International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 2, Issue 2 (March-April 2014), PP. 59-63

COMPARATIVE STUDY BETWEEN FIBER OPTIC AND COPPER IN COMMUNICATION LINK

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Abstract—Fiber Optics and Copper wires are the two prominent communication links used in modern communication and play a great role. A lot of articles have been written comparing these two technologies. Each of this communication links has its own advantages and disadvantages over the other. In this paper, both fiber optics and copper are evaluated and compared regarding their advantages and disadvantages based on bandwidth, cost, weight, size and flexibility, signal loss, information capacity, safety and immunity .In today's modern-world communication demand, having an understanding of how these interconnects and interfaces devices is critical to successful system design.

Key words: Fiber Optics, Electric copper wire, Communication links

I. INTRODUCTION

Fiber optics communication is a technology that is use to transmit signals like data, video or voice which is modulated with pulse of light that serves as an electromagnetic carrier wave send down a glass tube over a long distance with very little attenuation or loss. This modulated pulse of light propagates through the glass tube using the principle of total internal reflection (TIR). A fiber optics communication link also known as a fiber channel is a system which provides a point-to-point data connection between two points. It comprises of data transmitter consisting of a laser diode or Light Emitting Diode (LED) which convert electric signal to light, a transmission fiber in which the modulated light propagate, and a receiver which consist of a photo detector that converts light to electric signal.

The use of fiber optics was generally not available until 1970 when Corning Glass Works was able to produce a fiber with a loss of 20dB/km. Today's optical fiber attenuation ranges from 0.5dB/km to 1000dB/km depending on the optical fiber used. The applications of optical fiber communications have increased, at a rapid rate, since the first commercial installation of a fiber-optic system in 1977. Telephone companies began early on, replacing their old copper wire systems with optical fiber lines. Today's telephone companies use optical fiber throughout their system as the backbone architecture and as the long-distance connection between city phone systems. Cable television companies have also begun integrating fiber optics into their cable systems. The trunk lines that connect central offices have generally been replaced with optical fiber. A fiber-optic system is similar to the copper wire system that fiber optics is replacing [1- 6]. Figure 1 shows a fiber optic cable.

Copper occupies the same family of the periodic table as silver and gold, since they each have one s-orbital electron on top of a filled electron shell which forms metallic bonds. This similarity in electron structure makes them similar in many characteristics. All have very high thermal and electrical conductivity, and all are malleable metals. Among pure metals at room temperature, copper has the second highest electrical and thermal conductivity, after silver. Figure 2 and 3 shows coaxial copper cable and twisted pair cable [15-18].

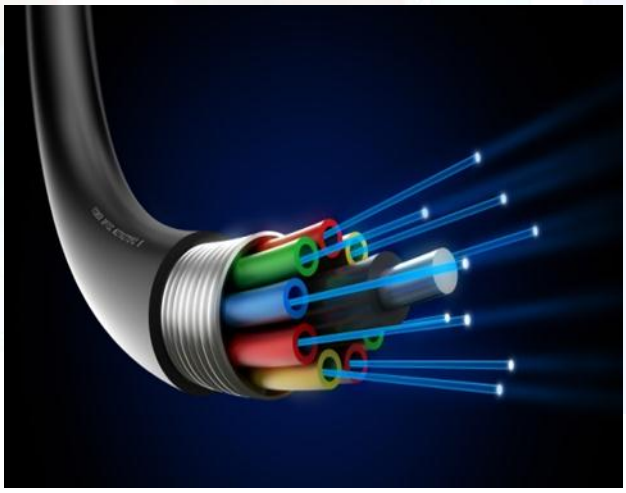

Figure 1: Fiber optics communication link [3].

