



# Guide To Fiber Optics & Premises Cabling

## Fiber Optic Testing

Testing is used to evaluate the performance of fiber optic components, cable plants and systems. As the components like fiber, connectors, splices, LED or laser sources, detectors and receivers are being developed, testing confirms their performance specifications and helps understand how they will work together. Designers of fiber optic cable plants and networks depend on these specifications to determine if networks will work for the planned applications.

For the purposes of this particular page, we will focus on the installed cable plant, but other pages on this website will cover many more aspects of fiber optic testing. See the Test section of the [FOA Online Guide](#) for much more detail.<sup>1</sup>



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<sup>1</sup> <http://www.thefoa.org/tech/ref/contents.html#Test>



After fiber optic cables are installed, spliced and terminated, they must be tested. For every fiber optic cable plant, you need to test for continuity and polarity, end-to-end insertion loss and then troubleshoot any problems. If it's a long outside plant cable with intermediate splices, you will probably want to verify the individual splices with an OTDR test also, since that's the only way to make sure that each splice is good. If you are the network user, you may also be interested in testing transmitter and receiver power, as power is the measurement that tells you whether the system is operating properly.

Testing is the subject of the majority of industry standards, as there is a need to verify component and system specifications in a consistent manner. A list of fiber optic standards<sup>2</sup> is on the FOA website in Tech Topics and the FOA's own test standards are available free.<sup>3</sup> Perhaps the most important test is insertion loss of an installed fiber optic cable plant performed with a light source and power meter (LSPM) or optical loss test set (OLTS) which is required by all international standards to ensure the cable plant is within the loss budget before acceptance of the installation.

Testing fiber optics requires special tools and instruments which must be chosen to be appropriate for the components or cable plants being tested.<sup>4</sup>

### **Getting Started**

Even if you're an experienced fiber optic tech, make sure you remember these things.

#### ***1. Have the right tools and test equipment for the job.<sup>5</sup>***

- Optical inspection microscope, 100-200X video scope recommended
- Source and power meter, optical loss test set (OLTS) or test kit with proper equipment adapters for the cable plant you are testing.
- Reference test cables that match the cables to be tested and mating adapters, including hybrids if needed
- Fiber Tracer or Visual Fault Locator
- Cleaning materials - dry cleaning kits or lint free cleaning wipes and pure alcohol
- Optional: OTDR with launch and/or receive cables for outside plant jobs and troubleshooting

#### ***2. Know how to use your test equipment***

Before you start, get together all your tools and make sure they are all working properly and you and your installers know how to use them. It's hard to get the job done when you have to call the manufacturer from the job site on your cell phone to ask for help. Try all your equipment in the office before you take it into the field. Use it to test every one of your reference test jumper cables in both directions using the single-ended loss test to make sure they are all good. If your power meter has internal memory to record data be sure you know

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<sup>2</sup> <http://www.thefoa.org/tech/standards.htm>

<sup>3</sup> <http://www.thefoa.org/tech/ref/1pstandards/index.html>

<sup>4</sup> <http://www.thefoa.org/tech/ref/testing/Instruments/instr.html>

<sup>5</sup> <http://www.thefoa.org/tech/ref/testing/Instruments/instr.html>

how to use this also. You can often customize these reports to your specific needs - figure all this out before you go it the field - it could save you time and on installations, time is money!

### **3. Know the cabling network you're testing**

This is an important part of the documentation process we discussed earlier. Make sure you have cable layouts for every fiber you have to test and have calculated a loss budget<sup>6</sup> so you know what test results to expect. Prepare a spreadsheet of all the cables and fibers before you go in the field and print a copy for recording your test data. You may record all your test data either by hand or if your meter has a memory feature, it will keep test results in on-board memory that can be printed or transferred to a computer when you return to the office.

**A note on using a fiber optic source:** eye safety.<sup>7</sup> Fiber optic sources, including test equipment, are generally too low in power to cause any eye damage, but it's still advisable to check connectors with a power meter before looking into it. Besides, most fiber optic sources are at infrared wavelengths that are invisible to the eye, making them more dangerous. Connector inspection microscopes focus all the light into the eye and can increase the danger. Some telco DWDM and CATV systems have very high power and they could be harmful, so better safe than sorry.

