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Enhancing Signal Production For Promulgating Information in a Fiber Optic Communication System

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ABSTRACT: *Fiber optic communication systems are important telecommunication infrastructure for world-wide broadband networks. It is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. Fiber optic communications systems are widely employed for applications ranging from major telecommunications backbone infrastructure to Ethernet systems, broadband distribution and general data networking. Wide bandwidth signal transmission with low delay is a key requirement in present day applications. This paper focuses on ways for improving the data speed of a fiber communication link. It gives an overview of fiber optic communication systems and discusses their technological trend towards the next generation. The conclusions of this paper were made on the basis of different study of each possible ways to improve output with the advent of information and communication technology.*

KEYWORDS*: Fiber optic, Attenuation, splicing, Fiber degradation, Telecommunication, Bandwidth.*

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I. INTRODUCTION

The rapid growth in information technology and broadband applications has been driving the strong demand for bandwidth in the telecommunications networks [1]. The major driving force behind the spread in the use of fiber optics communication is the high and rapidly increasing consumer and commercial demand for more telecommunication capacity and internet services [2]. With fiber optic technology capable of providing the required information capacity larger than both wireless connections and copper cable [1-3], fiber optic communications can offer a unique solution to the ever increasing demand in the future. In recent years, the Fiber optic industry has experienced a remarkable growth and speedy technological changes [4]. Fiber Optic communication can offer a unique solution to the ever increasing demand in the future. Improvements in technology have enabled more data to be conveyed through a single optical fiber over long distances [5]. The transmission capacity in optical communication networks are greatly improved using wavelength division multiplexing [5]. Recent fiber-optic communication systems basically includes 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, multiple kinds of amplifiers and an optical receiver to recover the signal as an electrical signal[7]. In the system, the transmitter of light source generates a modulated light stream to enable it to carry the data. A pulse of light indicates a “1” and the absence flight indicates "0". This light is transmitted down a very thin fiber of glass presented by the detector [6].The detector converts the pulses of light into equivalent electrical pulses. In this way, the data can be transmitted as light over great distances [7]. Regardless of the benefits of utilizing optical fiber for communication such as its high reliability over long distances, low attenuation, low interference, high security, very high information capacity, longer life span and ease of maintenance[7-8], research is still ongoing to further improve on the present fiber optics communication system, and also to solve some of the challenges facing it. Different techniques and components are used by system network providers that provide extremely high data rates over long distances, as would be discussed in subsequent topics of this work.

II. 2.0 PRINCIPLES OF A FIBER OPTIC COMMUNICATION SYSTEM

A basic fiber optic communication system consists of a transmitting device, which generates the light signal, an optical fiber cable which carries the light and a receiver which accepts the light signal transmitted. Unlike copper wire based transmission where the transmission entirely depends on electrical signals passing through the cable, the fiber optics transmission involves transmission of signals in the form of light from one point to the other [8]. It consists of a transmitting and receiving circuitry, a light source and detector devices like the ones shown in the figure 1. Fiber optic communication systems consists of an optical transmitter to convert an electrical signal to an optical signal for transmission through the optical fiber, a cable containing several bundles of optical fibers, optical amplifiers to boost the power of the optical signal, and an optical receiver to reconvert the received optical signal back to the original transmitted electrical signal[9]. The transmitter circuitry, converts the input data in the form of electrical signals into light signal with the help of a light source. The light beam from the source is carried by a fiber optic cable to the destination circuitry wherein the information is transmitted back to the electrical signal by a receiver circuit. The Receiver circuit consists of a photo detector along with an appropriate electronic circuit, which is capable of measuring magnitude, frequency and phase of the optic field.

