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Why More RF Engineers Are Choosing Fiber Connectors

Many applications, including indoor distributed-antenna and satcom systems, are adopting RF-over-Fiber technology, making it a useful technology for an RF engineer's toolbox. Here's why.

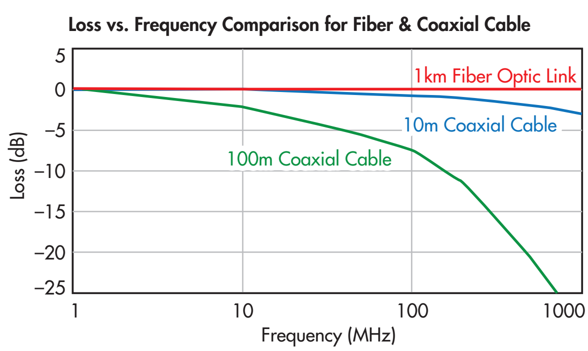
RF-OVER-FIBER TECHNOLOGY HAS been increasing in capability and dropping in cost over the past decade. Coupling these factors with the rising cost of coaxial-cable material has prompted many designers to choose RF-over-Fiber optic systems for distributed-antenna systems (DASs) and small-cell applications. Compared to traditional RF-transmission-line technologies, fiber optics offer additional benefits such as low loss, interference immunity, high reliability, and security.

RF-over-Fiber refers to the use of fiber-optic transmission cabling and RF-to-optical signal-conversion equipment that is used to transmit RF signals—generally over long distances. With many of the latest converters, the RF signal is sent directly to the electronics that power a laser diode. That diode is then used to transmit the optical signal along a single-mode fiber cable. The optical signal can be intensity-modulated. High-dynamic-range and low-noise applications typically employ a distributed-feedback (DFB) semiconductor laser. However, for lower-performance requirements, a Fabry-Perot (FP) laser is often implemented.

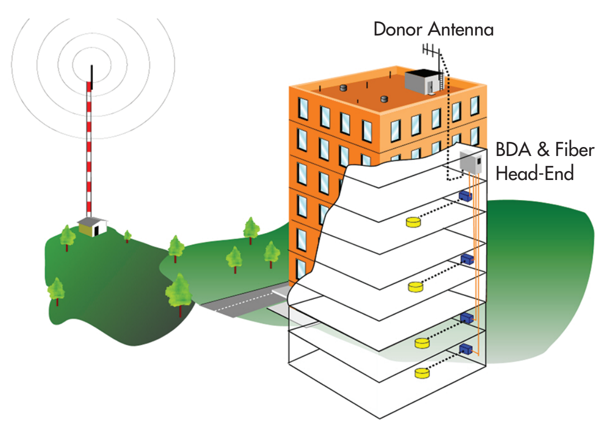
The optical fibers are made using a time-intensive and somewhat expensive process involving high-quality, specialized glass. This glass is formed into fibers with emphasis on an extremely consistent outer diameter and special jacketing. Specialized connectors and fiber-processing tools are needed to connect two fiber-optic lines together and reduce reflective losses. The single-mode fiber that serves RF applications will use an angle-physical-contact (FC/APC) connection.

For the optical-to-RF (O/RF) conversion, a high-speed PIN diode typically converts signals at a rate of 0.9 amperes per watt. Fortunately, the PIN diode has a relatively linear response curve, which limits the nonlinearities and distortion introduced into the signal chain by the conversion. Once it is converted into RF energy and amplified, the RF signal can be transmitted over short runs with traditional RF transmission lines to remote radio heads (RRUs) and then distributed antennas.

