Choosing the Right Reference Method

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WHEN AND WHY TO USE THE ONE-CORD, TWO-CORD AND THREE-CORD REFERENCE METHODS

Over the past decades, network data rates have tremendously increased. This has resulted in pushing the limits of fiber optic components, including test instruments. Tight loss budget and short distance links are often encountered. Accuracy is no longer a luxury; it has become vital in ensuring valid measurements for both outside and inside plant testing.

Proper references are key to ensure accurate and valid measurements. This means that in addition to an accurate instrument, good test cords and a proper reference technique must also be adopted.

However, there seems to be lot of confusion when choosing the appropriate reference method. Even if the test set comes with preprogrammed reference routines, one still must know which routine should be used; and, this is where it becomes challenging.

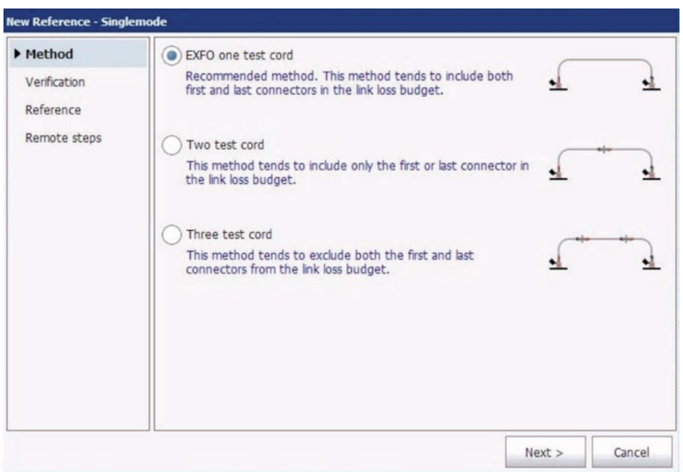


Figure 1. Preprogrammed reference routines in the MAX-940/945 OLTS

This application note examines the one-cord, two-cord and three-cord reference methods proposed by various standards bodies regarding how and when they should be used.

But before discussing methods, we should first consider the grade or quality of the test cord to be used. A wide variety of test cords exist on the market. They can be classified into two main categories, namely, standard and reference grades.

Reference grade cords are recommended, since their connectors will exhibit better insertion loss (IL) and return loss (RL) than most standard grade cords. Reference grade test cords do not become a limiting factor in testing performances and/or limits. They also ensure improved repeatability from one measurement to another.

For multimode tests, it becomes even more important to use EXFO's reference grade test cord specifically: Encircled-flux (EF) conditioners are installed within the test unit. To maintain EF conditions, EXFO provides test cords with controlled fiber core size and geometry. Test cords are consumable and occasionally need to be replaced. The internal conditioner with EF *transparent* test cords design is one of the best cost-effective solutions on the market.

Connectors must be kept clean and free of defects, as they may play a major role in the overall loss and ORL being measured. Inspection tools, such as the FIP-430B fiber inspection probe, are critical and must be used to validate a connector's state; cleaning alone or using brand new test cords out of the bag does not ensure connector cleanliness. Without an inspection tool, achieving accurate and repeatable results will become a challenge.

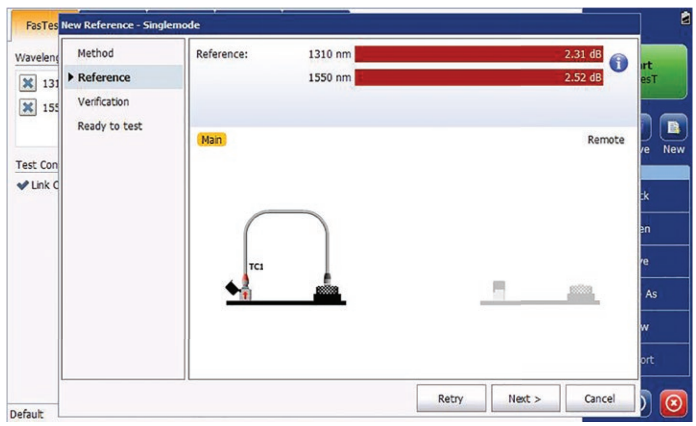


Figure 2. Failing references due to damaged or dirty connectors

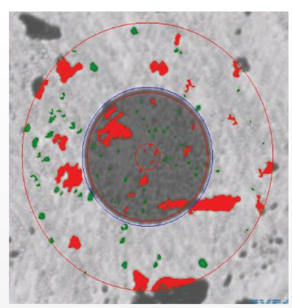


Figure 3. Bad, dirty or damaged connector.

