Trends in Fiber Testing and Certification

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Bicsi

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Agenda

• Standards Update
  – Relevant standards
  – Updates

• Some Basics
  – Tests defined in standards
  – Terminology

• Testing
  – End-face Inspection/Certification
  – Tier 1
  – Tier 2
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A Brief Note on Standards

The wonderful thing about standards…

ISO 11801  TIA-526-14B  JSA/JSI
IEC  TIA-568  BICSI
CENELEC  ANSI  ISO 14763-3
IEC 61280  EIA/TIA  CSA
AS/NZS

…is there are so many to choose from!
Relevant TIA Standards

• TIA-568.3: “Optical Fiber Cabling and Components Standard”
  – Section 7: “Optical fiber transmission performance and test requirements”
  – Annex C (Informative): “Guidelines for field-testing length, loss, and polarity of optical fiber cabling”
• TIA-526-14-B: “Optical power loss measurements of installed multimode fiber cable plant”
• TIA-526-7: “Measurement of optical power loss of installed single-mode fiber cable plant”
Standards Update (TIA)

• 568.3 – Optical fiber cabling and component standard
  – Being updated to revision “D” – along with 568.0 and 568.1
    • Draft 4 open for ANSI/TIA Ballot – Expect it to be ratified at June meeting in Quebec
    – Transmission performance and test requirements will be in Clause 7
    – Annex D will provide guidelines for field testing

• ANSI/TIA-526-14-C-2015
  – Test procedures for installed multimode fiber cable plant
  – Ratified at February meeting – released in April
  – Adaptation of IEC 61280-4-1 Ed. 2.0
  – Encircled Flux for 850nm/50 micron

• ANSI/TIA-526-7
  – Test procedure for installed single mode fiber cable plant
  – Ballot open to adopt IEC 61280-4-2 Ed 2.0
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Tests Defined in the Standards

• End Face Inspection/Certification
  – Ensure pristine end-face condition PRIOR to mating

• Tier 1 Certification
  – Loss/Length/Polarity

• Tier 2 Certification
  – Optical Time Domain Reflectometer (OTDR)
Channels and Links – Applies to Fiber as Well

Connections and splices possible

Equipment Cord

Optical Patch Panel

Link

Optical Patch Panel

Equipment Cord

Equipment Cord

Equipment
**dB vs. dBm**

- **dBm** = an ABSOLUTE measurement of power
  - (1mW = 0dBm)
- **dB** = a RELATIVE measurement
- Loss is a Reference Measurement (not an Absolute Measurement)
- First step in an accurate loss measurement is performing a reference!
- Purpose of a reference is to “zero out” any test cables and connectors

![Diagram of dB vs. dBm with Tx and Rx connectors showing 2 dB, .5 dB, 5 dB, and a total loss of 7.5 dBm]
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Example: SM-UPC Standard

<table>
<thead>
<tr>
<th>ZONE NAME</th>
<th>SCRATCHES</th>
<th>DEFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. CORE (0–25μm)</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>B. CLADDING (25–120μm)</td>
<td>No limit &lt;= 3μm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None &gt; 3μm</td>
<td>No limit &lt; 2μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 from 2–5 μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>None &gt; 5μm</td>
</tr>
<tr>
<td>C. ADHESIVE (120–130μm)</td>
<td>No limit</td>
<td></td>
</tr>
<tr>
<td>D. CONTACT (130–250μm)</td>
<td>No limit</td>
<td>None =&gt; 10μm</td>
</tr>
</tbody>
</table>

Pass or Fail??

SUBJECTIVE INSPECTION

VS.

OBJECTIVE INSPECTION

FAIL

3.0μm

2.4μm

8.6μm

TIA-568, 526-7, 526-14 all require IEC 61300-3-35 be used PRIOR to mating fibers
What Makes a BAD Fiber Connection?

Today’s connector design and production techniques have eliminated most of the challenges to achieving Core Alignment and Physical Contact.

What remains challenging is maintaining a Pristine End-face. As a result, CONTAMINATION is the #1 source of troubleshooting in optical networks.

