
*If installers are not yet required to be EF compliant in their optical fiber testing, it is not too soon to start preparing for the inevitable.*

# ENCIRCLED FLUX: Real or Imaginary?

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*In optical fiber testing, variability of up to 40 percent has been a common occurrence when two different testers give two different results. Encircled flux (EF) is a metric for defining launch conditions on multimode optical fiber that reduces the measurement uncertainty in link loss measurements shown by different test equipment. EF correlates test results to conservative launch-condition performances in gigabit Ethernet optical fiber transceivers, and refers to the ratio between the transmitted power at a given radius of an optical fiber core and the total injected power.*

EF was approved in October 2010 with the publication of ANSI/TIA-526-14-B Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant.

Interest in EF has increased over the past six months—a trend that will likely continue with the publication of TIA-TSB-4979, Practical Considerations for Implementation of Encircled Flux Launch Conditions in the Field, which is targeted for release in 2014.

This article describes the EF testing method and the practical considerations for implementing the method. ANSI/TIA-526-14-B assumed installers were already implementing best practices for optical fiber field testing, but as anyone in the technical support field will tell you, that assumption is often untrue. There are now four pieces to the jigsaw puzzle that make for a successful Tier 1 optical loss measurement—the light emitting diode (LED) source, the reference, reference grade connectors, and EF as the final piece. Each of these pieces must be done correctly to achieve optimum results.

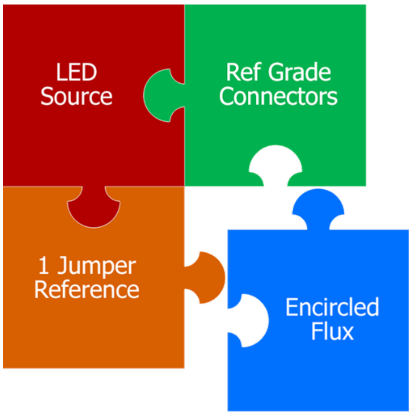


*Figure 1: Encircled flux (EF) is the final piece of the puzzle for successful Tier 1 Optical loss measurement.*

## The Source

When testing multimode optical fiber links, the user theoretically has the option of testing with either a vertical cavity surface emitting laser (VCSEL) or an LED. However, ANSI/TIA-526-14-B specifies the source must have a spectral width of between 30 nanometers (nm) and 60 nm, which is easily achieved with an LED source. A VCSEL source has a spectral within the region of just 0.65 nm, which is not even close to the required 30 nm, making its use a violation of some industry standards. Previous standards included clauses that allowed the user to use a VCSEL, but those clauses have been removed, and VCSELS are no longer allowed. The reasoning is that the VCSEL launch into the optical fiber varies substantially between different VCSEL sources, increasing measurement uncertainty to a point where it is no longer acceptable. The VCSEL launch is also under filled, resulting in an optimistic loss measurement reading.

There is a long held belief that the light source used for testing should be the same as the light source of the active equipment. This is not a bad argument if we dismiss the measurement uncertainty associated with using a VCSEL and ignore the loss values defined in IEEE 802.3 for 10GBASE-SR that are based on an LED source. More important is whether the cabling vendor will accept an application warranty if the optical fiber system is tested with a VCSEL. Most will not, due to the uncertainty of the measurement. That is why most test equipment vendors no longer offer a VCSEL option for customers. As with all cabling standards, it is the responsibly of the individual testing and warranting the system to ask what type of source is to be used when testing. If in doubt, review the test equipment vendors' data sheet and verify requirements with the vendor offering the warranty for the cabling system.

## The Reference

Setting the reference incorrectly can lead to optimistic and negative loss results. Negative results are the largest cause for failed system acceptance and denial of warranty. A negative optical loss suggests an amplification of the optical signal, which is impossible in a passive system. Sadly, many technicians still set a reference through a bulkhead adapter and then simply connect to the optical fiber under test *(see Figure 2)*.

