P-ISSN: 2659-1561
E-ISSN: 2635-3040

Research Article

Optical Fiber: A Tool for Modern Communication

Aniefiok O. Akpan

Physics Department, Akwa Ibom State University, PMB 1167, Ikot Akpaden, Mkpat Enin Lga, Akwa Ibom State, Nigeria
Email: aniefiokotu@gmail.com, aniefiokakpan@aksu.edu.ng

Received: Feb 1, 2020 **Accepted:** Feb 8, 2020 **Published:** Feb 12, 2020

Abstract: Data communications sometimes are slow. Often information gets leaked or may even get tapped. Data often is lost while being transferred from one place to another between components. Presence of noise leads to reduction of clarity of video on TV sets. There is a solution which eliminates many of these problems. The solution is optical fibre cable communication. Due to its speed, data securing capacity and lesser distortion of signals it is widely used means of communication. Demand of optical fiber communications are increasing rapidly. The working of optical fibre, its advantages, disadvantages, and applications are discussed in this article.
Keywords: Optical fiber, Tool, Modern communication, Data communication.

Introduction

Many years ago all information was transferred in an analog format, which meant that the message was transmitted essentially as an exact copy of the original. The best example comes from early telephones. When a person spoke on the telephone, a microphone in the handset converted the sound waves from the voice into an electrical signal (varying electrical voltage or current), which mimicked the variations in air pressure produced by the person's voice. This analog signal was sent along electrical wires to its destination, where the electrical signal drove a small loudspeaker and recreated the sound of the caller's voice.

The principal problem in this scheme was that the electrical signal became distorted in its passage from caller to listener. And, in addition, the electrical signal had to be amplified along its way to counteract the loss of energy that naturally occurs to all electrical signals passing along wires. Amplification itself adds some distortion, as well as electronic systems as a fundamental natural phenomenon. All these problems can be circumvented if the transmitted electrical signals are digitised – represented in a binary code.

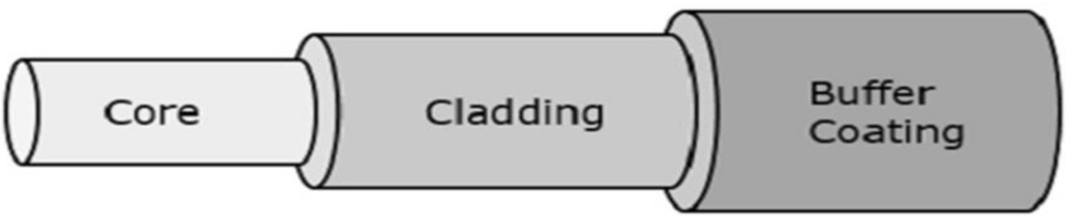
Optical communication systems have a long history. Ancient man signalled smoke and fire, often relaying messages from mountain top. However, this optical communication scheme had limited transmission capacity. They could serve as a warning, as Queen Elizabeth the first of England planned when she had a network of born fires erected to be set in event of a sea born invation from Spain. The smoke signals transmitted by native Americans had the capacity to transmit various messages. Since the end of the eighteenth century massages have been passed by semaphores- the use of flags to indicate the transmission of one letter at a time. This form of communication could transmit information at a rate of about one letter per second over a direct line of sight, although messages could be relayed over long distances. Such means of communication were not very secured, anyone in the line of sight to the message sender could read the information if the code was known. The massage could also be intercepted and altered during the relay process as the Count of Monte Cristo did to his advantage.

As a result of these set backs, fibre optic communications system are widely employed today for applications ranging from major telecommunications backbone infrastructure to Ethernet systems, broadband distribution, and general data networking.