## **Visual Inspection**

### **Visual Tracing**



Continuity checking with a visual fiber tracer makes certain the fibers are not broken and to trace a path of a fiber from one end to another through many connections, verifying duplex connector polarity for example. It looks like a flashlight or a pen-like instrument with a light bulb or LED source that mates to a fiber optic connector. Attach the fiber to test to the visual tracer and look at the other end of the fiber to see the light transmitted through the core of the fiber. If there is no light at the end, go

back to intermediate connections to find the bad section of the cable.

A good example of how it can save time and money is testing fiber on a reel before you pull it to make sure it hasn't been damaged during shipment. Look for visible signs of damage (like cracked or broken reels, kinks in the cable, etc.). For testing, visual tracers help also identify the next fiber to be tested for loss with the test kit. When connecting cables at patch panels, use the visual tracer to make sure each connection is the correct two fibers! And to make certain the proper fibers are connected to the transmitter and receiver, use the visual tracer in place of the transmitter and your eye instead of the receiver (remember that fiber optic links work in the infrared so you can't see anything with your eye anyway - but you may be able to

<sup>6</sup> <http://www.thefoa.org/tech/lossbudg.htm>

<sup>7</sup> <http://www.thefoa.org/tech/ref/safety/safe.html>

use your digital camera or cell phone camera.)

## Visual Fault Location



A higher power version of the fiber tracer called a visual fault locator (VFL) uses a visible laser that can also find faults. The red laser light is powerful enough for continuity checking or to trace fibers for several kilometers, identify splices in splice trays and show breaks in fibers or high loss connectors. You can actually see the loss of light at a fiber break by the bright red light from the VFL through the jacket of many yellow or orange simplex cables (excepting black or gray jackets, of course.) It's most important use is finding faults in short

cables or near the connector where OTDRs cannot find them.

You can also use this gadget to visually verify and optimize mechanical splices or prepolished-splice type fiber optic connectors. By visually minimizing the light lost you can get the lowest loss splice. In fact- don't even think of doing one of those prepolished-splice type connectors without one. No other method will assure you of high yield with those connectors.

A note on VFL eye safety. VFLs use visible light. You will find it uncomfortable to look at the output of a fiber illuminated by a VFL. That's good, because the power level is high and you should not be looking at it. When tracing fibers, look from the side of the fiber to see if light is present.

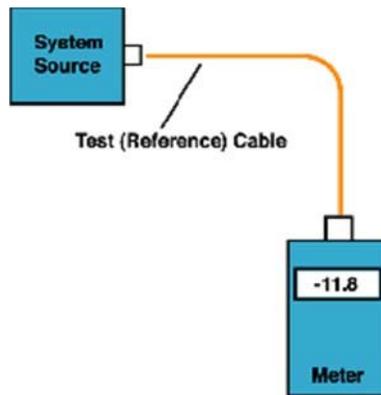
## Optical Power - Power or Loss? ("Absolute" vs. "Relative" Measurements)

Practically every measurement in fiber optics refers to optical power measured in dB. The power output of a transmitter or the input to receiver are "absolute" optical power measurements, that is, you measure the actual value of the power. Loss is a "relative" power measurement, the difference between the power coupled into a component like a cable, splice or a connector and the power that is transmitted through it. This difference in power level before and after the component is what we call optical loss and defines the performance of a cable, connector, splice, etc. Take a minute and read about "dB," the measurement unit of power and loss in optical fiber measurements.<sup>8</sup>

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<sup>8</sup> <http://www.thefoa.org/tech/ref/basic/dB.html>

## Measuring power



Power in a fiber optic system is like voltage in an electrical circuit - it's what makes things happen! It's important to have enough power, but not too much. Too little power and the receiver may not be able to distinguish the signal from noise; too much power overloads the receiver and causes errors too.

Measuring power requires only a power meter (most come with a screw-on adapter that matches the connector being tested), a known good fiber optic cable (of the right fiber size, as coupled power is a function of the size of the core of the fiber) and a little help from the network electronics to turn on the transmitter. Remember when you measure power, the meter must be set to the proper range (usually dBm, sometimes microwatts, but never "dB" - that's a relative power range used only for testing loss!) and the proper wavelength, matching the source being used in the system (850, 1300, 1550 nm for glass fiber, 650 or 850 nm for POF). Refer to the instructions that come with the test equipment for setup and measurement instructions (and don't wait until you get to the job site to try the equipment, try it in the office first!)