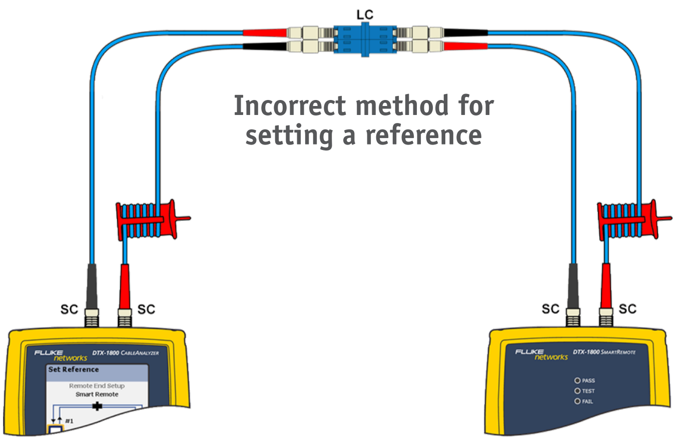


*Figure 2: Setting a reference through a bulkhead adapter is an incorrect method.*

It is essential to follow the industry standards and set a reference using a single test reference cord. Many know this as the 1 Jumper Method of Method B for multimode optical fiber and Method A.1 for singlemode optical fiber. When setting a reference using a bulkhead adapter as shown in Figure 2, measurement uncertainty starts with whatever the loss is in that bulkhead adapter. Since there is no way to know that loss, measurement uncertainty could be as high as 1.5 dB.

The loss in the bulkhead adapter is removed from the loss measurement, which is how the results indicate a negative loss. One can get around this by adding a short jumper after setting the reference, but that can add more uncertainty to the measurement.

The optical fiber in Figure 2 is coiled around a mandrel. If not using a mandrel, the results will be pessimistic by up to 0.4 dB and probably unstable depending on whether the source is over filled or under filled. Consequently, perfectly good links could be showing a false fail.

Another common problem is that many want to use bend insensitive multimode fiber (BIMMF) test reference cords. These are not suitable for use with dual wavelength testers. With BIMMF, the standard 25 millimeter (mm) mandrel will not strip out the higher order modes at 850 nm resulting in pessimistic 850 nm losses. It will perform as if there was no mandrel at all. A 4 mm mandrel could be used but then 1300 nm measurements will be incorrect.

To achieve reliable measurements, optical fiber test equipment that has interchangeable adapters on the input ports is required. This allows for setting a 1 Jumper Reference in accordance with TIA and more importantly, in accordance with the cabling vendor requirements since they issue the cabling warranty. It is also important to purchase the correct adapters and test reference cords to go with them. Too many installers have the correct optical fiber equipment but not the right adapters or hybrid test reference cords.

Working in the Technical Assistance Center, I had a call come in where the installer was denied their warranty application after submitting results that contained negative loss readings. Further investigation revealed that the installer set a reference through a bulkhead adapter against the requirements of the cabling vendor and industry standards. The installer is now looking at having to retest more than 7,000 optical fiber links. While the installer is at fault, the responsibility for training lies with all of us, including test equipment vendors. Many global seminars and webinars have been conducted over the years through organizations such as BICSI and The Fiber Optic Technology Consortium (FOTC), yet poor referencing still occurs. To address this, test equipment vendors are creating automated wizards to walk technicians through the reference procedure process with the use of animated setup screens *(see Figure 3)*. While not a substitute for hands-on training, it will hopefully help prevent the all-too-often "I did not know" or "I have always done it this way" response.