Parts of an Optical Fiber

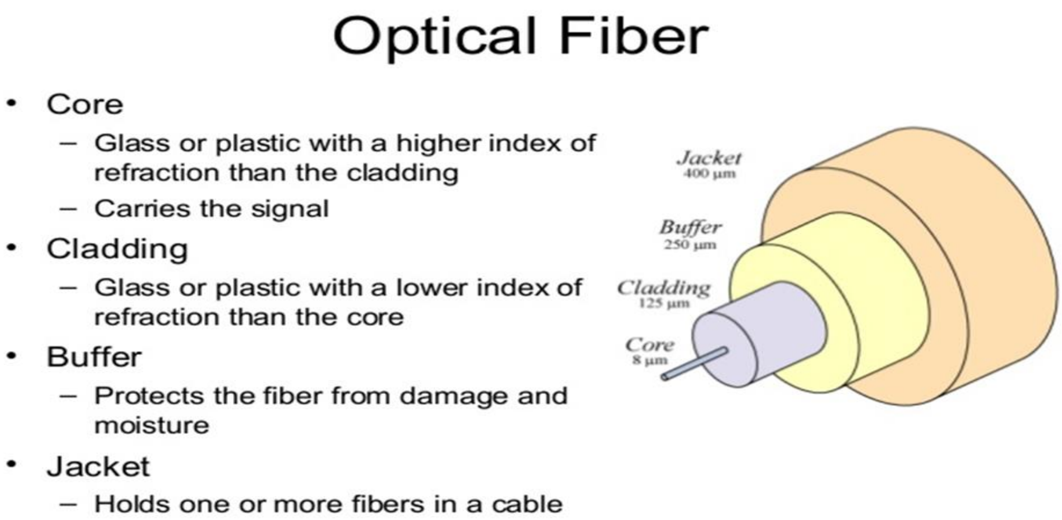
An optical fiber (or optical fibre) is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair. Optical fibers are used most often as a means to transmit light between the two ends of the fiber and find wide usage in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data rates) than wire cables.

The most commonly used optical fiber is **single solid di-electric cylinder** of radius **a** and index of refraction n_1. The following figure explains the parts of an optical fiber.



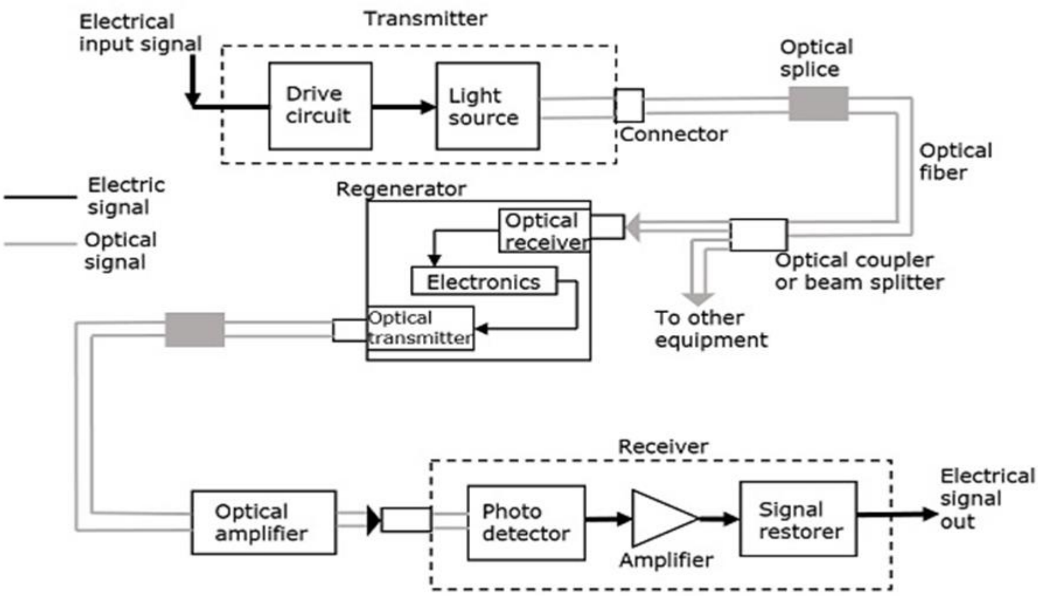
Parts of an Optical fiber

This cylinder is known as the Core of the fiber. A solid di-electric material surrounds the core, which is called as Cladding. Cladding helps in reducing scattering losses, adds mechanical strength to the fiber and protects the core from absorbing unwanted surface contaminants.