• A single particle mated into the core of a fiber can cause significant back reflection, insertion loss and even equipment damage.
Inspect Before You Connect℠

Follow this simple “INSPECT BEFORE YOU CONNECT” process to ensure fiber end faces are clean prior to mating connectors.
Inspect and Clean Both Connectors in Pairs!

Inspecting BOTH sides of the connection is the ONLY WAY to ensure that it will be free of contamination and defects.

Patch Cord (“Male”) Inspection

Bulkhead (“Female”) Inspection

Patch cords are easy to access and view compared to the fiber inside the bulkhead, which is frequently overlooked. The bulkhead side may only be half of the connection, but it is far more likely to be dirty and problematic.
Cleaning Best Practices

- Many tools exist to clean fiber
- Many companies have their own “best practices”
- Dry clean first. If that does not clean, then try wet cleaning.
- Always finish with dry cleaning!
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What is Tier 1 Fiber Certification?

• Tier 1 Fiber Certification:
  • Measure Length
  • Measure Loss
  • Check Polarity

• Ensure Loss does not exceed a “limit” (AKA loss budget)
• Document results
A Consistency Challenge

Two Technicians, Two Testers Four Loss Measurements

Tech A Tester A
Tech B Tester A
Tech A Tester B
Tech B Tester B

If different results – different best practices

How Close Will the Results Be? How Close is “Good Enough”?
A Consistency Challenge

Two Technicians, Two Testers Four Loss Measurements

How Close Will the Results Be?
How Close is “Good Enough”?

If different results – different tester specifications
Leading Causes of Inconsistent Results

1. Not following IEC 61300-3-35

2. Not using Test Reference Cords (TRCs)

3. Multimode Transmitter Launch Condition

4. Errors with Referencing
Test Reference Cords (TRCs)

- Use high performance connectors
  - Optimal optical and geometrical characteristics
    - Numerical aperture (NA)
    - Core/ferrule concentricity
- When mated with other TRCs produce near zero loss and reduces uncertainty
- Called for in various standards for loss measurements of installed fiber cabling

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Cylindrical connector style</th>
<th>Rectangular connector style</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MMF</td>
<td>SMF</td>
</tr>
<tr>
<td>Eccentricity of core centre to ferrule outer diameter</td>
<td>&lt;1 μm</td>
<td>&lt;0.3 μm</td>
</tr>
<tr>
<td>True position of the fibre core</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Exit angle</td>
<td>≤0.2°</td>
<td>≤0.2°</td>
</tr>
<tr>
<td>Accuracy of ferrule diameter</td>
<td>±0.5 μm</td>
<td>±0.5 μm</td>
</tr>
<tr>
<td>Attenuation between 2 reference connectors</td>
<td>≤0.10 dB</td>
<td>≤0.20 dB</td>
</tr>
</tbody>
</table>
Losses associated with mating of TRCs

### Table G.1 – Expected loss for examples (see NOTE 1)

<table>
<thead>
<tr>
<th>Termination 1</th>
<th>Termination 2</th>
<th>Attenuation requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM reference grade</td>
<td>SM reference grade</td>
<td>≤0.2 dB</td>
</tr>
<tr>
<td>SM reference grade</td>
<td>SM standard grade</td>
<td>≤0.5 dB</td>
</tr>
<tr>
<td>SM standard grade</td>
<td>SM standard grade</td>
<td>≤0.75 dB</td>
</tr>
</tbody>
</table>

NOTE 1 Table G.1 shows the required performance of standard and reference grade SC connectors in accordance with IEC 60874-14-2. These values are found in other, but not all, performance standards for connecting hardware.

NOTE 2 Current studies by JWG8 of IEC SC86A and SC86B on reference grade terminations may produce values for other connector styles.

