OPGW and ADSS Fiber-Optic Cables

Splicing, Testing, and Troubleshooting

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Topics Overview

➢ Brief history of fiber-optic communications
➢ About optical fibers
➢ Fiber-optic cables
➢ Handling, splicing, and testing fiber-optic cables
➢ Fiber-optic accessories - patch-panels, splice boxes, connectors and patch cords
➢ Fiber-optic testing – power meter, OTDR, and optical spectrum analyzer
➢ Standards, objectives, and recommendations
Brief History

➢ 1880 – Alexander Graham Bell and his photophone
➢ 1963 – Junichi Nishizawa proposed use of optical fibers for communications
➢ 1966 – Kao and Hockham published a seminal paper on fiber-optic communications and claims that the optical fiber attenuation of 20 dB/km is possible
➢ 1980s – wide adoption of optical fibers in communications
➢ 2009 – Kao receives Nobel Prize in Physics
Brief History

➢ The lasers deployed in optical communications typically operate at or around 850 nanometers (nm) (first window), 1310 nm (second window), and 1550 and 1625 nm (third and fourth window).

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength Range</th>
<th>Description</th>
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<tbody>
<tr>
<td>O band</td>
<td>1260 to 1360 nm</td>
<td>original</td>
</tr>
<tr>
<td>E band</td>
<td>1360 to 1460 nm</td>
<td>extended</td>
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<tr>
<td>S band</td>
<td>1460 to 1530 nm</td>
<td>short wavelengths</td>
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<tr>
<td>C band</td>
<td>1530 to 1565 nm</td>
<td>conventional (&quot;erbium window&quot;)</td>
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<tr>
<td>L band</td>
<td>1565 to 1625 nm</td>
<td>long wavelengths</td>
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<tr>
<td>U band</td>
<td>1625 to 1675 nm</td>
<td>ultra-long wavelengths</td>
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Optical Fibers

➢ An optical fiber is a glass or plastic fiber that carries light along its length.
➢ Optical fiber consists of a core, cladding, and a protective outer coating.
➢ Cladding is the glass material that surrounds the core of an optical fiber and its lower index of refraction (compared to that of the core) causes the transmitted light to travel down the core.
Multimode and Singlemode Optical Fibers

Fibers are frequently classified by the number of modes they transmit:

- **Multimode fiber** allows the transmission of many modes. Multimode fiber introduces multimode distortion which often limits the bandwidth and length of the link.

- A **singlemode fiber** is efficient only for a single mode of propagation and is frequently used in communications that require long distances and high data rates.
Optical Fibers

- Multimode fibers have a fiber core diameter of either 50 or 62.5 microns.
- Singlemode fibers have a fiber core diameter of 9-10 microns.
Types of Fiber-Optic Cables

➢ In most applications, optical fiber must be protected from the environment using a variety of different cabling types based on the type of environment in which the fiber will be used.

➢ Cabling provides the fiber with protection from the elements, added tensile strength for pulling, rigidity for bending, and durability.

➢ Optical cables are installed in various environments (aerial, buried, duct, tunnel, underwater, etc.) and are therefore exposed to different environmental conditions.
Types of Fiber-Optic Cables

- For the utility communication system, OPGW, OPPC, and ADSS cables are commonly installed on transmission line towers, or fiber-optic cable supported by a metallic messenger (lashed or figure 8-style cables).
- Inside of the substation fiber-optic cables are usually put in the underground duct.
- All-dielectric cables can also be buried directly into the ground (very seldom → problems with gophers and other rodents).
Types of Fiber-Optic Cables

➢ Optical Ground Wire (OPGW)
  ▪ The primary function of OPGW is to be a shield wire for a transmission line.
  ▪ The secondary function of OPGW is to house optical fiber for data and communications.
  ▪ Only singlemode fibers are used for OPGW.
Types of Fiber-Optic Cables

➢ Optical Ground Wire (OPGW)

- Splice box
- 3 to 5 km (splices)
- up to 80 km (regenerators)
- OPGW
- Conventional Ground Wire
- Fiber-Optic Distribution Panel
- Fiber-Optic Equipment
- Control Room
- Terminal box
- Non-Metallic Fiber-Optic Cable
- Fiber-Optic Regenerator (cabinet on the ground or on the tower or underground equipment enclosure)
- Splice box
- Fiber-Optic Distribution Panel
- Fiber-Optic Equipment
- Control Room
- Non-Metallic Fiber-Optic Cable
- Terminal box
Types of Fiber-Optic Cables