Optical Fiber Communications

The communication system of fiber optics is well understood by studying the parts and sections of it. The major elements of an optical fiber communication system are shown in the following figure.



Fiber optics communication system

The basic components of a fiber optics communication system are light signal transmitter, the optical fiber, and the photo detecting receiver. The additional elements such as fiber and cable splicers and connectors, regenerators, beam splitters, and optical amplifiers are employed to improve the performance of the communication system.

Working Principle of Fiber optics Communication System

The **Optical fiber communication process** transmits a signal in the form of light which is first converted into the light from electrical signals and transmitted, and then vice versa happens on the receiving side. Optical fibers typically include a transparent core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by the phenomenon of total internal reflection which causes the fiber to act as a waveguide. Fibers that support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those that support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a wider core diameter and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 1,000 meters.

Transmitter

On the transmitter side, first if the data is analog, it is sent to a coder or converter circuit which converts the analog signal into digital pulses of 0,1,0,1…(depending on how the data is) and passed through a **light source transmitter circuit**. And if the input is digital then it is directly sent through the light source transmitter circuit which converts the signal in the form of light waves. Although the original telecommunications fibre optic systems would have used large lasers, today a variety of semiconductor devices can be used.

The most commonly used devices are light emitting diodes, LEDs, and semiconductor laser diodes. The simplest transmitter device is the LED. Its main advantage is that it is cheap, and this makes it ideal for low cost applications where only short runs are needed. However they have a number of drawbacks. The first is that they offer a very low level of efficiency. Only about 1% of the input power enters the optical fibre, and this means that high power drivers would be needed to provide sufficient light to enable long distance transmissions to be made. The other disadvantage of LEDs is that they produce what is termed incoherent light that covers a relatively wide spectrum. Typically the spectral width is between 30 and 60 nm. This means that any chromatic dispersion in the fibre will limit the bandwidth of the system.

In view of their performance, LEDs are used mainly in local-area-network applications where the data rates are typically in the range 10-100 Mb/s and transmission distances are a few kilometres. Where higher levels of performance are required, i.e. it is necessary that the fibre optic link can operate over greater distances and with higher data rates, then lasers are used. Although more costly, they offer some significant advantages. In the first instance they are able to provide a higher output level, and in addition to this the light output is directional and this enables a much higher level of efficiency in the transfer of the light into the fibre optic cable. Typically the coupling efficiency into a single mode fibre may be as high as 50%. A further advantage is that lasers have a very narrow spectral bandwidth as a result of the fact that they produce coherent light. This narrow spectral width enables the lasers to transmit data at much higher rates because modal dispersion is less apparent. Another advantage is that semiconductor lasers can be modulated directly at high frequencies because of short recombination time for the carriers within the semiconductor material.

Laser diodes are often directly modulated. This provides a very simple and effective method of transferring the data onto the optical signal. This is achieved by controlling current applied directly to the device. This in turn varies the light output from the laser. However for very high data rates or very long distance links, it is more effective to run the laser at a constant output level (continuous wave). The light is then modulated using an external device. The advantage of using an external means of modulation is that it increases the maximum link distance because an effect known as laser chirp is eliminated. This chirp broadens the spectrum of the light signal and this increases the chromatic dispersion in the fibre optic cable. The fibre optic cables operate because their cladding has a refractive index that is slightly lower than that of the core. This means that light passing down the core undergoes total internal reflection when it reaches the core / cladding boundary, and it is thereby contained within the core of the optical fibre. The light waves received from the transmitter circuit to the fiber optic cable is now transmitted from the source location to the destination and received at the receiver block.