### Table F.1 – Expected loss for examples (Note 1)

<table>
<thead>
<tr>
<th>Termination 1</th>
<th>Termination 2</th>
<th>Attenuation requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM Reference grade</td>
<td>MM reference grade</td>
<td>≤ 0.1 dB</td>
</tr>
<tr>
<td>MM Reference grade</td>
<td>MM standard grade</td>
<td>≤ 0.3 dB</td>
</tr>
<tr>
<td>MM standard grade</td>
<td>MM standard grade</td>
<td>≤ 0.5 dB (note 2)</td>
</tr>
</tbody>
</table>

NOTE 1 Table F.1 shows the required performance of standard and reference grade terminations in accordance with IEC 60874-19-1. These values are found in other, but not all, performance standards for connecting hardware.

NOTE 2 97% of individual connections are required meet this attenuation limit. As a minimum of two connections are present within installed cabling, a value of 0.5 dB is quoted on a statistical basis.
Multimode Launch Conditions

- Different multimode light sources = different modal power distributions (commonly referred to as launch conditions)
- Launch conditions directly impact link loss measurements accuracy
  - LED *overfills* a multimode fiber tending to overstate loss
  - Laser *underfills* a multimode fiber tending to understate loss
Encircled Flux (EF)

- Ratio between the transmitted power at a given radius of the fiber core and the total injected power.
- Defined in IEC 61280-4-1 standard to characterize the launch conditions of MMF test sources.
- Is measured at the launch cord connector – NOT at the source output.
- Replaces older “launch condition” requires such as Coupled Power Ratio (CPR).
- Can be achieved by using a universal or matched modal controller (TSB-4979).
• Universal Controller
  – For legacy sources
  – Adds a “black box” to the output of the legacy source

• Matched Controller
  – Specific source matched with specific launch cord
  – Launch cord may have additional conditioning
Correct Steps for Referencing

- Select and configure appropriate limit
- Set reference method on device
- Let sources warm up for 5 min
- Connect devices together according to reference method selected (IBYC)
- Perform reference
- Verify reference (IBYC)
- Test (IBYC)
Setting Reference – Three options:

- 1 Cord Reference
  - Connect the OLTS together w/TRC – reference power meter (set to 0dB)

- Disconnect the fiber at the power meter. Connect a TRC to the power meter. Connect to the fiber system under test

OLTS = Optical Loss Test Set. Typically has Light Source and Power Meter at both ends. Simplex shown for clarity.
Setting Reference – Three options:

- 2 Cord Reference

  Connect the OLTS together using two TRCs and an adapter – reference power meter (set to 0dB)

- Disconnect the fibers at the adapter and connect the system to be tested.
Setting Reference – Three options:

- **3 Cord Reference**
  - Connect the OLTS together with two TRCs, two adapters AND a third TRC – reference power meter (set to 0dB)

- Disconnect the fibers at the adapters, remove the third TRC and connect to the system to be tested.
• Connect test cords together and measure loss

• Ensure no “gainers”
  – Negative loss on most loss test sets

• Ensure loss does not exceed the values for TRC-TRC connections
  – Multimode $\leq 0.1$ dB
  – Single mode $\leq 0.2$ dB

• Save result for proof of good reference
Summary of Reference Methods

- Difference is the number of bulkhead (coupler) connections included in the loss measurement.
- Use the method recommended by your local standards OR by your vendor!
- For link testing, 1 cord method is universally recommended

Losses included in measurement based on reference method

Light Source → Fiber System under Test → Power Meter
Acceptable loss is based on several factors:
- Number of connections
- Number of splices
- Loss per Km (at specific wavelengths)

Maximum allowable losses (TIA)
- Loss per connection = 0.75 dB
- Loss per splice = 0.3 dB
- Loss per Km (slope)
  - 850 nm = 3.5 dB
  - 1300 nm = 1.5 dB
  - 1310 nm = 1.0 dB
  - 1550 nm = 1.0 dB

For Tier 1 Certification the user must tell the OLTS how many connections and splices are in the fiber system under test.
Tier 1 Fiber Certification Example

