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Fiber Optic Installer's Field Manual

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Bob Chomycz

FIBER OPTIC INSTALLER'S FIELD MANUAL

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PREFACE

I am very pleased to offer to you *Fiber Optic Installer's Field Manual*. The primary objective of this book is to introduce the reader to fiber optic communications, fiber components, and installation techniques. My emphasis is on practical installation techniques using industry standards.

The approach I have chosen for this book is not highly theoretical, nor do I attempt to cover the physics of lightwave communications. There are already many good books available that discuss the theoretical aspects of fiber optics, but only a few that deal with the practical aspects of fiber optics in the real world. Because of the unique nature of this medium, many conventional electrical wire implementation techniques are not applicable. Employees working with fiber optics need to understand not only the basic theory but also the practical methods used to implement this technology. This book attempts to accomplish that task.

Fiber Optic Installer's Field Manual will be of primary interest to the following professions: technicians, electricians, cable installers, testers, telecommunications personnel, data communications personnel, engineers, technologists, tradespeople, students, and any others with an interest in the field, regardless of their level of knowledge.

Bob Chomycz

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CHAPTER 1
INTRODUCTION

1.1 THE FIBER OPTIC REVOLUTION

Over the last 20 years, a quiet revolution has been changing the world of communications. Indirectly, it will affect all our lives by enhancing our ability to communicate large amounts of information over vast distances with extreme clarity and reliability. This revolution centers on the replacement of existing copper wire communication cables with thin strands of glass fibers that carry light pulses.

Since the earliest recorded history, light has been used to communicate over distances, although the techniques employed have often been slow and cumbersome. Communication has been limited by atmospheric conditions—usually an impossibility in fog or heavy rain, for example—and restricted to line-of-site operation. As early as the ancient Greeks and Phoenicians, sunlight was reflected off mirrors for signaling between towers, and this technique continued into the modern era with several variations. Eventually, sunlight was replaced by artificial light, and the on/off signaling became more structured until it resembled a Morse code. The military, for example, still uses a version of this technique for low-speed communication between ships.

In the late nineteenth century, Alexander Graham Bell worked on a design for a "Photophone," for sending voice over a light beam. Sunlight was reflected off a mirror that vibrated to voice sound waves. The receiver was a photocell connected to an electric current that passed to a speaker. The idea was good, but the technology was not yet in place to use it practically.

After the laser was invented in 1958, further studies were performed with light communication in air. Lasers provided a narrow band of light radiation that could be bent with mirrors. Communication by light was still not practical because it required a clear line-of-sight; fog or rain still presented a problem of obstruction to the link. Experiments continued with light propagation in a glass medium. Conclusions showed glass to be preferable to air for two reasons—its constant nature and its ability to remain unaffected by environmental variations.

In 1970, the first low-loss optical fiber was developed. The optical fiber, made from silica glass about 250 micrometers (mm) in diameter—about the size of a human hair—was used to propagate light in a lab environment. This was the beginning of fiber optics.

Shortly after this, the process of manufacturing thin glass fiber strands was perfected and, in the mid 1970s, Corning Inc. made fiber optic cable available commercially. This launched the fiber optic revolution. Short-distance systems were subsequently tested by many telephone companies. With the continual refinement of the technology, communication distances increased and more products became available.

In 1980, Bell announced the installation of 611 miles of optical fiber in its northeast U.S. corridor. Likewise, Saskatchewan Telephone announced the installation of 3600 km of optical fiber in Canada. At the 1980 Lake Placid Winter Olympics, fiber optics was first used to transmit television signals. In the years that followed, fiber optics gradually gained popularity in the telecommunications world. Today, it is a widely accepted and proven technology. The replacement of old wire communication lines with new fiber optic cable is now the norm for many applications.

The basic principle of the on/off light communication used in the past is similar to the principle used in fiber optics today. The information signal to be transmitted controls a light source by turning it on and off in a particular coded sequence, or by varying its intensity. The light is then coupled into an optical fiber that guides it for the distance of the communication. At the receiving end, a detector decodes the light and reproduces the information signal.