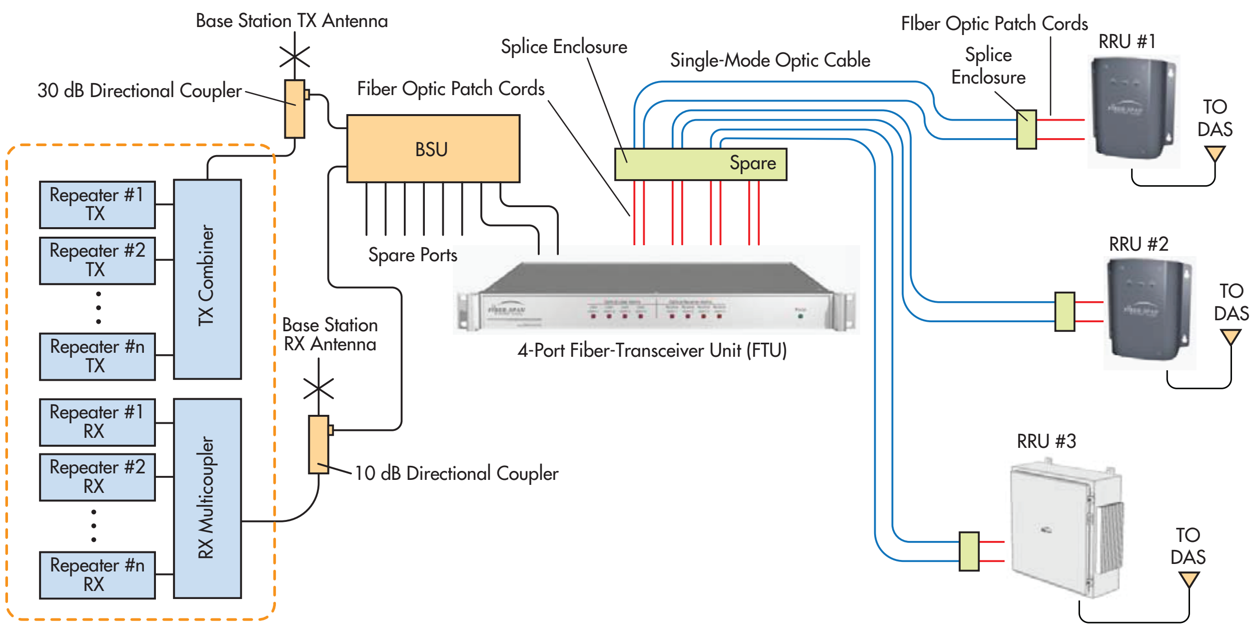
The key benefit of using fiber-optic cables for long-distance RF signal transmission is that fiber-optic transmission exhibits less than 0.5 dB of signal loss per kilometer of transmission. Coaxial cables tend to suffer loss ranging from tens to hundreds



1. The transmission loss suffered by fiber-optic links is substantially less over distance when compared to a coaxial or waveguide transmission line. *(Courtesy of ViaLite)*



2. Using an RF-to-Fiber conversion can translate into much lower interference in the transmission line, as optical fibers are not conductive and not susceptible to RF interference. *(Courtesy of The Jack Daniel Company)*



3. An RF-over-Fiber system requires an RF-to-optical and optical-to-RF conversion for transmission and reception from remote radio units. *(Courtesy of Fiber-Span)*

of times worse than fiber optics. This loss depends on the frequency of the RF signals *(Fig. 1)*.

Although fiber-optic and RF cables have similar bending radius limits, fiber optics suffer additional loss from bends. Thus, they usually operate better under direct-run installations. Such straighter runs do not always pose a major challenge, as fiber-optic cabling is non-metallic and can be located near high-voltage and electrical cabling more safely.

The non-metallic and optical conversion in the RF-over-Fiber system also eliminates electromagnetic interference (EMI) and RF interference (RFI) from the transmission line *(Fig. 2)*. Resistive elements also produce noise naturally. As a result, fiber-optic systems tend to introduce less noise into the signal chain than coaxial cabling. Nevertheless, any interference encountered by the RF-to-optical or optical-to-RF conversion electronics will translate to noise and interference in the converted signal.

SAY GOODBYE TO MAINTENANCE WOES

While coaxial cables usually suffer from corrosion, moisture ingress, connector loosening, sparking from overvoltage, and dielectric breakdown, such factors are generally not concerns for fiber-optic lines. Particulates could build up within a fiber-optic connector, which would increase losses at the connector. Additionally, fiber-optic cables can be resilient in high-heat scenarios.

A distinct difference between fiber-optic and coaxial cables is that the conversion electronics "compress" the power envelope of the RF transmission *(Fig. 3)*. As a result, any electrical surges or noise outside of the transmission band of the RF-to-optical transmitter will not be carried through the optical conversion. Yet this bandpass-like function also reduces the maximum frequency of transmission through an optical line. Commonly available equipment ranges to 4 GHz.

As is the case with an RF system, there is a maximum power of transmission that an optical transmitter, the optical fiber, and the optical receiver can sustain and operate with linearity. The total power is a composite of all signal power across the whole bandwidth of the conversion operation. Often, bandpass filters are employed to enable passing of the bands of interest while limiting power in non-useful frequencies. This approach increases the channel-power headroom. The optical transmission system also is similar to an RF system in that it can induce interference if the same frequency of light is present on the fiber. To enable duplex operation, multiple fibers can be used for multiple uplink and downlink lanes.

Under conditions where limited fibers are available, duplexing can be done on a single fiber using different frequencies of transmission. This approach is called wavelength-division multiplexing (WDM). An optical fiber has a minimum and maximum frequency of operation, much as the different frequencies within a waveguide propagate with different transmission coefficients. Unlike an RF system, however, optical fiber lines are unidirectional and can have multiple frequencies transmitting in the same or different directions along the fiber.

Fiber optics have traditionally been cost-prohibitive in certain applications. But as the demand increases for multiple services and extremely wide-bandwidth operation, the return-on-investment considerations for RF-over-Fiber could certainly exceed those of coaxial cable. mw