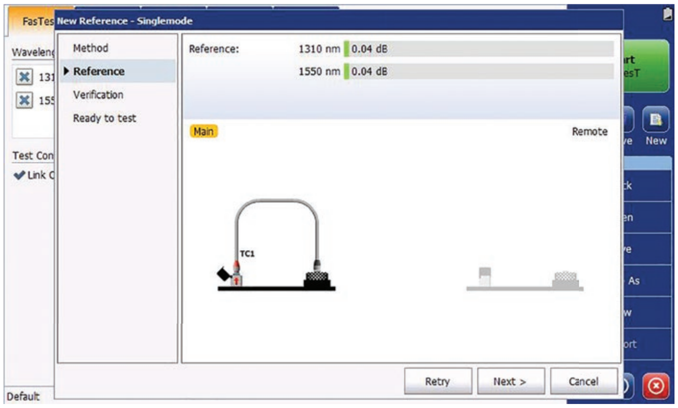


Figure 4. Good references using good connectors

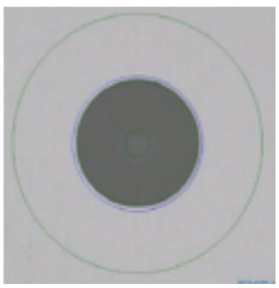


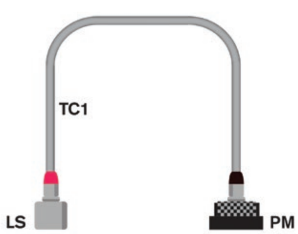
Figure 5. Good connector

REFERENCE METHODS

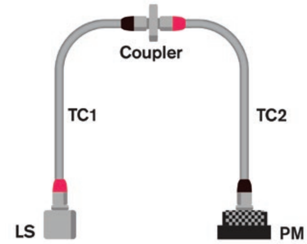
One-cord reference method

Formerly known as method B, the one-cord reference method is the most commonly used method in the industry. This is the preferred method, as it will yield the most accurate testing results; it is also the method recommended by TIA and IEC. The one-cord method allows for testing of the fiber optic link from end-to-end including losses from all connectors. Including connector losses becomes very important as the link gets shorter, since connectors are the major contributor to the overall loss, not the fiber itself.

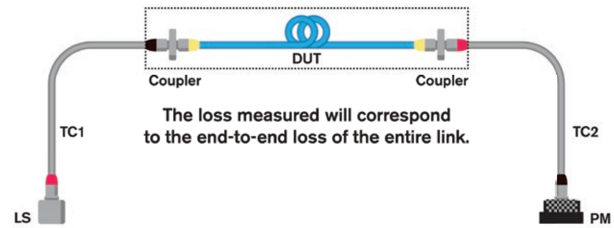
Step 1: The first step consists of connecting a test cord from the light source (LS) to the power meter (PM). After the connection has been made, set the reference at each available wavelength.



Step 2: The second step, also known as the verification step, requires measuring the loss of the connectors to be in contact with the eventual device under test (DUT). Without this step, it is hard to know if the connector is dirty or damaged since, during the reference step above, it is connected to an open beam detector. Moreover, the second test cord condition is unknown as it was not present during the reference.



When the verification and its loss value have proven to be within specifications (0.25 dB for singlemode reference grade, 0.15 dB for multimode reference grade and 0.75 dB for standard grade) the second test cord remains in place and testing can then be performed:



Open beam vs. mated connection

When referencing the test cord (step 1), the ferrule does not make contact with the detector window. Because of this, the connector will not exhibit the same loss when mated to another ferrule. Imperfections due to defects, scratches or even dust and dirt may not exhibit the same loss. When mated connectors are used to measure the link under test, it is imperative to verify the connector loss once mated to confirm that we are in fact using a connector exhibiting good performance and that is ready for testing.