Although light travels in a straight line in free space, the glass properties of the optical fiber guide the light around bends and allow fiber optic cable routes to work like standard copper wire cable routes, with some restrictions. The distance of propagation is determined mainly by the loss of the light in the optical fiber and by the rate of the on/off signaling. At the other end of the optical fiber the light is coupled to a light-sensitive photodetector which converts the pulsing light signal back to a usable electrical signal.

Today's fiber optic technology can support transmission rates of over 9 billion light pulses per second. This translates to over 129,000 simultaneous telephone calls. A standard 200-fiber cable can carry over 12 million telephone conversations compared to the 10,000 conversations a similar-sized copper cable can carry.

Optical fiber doesn't care what type of signal it is propagating. This makes it a versatile medium, available for practically all types of communication, including telephone, video, television, images, computers, local area networks (LANs), wide area networks (WANs), control systems, and so on. One fiber optic cable installation can be used for many applications.

As this lightwave revolution continues to develop and grow, we can expect better and more abundant service for our everyday needs. In fact, we are already benefiting from optical fiber's versatility in many practical areas of our lives. Already, many of our phone calls use fiber optic facilities. Cable TV companies are adding fiber optics to their networks so we can enjoy a larger selection of channels with better quality. Interactive television, which uses fiber optics, is being tested in many locations. Fiber optics is also used in many industries to carry high-speed computer data throughout a factory or across countries.

1.2 BASIC TRANSMISSION

Fiber optics involves the transmission of information by light through long transparent fibers made from glass or plastic. A light source modulates a light-emitting diode (LED), or a laser turns on or off or varies in intensity in a manner that represents the electrical information input signal. The modulating light is then coupled to an optical fiber that propagates the light. An optical detector at the opposite end of the fiber receives the modulating light and converts it back to an electrical signal which is identical to the input signal.

Light transmission techniques can be divided into three major categories: digital modulation, analog modulation, and digital modulation with analog-to-digital conversion. Digital modulation involves the conversion of the electrical digital input signal into a similar coded sequence of on or off (digital) light pulses (see Fig. 1.1*a*). Because all computer communications use electrical digital communications, this type of modulation is well suited for computer data transmission.

Analog communication signals, such as for voice or video transmission, vary in electrical amplitude and period. Analog modulation converts this electrical input signal into an optical signal of similarly varying light intensity (see Fig. 1.1*b*). This technique can be relatively inexpensive and is often used in fiber optic modem applications.

Analog signals can also be converted to a digital format using an analog-to-digital converter (A-to-D converter) before the modulation step. Digital light signals are then propagated in the optical fiber (see Fig. 1.1c). At the other end, the digital light signal is converted to an electrical digital signal by the detector. Then a second analog-to-digital converter converts the digital signal back into its original analog form. This technique provides signal conformity with other digital signals and allows a number of signals to be combined into an optical fiber aggregate using multiplexing equipment.

The transmission techniques shown in Fig. 1.1 show information transmission in only one direction. However, most systems require full, simultaneous two-way communications. Therefore, a second identical set of modulation and detection devices is implemented in the opposite direction to form a fully functional two-way communication system (see Fig. 1.2).

