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Recent trend and effect of free space optical communication: Overview and analysis

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Abstract

The Free - Space Optical (FSO) Communication technology is used to transmit the data through light propagation in free space like atmosphere, space, vacuum, or something similar. It is a line-of-sight technology that uses invisible beams of light to provide optical bandwidth connections that can send and receive voice, video, and other information. This wireless mode of communication is anticipated to gain a huge market value in the coming years. In the recent past Free-Space Optical Communication technology proved to be an important replacement to radio frequency communication. Since data gets damaged in a long-distance transmission in Optical Fiber the FSO Communication is considered much better than Optical Fiber Communication. This wireless communications technology such as much higher bandwidth, low probability of intercept for higher security, low power requirements, and much smaller packaging to make them portable so this FSO Communication is anticipated to gain a huge market value in the coming years. It is needed for higher bandwidth as well as fast wireless communication. This paper provides the recent trends and role of FSO Communication in networking and communication systems. A brief description on the purpose of FSO communication and its application. The main effects of the advantages and disadvantages of FSO communication over other types of communications.

Keywords: Free - Space Optical (FSO), Optical communication, Radio frequency (RF), Attenuation, Transmission, bandwidth, Local Area Network (LAN)

1. Introduction

Communication is important to all and communicating effectively is the most important which enables us to get the information and to pass the information. So transferring of information from one place to the other is important. So, communication devices are built to deliver the information accurately in less time. One such communication is Optical communication. Optical communication is a communication to transmit data by using light impulse to carry the information. At the early stage of visual communication fire, smoke, flags, etc. are used which led to the invention of optical communication. In modern fiber-optic communication the electrical signal is converted to optical signals and transmitted through optical fiber, in the destination end the optical receiver receives the optical signal and converts to electrical signal. Since the fiber - optic communication gives hundred times higher bandwidth than ordinary electrical communication it is used in military, governments, industries and in many other places for transmitting the data. Even though it has great speed, higher bandwidth and high carrying capacity it very fragile. If it breaks it is very difficult to fix and there will be a data loss. So these cables are more delicate and cost efficient to install. So wireless communication is needed to overcome this problem.

As Radio frequency (RF) spectrum is overcrowded with respect to increasing throughputs requirements. To avoid spectrum conflict an alternative solution is provided by Free-Space Optical (FSO) Communication. In Free-Space Optical (FSO) Communication data is transmitted in the form of light it needs no medium to travel so it provides high bandwidth, cost efficient, probability of error is less. Since it require no medium to travel it is used to communicate in the space. The installation of Free -Space Optical system is easy and can be done quickly. Unlike radio frequency wave it use invisible rays to transmit which is safe to all. It is used in the place where physical connections are difficult due geographical location or high cost and other considerations. It is also unlimited long range operation and license free. Since it is communicate using light it delivers the data at the speed of the light, it is also power efficient and cost - effective in wireless transmission many industries will use FSO Communication.

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So this communication system is expected to grow exponentially in the upcoming years. Its operating wavelength ranges from 780 nm to 1600 nm. The communication is capable of transferring 1.5 Gbps of data over audio and video communications through air. It requires electrical to optical converter at the senders end and electrical to optical converter at the receivers end. The use distance can be varied between 300 m to 5 km, if it has enough speed and other requirements it can be transmitted from a distance till 11 km.

So in this paper we are going to see about the recent changes in the FSO communication and its effects in the day to day problems and also an overview and analysis of the FSO communication in the future.

2. History of Free - Space Optical Communication

The early stage of communication in a long - distance the information was sent by a person to warn other people of some other danger or to pass some other information, but that way of communication often too slow. So in order to increase the transferring speed of physical information, people started to send the information through air, by using birds like eagle to communicate. In ancient times the information were sent by some instruments, like drums and while some sent the information using fire-smoke signals. By this they can able to communicate nearly a real-time communication in a medium distances. But these systems were used in a limited geographical areas.

In the early form the information was conveyed using the means of visual signals like fire torch, smoke, hydraulic telegraph, semaphores. Using light to carry information to communicate is known as optical telecommunication or optical communication. It all started on 19th February, 1880 at Bell's Volta laboratory in Washington D.C. were Alexander Graham Bell and his assistant Charles Sumner Tainter invented the device photophone. In December 1880, the patent for the photophone was issued. It is a telecommunication device that allows transmission of audio in a beam of light. The photophone was an antecedent to the fiber optic communication systems. In Fiber-optic communication infrared light was used as a source of transmitting data from one end of the fiber to the other end of the fiber. The infrared light is invisible to human eye since it has greater wavelength than red or any other visible light. It is an electromagnetic radiation a form of carrier wave that is used to carry information in the optical fiber. The optical fiber is advantageous over electrical wiring due high bandwidth, to connect long distance, or the ability to withstand to electromagnetic interference. In this way of transmission we can transmit audio and video through local area networks or wide area networks.

