OPTICAL FIBER COMMUNICATION

Fiber-optic communication is a method of transmitting information from one place to another by sending light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. First developed in the 1970s, fiber-optic communication systems have revolutionized the telecommunications industry and played a major role in the advent of the Information Age. Because of its advantages over electrical transmission, the use of optical fiber has largely replaced copper wire communications in core networks in the developed world.

The process of communicating using fiber-optics involves the following basic steps: Creating the optical signal using a transmitter, relaying the signal along the fiber, ensuring that the signal does not become too distorted or weak, and receiving the optical signal and converting it into an electrical signal.

The need for reliable long-distance communication systems has existed since antiquity. Over time, the sophistication of these systems has gradually improved, from smoke signals to telegraphs and finally to the first coaxial cable, put into service in 1940. As these communication systems improved, certain fundamental limitations presented themselves. Electrical systems were limited by their small repeater spacing (the distance a signal can propagate before attenuation requires the signal to be amplified), and the bit rate of microwave systems was limited by their carrier frequency. In the second half of the twentieth century, it was realized that an optical carrier of information would have a significant advantage over the existing electrical and microwave carrier signals.

Technology

Modern fiber-optic communication systems generally include an optical transmitter to convert an electrical signal into an optical signal to send into the optical fiber, a cable containing bundles of multiple optical fibers that is routed through underground conduits and buildings, multiple kinds of amplifiers, and an optical receiver to recover the signal as an electrical signal. The information transmitted is typically digital information generated by computers, telephone systems, and cable television companies.

Transmitters: The most commonly-used optical transmitters are semiconductor devices such as light-emitting diodes (LEDs) and laser diodes. The difference between LEDs and laser diodes is that LEDs produce incoherent light, while laser diodes produce coherent light. For use in optical communications, semiconductor optical transmitters must be designed to be compact, efficient, and reliable, while operating in an optimal wavelength range, and directly modulated at high frequencies.

Fiber: Optical fiber consists of a core, cladding, and a protective outer coating, which guides light along the core by total internal reflection. The core, and the lower-refractive-index cladding, are typically made of high-quality silica glass, though they can both be made of plastic as well. An optical fiber can break if bent too sharply. Due to the microscopic precision required to align the fiber cores, connecting two optical fibers, whether done by fusion splicing or mechanical splicing, requires special skills and interconnection technology.

Amplifiers: The transmission distance of a fiber-optic communication system has traditionally been limited primarily by fiber attenuation and second by fiber distortion. The solution to this has been to use opto-electronic repeaters. These repeaters first convert the signal to an electrical signal then use a transmitter to send the signal again at a higher intensity. Because of their high complexity, especially with modern wavelength-division multiplexed signals, and the fact that they had to be installed about once every 20 km, the cost for these repeaters was very high.

Receivers: The main component of an optical receiver is a photodetector that converts light into electricity through the photoelectric effect. The photodetector is typically a semiconductor-based photodiode, such as a p-n photodiode, a p-i-n photodiode, or an avalanche photodiode. Metal-semiconductor-metal (MSM) photodetectors are also used due to their suitability for circuit integration in regenerators and wavelength-division multiplexers. The optical-electrical converters is typically coupled with a transimpedance amplifier and limiting amplifier to produce a digital signal in the electrical domain from the incoming optical signal, which may be attenuated and distorted by passing through the channel. Further signal processing such as clock recovery from data (CDR) by a phase-locked loop may also be applied before the data is passed on.

Wavelength-division multiplexing: Wavelength-division multiplexing (WDM) is the practice of dividing the wavelength capacity of an optical fiber into multiple channels in order to send more than one signal over the same fiber. This requires a wavelength division multiplexer in the transmitting equipment and a wavelength division demultiplexer (essentially a spectrometer) in the receiving equipment. Arrayed waveguide gratings are commonly used for multiplexing and demultiplexing in WDM. Using WDM technology now commercially available, the bandwidth of a fiber can be divided into as many as 80 channels to support a combined bit rate into the range of terabits per second.

Comparison with electrical transmission

The choice between optical fiber and electrical (or copper) transmission for a particular system is made based on a number of trade-offs. Optical fiber is generally chosen for systems requiring higher bandwidth or spanning longer distances than electrical cabling can accommodate. The main benefits of fiber are its exceptionally low loss, allowing long distances between amplifiers or repeaters; and its inherently high data-carrying capacity, such that thousands of electrical links would be required to replace a single high bandwidth fiber. Another benefit of fiber is that even when run alongside each other for long distances, fiber cables experience effectively no crosstalk, in contrast to some types of electrical transmission lines.

In short distance and relatively low bandwidth applications, electrical transmission is often preferred because of its

- Lower material cost, where large quantities are not required.
- Lower cost of transmitters and receivers.
- Ease of splicing.
- Capability to carry electrical power as well as signals.
- Ease of operating transducers in linear mode.

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