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Technical Bulletin

Guidelines For Testing And Troubleshooting Fiber Optic Installations

This is intended as an overview and installation checklist for all managers, engineers and installers on the overall process of testing and troubleshooting a fiber optic communications system. This document is based on the FOA books (see references) and the FOA Online Reference Guide. You should also download a copy of the NECA/FOA 301 fiber optic installation standard as a reference.

1. Once a fiber optic cable plant, network, system or link is installed, it needs to be tested for four reasons:
   a. to insure the fiber optic cable plant was properly installed to specified industry standards.
   b. to insure the equipment intended for use on the cable plant will operate properly on the cabling
   c. to insure the communications equipment is working to specifications
   d. to document the cable plant and network for reference in case of future problems

2. Tools and Test Equipment Needed
The following tools are needed to test and troubleshoot the fiber optic cable plant, system or link properly.
   a. Optical Loss Test Set or power meter and test source with optical ratings matching the specifications of the installed system (fiber type and transmitter wavelength and type) and proper connector adapters. An OLTS that merely tests cable plant loss may not include a calibrated power meter needed for testing transmitter and receiver power, so a calibrated power meter and source are a better choice for link or system testing.
   b. Reference test cables with proper sized fiber and connectors and compatible mating adapters of known good quality. These do not generally need to be “reference quality” but only in good condition, generally defined as having connector losses of less than 0.5 dB.
   c. Visual fiber tracer and/or visual fault locator (VFL)
   d. Connector inspection microscope with magnification of 100-200X and fixturing for proper connectors. Video microscopes are recommended.
   e. Cleaning supplies intended specifically for the cleaning of fiber optic connectors.
   f. Optional: OTDR with long launch and receive cables (100 m for Multimode, 1 km or more for singlemode)

3. Testing And Troubleshooting The Installed Cable Plant

All fiber cable plants require certain basic tests to insure they were installed correctly and meet expected performance values. These are guidelines for testing and troubleshooting the cable plant itself. The most valuable data one can have for troubleshooting is the installation documentation.

Note - Cleaning: *Before any testing, connectors should be cleaned carefully to ensure that no dirt is present on the end face of the connector ferrule as this will cause high loss and reflectance. Protective caps on connectors, often called "dust caps" – some say that's because they usually contain dust – do not necessarily keep connectors clean. Use cleaning supplies intended for cleaning fiber optic connecotrs only as other materials my leave residue or cause harm to the connectors.*

3.1. What Can Go Wrong?

There are a number of possible problems with fiber optic cable installations that are caused by installation practice. These include:

a. Damage to the cable during installation caused by improper pulling techniques (such as not pulling the fiber cable by the strength member,) excess tension, tight bends under tension, kinking or even too many bends. Most of these problems will be seen on all fibers in the cable.
b. Damage to the fibers in the cable during cable preparation for splicing or termination. Fibers may be broken or cracked during cable jacket or buffer tube removal or fiber stripping. This may affect all fibers in the cable or buffer tube or just one fiber.
c. High loss splices caused by improper splicing procedures, especially poor cleaving on mechanical splices or improper programming of fusion splicers. Most fusion splicers give feedback on most problems if the operator is properly trained. Individual fibers can be damaged when being placed in splice trays or tubes of fibers damaged during placement in splice closures.
d. High loss connectors may be caused by bad processes or damage after termination. Adhesive/polish connectors may have poor end finishes or cracks in the fiber at the end of the ferrule or internally. Prepolished/splice connectors are generally high loss due to poor mechanical splicing processes during termination causing high internal loss.

3.2. Testing And Troubleshooting Steps For Installed Cable Plants

FOA Standard FOA-1: Testing Loss of Installed Fiber Optic Cable Plant, (Insertion Loss, TIA OFSTP-14, OFSTP-7, ISO/IEC 61280, ISO/IEC 14763, etc.)
FOA Standard FOA-4: OTDR Testing of Fiber Optic Cable Plant (TIA FOTP-8/59/60/61/78, ISO/IEC 14763, etc.)
FOA Standard FOA-2: Testing Loss of Fiber Optic Cables, Single Ended, (Insertion Loss, TIA FOTP-171, OFSTP-7, , ISO/IEC 14763)

3.2.1. Before installation, it is advisable to test all cable as received on the reel for continuity using a visual tracer or fault locator. Cables showing signs of damage in shipment may need OTDR testing to determine if the cable itself is damaged. Obviously, no cable showing damage should be installed.