Working with dirty or damaged test cord connectors may result in a series of invalid loss results. Worst case scenario: test cord connectors that are cleaned after referencing may even result in negative loss.

A full traceability of the reference and verification values is integrated into the application into EXFO's 940/945 OLTS Series. End customers require more and more of these values as proof that the job has been done properly. Skipping or neglecting verification steps may result in costly additional work, where a new series of measurements must be performed.

A step-by-step assistant with integrated animations and diagnostics helps field technicians perform the reference and verification steps as required and identifies faulty test cords before going any further.

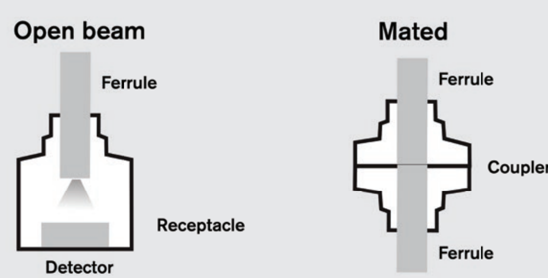


Figure 6. Open beam vs. mated connection

EXFO's one cord reference method

Introducing FasTesT™, EXFO's one-cord reference method for fully automated bidirectional loss measurement

FasTesT™ is the method which established EXFO's FOT-930 MaxTesters as the standard for optical loss tests for applications with high fiber counts, such as FTTH PON networks, structured cabling and data center installs. FasTesT™ makes it possible to cut testing time by half through the capability of running a fully automated bidirectional test without having to disconnect and switch the fibers from source to power meter ports during the process.

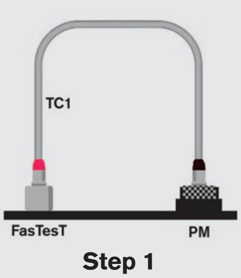
Instruments on both sides are emitting and receiving light from a unique FasTesT™ port with a mated connection. Like any other method, the test cord connected to the source needs to be present when a reference is performed. Having a source on both sides requires a reference to be set with a test cord connected to each source, leaving only the two-cord and three-cord reference method available… unless you come up with an innovative, patent-pending, reference process such as FasTesT™, EXFO's one-cord method. This innovation lets you perform measurements with less uncertainties and loss values, which include the first and last connectors.

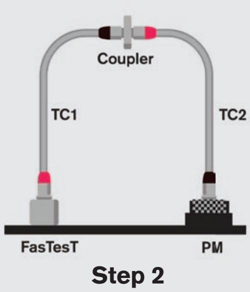
Figure 7. The dotted rectangle indicates what is included in each loss measurement

FasTesT™ requires a few steps that are well integrated into a reference assistant. This assistant includes visual animations and clear diagnostics.

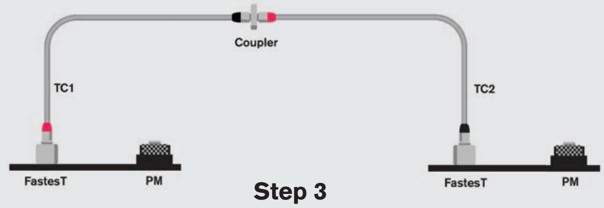
Test cord verification

The process starts with test cord verification, which is a mandatory step for this method. The assistant requires measurement of the first test cord (TC1) in loopback with the test unit's large surface detector. It then requires the addition of the second test cord (TC2) and remeasuring. At this point, the assistant has obtained a very precise measurement of the connectors, which will be in contact with the eventual DUT. If the loss values are out of an expected range, the user will be invited to inspect, clean or change the test cord(s) before going any further.