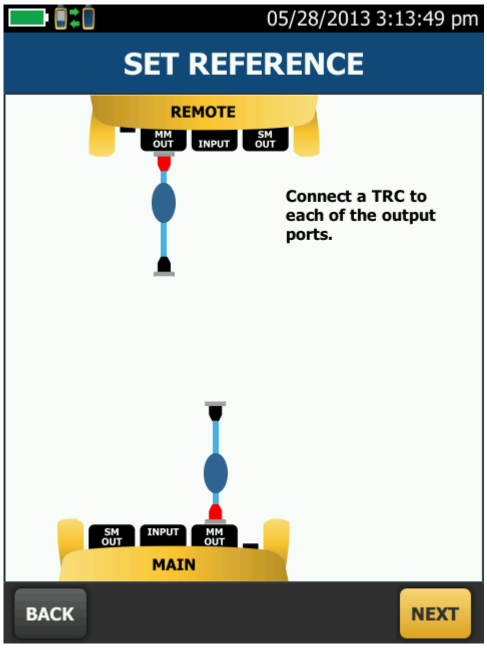


*Figure 3: To address poor referencing, test equipment vendors are creating automated wizards to walk the technician through the reference procedure process.*

## Reference Grade Connectors

Bad test cords lead to poor and inconsistent test results. ANSI/TIA-526-14-B discusses the use of reference grade connectors but does not define them. ISO/IEC 14763-3, Testing of Optical Fiber Cabling, defines a multimode optical fiber reference grade connector to have a loss of <0.10 dB. For some, that comes as a shock as traditionally anything better than <0.5 dB is considered acceptable. Why such low values? In ISO/IEC 14763-3, the first and last mated connections must have a multimode loss of <0.3 dB and a singlemode loss of <0.5 dB, which can only be achieved with reference grade connectors. But there is more to what the standards say.

With the introduction of low-loss (<0.35 dB) multifiber push-on (MPO) to LC modules, the connector at the end of the test cord needs to be better than the 0.5 dB most have become accustomed to using. The low loss of <0.35dB is achieved by having an LC connector rated at <0.15dB. Consequently, if the test cord is not <0.15 dB, chances of hitting the <0.35 dB loss for the module are slim.

If using a 1 Jumper reference, the test reference cords can be verified. Once the 1 Jumper reference has been made, the cords are removed from the input ports. A quality cord is then inserted into the input ports, the main and remote units are joined together using a singlemode-rated bulkhead adapter and the test is run. The loss result should be saved and become part of the system documentation. Anyone reviewing the test results will have increased confidence in the measurements. It will also reduce finger pointing if two tests were done on different days with different outcomes. Using a 1 Jumper reference and verifying the test reference cords dramatically improves the consistency of optical loss testing. However, there is one final element that can still result in a 40 percent uncertainty between different test equipment vendors—the launch of the optical source into the optical fiber. That is where EF comes in as the missing piece of the puzzle.

## Encircled Flux

One would think that setting a 1 Jumper reference and verifying the test reference cords at <0.1 dB would result in the same outcome even if using different vendors' equipment. Unfortunately, it does not. TIA standards have always defined the launch condition from a multimode optical source in the form of coupled power ratio (CPR) to reduce the measurement uncertainty caused by different light sources. The flaw in CPR Started to reveal itself back in 2006 with the publication of ISO/IEC 14763-3 where CPR was dropped in favor of modal power distribution (MPD) to better define the launch condition. The CPR verification was a curious process. If CPR verification was for 50/125 micron (µm) multimode optical fiber, the optical source was connected to the power meter using a 50/125 µm multimode optical fiber cord. The optical power in dBm was recorded.

Next, the cord was removed from the input port on the power meter. A 5/125 µm singlemode optical cord was connected to the input port on the power meter and the two cords were coupled usmg a bulkhead adapter. The power was then measured again and referenced against a look-up table in ANSI/TIA-526-14-A. The 5/125 µm cord the issue here. The CPR process at 850 nm only looks at the modes in the middle of the core. The modes outside of 5µm are ignored, and that is where the sometimes extreme variation between sources is observed.