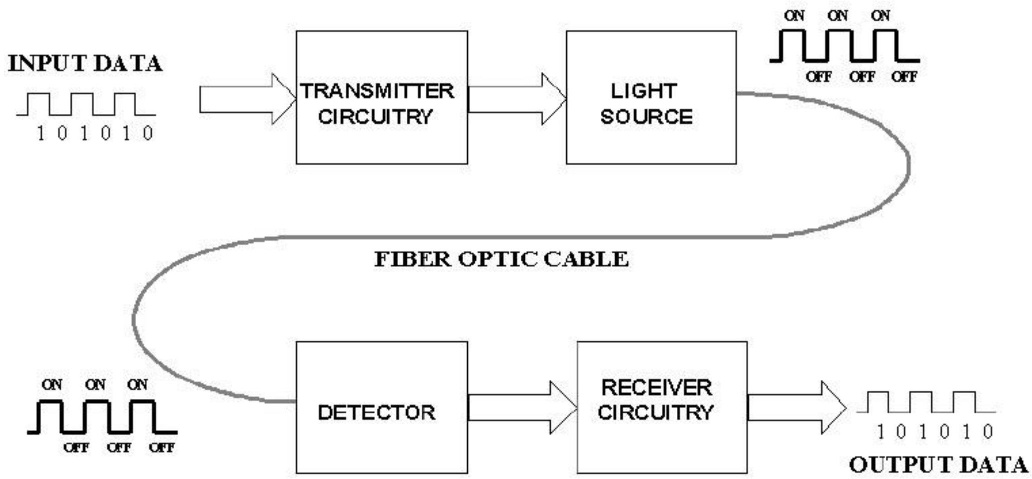

Figure 1: Basic principles of a Fiber Optic Communication System [1]

TRANSMITTER: Optical transmitters are mostly made of semiconductor devices such as light-emitting diodes and laser diodes [7]. According to [8-9] Light Emitting diodes (LEDs) produce incoherent light that covers a relatively wide spectrum. As a result of this, any chromatic dispersion in the fiber will limit the bandwidth of the system. LEDs offers low level efficiency and relatively wide spectral width of 30–60 nm, with only about 1% of input power or about 100 microwatts [8]B. However, due to their relatively simple design and low performance, LEDs are used mainly in local -area-network applications where the data rates are typically in the range10-100 Mb/s and transmission distances are a few kilometers [10]. LEDs are very useful for low-cost applications. Laser diodes have a very narrow spectral bandwidth as a result of the fact that they produce coherent light [11]. It poses some significant advantages; the narrow spectral width enables the lasers to transmit data at much higher rates because modal dispersion is less apparent. Light output is directional and this enables a much higher level of efficiency in the transfer of the light into the fiber optic cable. Laser diodes are used for higher data rate [12]. Semiconductor lasers can be modulated directly at high frequencies because of short recombination time for the carriers within the semiconductor material [12]. 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 [13]. The transmitter unit converts an electrical signal to an optical signal. The light source performs the actual conversion from an electrical signal to an optical signal through the driving circuit. Recently, improvements have made these sources more reliable. Both sources are modulated using either direct or external modulation techniques. A few of such comparisons of these two sources are given below.

CHARACTERISTICS	LASER DIODE	LIGHT EMITTING DIODE
Speed	Faster	Slower
Spectral Width	Narrower	Wider
Ease of Operation	Easier	More Difficult
Output Power	Higher	Lower
Numerical Aperture	Smaller	Larger
Cost	More Expensive	Less Expensive
Current	Threshold current (5- 40mA)	Drive current (50 - 100mA at Peak)
Lifetime	Long	Longer
Modulation bandwidth	High, Tens of MHz to tens of GHz	Moderate, Tens of KHz to tens MHz
Eye Safety	Most be rendered Eye-Safe	Eye-Safe

Fiber Type	Single mode and Multimode	Multimode Mode only
Available Wavelength	0.78 to 1.65 mm	0.66 to 165 mm

Table 1: Comparison between Laser Diode and Light Emitting Diode.

