Fiber-to-the-Antenna Installation Best Practices for the Tower Hand

Business White Paper

The Network of Networks

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Consumer appetite for high-speed mobile devices and services shows no sign of slowing. Smart phones and tablet computers are flying off retail shelves around the world, promising consumers high-speed data services. The International Telecommunications Union reports that mobile broadband subscriptions reached 1.2 billion in 2011*, and millions of new customers sign up each week. Meanwhile, device manufacturers and wireless service providers have begun introducing LTE/4G-capable products.

As a result, network capacity is increasingly strained, and mobile operators are working hard to upgrade their infrastructure and provide the bandwidth their customers demand. In an effort to meet current and future demand for LTE/4G services, providers are taking fiber optic technology to the top of the cell tower. Replacing traditional coaxial-based systems with fiber networks can help providers squeeze more capacity out of their towers. That’s why next-generation, fiber-to-the-antenna (FTTA) architectures are now the primary focus of global OEMs.

What does this change mean for the tower hand? Increasingly, mobile service providers need technicians who are knowledgeable and skilled in fiber cable installation, testing and repair. Proper fiber handling techniques must be followed to ensure reliable FTTA installation and performance. And advanced knowledge of fiber optic test equipment and troubleshooting will become more valuable as existing cell towers are retrofitted with second- and third-generation FTTA systems.

Standardized guidelines for handling fiber on the cell tower do not currently exist, although some are expected soon. The International Wireless Industry Consortium has tasked its Installation Best Practices Committee (chaired by the author of this paper) to develop fiber installation guidelines for the industry. Finalized guidelines are expected in the fourth quarter of 2012. In the interim, this paper provides a primer for the tower hand seeking more knowledge about fiber optic communications on the cell tower.

Cabling Architectures

While a number of different system designs have been deployed, FTTA cabling architectures generally consist of a smaller base band unit (BBU) at the bottom of the tower and multiple fiber-fed remote radio units (RRUs) at the top of the tower. Fiber cables replace coaxial feeders running up the tower in order to support advanced technologies such as LTE/4G, which often call for antennas to be multiple in multiple out (MIMO), requiring two or more feeds per antenna to operate.

FTTA design continues to evolve. For example, point-to-point cabling was the early standard for fiber-fed architectures. However, new forward-looking designs incorporate multi-fiber cables for future capability. Hybrid fiber/power cables are gaining traction with some carriers due to the decreased number of tower attachment points. Pre-terminated fiber assemblies have been the norm, but OEMs and mobile operators are exploring more flexible cut-to-fit solutions for the future. Field-mounted fiber optic connectors, for example, allow fiber cables to be cut to length and terminated onsite, eliminating the need to stock varying cable lengths and devise slack storage methods on the tower. Field-mount connectors also reduce installation delays caused by not having the proper fiber cable length on hand at the site.
Types of Fiber

An optical fiber transmits light through a flexible, transparent strand of pure glass not much wider than a human hair. It functions as a waveguide, or “light pipe,” to direct the light. On a cell tower, an optical transceiver module inside the tower-mounted radio converts the optical signal into electrical signals for modulation by the radio.

While many different types of fiber optic cable exist, singlemode fiber (SMF) and multimode fiber (MMF) appear most often in tower installations. In general, SMF can operate at a higher bandwidth than MMF. Both types of fiber meet or exceed the current requirements of both the Common Public Radio Interface (CPRI) and Open Base Station Architecture Initiative (OBSAI) specifications for RRU communications.

SMF and MMF currently cost about the same. However, the cost of the associated optical transceiver module differs greatly. MMF can be used with a low-cost transceiver, while SMF requires a higher precision laser transceiver. While MMF may offer a lower initial cost at installation, the higher data rates, bandwidth and extended distance capacities supported by SMF ensure a more future-safe system.

Fiber Optic Cable Construction

A fiber optic strand consists of a core and a cladding. The core is made of an ultra-pure glass that provides an optical path for the light. The cladding is also made of glass, but it has been intentionally polluted to have a different refractive index to prevent light from escaping the core. The cladding essentially acts as the guardrail for the light, continually reflecting it back into the core. The core and cladding are surrounded by a protective plastic coating, which is stripped away prior to splicing or terminating connectors.