3.2.2. Test insertion loss after installation

a. After installation, splicing (if applicable) and termination, all cables should be tested for insertion loss using a source and meter or OLTS (optical loss test set) according to standards OFSTP-14 for multimode fiber, OFSTP-7 for singlemode fiber. *See FOA Standards for simplified explanations of these standards: http://www.thefoa.org/tech/ref/1pstandards/*

b. Generally cables are tested individually (connector to connector for each terminated section of cable and then a complete concatenated cable plant is tested "end-to-end", excluding the patchcords that will be used to connect the communications equipment which are tested separately.

c. It is the concatenated cable test that is used to compare to the link power budget and communications equipment power budget to insure proper operation.

d. Insertion loss testing should be done at the wavelength of intended operation if known or at two wavelengths with appropriate sources (850/1300 nm with LEDs for multimode fiber, 1310/1550 nm with lasers for singlemode fiber, 1490 for FTTH.)

e. Unless standards call for bi-directional testing, double-ended testing with both launch and receive cables (OFSTP-7/14) is adequate.

f. Data on insertion loss of each fiber should be kept for future comparisons if problems arise or restoration becomes necessary. Recording data on a label inside the patchpanel or enclosure is common practice.

g. Long cables with splices may be tested with an OTDR to confirm splice quality and detect any problems caused during installation, but insertion loss testing with an OLTS (light source and power meter) is still required to confirm end-to-end loss. Cables with insertion loss near expected values do not also need OTDR testing. Cables tested with an OTDR should have the data kept on file for future needs in restoration.

3.2.3. Troubleshooting

a. First determine if the problem is with one or all the fibers in the cable. If all fibers are a problem, there is a likelihood of a severe cable installation problem. If all fibers are broken or have higher than expected loss, an OTDR will show the location of the problem on longer cables but premises cables may be too short and need physical inspection of the cable run. If the problem is caused by kinking or too tight a bend, the cable will have to be repaired or replaced. Generally OSP cables will be spliced as in a restoration and if the cable is a short OSP cable or a premises cable, replaced.

b. High loss fibers have several potential causes, but bad splices or terminations are the most likely cause for field terminated cables. In some cases, using improper termination practices will result in high loss for all fibers, just as in kinking or bending losses, not just one fiber.

c. Testing for high loss fibers should start with microscope inspection of terminations for proper polish, dirt, scratches or damage.

d. If dirt appears to be the problem, clean the connectors and retest.

e. If other connector damage is found on visual inspection, retermination will probably be necessary. Sometimes scratches can be polished out with diamond film by an experienced technician.

f. Prepolished splice connectors with internal splices will generally look OK when inspected with a microscope unless damaged after installation. The most likely cause of loss with these connectors is high splice loss in the internal splice. They can be tested with a visual fault locator coupled into the fiber at the far end. High light loss will be seen as an illumination of the connector ferrule. Some connectors have translucent backshells and can be tested with a VFL coupled directly into the connector.
g. If the reason for high loss is not obvious and the connectors are adhesive/polish style, the problem may be a fiber break in the back of the connector. A VFL may help in finding fiber breaks, depending on the connector style and the opacity of the cable jacket.
h. Cables with a fiber or fibers showing very high loss or no light transmission at all should be tested for obvious breaks in the pigtail fiber or cable, generally at the splice or connector, with a visual fault locator or high resolution OTDR if the cable is of sufficient length
i. Splice loss problems can be pinpointed during OTDR testing. Confirmation with a VFL should be done if the length from the end of the cable is short enough (~2-3 km) where a VFL is usable. The VFL can find high loss splices or cracks in fibers caused by handling problems in the splice tray.
j. High loss links where the excessive loss is only a few dB can be tested like a patchcord with a single-ended test with a source and power meter. When tested in this manner, a high loss connector will show high loss when connected to the launch cable connector but not when connected directly to the power meter detector which picks up all the light from the fiber.