To measure power, attach the meter to the cable attached to the source that has the output you want to measure (see diagram above). That can be at the receiver to measure receiver power, or using a reference test cable (tested and known to be good) that is attached to the transmitter to measure output power. Turn on the transmitter/source and give it a few minutes to stabilize. Set the power meter for the matching wavelength and note the power the meter measures. Compare it to the specified power for the system and make sure it's enough power but not too much.

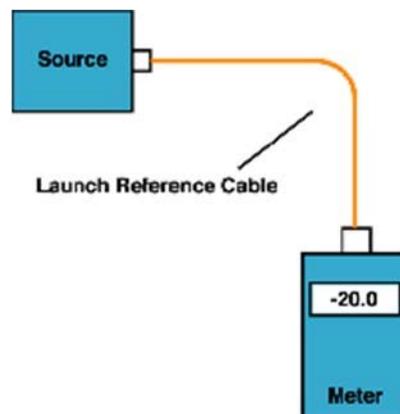
## Testing Loss

Loss of a cable is the difference between the power coupled into the cable at the transmitter end and what comes out at the receiver end. Testing for loss (also called "insertion loss") requires measuring the optical power lost in a cable (including fiber attenuation, connector loss and splice loss) with a fiber optic light source and power meter (LSPM) or optical loss test set (OLTS.) Loss testing is done at wavelengths appropriate for the fiber and its usage.

Generally multimode fiber is tested at 850 nm and optionally at 1300 nm with LED sources. Singlemode fiber is tested at 1310 nm and optionally at 1550 nm with laser sources. The measured loss is compared to the estimated loss calculated for the link, called a "loss budget."<sup>9</sup>

The insertion loss measurement is made by mating the cable being tested to known good reference cables with a calibrated launch power that becomes the "0 dB" loss reference. Why do you need reference cables to measure loss? Why can't you just plug the cable to test into a source and power meter and measure the power? There are several reasons:

- You need a cable to measure the output power of the source for calibration of "0 dB" loss.
- In order to measure the loss of the connectors you must mate them to a similar, known good, connector.
- *This is an important point often not fully explained.* When we say connector loss, we really mean "connection" loss - the loss of a mated pair of connectors. Thus, testing connectors requires mating them to reference connector which must be high quality connectors themselves to not adversely affect the measured loss when mated to an unknown connector.
- Testing with reference cables on each end simulates a cable plant with patchcords connecting to transmission equipment.



In addition to a power meter, you need a test source. The test source should match the type fiber (generally LED for MM or laser for SM) and wavelength (850, 1300, 1550 nm) that will be used on the fiber optic cable you are testing. If you are testing to some standards, you may need to add some mode conditioning, like a mandrel wrap, to meet the standard launch conditions.

You generally need one or two reference cables, depending on the test we wish to perform.

<sup>9</sup> <http://www.thefoa.org/tech/lossbudg.htm>

The accuracy of the measurement you make will depend on the quality of your reference cables, since they will be mated to the cable under test. The quality and cleanliness of the connectors on the launch and receive cables is the most important factor in the accuracy of loss measurements. Always test your reference cables by the patchcord or single ended method shown below to make sure they're good before you start testing other cables!

Standards groups have never been able to successfully specify the quality of reference cables in terms of tightly toleranced components like the fiber and connectors. The best recommendation for qualifying reference cables is to choose cables with low loss, tested "single-ended" per FOTP-171 below.



### Reference cables and mating adapter

In order to mate the reference cables to the cables you want to test, you need mating adapters. Mating adapters are as important to low connection loss as the quality of the connectors since the mating adapter is responsible for aligning the two connector ferrules correctly. Mating adapters must be kept clean, like connectors and discarded after some number of uses as they wear out from repeated matings. Mating adapters may have alignment sleeves made from plastic, metal or ceramic. Plastic alignment sleeves used on the cheapest mating adapters should not be used for testing as they wear out in only a few insertions, leaving dusty residue on the connectors. Metal adapters are good for many more insertions and provide a better alignment, so they are acceptable. Ceramic alignment sleeves are the best, providing the best alignment and practically never wearing out.