Coated fibers may be individually jacketed with a polymer coating, such as PVC. This construction usually incorporates a strength element, such as stranded aramid polymer yarn. Two such jacketed fibers may then be bundled together in a five- to seven-millimeter construction to form a jumper cable. Alternatively, multiple coated fibers can be grouped together in buffer tubes and arranged with a fiberglass central strength member (CSM) to form a multi-fiber feeder cable. In a multi-fiber feeder cable, the coated 900-micron fibers are color coded for easy identification. This color coding follows a standard pattern per the U.S. Energy Information Administration (EIA) specifications.
Fiber Optic Connectors

Fiber optic cables are terminated with fiber optic connectors. The construction of the connector involves precise alignment of the end of the fiber with the end of the connector’s ceramic ferrule, which mates with the fiber receptacle. Fiber connectors can be UPC (ultra-physical contact) or APC (angle-physical contact). Generally, UPC is used for purely digital communication applications, such as the CPRI protocol commonly used in FTTA. In situations where analog signals will be transmitted, APC-type connectors are recommended.

The most common type of fiber connector in FTTA installations is the LC connector, which is characterized by its small size and positive latching feature. It commonly appears in a dual configuration with two connectors mated or snapped together, which is called a duplex configuration. This configuration typically provides one connector for signal transmission and the other for signal reception. Most RRU manufacturers use a duplex LC connector, which resides in either a bulkhead port or a maintenance hatch in the body of the radio unit.

Fiber optic connectors can be pre-terminated in the factory or field terminated by the tower hand during installation. In early FTTA deployments, pre-terminated cable assemblies, which come in pre-determined lengths, emerged as the standard solution. However, using pre-terminated cable has led to potentially costly challenges, including:

- Delayed installation if the available cable proved too short.
- The need to provide slack storage if the cable was too long.
- Discarded cable in the event of connector damage.
- Inventory issues where mobile operators or their distributors had to stock multiple lengths of cable in order to ensure that the right cable is always available in the field.

Pre-terminated cable remains the standard. However, OEMs and installers are beginning to consider field-mount fiber connectors for FTTA construction. The installation of fiber connectors at the site mimics the hard-line coaxial installation process of the past, where tower hands terminated coaxial cables in the field. Field termination eliminates the problems associated with pre-determined cable lengths.

Modern field-mount fiber connectors are quick and easy to install with minimal tools and training, and their operational life and performance closely matches that of factory-terminated connectors. Due to these benefits, the wireless industry may adopt field-mount connectivity in the future.
Fiber Handling Recommendations

Bend Radius

When installing fiber cables, tower hands should pay attention to the minimum bend radius of the fiber. Standard fiber (complies with ITU-T recommendation G.652D) can maintain a minimum bend radius of five to 15 times the fiber cable diameter. Functionally, this corresponds to about three centimeters, or about one inch. Failure to observe the recommended bend radius can result in stress to the fiber optic core and signal loss due to light being lost into the cladding from macrobending.

Bend-insensitive fiber (G.657A/B) is often selected for RRU jumpers because it is more flexible and has a much tighter minimum bend radius than standard fiber.

Tensile Strength and Support

Fiber optic cable has a tensile load rating that defines the maximum vertical rise that the cable can withstand without additional support. Cable weight is also a factor. The maximum vertical rise can be calculated using the formula:

Maximum vertical rise = (1/2 x maximum long-term tensile load)/cable weight

Using this formula, a typical jacketed 24-fiber cable can be suspended approximately 1,700 feet using a Kellems grip. However, the cable must also be secured to the tower periodically (every three to five feet) to avoid stress from the external environment (unless secured inside a monopole).

Hoisting

If a fiber cable is pre-terminated with connectors prior to hoisting, a pulling sock is used to provide the hoisting grip, transmit the tensile force to the cable, and protect the fiber connectors during transit up the tower.

Multi-fiber connectors, such as the MPO (multi-fiber push on) connector, are beginning to appear in FTTA applications incorporating tower-mounted terminals. Using these connectors simplifies both the connection process and the pulling sock arrangement because only a single connector needs to be installed and protected.
Tower Clamps

Fiber optic cable manufacturers recommend clamping the fiber optic cable every three to five feet on monopole exterior, self-support and guyed towers to ensure that the cable does not move about in the wind. Stainless steel cable ties are not recommended. Rigidly anchoring the fiber optic cable to the tower subjects the cable to shear stresses both from the compression of the cable tie and the vibration of the tower structure. Instead, fiber cable hangers that isolate the fiber cable from the vibration of the tower and permit some vertical motion with temperature change are recommended.

