connector loss included in reference.
3. The measured loss of the cable plant is diminished by the unknown connector loss value included in the reference.
4. Unknown connector loss in reference causes greater measurement uncertainty.
5. If reference connectors are dirty, then cleaned, can result in "gain" not loss.

Note: This method is often used with connectors that are different from the interface connections on the source and power meter, e.g. testing LC connectors with a test set that has ST connectors.

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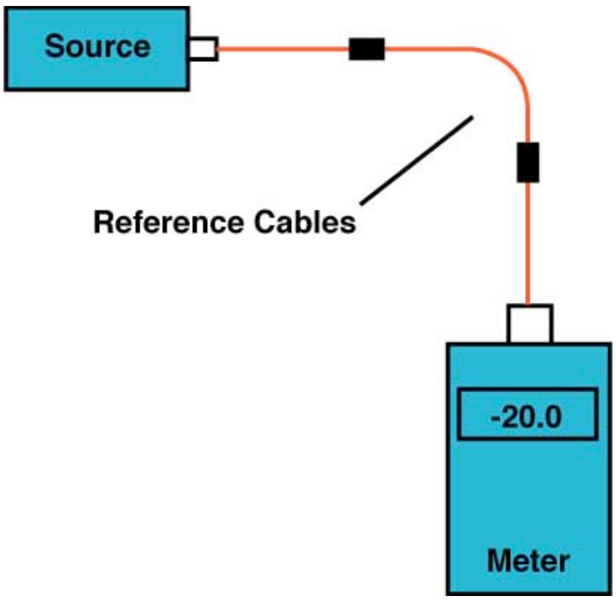
Setting "0 dB Loss" Reference, Method C

Figure 4. 3 Cable Reference (Method C)



1. Set reference with launch and receive cables plus a "golden cable" reference.
2. Remove "golden cable" and replace with cable under test to make measurement.
3. Includes two unknown connector losses in reference value.
4. The measured loss of the cable plant is lower by the losses of the two unknown connections in the reference measurement.
5. Unknown connector losses in reference causes highermeasurement uncertainty.
6. If reference connectors are dirty, then cleaned, can result in "gain" not loss.

Note: This method is often used with duplex male/female connectors that are different from the interface connections on the source and power meter, e.g. testing MT-RJ connectors with a test set that has ST connectors.

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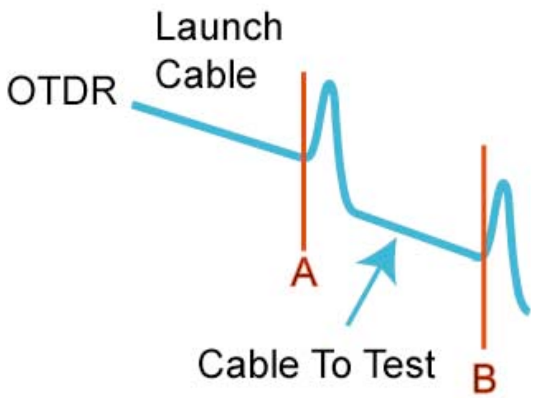
OTDR Testing, Single Ended

Figure 5. OTDR Test



1. Reference cable is launch cable (sometimes called pulse suppressor) which allows OTDR initial pulse to settle down and measurement of first connector on cable to test
2. First cursor precedes reflection peak from cable plant under test
3. Second cursor precedes reflection peak from last connector
4. Calculates loss implied from backscatter measurement.
5. Does not include connector on far end *unless you use a receive cable, now required in ISO/IEC standards. That will add another connector loss.*
6. Used laser which typically has lower loss than LEDs in multimode fiber.
7. Measurements are directional - loss may be different in each direction.

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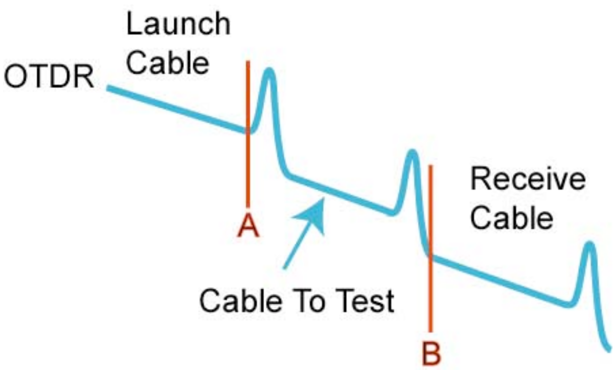
OTDR Testing, Double-Ended

Figure 5. OTDR Test (With receive cable)



1. Reference cable is launch cable (sometimes called pulse suppressor) which allows OTDR initial pulse to settle down and measurement of first connector on cable to test.
2. Receive cable added to far end makes testing more relevant but much less convenient.
3. First cursor precedes reflection peak from cable plant under test
4. Second cursor follows reflection peak from last connector
5. Calculates loss implied from backscatter measurement.
6. Does include connector on far end.
7. Used laser which typically has lower loss than LEDs in multimode fiber.
8. Measurements are directional - loss may be different in each direction.