Figure 2: Coaxial copper cable [3]

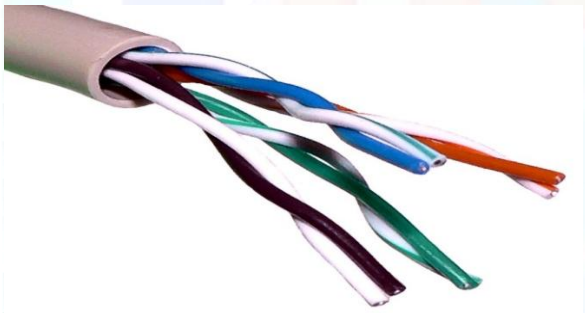

Figure 3: Twisted pair cable [3]

II. COMPARATIVES ANALYSIS

Optical fiber offers many advantages over coaxial cable for the transmission of radio frequency (RF) signals in antenna-remoting applications, as well as cellular networks and cable television (CATV) signal distribution networks [2]. Copper is also superior in others approach such as in electronics hardware compatibility because it is implemented earlier. However, innovations in fiber technology make it chosen as the new approach in communication system. The performance of each cable is discussed in this section.

a. Bandwidth

In network communications, bandwidth means rate of data

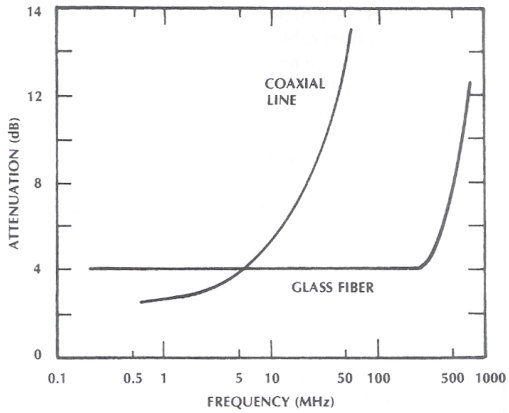

Figure 4: Effective attenuation of a 1 km length of coaxial line and glass fiber. The 3 dB bandwidth of the fiber is 500 MHz [8]

transfer. It is the amount of data that can be transfer from one point to another at any given time. A UTP cat 6 copper wire, has a maximum bandwidth of 1Gbps, while a cat 5e has a maximum bandwidth of 100Mbps, while fibre cable transmit 10Gbps or more, this is why they are recommended for network backbones. Another bandwidth related parameter is the bandwidth-distance product. It is normalise to 1km and is used to predict the effect of link bandwidth for other length which is usually expressed in MHz/KM or GHz/km. The bandwidth-distance product for multimode fibre is 500MHz/km, so a 500m laser can transmit 1GHz.A UTP cat 6 that is optimized can transmit 500MHz over only 100meters that is its bandwidth-distance product is 50MHz/km.

b. Cost

Cost is one of the important considerations in a system design. There are two different types of materials used in cable manufacturing, silicon dioxide, which is abundant and transparent plastic [8].In fiber, the equipment cost is higher because it requires to get all signal formats on and off the fiber [4]. Optical fiber is also slightly more expensive than the ubiquitous Cat 5e unshielded twisted pair (UTP) copper cable, but it is far less expensive than the premium quality Cat 6, Cat A6, Cat 7, or CX4 cables required especially for10Gbs electrical links. No 10Gbs link standard will support Cat 5e, upgrading to 10Gbs required to install either fiber cable or new copper media that cost 5 to 10 times more than fiber cost [5]. Thus, the savings achieved by this approach makes fiber a very viable option compared to copper.

c. Weight, Size and Flexibility

Fibers are smaller and lighter compare to the metals cables especially copper base. Optical fiber occupies less space in conduits than copper cabling and weighs less too.

Optical fiber safely sustains a tighter bend radius than any copper cables. Flexibility in fiber is attractive for installations containing many turns along the transmission path due to the materials used in manufacturing unlike copper which use metal. There is also some loss at a very tight bend in fiber. Fiber's tighter bend radius, smaller size, lower weight and ability to be bundled freely without worrying about cross-talk make cable management much easier. This is why fibers are moving forward to take over the aeronautical system technology due to these improvements especially in space-ship and satellite circuitry design [17].

d. Signal Loss

The low signal attenuation performance and superior signal integrity found in fiber optical systems facilitates much longer runs for signal transmission than metal-based systems [10].Attenuation can be losses attributed to microscopic and macroscopic impurities in the fiber material and structure, which cause absorption and scattering of the light signal. Figure 4 shows the attenuation cause by using fiber and coaxial cables for 1 km link distances. Attenuation is a function of the wavelength, and the loss is usually stated in dB/km [9]. Optical pulses traveling through fiber suffer very little attenuation because the fiber absorbs light only weakly. An optical signal still retains 50 % of its signal strength after traveling 12 km over a single mode fibers, independent of the data rate (-.25 dB/km) [12]. Others factors contributing in signal loss or degradation are $_{\text{dispersion}}$, connectors, splices and bending effect.