In order to measure loss, we need to set our reference power for loss our "0 dB" value. Correct setting of the "0 dB" reference launch power is critical to making good loss measurements!

Clean your connectors<sup>10</sup> and set up your equipment like this:

Turn on the source and select the wavelength you want for the loss test. Turn on the meter, select the "dBm" or "dB" range and select the wavelength you want for the loss test. Measure the power at the meter. This is your reference power level for all loss measurements. If your meter has a "zero" function, set this as your "0" reference.

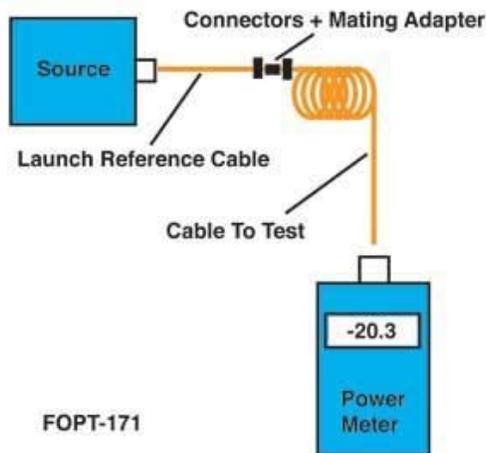
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<sup>10</sup> <http://www.thefoa.org/tech/ref/termination/cleaning.html>

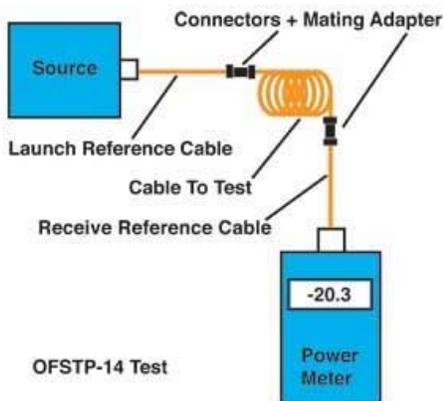
Some reference books and manuals show setting the reference power for loss using both a launch and receive cable mated with a mating adapter or even three reference cables. Industry standards, in fact, include all three methods of setting a "0dB loss" reference<sup>11</sup>. The two or three cable reference methods are acceptable for some tests and are the only way you can test if the connectors on the cable plant are not the same as your test equipment, but it will reduce the loss you measure by the amount of loss between your reference cables when you set your "0dB loss" reference.<sup>12</sup> Also, if either the launch or receive cable is bad, setting the reference with both cables hides the fact. Then you could begin testing with bad launch cables making all your loss measurements wrong. EIA/TIA 568 and OFSTP-14/7 allows any method as long as the method is reported with the data.

## Testing Loss

Single-ended testing (e.g. patchcords)



Double-ended testing (installed cable plants)



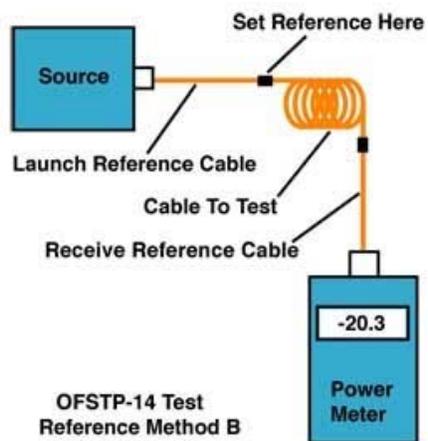
<sup>11</sup> <http://www.thefoa.org/tech/ref/testing/5ways/fiveways.html>

<sup>12</sup> <http://www.thefoa.org/tech/ref/testing/test/conntypes.html>

There are two methods that are used to measure loss, a "patchcord test" which we call "single-ended loss" (TIA FOTP-171) and an "installed cable plant test" we call "double-ended loss" (TIA OFSTP-14 (MM) and OFSTP-7 (SM)).<sup>13</sup> Single-ended loss uses only the launch cable, while double-ended loss uses a receive cable attached to the meter also.

Single-ended loss is measured by mating the cable you want to test to the reference launch cable and measuring the power out the far end with the meter. When you do this you measure the loss of the connector mated to the launch cable and the loss of any fiber, splices or other connectors in the cable you are testing. Since you are aiming the connector on the far end of the cable mated to the power meter at a large area detector instead of mating it to another connector, it effectively has no loss so it is not included in the measurement. This method is described in FOTP-171 and is shown in the drawing. An advantage to this test is you can troubleshoot cables to find a bad connector since you can reverse the cable to test the connectors on the each end individually.