Note: This is the method now required by the new (2011) version of OFSTP-14.

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Different Results From Different Reference Methods

So just how much does the loss of a cable plant change with the different methods? As an experiment, I tested a 520 meter simulated cable plant with multimode fiber all four ways at 850 nm using several different sets of reference cables to see the results. Using 10 different sets of reference cables and making multiple measurements allowed us to make an average of each measurement, comparable to what several different test crews might find, plus calculate the standard deviation, a statistical indication of the repeatability of the measurement.

Test Method	Results (loss , standard deviation)
Method B: 1 Cable Reference	2.96 dB , +/- 0.02 dB
Method A: 2 Cable Reference	2.66 dB, +/- 0.20 dB
Method C: 3 Cable Reference	2.48 dB, +/- 0.24 dB
OTDR (single ended, no receive cable)	1.91 dB / 2.05 dB (2 directions)

Note how the loss of our test cable plant reflects the comments we made above. The one cable reference method has higher loss than the other methods, but it also has much less measurement uncertainty. The 2 and 3 cable reference methods have less loss because we have subtracted the connector loss(es) included when we set the reference for 0 dB loss, and the uncertainty is higher because of the greater variance when connected to the reference cables. And the OTDR measurement is significantly lower than the other three methods.

What is the loss of this cable plant? Well all four of those measurements are strictly according to international standards, so you can take your choice! However, it might cause a problem if you attach some network electronics.

Most network specifications have been written around a loss test that uses a one cable reference method, as does the EIA/TIA 568B test method. If your cable has been tested with any other method, the lower loss you measure will give you a false measurement of system margin. If you are dealing with new, fast networks like Gigabit Ethernet or Fibre Channel which have much smaller operating power margins, you could be in trouble.

If your test equipment has ST or SC connectors and you must test LCs on the cable plant, you may have no choice but to use a Method A 2-cable reference. To compare these test results with a Method B, you must add an estimated loss for the connector included in the reference measurement, say 0.3-0.5 dB for a typical connector on a high-quality factory-made patchcord.

If your test equipment has ST or SC connectors and you must test duplex male/female connectors like the MT-RJ on the cable plant, you may have no choice but to use a Method C 3-cable reference. To compare these test results with a Method B, you must add an estimated loss for the connectors included in the reference measurement, say two times 0.75 dB for a typical MT-RJ connector on a high-quality factory-made patchcord.

The different loss obtained in OTDR measurements comes from it's completely different methodology. OTDRs use backscattered light to imply the measurement while insertion loss is measured directly by transmission. All OTDRs use laser sources which inject light generally only in the center of the core of the fiber where loss is lower. And a single-ended measurement, which most tech use, does not test the connector on the far end. Recent standards mention and sometimes require a receive cable for OTDR tests, which would have added 0.2-0.3 dB to the loss measured in the test detailed above. But having to use a receive cable with an OTDR negates its advantage of being able to be tested from one end by a single technician.

Sources Of Measurement Uncertainty

There are many sources of measurement uncertainty when making fiber optic loss measurements, but some have higher likelihood than others. Let's examine some of them.

Technician Training And Understanding

Twenty-five years experience in the fiber optic test equipment and training business convinces me that the biggest single factor in measurement uncertainty is the technicians understanding of testing methodology and uncertainty (or lack thereof.) That is precisely the reason for this document. Every tech should be required to study this document and practice making measurements in their office or lab, using the equipment they generally use, to determine 1)how it works, 2)how to make measurements and 3)how to be consistent.

Test Equipment

Several factors related to test equipment cause many problems. Most equipment will make good measurements if used properly. Some test equipment is hard to understand and techs routinely misuse it. Often manufacturers do not provide applications explanations, only directions on using the instruments, so the tech who knows how to use the instrument itself is left to his own devices on how to use it. Some equipment is sensitive to battery charge level, especially the output of the source. When the battery charge drops, the source output drops, causing measurements of higher loss unless the reference is frequently reset. And most test equipment manufacturers do not addres the issue of mode power distribution (below) in any understandable manner.