- One Fiber Reference
- 2 connections (default for one fiber reference)
- No splices
- 300 meters of MMF
- Loss limit at 850nm:
  - 0.75 dB per connector 1.5dB
  - 300 meters (3.5 dB per km) 1.05dB
  - Total 2.55 dB
- Loss limit at 1300nm:
  - 0.75 dB per connector 1.5dB
  - 300 meters (1.5 dB per km) 0.45dB
  - Total 1.95dB

<table>
<thead>
<tr>
<th></th>
<th>Fiber 1</th>
<th>Fiber 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss</td>
<td>0.78 dB</td>
<td>1.36 dB</td>
</tr>
<tr>
<td>Limit</td>
<td>2.55 dB</td>
<td>2.55 dB</td>
</tr>
<tr>
<td>Margin</td>
<td>1.77 dB</td>
<td>1.19 dB</td>
</tr>
</tbody>
</table>

Limit is based on settings
Loss is measured
Margin in calculated
• In this context, application is the protocol that will “ride” on the fiber.
  – Typically Ethernet or Fiber Channel
• What is the connection between the “limit” on the previous slide and what the application requires?
  – Very little…

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>1GbE</th>
<th>10GbE</th>
<th>40/100GbE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loss (dB)</td>
<td>Length (m)</td>
<td>Loss (dB)</td>
</tr>
<tr>
<td>OM3</td>
<td>4.5</td>
<td>1000</td>
<td>2.6</td>
</tr>
<tr>
<td>OM4</td>
<td>4.8</td>
<td>1100</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Loss and Length Limits at 850nm
Most Enterprise Optical Loss Test Sets will report “Compliant Networks” based on loss measurement.

Cautions! –
- Can “PASS” generic limit, but have too much loss for specific application.
- Most testing performed is on links – but applications run on channels.

If the Application to be carried on the fiber is known, use Application (Network) limit.
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Tier 2

- OTDR testing is an optional supplement to Tier 1
- Shows loss per event
- Shows reflectance per event
- Shows overall optical return loss
- Measures length
3 Things to Remember

1. Use a launch fiber
2. Don’t add a sacrificial cord to the launch fiber
3. Use a tail fiber

- Trace View

<table>
<thead>
<tr>
<th>Event</th>
<th>Distance m</th>
<th>Loss dB</th>
<th>Reflect. dB</th>
<th>T. Loss dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.88</td>
<td>0.000</td>
<td>34.64</td>
<td>0.007</td>
</tr>
<tr>
<td>2</td>
<td>23.64</td>
<td>0.156</td>
<td>-49.79</td>
<td>0.007</td>
</tr>
<tr>
<td>3</td>
<td>43.11</td>
<td>0.000</td>
<td>-48.43</td>
<td>0.169</td>
</tr>
<tr>
<td>4</td>
<td>45.39</td>
<td>0.275</td>
<td>-50.09</td>
<td>0.169</td>
</tr>
</tbody>
</table>

- Schematic View

<table>
<thead>
<tr>
<th>Link Table</th>
<th>Laser nm</th>
<th>Link Loss db</th>
<th>Link Ori dB</th>
<th>Fiber End m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1300 (3ns)</td>
<td>0.478</td>
<td>34.44</td>
<td>70.22</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alarms</th>
<th>Distance m</th>
<th>Fault Detected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20.88</td>
<td>Bad or dirty connector</td>
</tr>
</tbody>
</table>
Conclusion

Ensure Your Results Are Accurate and Consistent

1. Treat your test reference cords AND the fiber under test with respect – inspect and clean ALL fibers ALL the time
   • Inspect Before You Connect℠
   • IEC 61300-3-35 Certification

2. Understand reference methods and their impact on limit, loss, and margin
   • Reference method chosen in tester setup is correct and matches actual physical setup
   • Verify and check the reference often
   • Use test reference cords

3. Understand your multimode launch condition and have a plan to move to Encircled Flux
   • Standard modal power distribution = consistent loss results between testers

4. Complement your Tier 1 certification with Tier 2 certification
Trends in Fiber Testing and Certification

Thank-you for attending

Questions?

Ed Gastle

JDSU