➢ For all types of OPGW, the three most important design parameters are:
  ▪ Fault Current Carrying Capacity
  ▪ Diameter Requirement
  ▪ Fiber Count

➢ These three factors determine the size and strength of the cable required.
Types of Fiber-Optic Cables

➢ All-Dielectric Self Supporting (ADSS)
➢ No metallic parts
➢ Typically installed below phase conductors
Fiber-Optic Cables Handling

➢ The minimum bending radius for fiber optic cable should be specified by manufacturer and followed by designers and installers.
There are two basic types of splices:
- Mechanical splices
- Fusion splices

With a mechanical splice the fibers are not permanently joined, just precisely held together so that light can pass from one to another.

Mechanical splicing is usually used only as a temporary solution.
Fusion splices are made by positioning cleaned, cleaved fiber ends between two electrodes and applying an electric arc to fuse the ends together.

Technology improvements result in very low splice losses, typically in the range of 0.05 dB or less for singlemode and multimode fibers.
Fiber-Optic Cables Testing

- All the tests can be done using power meter (assuming there is an access to both ends of the fiber) or OTDR.
- OTDR finds and characterizes reflective and non-reflective events in a strand of fiber.
- Test equipment is required only on one end of cable.
- Transmits high-power light pulses to measure any light reflected from each pulse.
- Best practice to perform measurements in both directions.
Fiber-Optic Testing
Optical Loss Test Set (OLTS)

- OLTS, also referred to as Power Meter test, measures the total amount of light loss of an optical link.
- Specific wavelength light source with a known transmit power connected to one fiber end.
- Power meter connected on other end to evaluate overall light loss measure in decibels (dB). Many units will also show lengths of the tested fiber.
Event A is a near-end reflection and dead zone. Event B is usually representing the splice loss (or possibly a bend in the fiber). Event C is a reflective event caused by mechanical splice or crack in the fiber. Event D is representing an end of the fiber. Connectors always show both reflection and loss.

Distance Noise

Slope of trace represents the fiber attenuation coefficient in dB/km

Distance
Optical Spectrum Analyzer

➢ New types of fibers and new high bit rate applications require new and more advanced testing methods.
➢ Use of optical spectrum analyzer and tests at 1625 nm wavelength are becoming more common, even in electric utility arena.
When to Test Fiber-Optic Cables?

- **Manufacturing reel testing** is performed by cable manufacture to ensure each reel meets minimum specification requirements.

- **Pre-installation testing** is performed by Installation Contractor for reel length and shipment damage verification.

- **Post-installation testing** should be performed on each segment immediately after installation prior to splicing or terminating.
Final Acceptance Testing

- End-to-End bi-directional OTDR test including splice points and connectors.
- Results compared against baselines and specifications.
- Documents original operating conditions for future testing.
- Analytical verification including:
  - Improper Splicing
  - Dirty/Damaged Connectors
  - Optical Link Budgets
Standards, Objectives, and Recommendations

➢ ANSI/EIA/TIA-455-A: Standard Test Procedures for Fiber Optic Fibers, Cables and Transducers, Sensors, Connecting and Terminating Devices, and other Fiber Optic Components

➢ ANSI/TIA/EIA-526-7-1998: Optical Power Loss Measurements of Installed Single-mode Fiber Cable

➢ ANSI/TIA/EIA-526-14-B-2000: Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant

➢ ANSI/TIA/EIA-598A: Optical Fiber Cable Color Coding

➢ IEC 60793-1-1: Fiber Measurement Methods and Test Procedures, 2017
Conclusions

➢ OTDR full trace analysis is carried out when a compliance of the installation is required to be established along with the compliance of other fiber-optic components.

➢ It is important to keep in mind that many of the fiber-optic standards and recommendations used today are very old and/or obsolete.

➢ Fiber-optic splicing and testing specification should be given to installation/testing contractors prior to testing of the OPGW, ADSS, and/or other fibers.

➢ Fiber test results need to be reviewed and verified while the contractor is still on the job.
Further Reading

- Corning, “Application Note AN103, Single Fiber Fusion Splicing,” June 2009
- Anritsu Corporation, “Understanding OTDRs,” Issue 1, 2011
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