Receiver

Now on the receiver side the **photocell**, also known as the light detector, receives the light waves from the optical fiber cable, amplifies it using the amplifier and converts it into the proper digital signal. Now if the output source is digital then the signal is not changed further and if the output source needs analog signal then the digital pulses are then converted back to an analog signal using the decoder circuit. Light travelling along a fibre optic cable needs to be converted into an electrical signal so that it can be processed and the data that is carried can be extracted. The component that is at the heart of the receiver is a photo-detector. This is normally a semiconductor device and may be a p-n junction, a p-i-n photo-diode or an avalanche photo-diode. Photo-transistors are not used because they do not have sufficient speed.

Once the optical signal from the fibre optic cable has been applied to the photo-detector and converted into an electrical format it can be processed to recover the data which can then be passed to its final destination. The whole process of transmitting an electrical signal from one point to the other by converting it into the light and using Fiber optic cable as transmission line is known **as Optical Fiber Communication.**

Connector basics

The fibre optic connector basically consists of a rigid cylindrical barrel surrounded by a sleeve. The barrel provides the mechanical means by which the connector is held in place with the mating half. A variety of methods are used to ensure the connector is held in place, ranging from screw fit, to latch arrangements. The main requirement is that the end of the fibre optic cable is held accurately in place so that the maximum light transfer occurs. As it is imperative that the optical fibre is held securely and accurately in place, connectors will normally be designed so that the fibre is glued in place, and in addition to this strain relief is also provided. Fibre ends may also be polished. For single mode fibre, the ends may be polished with a slight convex curvature so that the centres of the cables from the two connectors achieve physical contact. This approach reduces the back reflections, although the level of loss may be slightly higher.

Repeaters and amplifiers

There is a maximum distance over which signals may be transmitted over fibre optic cabling. This is limited not only by the attenuation of the cable, but also the distortion of the light signal along the cable. In order to overcome these effects and transmit the signals over longer distances, repeaters and amplifiers are used. Opto-electric repeaters may be used. These devices convert the optical signal into an electrical format where it can be processed to ensure that the signal is not distorted and then converted back into the optical format. It may then be transmitted along the next state of the fibre optic cable.

An alternative approach is to use an optical amplifier. These amplifiers directly amplify the optical signal without the need to convert the signal back into an electrical format. The amplifiers consist of a length of fibre optic cable that is doped with a rare earth mineral named Erbium. The treated fibre cable is then illuminated or pumped with light of a shorter wavelength from another laser and this serves to amplify the signal that is being carried. In view of the much reduced cost of fibre optic amplifiers over repeaters, amplifiers are far more widely used. Most repeaters have been replaced, and amplifiers are used in virtually all new installations these days. Fibre optic transmission of data is generally used for long distance telecommunications network links and for high speed local area networks. Currently fibre optics is not used for the delivery of services to homes, although this is a long term aim for many telcos. By using optical fibre cabling here, the available bandwidth for new services would be considerably higher and the possibility of greater revenues would increase. Currently the cost often this is not viable, although it is likely to happen in the medium term.

Optical fibre construction

Fibre optic technology relies on the fact that it is possible to send a light beam along a thin fibre suitably constructed. A fibre optic cable consists of a glass or silica core. The core of the optical fibre is surrounded by a similar material, i.e. glass or silica, called the cladding, that has a refractive index that is slightly lower than that of the core. It is found that even when the cladding has a slightly higher refractive index, the light passing down the core undergoes total internal reflection, and it is thereby contained within the core of the optical fibre. The Outside the cladding there is placed a plastic jacket. This is used to provide protection to the

 P-ISSN: 2659-1561
E-ISSN: 2635-3040

optical fibre itself. In addition to this, optical fibres are usually grouped together in bundles and these are protected by an overall outer sheath. This not only provides further protection but also serves to keep the optical fibres together.

