

# DETRIMENTAL EFFECT OF WEATHER CONDITIONS ON FSO BASED SYSTEM SURVEY

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## ABSTRACT

Over the last two decades Free Space Optical (FSO) communication is preferred over the radio frequency communication and microwave systems because of its license-free long-range operations, small size, high bandwidth, low cost, no need of licenced frequency, absence of radiation hazards and immunity to interference. Free Space Optical communication has few limitations also like beam dispersion, scintillation. A well-known limitation of FSO is the effects of weather conditions on it. As we know that the free space optics is highly affected by the various atmospheric conditions which degrade the performance of FSO link. This paper includes the effect of the fog, snow, rain and Scintillation over the FSO links. This paper tells us how we can improve the performance of FSO by eliminating the effects of atmospheric conditions on the signal.

**Keywords:** Radio Frequency (RF), Vertical Cavity Surface emitting laser (VCSEL), Dense Wavelength Division Multiplexing (DFWDM), Bit error rate (BER).

## 1.INTRODUCTION

Free Space Optics uses the same principle and has the same capabilities as that of fiber optics, but at a lower cost, long range operation, high security and very fast deployment speed. FSO is a wireless communications technology which utilizes light for the transmission of data through the air in the similar manner as the fiber optics uses a fiber cable. Free Space Optics (FSO) works on the principle of laser driven technology which uses light sources and detectors to transmit and receive information, through the atmosphere same as Fiber Optic Communication (FOC) link. The motivation for FSO is to eliminate the effort of installing fiber optic cable, time, cost and yet maintaining the data rates upto 1gb/s and beyond for transmission of voice, video and data services. FSO technology transmission is very simple. There are two systems each has an optical transceiver. Optical transceiver consists of a laser transmitter and a receiver to provide full duplex capability. Each FSO system uses a high-power optical source (e.g. LASER or LED) plus a telescope that transmits light through the atmosphere to another telescope that receives. The receiving telescope connects to a high-sensitivity receiver (APD or PIN) through an optical fiber. FSO is an optical communication technology that uses light propagating in free space to transmit data between two stations. The technology is useful where the physical connection by the means of fiber optic cables is impractical. Free space optics (FSO) communication links have some distinct advantages over conventional microwave and optical fiber communication systems because of their high carrier frequencies, large capacity, enhanced security, high data rate. In fiber optic communications data is transmitted by modulated laser light containing the pulses of light within a glass fiber but in FSO these are transmitted in a narrow beam through the atmosphere. FSO systems are being considered for military systems because of their inherent benefits as most of the systems are rated for greater than 1 km in three or more lasers operating in parallel to mitigate distance-related issues. The stability and quality of the FSO link is highly dependent on atmospheric factors such as rain, fog, dust, snow, rain, heat and scintillation.

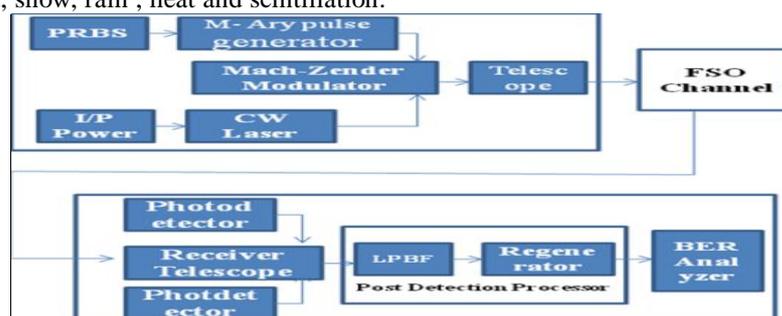


Figure 1 Block Diagram of FSO

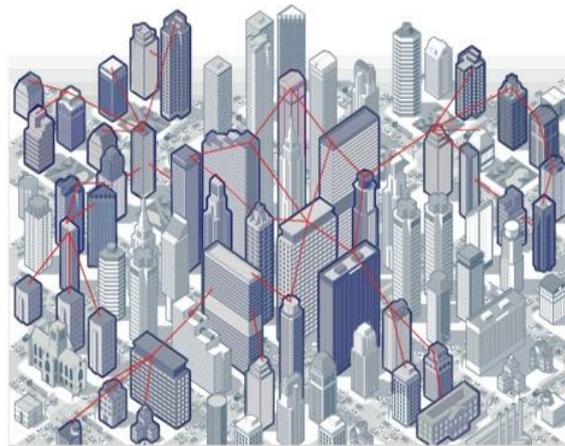


Figure 2 How FSO works

## 2. LITERATURE REVIEW

### 2.1 FSO—PRINCIPLES AND CLASSIFICATION

Based on the distance covered for communication FSO systems can be classified into indoor and outdoor FSO communication. A FSO system consists of a transmitter which is a modulated laser or light emitting diode (LED) which produces light for conveying data through space and a receiver such as an avalanche photo-diode or PIN which receives data close to collimated radiation independent of the transmitter pointing concentrated lens. Different components used in transceiver are solar radiation filters beam control optics, collection lens, optical amplifier and other electronics. Many indoor communication systems use only laser diode as light sources. The basic operating principles of indoor point to point systems and outdoor communication links are almost same but the designs can be different to accommodate various requirements. Some transmitter and receiver designs for long-range and short range FSO communication systems are satellite and atmospheric optical communications.