In a double-ended loss test, you attach the cable to test between two reference cables, one attached to the source and one to the meter. This way, you measure two connectors' losses, one on each end, plus the loss of all the cable or cables, including connectors and splices, in between. This is the method specified in OFSTP-14 (multimode, the singlemode test is OFSTP-7), the standard test for loss in an installed cable plant.

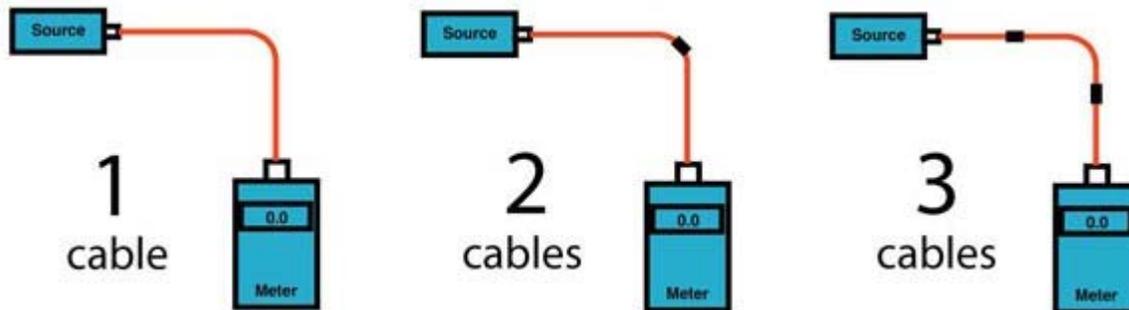


Single cable reference method preferred in some standards.

Note there are three methods of setting the reference, using one, two or three reference cables. The method originally called for in TIA-568 is the one cable method, but that method doesn't work with every type of connector and test equipment interfaces, so the standards now allow any method as long as it has been documented with the test data. Therefore most

<sup>13</sup> <http://www.thefoa.org/tech/ref/testing/test/OFSTP-14.html>

standards now allow for using either one, two or three reference cables as long as the test method is documented along with the test data<sup>14</sup>.



The test results you get when using each of these methods will be different due to the connections (0, 1 or 2) included in setting the "0 dB" reference.<sup>15</sup>

### The 2 Cable Reference, Formerly Method A

Set the reference with method A but do not change the output of the LS.

2 cable reference : [LS]-----ref cable-----0-[1]-----ref cable------(0-[1])[PM]

where "0" equals the output of the launch reference cable measured by [PM] as in the 1 cable reference, decreased by the loss of the connection [1] between the reference cables, so the [PM] now measures (0-[1]).

OFSTP-14/7: [LS]-----ref cable-----[A]-----cable to test-----[B]-----ref cable-----[PM]

Thus, with the power meter, we measure loss "L", we measure connection loss [A], the loss of the fiber and any intermediate connections or splices in the cable to test [CTT] and connection [B] but our "0 dB reference" is now "0-[1]" and the loss measured is

$$L = (0 - [1]) - ([A] + \text{CTT} + [B]) = \text{measured loss of the cable}$$

Note the measured loss is the same as the 1 cable reference decreased by the loss of the connection between the reference cables [1] when the "0 dB reference" was set, which is not necessarily the same as saying the loss measured does not include one of the connectors, since the loss of [1] is not necessarily the same as [A] or [B]. That unknown factor causes this method to be more uncertain (many would say "less accurate") than the 1 cable reference.

<sup>14</sup> <http://www.thefoa.org/tech/ref/testing/5ways/fiveways.html>

<sup>15</sup> <http://www.thefoa.org/tech/ref/testing/5ways/lossmath.html>



### Is it possible to compensate for the included connections?

Someone making this test who understands this issue could compensate for the difference by calibrating [1] this way:

Set reference by 1 cable reference :

[LS]-----ref cable-----0-[PM]

Add the receive reference cable and measure again:

2 cable reference: [LS]-----ref cable-----0-[1]-----ref cable-----[1][PM]

This test gives you a direct measurement of [1] which can now be added back in when testing the cable, giving you the same result as method B. But in order to do so requires the ability of the instruments to measure by the 1 cable reference, so it just adds another step to the process – why not just use 1 cable reference in the first place. The loss measured [1] will be slightly different each time the two connectors are mated, adding to the uncertainty of the measurement.