Optical fibre types

There is a variety of different types of fibre optic cable that can be used, and there are a number of ways in which types may be differentiated. There are two major categories: Step index fibre optic cabling and Graded index fibre optic cabling. The step index cable refers to cable in which there is a step change in the refractive index between the core and the cladding. This type is the more commonly used. The other type, as indicated by the name, changes more gradually over the diameter of the fibre. Using this type of cable, the light is refracted towards the centre of the cable. Optical fibres or optical fibers can also be split into single mode fibre, and multimode fibre. Mention of both single mode fiber and multi-mode fiber is often seen in the literature.

Single mode fiber

This form of optical fibre is the type that is virtually exclusively used these days. It is found that if the diameter of the optical fibre is reduced to a few wavelengths of light, then the light can only propagate in a straight line and does not bounce from side to side of the fibre. As the light can only travel in this single mode, this type of cable is called a single mode fibre. Typically single mode fibre core are around eight to ten microns in diameter, much smaller than a hair.

Single mode fiber does not suffer from multi-modal dispersion and this means that it has a much wider bandwidth. The main limitation to the bandwidth is what is termed chromatic dispersion where different colours, i.e. Wavelengths propagate at different speeds. Chromatic dispersion of the optical fibre cable occurs within the centre of the fibre itself. It is found that it is negative for short wavelengths and changes to become positive at longer wavelengths.

As a result there is a wavelength for single mode fiber where the dispersions is zero. This generally occurs at a wavelength of around 1310 nm and this is the reason why this wavelength is widely used.

The disadvantage of single mode fibre is that it requires high tolerance to be manufactured and this increases its cost. Against this the fact that it offers superior performance, especially for long runs means that much development of single mode fiber has been undertaken to reduce the costs.

Multimode fiber

This form of fibre has a greater diameter than single mode fibre, being typically around 50 microns in diameter, and this makes them easier to manufacture than the single mode fibres. Multimode optical fiber has a number of advantages. As it has a wider diameter than single mode fibre it can capture light from the light source and pass it to the receiver with a high level of efficiency. As a result it can be used with low cost light emitting diodes. In addition to this the greater diameter means that high precision connectors are not required. However this form of optical fibre cabling suffers from a higher level of loss than single mode fibre and in view of this its use is more costly than might be expected at first sight. It also suffers from multi-mode modal dispersion and this severely limits the usable bandwidth. As a result it has not been widely used since the mid 1980s. Single mode fiber cable is the preferred type.

Optical communication networks

Fiber optics links have been extremely installed worldwide. Most long distance (trunk) lines use single mode fiber and increasingly high data rates. A current standard is the 2.488 Gbit/s maximum data of SONET is designed to interface with the replaced existing communication networks that operate at various data rates. The lowest level SONET signal is called the synchronous Transport Signal Level 1 (STS-).,which has a data rate of 51.84 Mbit/s. Higher data rates are achieved by multiplexing N of these data streams up to a maximum of N = 48. SONET uses single mode fiber and different types of light source depending on the range involved. Short reach links (up to 2 km) use light emitting diode (LEDs) or multimode lasers operating at 1.31 m M: intermediate reach links (up to 15 Km) use 50 m W single or multimode lasers transmitters operating at 1.31 m M or 1.55m M. For local area network (LANs) that use LED sources and multimode Fiber Distributed Data Interface (FDDI) standard is common. This is a100 Mbits/s channel that through technological development allows interfacing of a FDDI optical network with twisted pair cable for final connection to transmit/receiver users of the network. In these hybrid systems that electrical connection is typically only the last 100m or so to the user from the fiber base part of the system. The standard for interfacing FDDI network via twisted-pair cables over these typically 10m connections is called the Twisted-Pair Distributed Data Interface (TPDDI).

Advantages of using fiber optics as a communication tool

Although fiber optics can solve data communications problems, they are not needed everywhere. Most computer data goes over ordinary wires. Most data is sent over short distances at low speed. In ordinary environments, it is not practical to use fiber optics to transmit data between personal computers and printers as it's too costly. Electromagnetic Interference is a common type of noise that originates with one of the basic properties of electromagnetism. Magnetic field lines generate an electrical current as they cut across conductors. The flow of electrons in a conductor generates a magnetic field that changes with the current flow.