#### 2.1.1 INDOOR FSO COMMUNICATION

Indoor FSO applications are appropriate to optical FSO systems that use wide divergence beams rather than narrow beams because these are confined to short distances which are suitable for point to point systems. These communication links can be classified as point and shoot links which are subdivided into infrared data association and retro-reflect links; and communication networks have two types namely the diffuse networks and line of sight networks. Such systems are also called as optical tele-point systems. Due to this fact atmospheric conditions do affect the indoor FSO systems, the power budget depends solely on the transmitter launch power, receiver sensitivity, and free space loss. Over the decades short-range wireless communications are using the infrared frequencies which have received extensive interest, and many potential applications of this technology have been suggested. Many applications include portable device such as laptop computers, portable telephones, and personal digital assistants. A high speed and power efficient indoor wireless infrared communication using code combining, where a multiple transmitter link design was used with a narrow field of view direction diversity receiver are used with pure diffuse link. The main goal was to eliminate the effect of inter symbol interference which can increase the data rates so that power efficient signaling schemes such as DPPM can be employed. A portable transceiver employs a transmitter of infrared LEDs and a receiver of photodiode arrays with multi-channel trans-impedance-summer architecture. The signal at receiver side achieved a BER of  $10^{-4.1}$  at a distance of 2 m away from the transmitter, even at a point 50 degree off the vertical axis of transmitter. The bit rate of the transceiver in an indoor non-directed infrared FSO link was up to 41 Mbit/sec to be extended to 105 Mbit/s using infrared LEDs with higher cut frequency.

#### 2.1.2 OUTDOOR FSO COMMUNICATION

The outdoor link uses an atmosphere as its natural medium of communication covers a long distance over 500 m. Sometimes due to atmospheric channel degradation long distance point-to-point systems will exceed the 4-5 km range. These systems use very high power lasers that operate in the Class 3B eye safety band to achieve optimum power link budget, which is high bit rate (e.g., 155 Mb/s). In order to improve a power budget, a trial 155 Mb/s link that covers a 4 km distance is used. The goal was to minimize the overall propagation loss and the receiver sensitivity as little could be done to reduce the losses. An erbium doped fiber amplifier (EDFA), a low power laser, was used as the source. Two astronomical telescopes named Schmidt-Cassegrain, 20 cm aperture and Avalanche photodiode was used. The results were as follows that the diameter was reduced to 0.5 m at the receiver which corresponds to 8 dB free space loss from a beam diameter of 2 m (20 dB free space loss). The main problem was to maintain the beam alignment which depends

on temperature. APD receivers are relatively costly but they helped to improve the receiver sensitivity and they are generally used for long distance systems. FSO is very beneficial for inter-satellite and deep-space communications but it can also be used in ground-to-space link, among mobile and stationary terminals, and Unmanned-Aerial-Vehicle to ground link. Other applications include quantum key, traffic management and telematics.

## **2.2 FSO- TECHNOLOGICAL ADVANTAGES**

The near infrared electromagnetic spectrum has a wavelength range of (800 nm and 1700 nm ) used in optical communication which often implies extremely high bandwidth, therefore higher data rates compared to other communication media. Also this technology requires no spectrum licensing requirements i.e. traffic free bands, no mutual interference between the FSO systems , no Fresnel Zone requirement and difficult to eavesdrop while transmitting data. This has been possible because the two optical technologies offer high speed bandwidth to meet demands. Same optical transmission wavelength (800 nm – 1700 nm) has been used in both of them. Also, two optical technologies both share the same system components and can transmit digital information using a particular range of protocols. The advantages of FSO communications include the reduction of cost incurred on fiber-optic cable, as well as time taken for deployments. The disadvantage of FSO communication link is that it is affected by atmospheric attenuation owing to aerosol particles such as fog, rain, haze and snow which causes fluctuations in the received light signal hereby limiting the availability of FSO and increasing the systems bit error rate. These includes the accumulation mode with particle diameters  $0.1 \mu m \ll 2.5 \mu m$ , the fine mode with diameter, less than  $2.5 \mu m$ , and the coarse mode with diameter  $> 2.5 \mu m$ . These particles shrink by evaporation as humidity decreases and grow in size in regions of high humidity. The atmospheric effects in the channel on laser beam propagation can be determined using the Mie theory which depends on the wavelength and size of particles.

