Pearson Technologies Inc.

4671 Hickory Bend Dr Acworth GA 30102 770-490-9991 www.ptnowire.com fiberguru@ptnowire.com

Interpretation of Test Results to Achieve High Reliability

Introduction

A prior article (9/25) presented the testing of fiber links required to indicate, or not, achievement of high installed reliability. This article presents recommendations on interpretation of the results from such testing. The prior article presented the tests polarity, insertion loss, OTDR, and microscopic inspection. We present the interpretation of each of these tests.

Interpretation of Polarity Testing

Polarity testing indicates correct paths between transceivers. Interpretation is simple: either the path between each transmitter and its intended receiver is correct (I,e. reliable connections) or not.

Interpretation of Insertion Loss and OTDR Testing

Insertion Loss Interpretation

Before we can present an interpretation of insertion loss test values, we must establish a strategy for calculating an 'acceptance value' (loss budget), which is the maximum insertion loss that will indicate reliable installation. To do this, we address a common misunderstanding. This misunderstanding is of how one calculates an acceptable loss value (the 'acceptance value'), which is calculated for each link in the network.

A common method is to calculate an insertion loss acceptance value by summing the maximum loss values for link components (that is, cable, connectors, and splices) *.
When we use this method, the calculation determines the maximum acceptance value if all components test at or below the maximum loss values stated by the relevant standards. **

The maximum losses stated in these standards were determined by matching maximum component loss values with both a maximum transmission distance and the maximum power loss below which the transceiver pair will function accurately. In FOA terminology, this matching is of the 'loss budget' to the 'power budget'. By definition, the power budget is a maximum value.

With this matching, the

maximum loss budget≤ power budget

Using the FOA-recommended nomenclature, the loss budget calculation is:

loss budget=

Link length)*(maximum dB/km)+number of connections)*(maximum dB/connection)
+(number of splices) *(maximum dB/splice)

where a 'connection' is a mated connector pair.

This is a commonly used method to calculate the maximum insertion loss acceptance value. But note the method by which the loss budget is determined: with maximum loss values for the link components. Do the maximum losses for each installed component represent reliable installation? This is the key question.

Reality is that all components have a typical value that is less than the maximum value. Because of this difference, it cannot be said that high installed reliability is demonstrated at installed loss values at maximum component losses. Another way to state this is that when properly and reliably installed, components will exhibit actual losses closer to the typical loss than to the maximum loss.

As use of the maximum component values might not indicate high installed reliability, one might consider calculating an acceptance value based on the typical loss for each component. It would be reasonable to expect high reliability to be indicated by an acceptance value calculated with typical component values.

With typical values, the loss budget calculation becomes

acceptance value = loss budget (typical)=
    Link length)*(typical dB/km)+number of connections)*(typical dB/connection)
    +(number of splices) *(typical loss/splice)

where a ‘connection’ is a mated connector pair.

With typical losses, the link loss would indicate reliable installation, when

Insertion loss ≤loss budget (typical)

While it seems attractive to use typical component values to calculate a maximum acceptance value, there is a risk: that of rejection of a reliably installed link with an insertion loss value slightly above the acceptance value. This is so because each component can have actual values distributed around the typical value. Some with be above; some, below. Hence, the risk.

Since maximum link loss calculations do not indicate installed reliability and typical calculations run an unacceptable risk, this author proposes a third method: calculate an acceptance value closer to the typical loss budget than the maximum loss budget. This will be called the ‘mid-point’ loss. This mid-point loss is halfway between the maximum and typical values, as presented below.

mid-point acceptance value=(loss budget+ loss budget (typical))/2

Interpretation with the Mid-Point Value

Interpretation of the mid-point value has three rules*:

Insertion loss test value≤ mid-point value, accept value
Insertion loss test value> maximum value, reject value
Mid-point value<insertion loss test value ≤ maximum value, investigate

Here are examples of mid-point acceptance values for OM3 and OS2.