Electromagnetic Interference does occur in coaxial cables, since current does cut across the conductor. Fiber optics are immune to this EMI since signals are transmitted as light instead of current. Thus, they can carry signals through places where EMI would block transmission.

High Bandwidth over Long Distances

Fiber optics have a large capacity to carry high speed signals over longer distances without repeaters than other types of cables. The information carrying capacity increases with frequency. This however, doesn't mean that optical fiber has infinit bandwidth, but it's certainly greater than coaxial cables. Generally, coaxial cables have a bandwidth parameter of a few MHz/km, where else the fiber optic cable has a bandwidth of 400MHz/km. (These figures are just approximations and do vary from cable to cable!) This is an important factor that leads to the choice of fiber for data communications. Fiber can be added to a wire network so it can reach terminals outside its normal range.

Data Security

Magnetic fields and current induction work in two ways. They don't just generate noise in signal carrying conductors; they also let the information on the conductor to be leaked out. Fluctuations in the induced magnetic field outside a conductor carry the same information as the current passing through the conductor. Shielding the wire, as in coaxial cables can reduce the problem, but sometimes shielding can allow enough signal leak to allow tapping, which is exactly what we wouldn't want.

P-ISSN: 2659-1561
E-ISSN: 2635-3040

There are no radiated magnetic fields around optical fibers; the electromagnetic fields are confined within the fiber. That makes it impossible to tap the signal being transmitted through a fiber without cutting into the fiber. Since fiber optics do not radiate electromagnetic energy, emissions cannot be intercepted and physically tapping the fiber takes great skill to do undetected. Thus, the fiber is the most secure medium available for carrying sensitive data.

Eliminating Spark Hazards

In some cases, transmitting signals electrically can be extremely dangerous. Most electric potentials create small sparks. The sparks ordinarily pose no danger, but can be really bad in a chemical plant or oil refinery where the air is contaminated with potentially explosive vapours. One tiny spark can create a big explosion. potential spark hazards seriously hinder data and communication in such facilities. Fiber optic cables do not produce sparks since they do not carry current.

Low power loss and hence long-distance transmissions

An important aspect of a fiber optic communication is that of extension of the fiber optic cables such that the losses brought about by joining two different cables is kept to a minimum. Joining lengths of optical fiber often proves to be more complex than joining electrical wire or cable and involves careful cleaving of the fibers, perfect alignment of the fiber cores, and the splicing of these aligned fiber cores. For applications that demand a permanent connection a mechanical splice which holds the ends of the fibers together mechanically could be used or a fusion splice that uses heat to fuse the ends of the fibers together could be used. Temporary or semi-permanent connections are made by means of specialized optical fiber connectors.

Ease of Installation

Increasing transmission capacity of wire cables generally makes them thicker and more rigid. Such thick cables can be difficult to install in existing buildings where they must go through walls and cable ducts. Fiber cables are easier to install since they are smaller and more flexible. They can also run along the same routes as electric cables without picking up excessive noise. One way to simplify installation in existing buildings is to run cables through ventilation ducts. However, fire codes require that such plenum cables be made of costly fire retardant materials that emit little smoke. The advantage of fiber types is that they are smaller and hence require less of the costly fire retardant materials. The small size, lightweight and flexibility of fiber optic cables also make them easier to be used in temporary or portable installations.

Disadvantages

Although fibre optic cables offer a far superior performance to that which can be achieved with other forms of cable, they nevertheless suffer from some levels of attenuation. This is caused by several effects.

Loss associated with the impurities: There will always be some level of impurity in the core of the optical fibre. This will cause some absorption of the light within the fibre. One major impurity is water that remains in the fibre.