The practical use of optical communication system came at the time of conflicts after many decades later. In the year 1904, when German used telegraphy transmitter to transmit during the Herero and Namaqua genocide. And during the World War I when the electrical wire communications were often cut in the trench warfare the German used a type of signal lamp in Morse code called Blinkgerät to communicate, it was used for a distance up to 4 km at day and up to 8 km at night, uses a filters at receivers end to decode the communications. At the end of the war these optical communication system were tested. On May 16, 1960 the first functioning laser was operated. At around

1960s the NASA started experiments which used a laser to communicate between Earth and space. This invention of laser revolutionized free-space optics and many organisations were interested to develop.

3. Free - Space Optical Communication Design

The Free - Space Optical communication system is a compact device that can be installed very easily. The Free - Space Optical communication system depends on transmission of an invisible and eye - safe laser light beams. They are transmitted by the light which through an optical lens and received using highly light sensitive photo - detector, it is placed at the receiver's end and equipped with a telescopic lens. This FSO communication system uses a light which is similar to an infrared TV remote controller as referred in [2].

The FSO communication system has two physical devices a transmitter and a receiver. The transmitter is at the sender's end and the receiver is at receiver's end. These transmitter and receiver are usually placed in a tall buildings or any other tall place to avoid physical obstruction since it is transferred by line of sight communication. Each FSO communication system is connected with a transmitter and a receiver in a full - duplex mode transmission. The Links basically operated between the range 780 - 1600 nm wavelength and use Optical to Electrical and Electrical to Optical converters.

In a FSO communication system there are three main components sender, transmitting medium and receiver. The components at the sender's end are a modulator, a transmitter, a light source. The light source for the optical communication can be a light - emitting diode (LED), semiconductor laser, or several lasers. For short distances like Local Area Network (LAN) the LEDs and semiconductor lasers can be used in FSO communication system. FSO communication system links for larger distances they use a light source which is a vertical - cavity surface - emitting lasers. At the sender's end information is converted into an electrical input of the data. This input is sent through the modulator. The process of a modulator is to encode the given electrical information into transmittable signal.

The transmittable signal are sent through the transmitter. The transmitter converts the electrical signal to optical signal representing 1's and 0's by varying the current flow through the light source. The light source will send the optical signal and the optical signal is amplified using a lens and sent to the receiver's end through the transmitting medium. In most of the FSO communication system the transmitting medium is air but in some cases the transmitting medium is outer space to communicate. Since the FSO communication is transmitted by line of sight there should not be any physical obstruction for the transmitting light.

The components at the receiver's end are a photo - detector, a receiver, a demodulator. The transmitted optical signal through the transmitting medium is collected using a lens and it is detected using a light detector and it is sent to the receiver. The receiver converts the optical signal into electrical signal using a photo - detector and this electrical signal is sent to a demodulator. The process of a demodulator is to recover the original information from the electrical signal.

4. Limitations of Free - Space Optical Communication

Even though Free - Space Optical Communication is more advantageous it has some disadvantage one of the major disadvantage is atmospheric disturbance. As the FSO communication is transferred by line of sight communication any obstruction in the path can affect the transmission. The transmitter and the receiver should be properly aligned while installation. In a clear weather condition it will be able to transmit the data. But any change in weather condition like rain, fog, temperature, etc. then there will be some change in the refractive index which leads to fading of the light intensity also known as scintillation as referred in [2]. Not only the weather conditions but also some of the physical interference like birds, trees, buildings, etc. can also blocks the light transmission which leads to error transmission. There can also be some transmission loss or known as loss due to attenuation, it is reduction of the intensity of the light beam it is due to the spread of beam over a long distance travel in a transmission medium. Transmission can also be loosed by absorption as some of the particles in the atmosphere like water molecules can absorb the signal. Some of the limitations are briefly explained:

A. Physical Drawbacks

Since this communication is a line of sight communication transmitter and the receiver should be properly aligned for the light to travel. Any hindrance in the path of the light transmission led to data loss. Also any birds, flying object, trees, tall buildings, etc. can block the transmitting light. So physical obstruction is main drawback for the FSO communication.