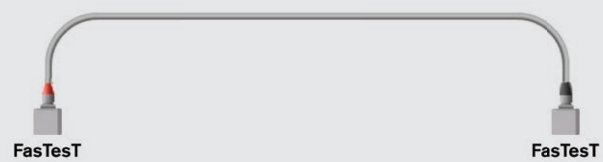




Reference

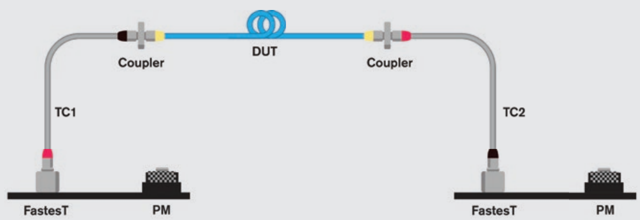


The reference is performed merely as a two-cord reference, but with this additional ingenious twist: Once the reference is known, along with the hardware that will be used for loss measurement, the assistant *subtracts* the connector loss measured during the verification step. This leaves the reference as represented below:



Ready to test

You are now ready to test. The large surface detectors on each side are not required anymore!

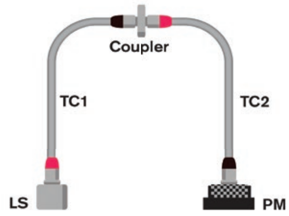


Two-cord reference method

Formerly known as method A, the two-cord reference method is used mainly when the connector on the power meter differs from the one on the fiber link to be tested. It involves using a hybrid test cord to match connector types between the link to be tested and the power meter. This method will yield less accurate test results than the recommended one-cord reference method, since it includes a connection mating in the reference. With today's interchangeable connector interfaces on testers, this method is less frequently used.

Optional step: Connect TC1 to the power meter to make a first measurement, which can serve as a verification value in a subsequent step. If it is not possible to connect TC1 due to, for example, a different connector type being used, then skip this step.

Step 1: The first step consists of connecting the two test cords together using a coupler. The user will then set a reference with TC1 and TC2 connected. The loss of both test cords and the connection are included in the reference.

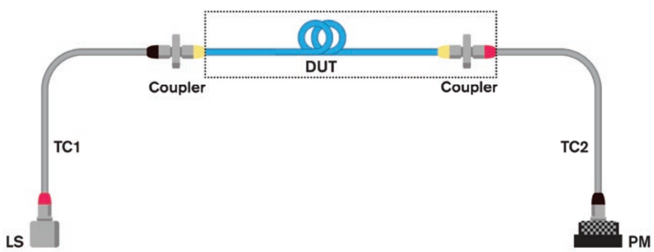


Impact of including connector mating in the reference:

1. May yield optimistic loss values if the loss exhibited by the connection is relatively high.

2. May yield negative loss readings if dirty (higher loss) when the reference is performed and cleaned afterwards during the actual measurement session.

Step 2: Disconnect test cord 1 from test cord 2. Connect the link to be tested.

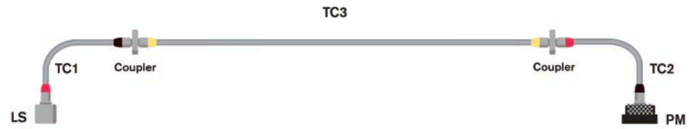


Using the two-cord method will provide optimistic results, the reason being that a connection is included in the reference and is referenced out of the loss measurement. The industry will often represent the results by excluding one connection (patch panel) from the measurement graphical representation, as shown using the dotted line above. This representation is only there to help the user understand the impact, since there is no guarantee that the connection included in the reference will exhibit a similar loss when connected to the link under test. Connectors will show variability and this is inevitable; variability will then translate into measurement uncertainty, which will be discussed later in this appliWcation note.

Three-cord reference method

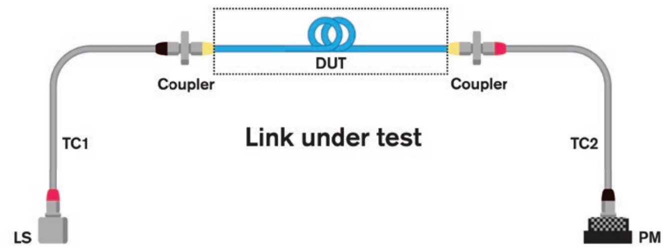
As stated earlier, it is recommended to use the one-cord reference method, which ensures the best possible accuracy when testing the fiber link from end to end. However, in some instances, it may not be possible to use the recommended method. Such cases may include situations where connectors at both ends of the DUT are from different types. These cases call for the three-cord method, formerly known as method C. Using this method, one must take extreme care of the connector state, as it may greatly impact measurements. If using bad, dirty or worn out connectors, results may become highly inaccurate and even yield negative loss readings (gain). This method includes two connections during the reference step.