Example 1: OM3, 850nm, Pigtailed Connectors

Table 1: OM3 Specifications

Specifications		Typical	Maximum
Attenuation Rate	dB/km	2.4	3.0
Connector loss	dB/pair	0.25	0.75
Splice loss	dB/splice	0.05	0.15

Table 2: OM3 Maximum Loss

	Max. dB/km		#km	=	dB
Cable Loss=	3	*	0.5	=	1.5
	Max. dB/connection		#pairs		
Connector Loss=	0.75	*	2	=	1.5
	Max. dB/splice		#splices		
Splice Loss=	0.15	*	2	=	0.3
			Max. Loss=	Total=	3.3

Table 3: OM3 Typical Loss

	Typ. dB/km		#km	=	dB
Cable Loss=	2.4	*	0.5	=	1.2
	Typ. dB/connection		#pairs		
Connector Loss=	0.25	*	2	=	0.5
	Typ. dB/splice		#splices		
Splice Loss=	0.05	*	2	=	0.1
			Typ. Loss=	Total=	1.8

Mid-Point Insertion Loss Acceptance Value= (3.3+1.2)/2=2.25 dB

Interpretation

Insertion loss test value≤ 2.25, accept value
Insertion loss test value> 3.3, reject value
2.25< Insertion loss test value ≤3.3, investigate

Example 2: OS2, 1310nm, Pigtailed Connectors

Table 4: OS2 Specifications

Specifications		Typical	Maximum
Attenuation Rate	dB/km	0.35	0.50
Connector loss	dB/conection	0.25	0.75
Splice loss	dB/splice	0.05	0.15

Table 5: OS2 Maximum Loss

	Max. dB/km		#km	=	dB
Cable Loss=	0.5	*	20	=	10.0
	Max. dB/connection		#connections		
Connector Loss=	0.75	*	2	=	1.5
	Max. dB/splice		#splices		
Splice Loss=	0.15	*	10	=	1.5
				Total=	13.0

Table 6: OS2 Typical Loss

	Typ. dB/km		#km	=	dB
Cable Loss=	0.35	*	20	=	7.0
	Typ. dB/connection		#connections		
Connector Loss=	0.25	*	2	=	0.5
	Typ. dB/splice		#splices		
Splice Loss=	0.05	*	10	=	0.5
				Total=	8.0

Insertion loss Acceptance Value= (13.0+8.0)/2=10.5 dB

Interpretation

Insertion loss test value≤ 10.5, accept value
Insertion loss test value> 13, reject value
8.0< Insertion loss test value ≤13.0, investigate

Investigation Means Four Steps

Investigation means four steps:

1. With an OTDR, measure the attenuation rate of each cable segment, the loss of each connection, and the loss of each splice.
2. Compare these measurements to OTDR acceptance values.
3. Perform microscopic inspection of each connector.
4. Perform VFL inspection of each splice and fiber within all enclosures.

In many cases, Step 2 will indicate a high loss component. If the high loss is in a cable segment, either the cable was defective or the installation was defective. This author’s experience is that defective cable is unusual and unlikely, but not impossible. Defective cable may indicate excessive attenuation rate and breaks in tight tube cables. Usually, breaks result from improper installation.

Defective installation is indicted by non-uniform attenuation rate within the segment and by breaks in tight tube cables. Non-uniformity can result from violations of bend radius, crush load rating, temperature operating range, or residual tension on the cable.

If the OTDR indicates high loss is at a connection, microscopic inspection of both connectors may indicate contamination or damage to the fiber. VFL testing can reveal bend radius violation near the connectors.

If high loss is at a splice, VFL testing can reveal either a high loss splice, a break within an enclosure, or bend radius violation near the splice.

It is possible that investigation reveals no defects, even though the insertion loss exceeds the mid-point value. In this case, one or more of the link components has loss above the typical. As no defects are found, the insertion loss value is accepted as indicating reliable installation.

OTDR Interpretation

The strategy of calculating the ‘mid-point value’ for acceptance is equally applicable to both insertion loss and OTDR loss measurements. With this strategy, OTDR acceptance values become:

> Attenuation rate acceptance value=(maximum attenuation rate+typical attenuation rate)/2
> Connector acceptance value=(maximum connection loss+ typical connection loss)/2
> Splice acceptance value=(maximum splice loss+ typical splice loss)/2

Tables x and y present mid-point OTDR acceptance values for OM3 and OS2 links.