### The 3 Cable Reference, Formerly Method C

Set the reference with method A but do not change the output of the LS.

Method C: [LS]-----ref cable----0-[1]-----ref cable-----[2]-----ref cable----- (0-[1]-[2])[PM]

where “0” equals the output of the launch reference cable measured by [PM] as in the 1 cable reference, decreased by the loss of the connections [1] and [2] between the reference cables, so the [PM] now measures (0-[1]-[2]).

OFSTP-14/7: [LS]-----ref cable-----[A]-----cable to test-----[B]-----ref cable-----[PM]

Now with the power meter, when we measure loss “L”, we measure connection loss [A], the loss of the fiber and any intermediate connections or splices in the cable to test [CTT] and connection [B] but our “0 dB reference” is now “0-[1]-[2]” and the loss measured is

$L = (0 - [1] - [2]) - ([A] + \text{CTT} + [B]) = \text{measured loss of the cable}$

The measured loss now is the same as 1 cable reference decreased by the loss of the connection between the reference cables [1] and [2] when the “0 dB reference” was set, which is not necessarily the same as saying the loss measured does not include one of the connectors, since having two unknown connectors causes this method to be more uncertain (many would say "less accurate") than either of the other methods.



## What Loss Should You Get When Testing Cables?

Before testing, preferably during the design phase, you should calculate a loss budget for the cable plant to be tested to understand the expected measurement results.<sup>16</sup> Besides providing reference loss values to test against, it will confirm that the network transmission equipment will work properly on this cable. While it is difficult to generalize, here are some guidelines:

- For each connector, allow 0.75 for prepolished/mechanical splice connectors\* (0.75 max per TIA-568) or 0.3-0.5 dB loss for adhesive/polish connectors. \*SSF type connectors
- For each splice, figure 0.2 dB
- For singlemode fiber, the loss is about 1.0 dB per km for 1310 nm sources, 1.0 dB per km for 1550 nm. This roughly translates into a loss of 0.1 dB per 600 feet for 1310 nm, 0.1 dB per 750 feet for 1550 nm.
- For multimode fiber, the loss is about 3.0 dB per km for 850 nm sources, 1 dB per km for 1300 nm (3.5 dB and 1.5 dB max per EIA/TIA 568). This roughly translates into a loss of 0.1 dB per 100 feet for 850 nm, 0.1 dB per 300 feet for 1300 nm.

Ex: For the loss calculation of 500 feet of multimode fiber (0.1 dB per 100 ft = 0.5 dB) with a pre-polished connector on each end (0.75 dB x 2 connectors = 1.5 dB) the calculation for approximate loss budget would be 0.5 dB + 1.5 dB = 2.0 dB. A reading of  $\leq 2.0$  dB “passes” in this scenario as it less than or equal to the loss budget.

## Troubleshooting Hints

If you have high loss in a cable, make sure to reverse it and test in the opposite direction using the single-ended method. Since the single ended test only tests the connector on one end, you can isolate a bad connector - it's the one at the launch cable end (mated to the launch cable) on the test when you measure high loss.

High loss in the double ended test should be isolated by retesting single-ended and reversing the direction of test to see if the end connector is bad. If the loss is the same, you need to either test each segment separately to isolate the bad segment or, if it is long enough, use an OTDR.

If you see no light through the cable (very high loss - only darkness when tested with your visual tracer), it's probably one of the connectors, and you have few options. The best one is to isolate the problem cable, cut the connector of one end (flip a coin to choose) and hope it was the bad one (well, you have a 50-50 chance!)

FOA Tech Bulletin on troubleshooting: <http://www.thefoa.org/tech/guides/TT3.pdf>.

Virtual hands-on tutorial on insertion loss testing: <http://www.thefoa.org/tech/ref/testing/test/VHO-IL/VHO-ILtest.htm>



Videos on testing including insertion loss are on the FOA Channel on



<sup>16</sup> <http://www.thefoa.org/tech/loss-est.htm>