FIBER OPTIC CABLE: The fiber-optic cable is the light transmission medium. It is a dielectric cylindrical waveguide made from low-loss materials. The cable includes the core, cladding, buffer and the protective jacket. The core of a fiber cable is a cylinder of plastic or glass that runs all along the fiber cable's length, and offers protection by cladding. The core of the waveguide has a refractive index a little higher than that of the cladding, so that light pulses is guided along the axis of the fiber by total internal reflection [14]. Optical fibers fall into two major categories, namely: step index optical fiber, which include single mode optical fiber and multimode optical fiber. Single mode optical fiber is a single strand of glass fiber with a core diameter of 8.3 to 10 microns that allows one light path. It carries a higher bandwidth than multimode fiber, but requires a light source with a narrow spectral width. The small core and single light-wave eliminates any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type. Multimode optical fiber has a higher bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core. It has a core diameter greater than or equal to 50 micrometers and allows several light paths, this leads to modal dispersion. Step-Index Multimode Fiber has a large core, up to 100 microns in diameter. As a result, some of the light rays that make up the digital pulse may travel a direct route, whereas others make a zigzag movement as they bounce off the cladding. These alternative pathways cause the different groupings of light rays, referred to as modes, to arrive separately at a receiving point. The pulse, an aggregate of different modes, begins to spread out, losing its well-defined shape. The need to leave spacing between pulses to prevent overlapping limits bandwidth that is, the amount of information that can be sent. Consequently, this type of fiber is best suited for transmission over short distances. Graded index optical fibers have their core refractive index gradually decrease farther from the centre of the core. The higher refractive index at the center makes the light rays moving down the axis advance more slowly than those near the cladding. Also, rather than zigzagging off the cladding, light in the core curves helically because of the graded index, reducing its travel distance. The shortened path and the higher speed allow light at the periphery to arrive at a receiver at about the same time.

PHOTO DETECTOR AND RECEIVER: The photo detectors is the main component of an optical receiver which convert light signal into electric signal using a photoelectric effect. Photo detectors are typically a semiconductor-based photodiode made from Indium gallium arsenide. PN photo diode and avalanche photo diode are the two main type of photo detector used for optical receiver in an optical communication system. The receiver accepts the light or photons and converts them back into an electrical signal. In most cases, the resulting electrical signal is identical to the original signal fed into the transmitter. There are two basic sections of a receiver. First is the detector that converts the optical signal back into an electrical signal. The second section is the output circuit, which reshapes and rebuilds the original signal before passing it to the output. Depending on the application, the transmitter and receiver circuitry can be very simple or quite complex. Other components that make up a fiber-optic transmission system, such as couplers, multiplexers, optical amplifiers, and optical switches, provide the means for building more complex links and communications networks. The transmitter, fiber, and receiver, however, are the basic elements in every Fiber-Optic system. Beyond the simple link, the Fiber-Optic medium is the fundamental building block for Optical communications. Most electrical signals can be transported optically. Many optical components have been invented to permit signals to be processed optically without electrical conversion. Indeed, one goal of optical communications is to be able to operate entirely in the optical domain from system end to end.

III. LOSSES IN A FIBER NETWORK

The losses associated with fiber optic networks occur at various stages of the installation. These losses are classified as Attenuation losses and Dispersion losses.

DISPERSION: Dispersion is the spreading of optical pulses as they travel along the fiber [15]. As the pulses spread, they overlap and are no longer distinguishable to the receiver as 0's and 1's. It limits the bandwidth of the Fiber because the spreading optical pulse limits the rate that pulses can follow one another on the fiber and still be distinguishable at the receiver. Thus, results in errors and loss of information. Dispersions can be Intermodal or Chromatic. Chromatic dispersion occurs as a result of the range of wavelength in the light source. Intermodal Dispersion can be eliminated by Single-mode fiber using the Zero-dispersion wavelength. The zero-dispersion wavelength is the wavelength or wavelengths at which material dispersion and waveguide dispersion cancel one another. Another way to alter the dispersion is changing the core size and the refractive indices of the material of core and cladding.