Loss associated with the cladding: When light reflects off the interface between the cladding and the core, the light will actually travel into the core a small distance before being reflected back. This process causes a small but significant level of loss and is one of the main contributors to the overall attenuation of a signal along an fibre optic cable.

Loss associated with the wavelength: It is found that the level of signal attenuation in the optical fibre depends the wavelength used. The level increases at certain wavelengths as a result of certain impurities.

Though fiber optic cables last longer, the installation cost is high.

The number of repeaters are to be increased with distance.

They are fragile if not enclosed in a plastic sheath. Hence, more protection is needed than copper ones.

Despite the fact that attenuation is an issue, it is nevertheless possible to transmit data along single mode fibres for considerable distances. Lines carrying data rates up to 50 Gbps are able to cover distances of 100 km without the need for amplification.

Conclusion

Fiber optic telecommunications systems make up the backbone of all modern communications networks. Whether voice, data, video, fax, wireless, e-mail, TV or otherwise, fiber optic cables worldwide transport the ever-increasing majority of our diverse information and communications. Fibers are used instead of metal wires because signals travel along them with lesser amounts of loss; in addition, fibers are also immune to electromagnetic interference, a problem from which metal wires suffer excessively. Fibers are also used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces, as in the case of a fiberscope. Specially designed fibers are also used for a variety of other applications, some of them being fiber optic sensors and fiber lasers.

Modern economies and societies rely on the availability, confidentiality and integrity of critical fiber optic network infrastructures to function properly and efficiently.

Conflicts of interest: There is no conflict of interest of any kind.

References

1. Alnajjar Satea Hikmat, Mohd Fareq Abd. Malekb and Mohd Sharazel Razallia. 2013. A Novel Approach for Evaluation of Enhancing Networks. Procedia Engineering, pp53, 497– 503.
2. Alwan, Virek. 2004. The physics behind fiber optics. Fiber Optics Technologies.
3. ARC Electronics. Brief Overview of Fiber Optics Cable Advantages Over Copper. The Basics of Fiber Optics Cable-A tutorial.
4. Arumugam, M. 2001. Optical fiber communication—An overview. Pramana Journal of Physics, 57(5-6): 849-869.
5. Fiber Optics Association. 2004. Understanding Fiber Optics Communications.
6. Goff, David R. 2002. A brief History of Fiber Optics Technology, Fiber Optics Reference Guide, 3rd Ed. Focal Press.
7. Hwang, J.K. and Choi, T.I. 2012. A complex communication network for distribution automation using a fiber optic network and WLANs. International Journal of Electrical Power & Energy Systems, 43(1): 812-817.

P-ISSN: 2659-1561
E-ISSN: 2635-3040

8. Li, X., Yu, J., Dong, Z. and Chi, N. 2013. Photonics millimeter-wave generation in the E-band and bidirectional transmission. IEEE Photonics Journal, 5(1): 7900107-7900107.

9. Malekiha, M., Yang, D. and Kumar, S. 2013. Comparison of optical back propagation schemes for fiber-optic communications. Optical Fiber Technology, 19(1): 4-9.

10. Sheng Li Chung, 2008. Emerging Technology for fibre optic data communication‖ Handbook of fibre optic data communication, III Edition, chapter 25, 2008.

11. Tapanes, E. and Carrol, D. Securing Fiber Optics Communication Links Against Tapping, Fiber Security Link-White Paper.

12. Wu, Z., Schmidt, D. and Lankl, B. 2013. Modulation-format-transparent polarization tracking using a neural network. IEEE Photonics Technology Letters, 25(7): 671-674.

13. Xu, W., Huang, X.G. and Pan, J.S. 2012. Simple fiber-optic refractive index sensor based on fresnel reflection and optical switch. IEEE Sensors Journal, 13(5): 1571-1574.

Citation: Aniefiok O. Akpan. 2020. Optical Fiber: A Tool for Modern Communication. International Journal of Recent Innovations in Academic Research, 4(2): 14-23.