3.2.4. Hints for troubleshooting

a. Having access to design specifications and installation documentation and specifications will greatly assist troubleshooting.
b. If possible, interview the installer to help uncover processes that may lead to issues in installation, such as pulling methods, lubrication, intermediate pulls, splicing or termination methods (like improper field termination of singlemode which can lead to high loss and reflection even when connectors look OK in a microscope.)

3.2.5. Testing And Troubleshooting Patchcords

FOA Standard FOA-2: Testing Loss of Fiber Optic Cables, Single Ended, (Insertion Loss, TIA FOTP-171, OFSTP-7, , ISO/IEC 14763)

Patchcords are short factory-terminated cables usually with standard heat-cured epoxy/polish connectors on each end. They are used to connect equipment to the cable plant and as reference cables for testing insertion loss.

3.2.5.1. Likely Problems

Most patchcord problems are connector problems, caused by damage due to handling or numerous matings when used as reference cables for testing other cables. Connectors may also be damaged by breaking fibers at the back of the connector due to excess stress during handling or by placing other equipment on top of them in enclosures or patch panels.

3.2.5.2. Testing And Troubleshooting Steps

a. All patchcords, especially those used as reference cables for insertion loss testing, should be tested for insertion loss.
b. Patchcords should be tested with an optical loss test set (optical power meter and source) using single-ended FOTP-171 methods with one reference cable used as a launch cable.
c. This will test the connector mated to the reference cable and the fiber in the patchcord, which is short enough it should have no measurable loss.
d. Since the connector connected to the power meter will not be connected to fiber but presented directly to the detector of the power meter, it effectively has no loss.
e. After testing in one direction, reverse the patchcord and test the other end.
f. In both directions, factory-made patchcords should have a loss of less than 0.5 or whatever performance the user has specified with patchcord vendors.
g. High loss connectors should be inspected with a microscope for dirt or damage.
h. If other connector damage is found on visual inspection, retermination will probably be necessary but may not be cost effective, so the patchcord should be replaced. Sometimes scratches can be polished out with diamond film by an experienced technician.
i. Some optical loss test sets include fiber interfaces on both source and meter ports, so all testing is done double-ended, even if the cable under test is directly connected to an input port. A test set such as this makes reverse testing less effective since reversing test direction may not have any significant effect. Test ports on an OLTS like this should be kept covered when not in use and cleaned periodically. Damaged fibers inside an OLTS will require factory repair.

4. Testing And Troubleshooting Communications Equipment

FOA Standard FOA-5 Fiber Optic Datalinks

FOA Standard FOA-3: Measuring Optical Power (Transmitter and Receiver Power, FOTP-95, Numerous ISO/IEC standards)

After the cable plant has been tested, the communications equipment should be properly connected using matching known-good patchcords. If the cable plant loss is within the loss budget of the equipment (including the loss of the patchcords), the communications link should work properly. If the link does not work, most likely potential problems are the following.

a. Improper connections
b. Cable plant problems
c. Malfunctions of communications equipment

4.1. Testing And Troubleshooting Steps For Communications Equipment

a. Improper connections. The system requires a transmitter be connected to a receiver, of course, so it is important to verify this connection for each link. Even if the cable plant is properly documented, fibers may have been crossed at intermediate connections, so using a visual tracer or visual fault locator will allow quick confirmation of the connection.
b. The functioning of the communications equipment:

i. If it is connected to the cable plant but not operating properly, begin by checking the power at the receiver on one end of the link.
ii. Disconnect the cable at the receiver input and measure power with an optical power meter. Make sure the equipment is trying to transmit a signal. Some equipment has a testing mode to force transmission of a test signal or the equipment may simply keep transmitting to try to complete a connection.
iii. If the receiver power is within specifications, the receiver or electronics beyond the link may be the problem. Use equipment diagnostics or consult the manufacturer for assistance.
iv. If the receiver power is too high, it may be overloading the receiver and an optical attenuator should be inserted at the receiver end to reduce the power to the proper level.
v. If the receiver power is lower than required by operating specifications, the cause is either low transmitter power or too much loss in the cable plant.
vi. To test transmitter power, disconnect the patchcord connecting the transmitter to the cable plant and measure the optical power. If the power is low, there is a problem with the transmitter or patchcord.
vii. To determine which is the problem, try testing the transmitter with a known good patchcord. If the power is then within spec, replace the bad patchcord and test the link again.
viii. If the transmitter power is low with a known good patchcord, the equipment may need maintenance (cleaning) of the output port or replacement.
ix. If the transmitter tests as good but receiver power is low, the problem is probably in the cable plant. First try to switch the communications link to spare fibers to see if that solves the problem. Next test the loss of the suspect fibers in the cable plant with an OLTS to determine if the cable plant loss is excessive.