To correctly specify the launch condition of a source, the entire 50 µm end face needs to be specified, not just the 5 µm in the middle. EF specifies the modal power across the entire end face of the launch with the use of template. One important point is that EF has to be met at the end of the test reference cord. Modern production techniques allow an EF compliant source without too much trouble. The challenge is that when adding the test reference cords, the EF template must be maintained to the end of the test reference cord.

TIA-TSB-4979 calls out two options for meeting EF requirements. The first is to use an external launch conditioner. This has one critical advantage in that it can turn any LED source into an EF-compliant solution, avoiding the need to buy new test equipment. However, push back is inevitable when users discover the high expense of external launch conditioners, their bulkiness and the need to replace them when the connector at the end breaks. Thankfully, many data center managers who are operating to tight optical loss budgets simply tell installers to include the cost of the launch conditioners into the bid.

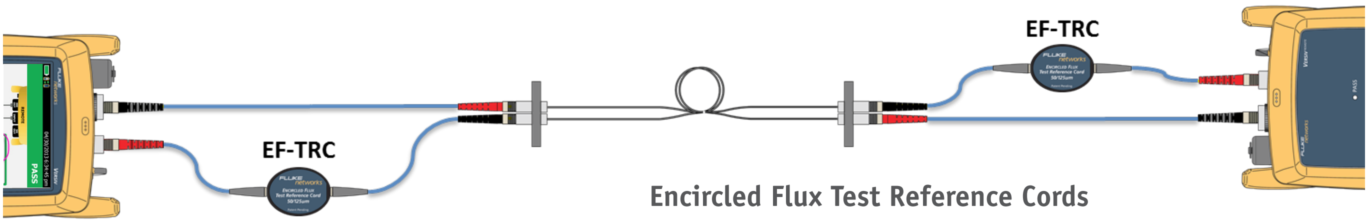


*Figure 4: To address poor referencing, test equipment vendors are creating automated wizards to walk the technician through the reference procedure process.*

The TSB gives the user a second option where the optical source is EF compliant and a tuned test reference cord is attached to the source *(shown in Figure 4)*. This is a proprietary solution, but the cords are less expensive than launch conditioners and less bulky. It does require the purchase of new test equipment. If existing test equipment has fixed input ports that do not allow a 1 Jumper LC reference, it might behoove installers to jump two generations of testers, making testing of optical fiber both EF and 1 Jumper compliant in accordance with the ANSI/TIA-526-14-B at the same time.

## Conclusion

EF has a real impact on system acceptance, especially if installing low-loss components. Operating to custom loss budgets based on the specification given by the vendor will result in ever-tightening margins. If installers are not yet required to be EF compliant in their optical fiber testing, it is not too soon to start preparing for the inevitable. Take a look at your field test procedures and ensure that your installers are following these current best practices:

- Do not set references through bulkhead adapters.
- At the very least, use mandrels to remove higher modes, but remember that mandrels are not a substitute for EF adapters.
- Use LEDs, not VCSELs, as the light source to avoid optimistic results.
- Invest in optical fiber test equipment with interchangeable adapters on the input ports.

- Verify test reference cords and do not use BIMMF as a test cord.
- Make sure to save measurements and make them part of the documentation.
- Create a strategy for EF compliance—whether using launch conditioners or selecting a proprietary solution. Keep in mind that vendors may start to insist on a 1 Jumper EF-compliant measurement before sending an engineer to troubleshoot a failing system. Installers may need to be ready and able to provide this information.

EF is real—it is not a method made up by test equipment manufacturers. I have been out in the field, seen different sources and conducted the testing. There is a difference in the launch conditions between different sources. Although there was some confusion over EF when the metric was first discussed, there is now complete agreement in the industry over the methodology and the proper test equipment. Up until the last few years, there was no need for a precise method and metric to define a predetermined launch condition from a multimode optical fiber source. But with tighter loss budgets and higher data rate systems, EF is becoming an increasingly important parameter to measure.

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