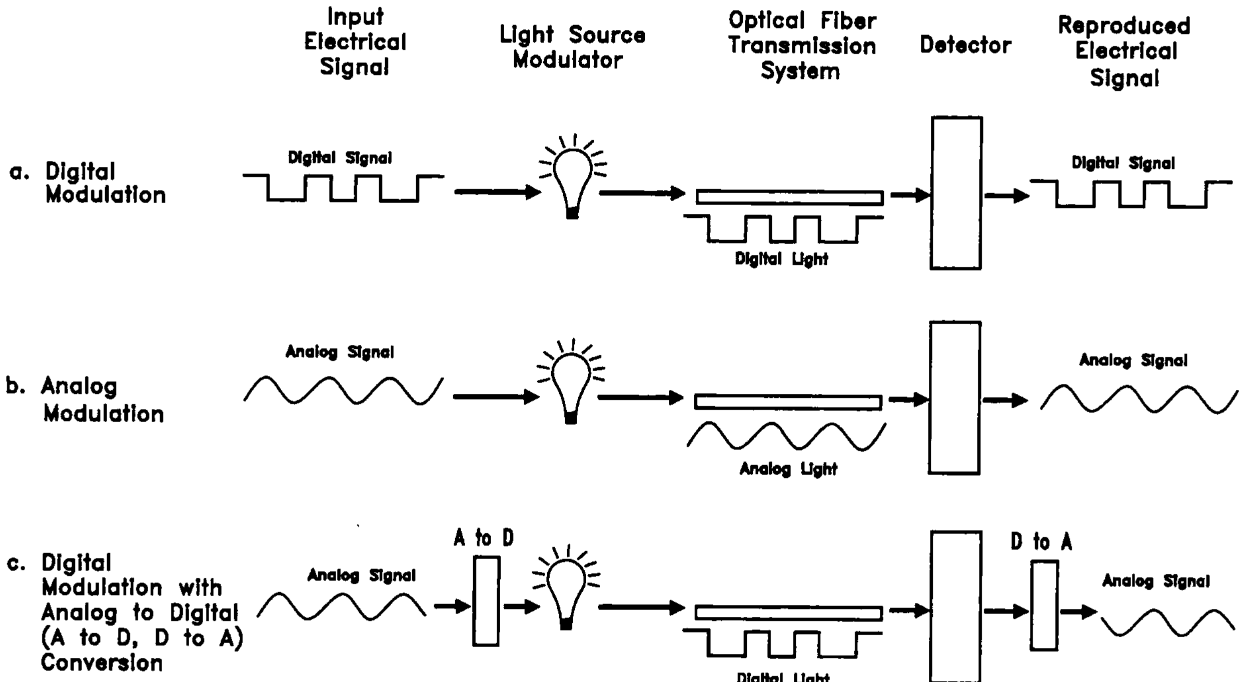

FIGURE 1.1 Fiber optic transmission basics.