B. Climatic Changes

In most of the cases air is the transmission medium for FSO communication system. Some particles in the atmosphere will absorb the transmitting light which led to attenuation. So climatic changes can affect the light transmission. How different types of climatic changes affects the transmission of light is described below as referred in [4]:

Rain: When it is raining while transmission the water molecules will act like a prism and refract the light and cause attenuation. If the rain gets heavy then the water droplet gets bigger and the transmitted light may get absorbed, scattered, or get blocked. So when it is raining while transmission in FSO communication system the signal sent will get fluctuated.

Snow: Snow has much bigger impact on transmission of light than rain since it is difficult for the light to penetrate and travel through the snow and the signal will get blocked. So it is difficult to communicate with FSO communication system in winter season while it is snowing.

Haze: During hot weather climate the temperature varies and the water gets evaporated and the air contains very small drops of water which makes difficult to see through it. While transmitting light through FSO communication system at that climate some of the light sent will get reflected or refracted and because of that the intensity of the light will be reduced.

C. Environmental Effect

Other environmental effect can also affect the transmission of light like smoke from the industries and dusts from construction sites can also affect the transmitted light. The

transmitted light can also lose its intensity power due to spreading of the light beam over a large distance it is also known as optical beam attenuation. These drawbacks are the major challenge for the future of FSO communication system. So while installing the FSO communication system for first time these limitations are to be considered.

5. Advantages of Free - Space Optical Communication

Communication through Radio Frequency (RF) is congested and even high cost to transmit signals with a small bandwidth and also high cost to get spectrum license. Whereas in Free space optical communication a license free network that delivers with better speed than broadband as it transmit using light it transmit the data at the speed of light. No need of any security system as transmission is done through line - of - sight so it is secured. It is very easy to install and have high bandwidth.

Laser beams are used to transmit the data so electro - magnetic and radio - magnetic waves cannot interfere so it has very low error rate and have high data rate. It has low power requirement for transmission per bit. Since the laser beams are straight and it is invisible to the human eye so it is highly impossible to detect laser beams and it is even impossible to intercept the data transmission the Free - Space Optical Communication so they have more security than any other wireless-based transmission systems. The uses of FSO communication system seems most suitable in a clear weather and short distance link establishment, such as last-mile connections to broadband network supports, and backbone links between buildings in a MAN or CAN surroundings. The advantages of FSO result from the basic features of a laser beam, especially from its high frequency, coherency and low divergence, which lead to efficient transfer of power to a receiver and a high data - carrying ability as referred in [6].

In RF communication the radiation produced are radio waves and microwaves, which is at the low-energy end of the electromagnetic spectrum. If RF radiation is absorbed by the body in large amounts then it can produce heat. This may lead to burns in the body and body tissue will get damage. But in FSO communication system the light used are safe to humans and it is operated between an eye safe ranges. We have seen the limitations of free - space optical communication, it is difficult to over all those climatic and environmental drawbacks but it has some main advantage which is it can be used as a communication device in outer - space. Since it is beyond atmosphere there is no particles to reduce the intensity and there is no climatic changes to affect the transmitted light.

FSO communication system has a wide area of connectivity in fields like the Base Transceiver Stations (BTS) the telephone service and the Local Area Networks (LAN to LAN) connections in the office building using the Gigabit Ethernet or with the Fast Ethernet. It can also use in the confidential networking areas like medical, financial and in military networks with temporary communication like transmission from cameras to large screen connection with Internet access as referred in [1]. Since the FSO communication system is stable and flexible, it is a good communication device for from one building to another building. It is also be used in the last mile problem for connection with optical fiber. The FSO communication system enables a quick recovery in the connections after any damage or any other disasters. And also it can be served as

an additional backup for the optical - cable network, so it will also match with other wireless communication technology.

So, most of the space communication can be communicated with FSO communication system since it has high throughput space station can also communicate with FSO communication system. The space communication is all about its security, speed in communication and no error in communication. FSO communication system is secured and have high bandwidth also it has very low error rate and have high data rate. Transmission is also done at the speed of light, So FSO communication system can be used in the space communication in the future for better and safe communication.