c. Cable Plant Problems
   i. High loss in the cable plant can be caused by damage after installation and testing. Use a visual tracer or visual fault locator to confirm continuity and an OLTS to test loss. See directions above on testing the loss of the cable plant.
   ii. If the cable plant is long enough (>100m), it can be tested with an OTDR to pinpoint problems.
   iii. If the cable plant loss is not the problem, there are other possible issues related to the bandwidth of the cable plant.
   iv. Multimode cable plants operating at 1300 nm with LED sources may have bandwidth problems caused by the total dispersion due to both chromatic and modal dispersion.
   v. Multimode cable plants operating at 850 nm with VCSEL sources on non-laser-optimized fiber (usually 62.5/125 FDDI grade fiber) may suffer nonlinear modal dispersion that can produce distorted pulses that will cause data transfer problems.
   vi. Multimode cable plants operating at 1300 nm with laser sources may have an improperly installed mode-conditioning patch cord (offset-launch) or none at all.
   vii. Singlemode links may suffer from problems caused by reflections at connectors or mechanical splices.

viii. Reflections in singlemode terminations or splices near the source may cause nonlinearities in the laser transmitter which distort pulse shapes, causing high bit error rates (BER).
ix. Reflections near the receiver or at both ends can cause multiple reflections in the cable that create "optical noise" that causes BER.
x. Reflections can be tested, if the cable plant is long enough (>100m), with an OTDR to pinpoint problems.
xi. Reflections can be reduced by introducing an index-matching gel or fluid in the joint (Vaseline or mineral oil works, but is messy to clean up) to see if that solves the problem.
xii. Highly reflective connectors or splices should be replaced as soon as possible. Remember most singlemode terminations are made by fusion splicing factory-terminated pigtails onto installed cabling.

5. Update Documentation
After completing tests, troubleshooting and repairs, update documentation to reflect the necessary procedures and any changes to the network. If the fix is to switch to spare fibers and suspect fibers are not fixed, not that on documentation to prevent future problems.

References

There are other FOA Technical Bulletins that should be used as references for the design and planning of the network. These documents can be downloaded from the FOA Tech Topics website. In addition to those, we recommend:

The FOA Reference Guide to Fiber Optics

The FOA Reference Guide to Fiber Optic Testing

The FOA Reference Guide to Fiber Optic Network Design

The FOA Reference Guide to Premises Cabling

The FOA Reference Guide to Outside Plant Fiber Optics

FOA Online Reference Guide, FOA website, www.thefoa.org

NECA/FOA-301 Standard For Installing And Testing Fiber Optic Cables
(NECA/FOA-301), *Download from FOA website*

FOA Tech Bulletins (Printable Reference Documents)
Designing and manufacturing fiber optic communications products for manufacturers of products using fiber optics . (PDF, 0.2 Mb)
Choosing, installing and using fiber optic products for communications network users. (PDF, 0.1 Mb) (this document)
Designing Fiber Optic Networks - for contractors, designers, installers and users and

the reference for the FOA CFOS/D Design Certification (PDF, 1.3 MB).
Installing Fiber Optic Cable Plants. (PDF, 0.2 Mb)
Troubleshooting fiber optic cable plants and communications systems. (PDF, 0.1 Mb)
Fiber Optic Restoration - how to plan ahead and restore networks quickly. (PDF, 0.1 Mb)

Note: This information is provided by The Fiber Optic Association, Inc. as a benefit to those interested in designing, manufacturing, selling, installing or using fiber optic communications systems or networks. It is intended to be used as a overview and guideline and in no way should be considered to be complete or comprehensive. These guidelines are strictly the opinion of the FOA and the reader is expected to use them as a basis for creating their own documentation, specifications, etc. The FOA assumes no liability for their use.

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The Fiber Optic Association, the professional society of fiber optics, has available on its website, www.foa.org, guides for end users on fiber optic network design and installation. The FOA also has a website offering free online self-study programs, www.fiberu.org.

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