In copper, when high speed electrical signals propagate along metal wires or circuit traces, in contrast, they dissipate energy by radiating the signal away into space. These losses increase drastically as the data rate increases and they require more complex signal processing in the transceiver and also limit the practical reach of a link [5].Thus, in single-line, voice grade copper systems require in-line signal repeaters for satisfactory performance over long distances with higher data rate [10].Optical fiber has low loss so that suitable for long distance system such as inter-state communication link. Copper has high loss but easy to integrate to other device. These factors make it suitable for short distance communication.

e. Safety and Immunity

Some of the most important advantages concern fiber's inherently superior dielectric properties. Since optical fiber has no metallic components, it is unsurpassed for providing complete electrical isolation as well as noise immunity. Electrical isolation is most important when it comes to eliminating ground loops. A ground loop is a condition where an unintended connection to ground is made through an interfering electrical conductor [10]. Generally, a ground loop connection exists when an electrical system is connected in more than one way to an electrical ground. Since there is no electrical conduction through fiber cable, equipment grounded at one end of the connection is completely isolated from the ground at the other end. Ground loops can be an especially irritating source of headaches in even the simplest sound systems and thus, using optical fiber signal transmission can eliminate these major sources of problems entirely.

Another advantage of optical fiber is its immunity to external noise. Electrical noise, also known as EMI (electromagnetic interference), and RFI (radio frequency interference), are unwanted electrical signals that produce undesirable effects and otherwise disrupt audio and data system [11]. Sources of EMI/RFI include lighting equipment, computers, electric motors, and radio and TV broadcasts. Fluorescent lights and power lines are a common source of annoying 60 Hz hum. Lightning can also be a common natural source of audio and data system interference and disruption [10].The interference from all these sources modifies and interacts with data signals in metal cables, causing data errors and transient unreliability. Even traditional high-quality "balanced" copper cables are susceptible to EMI/RFI and lightning problems. In summary, fiber optic cables are totally immune to any extraneous electrical fields, so they carry only clean signals [15-16].

f. Other Factors

Optical fiber cable work superior under harsh environments in comparison with its metallic counterparts. It is not fragile or brittle, not heavy or bulky, less prone to electrical interference, more resistant to corrosion, and has a life expectancy of up to thirty years [9].Also, optical fiber can withstand higher temperatures than copper wires. This means that even when the outside jacket surrounding the optical fiber has melted, an optical fiber system can still perform well.

Apart from telecommunications, optical fibers also apply in the medical field. Through this field, medical equipment such as fiberscope and endoscope play a significant role in diagnosing illness [17 -18]. Summary of the performance for fiber optics and copper wire is shown in table 1.

Table 1. Comparison between fiber optics and copper wire

Criteria	**Fiber optics**	**Copper wire**
Bandwidth	Large bandwidth	Low bandwidth
Cost	More cost	Less cost
Weight	Less weight	Heavier than fiber
Size	It occupied less space	It occupied large space
Flexibility	Very high tensile strength	Very low tensile strength
Signal loss	Low signal loss	Higher signal loss
Safety and immunity	Immune to EMI and RFI and crosstalk	Not immune to EMI and RFI and crosstalk

III. SUMMARY

Performance comparison between fiber optics and cable wire in communication has been presented. The invention of fiber-optic technology is a revolutionary departure from the traditional copper wires of twisted-pair cable or coaxial cable. Today, coppers wires are still used because they are cost effective and reliable and interconnect parallel machines. However, as machines become more powerful, wire density becomes critical, thus making optical fiber an alternatives source. There is no doubt as to the vast opportunities that fiber optic technology can give and it should be continuously researched and expanded to cater for future demands.

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