6. Future of Free-Space Optical Communication

Since the FSO communication system is more advantageous than RF communication mainly because of its license free network and have high bandwidth at the speed of light. These advantageous made most of the industries, companies and even military troops too are shifting towards the FSO communication system and to improve their technology. Since the laser beams are straight and it is invisible to the human eye so it is highly impossible to detect laser beams and it is even impossible to intercept the data transmission the Free - Space Optical Communication so they have more security than any other wireless-based transmission systems. This has been developed in response to a growing need for high - speed and tap - proof communication systems as referred in [6].

The next generation (NG) optical technologies will unveil certain unique features, namely ultra - high data rate, broadband multiple services, scalable bandwidth, and flexible communications for manifold end-users. Among the optical technologies, free space optical (FSO) technology is a key element to achieve free space data transmission according to the requirements of the future technologies, which is due to its cost effective, easy deployment, high bandwidth enabler, and high secured as referred in [5]. If the data is converted into an encoded form and transmitted in an encrypted connection then it will highly be increasing the security level. It is easy to install initially with high transmitting power in a very relatively low cost. And it can also rapidly installed in tall infrastructure to avoid any physical obstruction. Military troops usually do not stay at one place permanently they will have to move from one place to other so in that case wired communication is difficult and often cut. So militaries can adopted this FSO communication system which makes easier to communicate in areas like those. Many scientific labs like space research lab requires error - less communication and need speed for transmitting the data. So FSO communication system can also be adopted in these labs as it has very low error rate and as it transmit using light it transmit the data at the speed of light. It can also improve their technology in the space research. Thus, the FSO communication system can be applied in every industries for better communication system. The FSO communication system is transferred by line of sight communication so it has some limitation while transmitting in the atmosphere like any obstruction in the path can affect the transmission. But in the outer space the FSO communication system can transmit the light without any hindrance. Since nowadays most of the satellites are sent far from earth so FSO communication can be used to

communicate such situation and it may also improve the space technology because of its faster transmission.

The main problem in the Free - Space Communication system is to increase and to maximum the distance among transmitter and receiver and also to maximum their operational range. In the upcoming days, the FSO communication system's infrastructure must be able to modify to the 5th - generation (5G) and also the 6th - generation (6G) standards with the employment of high - speed detectors. Currently the FSO communication is best and secured way to communicate so many industries and companies are showing their interest to buy the FSO communication system. If the FSO communication system overcomes all the challenges it faced we can say that the FSO communication has an exponential growth in the upcoming days. So, the market rate and economic growth of the FSO communication system is expected to rise exponentially in the future [7].

Further, readers/ researchers are suggested to refer articles [8-18] to know more emerging technologies and their uses in many useful sectors. The researcher can find a research problem from these articles for their research work and continue towards to solve the respective problem for the betterment of society.

7. Conclusion

As we seen in this paper the Free - Space Optical (FSO) Communication technology will use the LED or the LASER light to transmit the data through light propagation in free space like atmosphere, space, vacuum, or something similar. Since it is a line-of-sight technology that uses invisible laser beams of light to provide optical bandwidth connections that can send and receive voice, video, and other information but any obstruction in the path can affect the transmission of light. In the recent past Free-Space Optical Communication technology proved to be an important replacement to radio frequency communication because the communication through Radio Frequency (RF) is congested and even high cost to transmit signals with a small bandwidth and also high cost to get spectrum license. Whereas in Free space optical communication a license free network that delivers with better speed than broadband as it transmits using light it transmit the data at the speed of light. Since data gets damaged in a long distance transmission in Optical Fiber the FSO Communication is considered much better than Optical Fiber Communication. Most of the companies and industries are shifting towards optical communication because of its speed in transmission, less error in transmission, cost - effective, easy to install, high bandwidth and high data rate. Military troops are also showing interest toward optical communication because the wired communication are often cut.

This wireless communications technology such as much higher bandwidth, low probability of intercept for higher security, low power requirements, and much smaller packaging to make them portable. So this FSO Communication is anticipated to gain a huge market value in the coming years. It is needed for higher bandwidth as well as fast wireless communication. FSO communication system are also will be used in outer - space communication because of its light speed in transmission and less error rate. Since nowadays most of the satellites are sent far from earth so FSO communication can be used to communicate such situation and it may also improves the space technology

because of its faster transmission. Currently the FSO communication is the best and secured way of communication. If the FSO communication system overcomes all the challenges it faced we can say that the FSO communication has an exponential growth in the upcoming days. Thus, the FSO communication system can be applied in every industries for better communication system

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