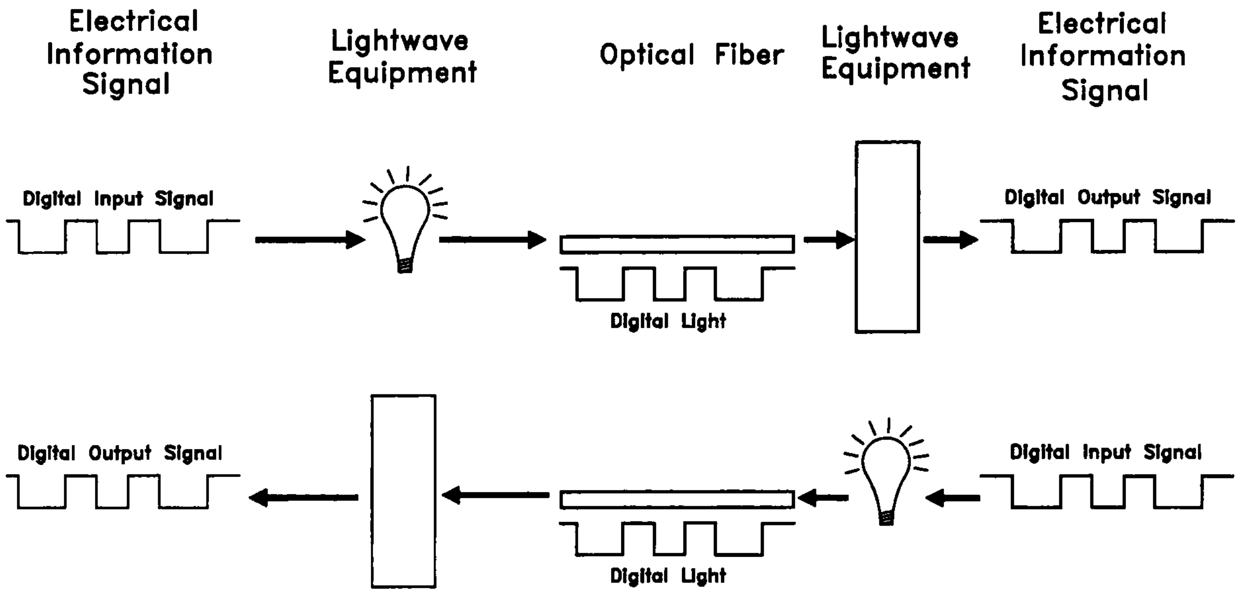

FIGURE 1.2 Two-way communications.

1.3 ADVANTAGES AND DISADVANTAGES

Optical fiber has become a popular medium for many communications requirements. Its appeal can be attributed to the many advantages that optical fiber has over conventional electrical transmission methods This lightwave transmission medium also has drawbacks, however, which should be examined before proceeding with an installation. The following sections describe some of these considerations.

Advantages

Large Capacity. Optical fiber has the capacity to transmit large amounts of information. With present technology, over 2,000,000 simultaneous telephone conversations can be placed on only two optical fibers. A fiber optic cable can contain as many as 200 optical fibers, which would increase the link capacity to over 200,000,000 conversations. Compare this to conventional wire facilities, in which a large multipair cable can carry 500 conversations, a coaxial cable can carry 10,000 conversations, and a microwave radio or satellite link can carry 2000 conversations.

Size and Weight. Fiber optic cable is much smaller in diameter and lighter in weight than a copper cable of similar capacity. This makes it easier to install, especially in existing cable locations (such as building risers) where space is at a premium.

Electrical Interference. Optical fiber is not affected by electromagnetic interference (EMI) or radio frequency interference (RFI), and it does not generate any of its own interference. It can provide a clean communication path in the most hostile EMI environment. Electrical utilities use optical fiber along high-voltage lines to provide clear communication between their switching stations. Optical fiber is also free of cross talk between fibers. Even if light is radiated by one optical fiber, it cannot be recaptured by another optical fiber.

Insulation. Optical fiber is an insulator. The glass fiber eliminates the need for electric currents for the communication path. Proper all-dielectric fiber optic cable contains no electrical conductor and can provide total electrical isolation for many applications. It can eliminate interference caused by ground loop currents or potentially hazardous conditions caused by electrical discharge onto communication lines such as lightning or electrical faults. It is an intrinsically safe medium often used where electrical isolation is essential.

Security. Optical fiber offers a high degree of security. An optical fiber cannot be tapped by conventional electrical means such as surface conduction or electromagnetic induction, and it is very difficult to tap onto optically. Light rays travel down the center of the fiber and few or none of them escape. Even if a tap is successful, it can be detected by monitoring the optical power received at the termination. Radio or satellite communication signals can easily be captured for decoding.

Reliability and Maintenance. Optical fiber is a constant medium and is not subject to fading. Properly designed fiber optic links are immune to adverse temperature and moisture conditions and can even be used for underwater cable. Optical fiber also has a long service life span, estimated at over 30 years for some cables. The maintenance required for a fiber optic cable is minimal; there is no copper in the cable that can corrode and cause intermittent or lost signals; and the cable is not affected by short circuits, power surges, or static electricity.

Versatility. Fiber optic communications systems are available for most data, voice, and video communications formats. Systems are available for RS232, RS422, V.35, Ethernet, Arcnet, FDDI, T1, T2, T3, Sonet, 2/4 wire voice, E&M signal, composite video, and many more.

Expansion. Properly designed fiber optic systems can easily be expanded. A system designed for a low data rate, for example, T1 (1.544 Mbps), can be upgraded to a higher data rate system, OC-12 (622 Mbps), by changing the electronics. The fiber optic cable facility can remain the same.