ATTENUATION: This is the loss of optical power as light travels through the fiber [15]. Attenuation in fiber optic cable are classified into intrinsic and extrinsic attenuation. Intrinsic attenuation occurs due to impurities inherent in the glass. When the light hits the impurity, it will either scatter or be absorbed. Scattering accounts for about 96% of attenuation and if the light is scattered at an angle that does not support continuous forward movement, the light is diverted out of the core and attenuation occurs. Absorption accounts for less and occurs when light is absorbed by the impurities in the glass. Absorption can be limited by controlling the amount of impurities in the manufacturing process. Extrinsic attenuation is the reduction of power caused by Microbending and Macrobending of the fiber cables. Macrobending is a large scale bend that is visible and is usually prevented by abiding by the minimum bend radius of the cable. Microbending is a small scale bend usually caused by pressure on the fiber. It is very localized and might not be clearly visible upon inspection. It is often corrected as you reverse the bend. Patch panel failures are failures that create malfunctions in the system by high attenuation [16]. Poor connection points can cause some of these malfunctions when the fiber was terminated with the appropriate connectors. When the fiber is spliced together poorly the signal inside the fiber optic cable can have large dB losses. If the connections were not inserted in the connectors correctly or the fiber cable has fractured parts in the glass, there can be very high attenuation to no signal propagation into other parts of the communication network. This is going to possibly show communication outages within the system. Installation failures are associated with failures that are caused when installing the fiber optic network. If a fiber optic cable is bent past the specification bending radius of the cable then the cable can fail instantly or could possibly fail over time. This might not be an automatic failure as mentioned but could be failures later in time as the fiber optics weaken. This mainly happens when the installer is not aware of the specification of the cable and not paying attention to what he or she is doing. Failures in fiber optics can also be caused by improper dressing and from terminating the fiber optic connections. This kind of installation failure is sort of an overlap from a patch panel failure. When fiber optic cable connections are terminated to the cable poorly, be it ST connectors, SC connectors or similar connectors for example, these cables can present a point of failure in the installation process. Terminating fiber optic cable can be a very hard skill to master. The last failure class is the failures that are related to the construction of the fiber optics networks. These cables are always going to be strung from pole to pole, similar to the high or medium voltage lines that form our electric grid.

IV. IMPROVING THE DATA SPEED AND DEVELOPMENT OF A FIBER OPTIC COMMUNICATION SYSTEM

REPEATERS AND AMPLIFIERS: This is a device used to improve the quality of siqnal transmitted over a fiber optic communication network. It is a form of amplifier that amplifies directly the optical signal without the need to convert the signal back into an electrical format. The amplifiers consist of a length of fiber optic cable that is doped with a rare earth mineral named Erbium. **I**mprovements in optical amplification, transmitter/receiver technology in fiber optics communication with Erbium doped fiber amplifier is important to achieve high quality transmission and signals with distorted waveform and low signal to noise ratio during transmission. The development of optical transceivers adopting new and advanced modulation technology, with excellent chromatic dispersion and optical signal to noise ratio tolerance is suitable for ultra-long haul communication systems. In the future, better technologies to enhance Erbium doped fiber amplifier performance will be developed achieve a higher output power.

IMPROVEMENTS IN LASER TECHNOLOGY: Extension of the present semiconductor lasers to a wider variety of lasing wavelengths very high output powers are of interest in some high density optical applications. Lasers have a very narrow spectral bandwidth as a result of they produce coherent light. This narrow spectral width enables the lasers to transmit data at much higher rates because modal dispersion is less apparent. Currently, laser sources are spectrally shaped through chirp managing to compensate for chromatic dispersion. Chirp managing involves the control of laser such that it undergoes a sudden change in its wavelength when firing a pulse. This occurs in a way that the chromatic dispersion experienced by the pulse is reduced. Single mode tunable lasers are of tremendous importance for future coherent optical systems. These tunable lasers laser in a single longitudinal mode that can be tuned to a range of different frequencies. In tunable lasers, light output is directional and this enables a much higher level of efficiency in the transfer of the light into the fiber optic cable. Semiconductor lasers can be modulated directly at high frequencies because of short recombination time for the carriers within the semiconductor material. Using the vertical cavity surface-emitting laser VCSELs is the newest laser structure.

