Engineering Services Department
800 17th St NW | PO Box 489
Hickory, North Carolina 28603-0489

800 743-2671
f 828 901-5533
www.corning.com/opcomm

Applications
Engineering Note

Measurement Variability during Field Insertion Loss Testing

AEN098, Revision 2

Key passive optical system components generally have corresponding optical performance specifications. Often times the associated limits are stated in relevant industry Standards and specifications, but also specified by the manufacturer and are included in a detailed customer specification. In an ideal world, these would all be the same, but many times there are differences, however slight. In any event, manufactures of passive optical products employ comprehensive quality systems to ensure that products shipped meet the relevant Standards or specifications. Once in the field these components are tested individually or as part of a system. The test results of the component product or system are then compared to specific optical performance requirements to determine their acceptability, usually by ensuring that the results show performance to be at or below the maximum specified loss value.

It is important to note that these measurement values may vary from actual reported or specified values provided by the manufacturer, and may even vary from test to test in the field for the same product or products. These differences in the measured values are the result of a number of extrinsic factors that are discussed in greater detail below. It should be emphasized that the purpose of field testing is to ensure that the performance of the installed product is acceptable within specified limits, and not meant to replicate testing conducted by the manufacturing facility.

To understand why these differences exist, it is necessary to look at the primary sources for the variation, which can broadly be split into three categories. Those are: the test equipment; the test method; and the components under test -- optical fiber, connectors, adapter sleeves, etc. Because of the number and types of sources of variability and the interactions between them, it can be very difficult to exactly replicate test measurement results provided by the manufacturer. For this reason, as well as others, industry Standards were developed to provide realistic, viable, and meaningful performance specifications that can be used by installation personnel to verify the integrity and performance of the installed components, product or system. Therefore, it is more practical to focus on meeting the specifications than to attempt to replicate particular factory test values.

Variation in the optical test equipment

Optical test equipment from reputable manufacturers is built and certified to minimum quality specifications, which is not to say that they are built the same, or that they will perform identically under similar circumstances. Although each unit may meet minimum requirements, differences in the construction of the units, the algorithms used, as well as in the component parts and subassemblies used to build the units often means that different units designed for the same purpose will indicate differences in the measured values. Two normally functioning test

Published: 01/07/2015

units of the same model type and generation, built by the same manufacturer using similar parts should be expected to perform similarly under the same conditions, but even then, some normal amount of variation should be expected, as they are not identical.

Manufacturers, such as Corning Optical Communications, most often use test equipment specially designed for use in a laboratory-type environment, in order to measure the loss of products as part of the production and quality control processes. This equipment is typically highly accurate and repeatable, very expensive, and is meant to sit on a bench top in the protected confines of a plant environment, and not be moved. Although accuracy and repeatability are important for field units as well, their size, portability, durability and cost are also equally important considerations and thus the design and construction of these units must be a good balance of all.

The following list shows some of the specifications for the hand held Corning Optical Communications OS type sources and OTS type meters that utilize 850 nm LED sources. The values for other wavelengths and/or fiber types may vary. Note that units that are out of calibration, damaged, or poorly maintained or malfunctioning (e.g., low battery or unstable power source) may experience higher levels of variation.

Optical Test Source Specifications:

Power level stability of the source:	+/- 0.1 dB at 23°C
Stability of source over temperature range	+/- 0.4 dB from –10 °C to + 50°C
Centerline wavelength of the source:	+/- 20 nm
Spectral width:	<= 50 nm
Coupled power ratio (CPR)	Between 16 – 20 dB for 50 /125 µm fiber at 850 nm for a Category 1 source

Optical Meter Specifications:

Accuracy of measurement:	+/- 0.2 dB at 23 □C
Linearity across power levels:	+/- 0.1 dB at 23 □C
Resolution:	+/- 0.01 dB

Note that these values do not account for variation resulting from other sources external to the test units, which are addressed below.