Step 1: Set the reference using three test cords to match connectors on the test set as well as those on the link to be tested.



Step 2: Once the reference has been performed, the TC3 is removed and the link to be tested is connected.

Test instrument vendors will often use a dotted line excluding both end connections from the measurement to illustrate that two connections are included in the reference step. As explained earlier in this document, this representation is only there to help the user understand that there is no guarantee that the connection included in the reference will exhibit a similar loss when connected to the link under test.



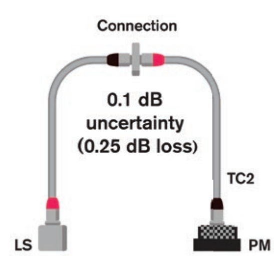
The three-cord method may also be used when testing MPO trunks. Since connectors will be unpinned most of the time, the reference procedure must include a third test cord to allow for the connection of the TC1 and TC2 pinned test cords. In this use case, fan-out must be used to convert from LC to MPO, including the appropriate gender.

Impact of connectors and reference types

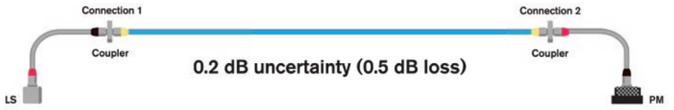
The impact of connectors and reference types becomes a greater factor as the link gets shorter. This is another reason why a one-cord reference method is preferred. To illustrate this, let's review an example using realistic values. We will consider variability (repeatability) of 0.1 dB and IL of 0.25 dB for each connection. These are hypothetic values and will of course differ from vendor to vendor.

A one-cord reference method will use 0 connections during the reference process. Remember that when the connection is made, it is only to verify the connector quality and that the connection is not referenced out.

A two-cord reference will include one connection during the reference process. This theoretically equals 0.1 dB of variability, which will add to the measurement uncertainty. We must also keep in mind that each connection will account for approximately 0.25 dB.



A three-cord reference will include two connections leading, theoretically, to 0.2 dB of variability, which will add to the measurement uncertainty. We must also subtract 0.5 dB from the overall losses.



Now, let's study the connector variability impact on the measurement uncertainty. For this example, we will test a link that exhibits a 2.5 dB loss using the one-cord method.

Using the two-cord method, the loss will become 2.5 – 0.25 = 2.25 dB. Since we have one connection using the two-cord method, our additional uncertainty will be 0.1 dB, which translates to a 4.4% additional uncertainty.

If we test the same link using the three-cord method, our loss will become 2.5 – 0.5 = 2 dB. Since we have one connection using the two-cord method, our additional uncertainty will be 0.2 dB, which translates to a 10% additional uncertainty.

As the losses decrease, the impact of connectors will become more significant in the measurement uncertainty. When testing short, singlemode fiber links comprising only two connections at both ends, the uncertainty can be equal to the link loss, leading to highly variable results and even negative loss readings if connectors on the link exhibit less IL than those using the reference cord.

CONCLUSION

Using good reference cords is serious business with significant impact on the accuracy and repeatability of the test being performed. Using good jumpers and following best practices involving thorough inspection and cleaning should be considered critical steps within the user workflow.

Whenever possible, a one-cord reference method should be used as recommended by the industry. The choice for a reference method depends on various factors, including the test instrument configuration, test cord inventory, the link configuration to be tested as well as the cabling/system vendor requirements. Reference types will play a major role in the quality of the fiber link certification and accuracy of results. Thorough care must be taken when executing all of the steps involved in the measurement, and that includes selecting the right test cord, test instruments, maintaining connector state, selecting the right reference method and executing it properly.

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