V. BENEFITS OF FIBRE-OPTIC COMMUNICATIONS

Fiber optic communication system has so many advantages which includes:

LONGER DISTANCE SIGNAL TRANSMISSION: A significant benefit of fiber-optic transmission is the capability to transport signals long distances due to its low attenuation and high signal transmission over metallic based systems. Basic systems are capable of sending signals up to 5 km over multimode fiber and up to

80 km over single mode without repeaters. Most modern Fib re-optic systems transport information digitally and Digital fiber -optic system can be repeated or regenerated virtually indefinitely.

TRANSMISSION OF MULTIPLE SIGNALS: Fiber has a bandwidth of more than 70 GHz using typical off-the-shelf Fiber-optic transport equipment. Several forms of video and audio signals can be transported over a single fiber using a combination of time-division multiplexing (TDM) and optical multiplexing

SMALL DIAMETER, LIGHT WEIGHT AND LONG LENGHT: The small diameter and size of a single fiber strand facilitates higher capacity in building conduits. The long length provide advantages to the end users. Due to the small diameter, it makes it possible to manufacture and install much longer lengths than metallic cable. A single core fiber weighs about 25 pounds per kilometer; RG-6 copper coaxial cable may be three to four times as much. In mobile and field productions for sports and news events, fiber is often the cable of choice due to space limitations in a mobile and electronic news gathering vehicle.

NOISE IMMUNITY: Signals traveling on a copper cable are prone to electromagnetic interference. The photons traveling down a fiber cable are immune to the effects of electromagnetic interference. A fiber -optic signal does not radiate any interference or noise. **EASE OF INSTALLATION AND UPGRADE**: Optical fibers can be installed with the same equipment used for the install coaxial cable and copper cable. The long length makes the installation of optical cable easier and less expensive with some modification due to limited pull tension, small size and bend radius of the fiber cable. Fiber-optic termination kits are now available that require no epoxy and special polishing. Simple cable stripping tools are used, similar to those used for copper coax, to prepare the fiber for termination. Epoxy-free connectors are available to terminate both multimode and single-mode fiber-optic cable. The connectors are already pre polished. Growth can be accommodated by installing spare fibers which is more affordable than installing additional fiber cables.

LOW TRANSMISSION LOSS, LARGE BANDWIDTH: Recent developments in Optical Fibers has resulted in production of Optical Fiber cables which exhibit very low attenuation or transmission loss in comparison with the best copper conductors because the optical carrier frequency yields a far greater potential transmission bandwidth than metallic cable systems. Information-carrying capacity of Optical Fiber system has proved far superior to the best copper cable systems.

SYSTEM RELIABILITY, SECURITY AND LOW COST: The dielectric nature of optical fiber makes it impossible to detect signal being transmitted through it. Accesing the fiber requires intervention that is easily detectable by security surveillance. This attribute makes fiber attractive to banks, governmental organization and other agencies. The system reliability involves the low loss property of Optical Fiber cables which reduces the requirement for intermediate repeaters to boost the transmitted signal strength. Hence fewer repeaters is used to enhance system reliability in comparison with conventional electrical conductor systems which also reduces the maintenance time and cost.

VI. CONCLUSION

This paper, discussed the importance of a fiber optic communication system for world-wide broadband networks. With focus on the possible ways for improving the data speed of a fiber communication link, this work gives an overview of fiber optic communication systems, the failures associated with it and ways to improve throughput by minimizing such failures to improve data speed in an already established network. There are various factor that affect the data speed in fiber optic communication where were discussed in preceding topics. In Conclusion, to enhance signal production in a fiber optic communication system, VCSELs LASER are specifically used as a transmitter. The fiber optic cable must be doped with a rare earth mineral named Erbium. Use wavelength-division multiplexing to increase data capacity to reduce dispersion and proper amplification which in turn increased the data speed. Though there is still much work to be done to support the need for faster data rates, the growth that has been experienced in the fiber optics communications industry has been enormous recent times. This rapid growth trend is expected to continue in the future as more research yields more breakthroughs for practical deployment.

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