Variations in the Test Method

Differences in measurement results caused by improper or inconsistent testing practices are generally considered to be the greatest source of variation, but such variation is also the most difficult to quantify. It is imperative that all test personnel follow the Industry Standard test methods developed and maintained by the Telecommunications Industry Association. ANSI/TIA/EIA 568B.1, Commercial Building Telecommunications Standard, is one of the most widely referenced standards for the testing of structured optical fiber cabling systems. TIA 568B.1 specifically recommends using a 1-jumper reference during testing of any optical fiber system, to improve the accuracy of the test results and to reduce variability. Corning Optical Communications further recommends a 2-jumper check to ensure the integrity of the test jumper itself, which is only assumed in the TIA method.

TIA 568B.1 also specifies the use of a mandrel wrapped test jumper during the attenuation

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testing of multimode links, again to improve accuracy and reduce measurement variability. Empirical data shows that when an LED is used and mandrel wrapping is not, that insertion loss results may increase by an average of 0.2 dB for 62.5/125 µm fiber and by 0.35 dB for 50/125 µm fiber. Note that following a proper reference, the test jumper should not be removed from the source. This is in recognition, by the industry, that just the simple act of remating a connector pair inherently introduces variability into the testing. In general, utilizing any test method differing from those recommended by the TIA Standards in any way may significantly increase measurement variability and reduce accuracy.

VCSEL sources, because of the smaller spot size of the launch, do not cause the high order modes in multimode fiber that are present when an LED source is used. Therefore, a mandrel is not needed when a VCSEL is used as the test source, and loss measurements and variability between measurements should be lower with a VCSEL than when an LED is used.

The test environment can also play a significant role, and the environment should be as clean as is reasonably achievable. The more harsh and variable the environment, the more the field measurement results can be expected to vary from factory measurements, as well as from each other.

Test jumpers and adapters should be of good quality and be of an appropriate design and construction for the product, component, or system being tested. They should be clean, in good repair, and only used with products of equal design; for example, single-mode systems must only be tested with equipment, jumpers, and adapters, specifically designed for use in testing single mode systems. Proper cleaning procedures should be utilized; components cleaned frequently, and dust caps placed on all connectors and adapters that are not in use.

Variations in the optical components

Similar to the test equipment, there are detailed Standards and specifications that dictate the design, construction, and performance requirements for optical fiber, optical connectors, and connector adapters. These specifications are aimed at ensuring the performance and interoperability of these products. Since the products being tested are not identical, however, some variation in the measurement results should be expected just due to a distribution in the performance of the various products. The variations will cause differences in loss values between the mated components. One major reason why the test values measured in the factory cannot be replicated in the field is simply because the test jumpers and test adapters utilized will be different.

The following lists specification values for some typical optical components. The ranges given are for 50/125 µm Corning InfiniCor 600 fiber and Corning Optical Communications multimode SC ceramic components. Other products likely have different specifications.

Optical Fiber		*Connector Geometry*	
Core diameter	50 +/- 3.0µm	Ferrule inside diameter	127-132µm
Cladding diameter	125 +/- 2.0µm	Ferrule outside diameter	2.50mm +/- 0.01mm
Core/cladding concentricity	<= 3.0µm		
Numerical aperture	0.200 +/- .015		
Core Non-circularity	<5%		
Cladding Non-circularity	<2.0%		

There are also specifications for connector endface geometry to ensure that mated connectors perform well, but minor differences in the specific geometries of two connectors mated together can cause differences in the measurement results. Durability testing outlined in TIA/EIA 568B.3, Optical Fiber Cabling Components Standard, requires that the maximum loss is maintained over the duration of the test for the connector pair, but does not require that the same value be obtained at every mating during the test. Furthermore, adapter inserts have a specification for inside diameter and how much force is applied to the ferrules in the connector pair. Adapters can cause angular and axial offset of connector ferrules. Dimensional variation of components can cause matings to produce differing loss values.

Summary

Each set of test equipment and test jumpers will produce a result that may vary from the previous test result, and obtaining the exact same value as with a previous test is unrealistic due to the reasons discussed previously. The goal is to compare a particular test value to the specification or maximum value allowed by the relevant Industry Standard, or Industry, customer, or manufacturer's specifications. If a test is performed according to the TIA/EIA standards, and a passing measurement is obtained, then the component should be considered as acceptable.

Published: 01/07/2015