Signal Regeneration. Present technology can provide fiber optic communication beyond 70 km (43 mi) before signal regeneration is required, which can be extended to 150 km (93 mi) using laser amplifiers. Future technology may extend this distance to 200 km (124 mi) and possibly 1000 km (621 mi). The savings in intermediate repeater equipment costs and in maintenance can be substantial. Conventional electrical cable systems, by contrast, can require repeaters every few kilometers.

Disadvantages

Electrical-to-Optical Conversion. Before connecting an electrical communication signal to an optical fiber, the signal must be converted to the lightwave spectrum [850, 1310, or 1550 nanometers (nm)]. This is performed by the electronics at the transmitting end, which properly formats the communication signal and converts it to an optical signal using an LED or solid-state laser. This optical signal is then propagated by the optical fiber. At the receiving end of the optical fiber, the optical signal must be converted back to an electrical signal to be useful. The cost of this additional electronics needed to convert the signal to light and back to an electrical signal should be considered in all applications.

Right of Way. A physical right of way for the fiber optic cable is required. The cable can be directly buried, placed in ducts, or strung aerially along the right of way. This may require the purchase or leasing of property. Some rights of way may be impossible to acquire. For locations such as mountainous terrain or some urban environments, other wireless communication methods may be more suitable.

Special Installation. Because optical fiber is predominantly silica glass, special techniques are needed for the engineering and installation of the fiber cable. Conventional wire cable installation methods, crimping, wire wrapping, or soldering, for example, no longer apply. Proper fiber optic equipment is also required to test and commission the optical fibers. Technicians must be trained in the installation and commissioning of the fiber optic cable.

Repairs. Fiber optic cable that becomes damaged is not as easily repaired as many copper cables. Repair procedures require a skilled technical crew with proper equipment. In some situations, the entire cable may need to be replaced. This problem can be further complicated if a large number of users rely on the facility. A proper system design with physically diverse routing to accommodate such contingencies is thus important.

Although there may be many advantages that favor a fiber optic installation, they should be weighed carefully against the disadvantages of each application. All the costs of the implementation and operation of fiber optic facilities should be analyzed.

1.4 APPLICATIONS

Fiber optic cable is currently being used as a communication medium for many different applications. Many telephone companies, for example, are deploying fiber optics to provide communication between their central offices (COs), throughout cities, across countries, and over long oceanic routes (see Fig. 1.3). Plans now exist to extend fiber right into the home for high-quality video telephone transmissions. Fiber optics provides a reliable, high-capacity link for voice, data, and video traffic.

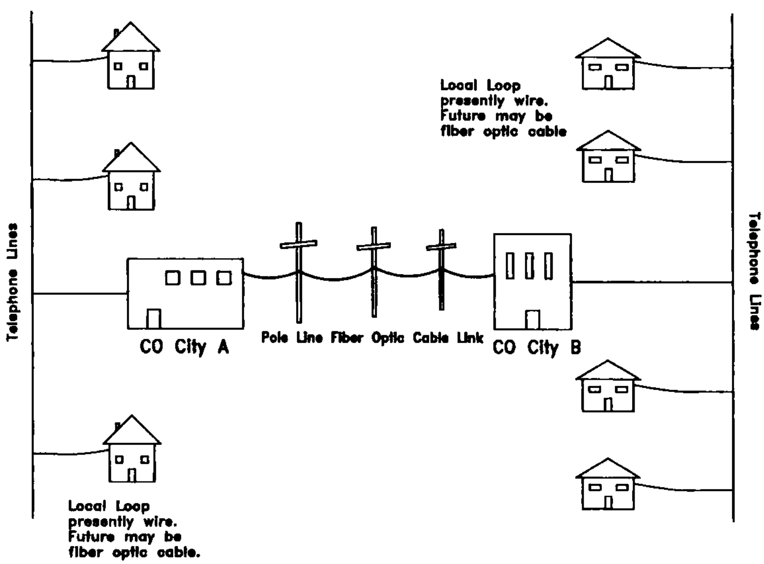

FIGURE 1.3 Fiber optics connecting central offices (COs).