Connector Cleaning

Fiber connectors are equipped with protective dust caps. Always leave the dust cap in place until the fiber connector is to be mated to the fiber optic transceiver in the RRU.

It is good practice to always clean the ferrule of the fiber optic connector before inserting it into the RRU. Cleaning can be accomplished using several different methods, including using pre-moistened wipes. However, a self-contained ferrule cleaning device, such as the CLETOP-S from NTT, makes cleaning on the tower top quick and easy, a benefit much appreciated by tower hands when they are suspended high in the air. The device allows the tower hand to simply plunge the ferrule into the cleaner aperture, where a controlled wiping action completes the cleaning.
Hybrid Cable

Hybrid, or composite, cable is being used more and more on towers. Hybrid cable contains both fiber and power conductors, usually enshrouded in a corrugated sleeve and a polymer jacketing material. This permits hybrid cable to be mounted with standard hard line coaxial cable hangers (assuming that the hybrid cable follows the standard 7/8-inch to 1-5/8-inch coaxial feeder outer dimensions).

Hybrid cables can be arranged for single, triple or six-RRU feeds. Generally, the elements inside the hybrid construction are individually jacketed. The jacketed cables are covered by a protective corrugation, which is overlaid with a final polymer jacketing material. The over-jacket and corrugation must be removed using the incorporated ripcords prior to installation at the RRU to permit access to the interior elements.

Aside from using great care in the armor removal process, tower hands should avoid allowing the fibers to drape over the exposed edge of the cut corrugation. Over time, this can lead to fatigue and failure of the fiber optic cable elements.

Slack Storage

Any excess fiber must be stored in a fashion that respects the minimum bend radius of the fiber cable and provides sufficient support to stabilize motion due to wind. Use of cable ties to secure fiber slack in loose loops is not recommended. Instead, a slack storage bracket or enclosure can be used to secure the cable slack safely for future use.
Fusion vs. Mechanical Splicing

Unfortunately, damage to fiber optic connectors is common in FTTA installations. If a fiber connector is damaged, either a whole new cable can be pulled or the damaged connector can be replaced.

Fusion splicing is one method for attaching a pre-terminated fiber connector with a fiber stub (called a pigtail) to the broken fiber cable. The fusion process involves melting the glass at the fusion point so that a seamless joint is created. This joint is structurally weak and must be reinforced with a splice sleeve.

Fusion splicing is not recommended for tower repairs because the required equipment is expensive and requires a power source, making tower-top repairs difficult. Moreover, the tower hand must be trained in fusion splicing techniques.

A field-mount solution with an internal mechanical splice offers an alternative method for repairing a broken fiber connector. Field-mount connectors with a mechanical (as opposed to a fuse-on) splice are well-suited for FTTA repairs. They can be installed quickly and easily using an inexpensive hand tool, and tower hands can learn to use them with minimal training. Field-mount connectors carry a proven track record of success. More than 10 million of them are installed today in harsh and demanding applications around the world.

Testing

Some installation companies include fiber testing as part of the site build documentation. A general knowledge of the types of measurements and the test instruments used is also helpful for verifying a successful field termination for repair.

Two important fiber measurements are insertion loss and return loss. Both are measured in decibels (dB). Insertion loss measures how much light signal is lost as it travels through the fiber optic cable from end to end. Return loss measures how much light is reflected due to impairments (microbends, macrobends, damaged or improperly installed connectors, etc.) in the fiber.

An optical source and power meter measures insertion loss, and an optical time domain reflectometer (OTDR) locates sources of return loss. These instruments are available from EXFO and other test equipment suppliers.
Summary

Fiber handling skills will be increasingly in demand as mobile service providers retrofit existing cell towers and build new ones with fiber-based FTTA systems. Tower hands who are knowledgeable and skilled in fiber installation, testing and repair will be essential for the construction and maintenance of FTTA architectures. The installation of fiber isn't that much different than hard-line coaxial cable installation. Using field-mount fiber connectors, the tower hand can draw on his existing knowledge to install fiber without the drawbacks and expense associated with factory-terminated cable. To learn more visit 3M.com/Wireless.

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