Reference Cables

It should be obvious that if one uses reference cables to connect to cables under test to measure connector loss, it is vitally important that the reference cables are top quality and kept in excellent condition. Reference cables should be tested daily using

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FOTP-171 method on the equipment they will be used on or after every 20-100 measurements. Reference cables should be discarded if single-ended loss exceeds 0.5 dB. They should be cleaned each time they are used (see below.)

Cleanliness

With fiber optics, our tolerance to dirt is near zero. Airborne particles are about the size of the core of SM fiber and are usually silica based- they may scratch connectors if not removed. Dirt can cause connector loss variations of tenths of a dB. Test equipment that has fiber-bulkhead connections need periodic cleaning, since they may have hundreds of insertions of test cables in short time frames.

Mismatched Fibers

Today, it is not uncommon to find a building or campus with two sizes of multimode fiber (50/125 and 62.5/125) and singlemode, often terminated in the same rack. Needles to say, color coding these different fibers is important.

When testing any fiber, it's necessary to use reference cables of the same fiber size. Testing 50/125 with 62.5/125 reference cables will give virtually no loss when going from the small fiber to the larger one, but 2-4 dB excess loss in the other direction. Connecting any MM fiber to SM will cause 15-20 dB excess loss.

Mode Power Distribution

Multimode fiber is called "multimode" because it transmits light in many "modes" or "rays" of light, which travel in curving (sine wave) paths. The light in some modes stays close to the center of the fiber core (called 'lower-order modes"), while others (called 'higher-order modes") go close to the edge of the core. The term "mode power distribution" or MPD is used to describe this phenomenon.

The lower-order modes traveling close to the center of the core actually travel shorter paths through the fiber than those traveling all the way to the outside of the core. The higher order modes suffer more attenuation simply because they travel through more glass in their longer paths down the fiber. Thus, as you go down a length of fiber, the higher-order modes are attenuated more, so that the light in the fiber becomes more concentrated in the center of the core, as shown in the lower fiber.

This has two effects that affect the loss of a cable plant . First, the attenuation coefficient (expressed in dB/km) of the fiber itself decreases along the fiber as the higher order modes are more attenuated, leaving only the lower loss central modes. This effect may take 1-2 km to reach equilibrium, and the attenuation coefficient of the fiber can be considerably less, as much as 1 dB/km at 850 nm, at the end of the second kilometer. Secondly, as the light concentrates in the center of the core, the loss at connectors or splices is reduced, as the geometric offset of a connector is less a factor when the light is concentrated in the center of the core.

Thus the measurement you make of loss is dependent on the distribution of light in the fiber. Even on a short 100m link, the fiber loss can vary by 0.1 dB or more, and

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the difference on every connection in the link can be as much as several tenths of a dB. If a link has 4 connections, the variations of the measurement caused by modal effects can be as much as 0.5 dB, while the entire link could have a loss of only 1.5 dB!

This uncertainty caused by MPD has led to the creation of standard test conditions. TIA-568 calls for a LED test source of specified power output and a launch reference cable wrapped around a mandrel or rod which attenuates the higher order modes in a fairly controlled fashion. Using a mandrel of a specified size for each type of fiber (See table below) will make the measured loss more predictable – and – *this is important* - lower.

In our experience, most installers are not aware of this requirement in TIA-568 and therefore do not use this test method. This can be a big mistake, as this test method will always give lower loss when testing any multimode link. Not using a mandrel wrap means you are starting with a handicap, so it's to your advantage to understand and use this method properly.

TIA-568 Specified Mandrel Size

Wrap 5 non-overlapping turns over the specified size mandrel		
	Cable/Fiber Type	
Fiber Size	3mm Jacketed Cable	900 micron Buffered Fiber
50/125 fiber	22mm	25mm
62.5/125 fiber	17mm	20mm

Source Wavelength

On long single mode runs, tens or hundreds of km, the wavelength of the source becomes critical, since fiber loss is wavelength dependent. A variation of 10 nm in source wavelength can cause variations of 0.05 dB/km in loss, not a problem on a fe km, but could be 5 dB on 100 km.

Summary

Getting reasonable test data on installed fiber optic cable plants is not difficult, if you 1)understand the test methodology, 2) know your test equipment, 3) keep equipment and particularly reference cables in good condition and 4) are consistent in making measurements.

Finally, know what measurement values to expect. Never try to test before doing a link loss calculation (http://www.thefoa.org/tech/lossbudg.htm and http://www.thefoa.org/tech/loss-est.htm). Compare measured values to calculated values and stop immediately if something looks amiss. Solve the problem before wasting more time.

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