Table 7: OM3 Mid-Point Acceptance Values

Specifications		Typical	Maximum	Mid-Point Acceptance Value
Attenuation Rate	dB/km	2.4	3.0	2.7
Connector loss	dB/conection	0.25	0.75	0.50
Splice loss	dB/splice	0.05	0.15	0.10

Table 8: OS2 Mid-Point Acceptance Values

Specifications		Typical	Maximum	Mid-Point Acceptance Value
Attenuation Rate	dB/km	0.35	0.50	0.40

Connector loss	dB/conection	0.25	0.75	0.50
Splice loss	dB/splice	0.05	0.15	0.10

Microscopic Interpretation

Microscopic inspection requires separate criteria for acceptance for each of the three regions of a connector face: core, cladding and ferrule surface.

There are four criteria for core acceptance. An acceptable core is round, clear, featureless, and flush. A round core indicates that the entire core is present. Clear indicates there is no uniform contamination of the surface, such as that from oil or grease. Featureless indicates no scratches, cracks, contamination, or other features that can block of divert light from its proper path. Without exception, contamination of the core, cladding, or ferrule surface results in rejection of a connector.

Flush indicates the end of the fiber is neither above nor below the surface of the ferrule. In the author's experience, connectors without flush cores have occurred in the past but are unlikely to occur at the time of this writing.

However, a core found unacceptable by these criteria may not exhibit excessive loss. With experience, a connector inspector learns that there are three types of cores: good, bad, and terrible. Bad cores violate the at least one of the four acceptance criteria but may not exhibit excessive loss. Small scratches in multimode cores are examples. If the inspection occurs prior to insertion loss testing, such connectors can be tagged to indicate the possibility that they may exhibit excessive loss. After OTDR testing, if the connectors (the connection) exhibits acceptable loss, the tag is removed. If the OTDR connection loss is excessive, the connectors are cleaned or replaced.

There are two criteria for cladding acceptance: clean and defect free. A clean cladding has no contamination that can increase loss by preventing full contact of fiber ends. Defect free means that the cladding is round and has no cracks or missing area. Note that defects in the cladding may not result in increased loss but indicate improper installation. Improper installation has the potential for reduced reliability.
Cladding defects may not increase loss but indicate improper installation.

There is one criterion for ferrule surface acceptance: clean. Any contamination of the ferrule surface can result in increased loss by preventing full contact of two ferrules.

There are two methods for performing connector inspection: with a handheld microscope or a video microscope. Handheld inspection has two advantages: examination of most of the end face of a connector and low cost.

A video microscope has two advantages: reduced inspection time and consistency of results. Video microscopes have reduced focus time. In addition, some incorporate software that enables automatic connector evaluation. Automatic evaluation reduces inspection time and improves consistency of results by removing variability between technicians. However, video microscopes present a reduced area for inspection, a disadvantage.

Automatic evaluation requires a specification. There is such a specification, IEC-61300-3-35-2022. However, it focuses on the center of the fiber and does not address multimode fibers or the entire ferrule area. Thus, it is possible to accept a connector with a video microscope operating with automatic evaluation and reject it with a manual microscope. This author's opinion is that its use is of limited value for field inspections.

In Closing

Interpretation of the test results indicates the level of reliability of the fiber installation.
Interpretation of polarity tests is straight forward: either the fibers are correctly connected or not.
Interpretation of microscopic inspection results is slightly more complicated, as it requires experienced inspectors. This is so, as some defects may not result in excessive loss, even though they indicate reduced reliability from improper installation.

Interpretation of the insertion loss and OTDR tests requires establishing a strategy for calculating acceptance values. The maximum values for insertion loss, attenuation rate, connector loss, and splice loss are determined by the standards. As presented, use of these values in calculation of acceptance values cannot indicate reliable installation of link components. We present an alternative, logical calculation, the mid-point acceptance value. Use of this method enables identification of conditions of reduced reliability from test values. However, although logical, there is no standard that requires use of the mid-point acceptance losses. Such use requires a decision on the part of managers of the network or the installation.

Eric R Pearson, CFOS/C/S/T/O/H/I

President

Pearson Technologies Inc.

For 45 years, Pearson Technologies Inc. has provided fiber training and consulting in North America, the Far East, and Europe. Mr. Pearson was a founding Director of the Fiber Optic Association, a Master Instructor for the FOA, and a BICSI Master Instructor.