## **3. CHALLENGES**

### **3.1 DIFFERENT WEATHER CONDITIONS**

Performance of FSO is affected by different weather conditions. There are different weather conditions like clear weather, rain, snow, fog etc. Each of these conditions is explained below.

**3.1.1 Clear Weather Condition:** When there is a clear weather; as we all know there very less attenuation or its amount is negligible. The amount of attenuation in the clear weather is from 0 to 3 dB/km.

**3.1.2 Rain Condition:** Rain has a distance-reducing impact on FSO, although its impact is significantly less than that of other weather conditions. This is because the radius of raindrops (200–2000 $\mu m$ ) is significantly larger than the wavelength of typical FSO light sources. Typical rain attenuation values are moderate in nature. For example, for a rainfall of 2.5 cm/hour, a signal attenuation of 6 dB/km can be observed. There are two conditions of Rain i.e. light rain & heavy rain.

**3.1.3 Snow Condition:** Snowflakes are ice crystals that come in a variety of shapes and sizes. In general, snow tends to be larger than rain. Whiteout conditions might attenuate the beam, but scattering doesn't tend to be a big problem for FSO systems because the size of snowflakes is large when compared to the operating wavelength. The impact of light snow to blizzard and whiteout conditions falls approximately between light rain to moderate fog, with link attenuation potentials of approximately 3 dB/km to 30 dB/km.

**3.1.4 Fog Condition:** Fog is the most detrimental weather phenomenon to FSO because it is composed of small water droplets with radii about the size of near infrared wavelengths. The particle size distribution varies for different degrees of fog. Weather conditions are typically referred to as fog when visibilities range between 0– 2,000 meters. Because foggy conditions are somewhat difficult to describe by physical means, descriptive words such as "dense fog" or "thin fog" are sometimes used to characterize the appearance of fog.

**3.1.5 Scintillation:** The variation of refractive index along the propagation path caused by slight temperature variations among different air pockets. It Acts like series of small lenses that deflect the beam into and out of the transmission path. It causes amplitude fluctuations at the receiver. It Can impact BER performance ,increases with distance. Therefore for long distance communication Multiple beam technology is used.

**Table:1** Attenuation for different conditions

Condition	attenuation
Clear weather	0.2 to 3 db/km
Rain	4 to 17 db/km
Snow	20 to 30 db/km
Light fog	40 to 70 db/km
Heavy fog	80 to 200db/km

## 4 FUTURE SCOPE

### 4.1 Light Point

Light Point's FSO products have multi-beam sending process. It overcomes atmospheric degradations and temporary beam obstructions by overlapping redundant infrared beams.



**Figure.3** Light point

### 4.2 AirFiber

Wireless communication can be made possible in any weather by combining FSO with Airfiber's products. AirFiber's products combine FSO with 60 GHz millimeter-wave.



**Figure.4** AirFiber

### 4.3 Terabeam

Terabeam's FSO products have advanced beam-steering features that update beam direction up to 300 times per second.



**Figure.5** Terabeam

#### **4.4 Improvement by Using Optical Interconnects and Amplifiers**

Opto-electronic devices when combined with fso promise large interconnection density, high distance bandwidth product, low power dissipation and superior crosstalk performance at high speeds. Optoelectronic devices are electrical-to-optical and optical-to-electrical devices that source, detect and control light. Interconnects like vertical cavity surface emitting lasers (VCSELs) enable high speed FSO. VCSEL is a laser diode that revolutionizes fiber optics communication by improving efficiency and increasing data speed. These emit energy at 850nm and 1300nm correspond to IR portion. Materials used are Gallium arsenide (GaAs), aluminium gallium arsenide (AlGaAs), Indium gallium arsenide nitride (InGaAsN). The VCSELs operate at 850nm with - divergence angle and the detector aperture is 80 80  $\mu\text{m}$ . Laser drivers, receivers (amplifiers), and router circuits are integrated on silicon chips and are included in the systems. Data can be fed to electrically to any of the silicon chips and routed to the VCSELs through driver circuits and can be readout electrically from each silicon chip independently. It has many advantages like it is easy to test, more efficient and have cheaper manufacturing. It has less current requirement to produce a coherent energy output. It emits a narrow circular beam which makes it easier to get the energy from the device into an optical fiber. Generally, today's FSO systems operate in the near wavelength range between roughly 750 nm to 1600nm. Usually we use 1550nm because of its different features such as it is compatible for long distances and gives us high data rates.

#### **4.5 Advanced DWDM FSO System**

This is one of the attractive applications in FSO. In this scenario, various kinds of wireless signals can be transmitted using DWDM full optical FSO links. Using DWDM we can get a good transmission over distances. DWDM is a technology that puts data from different sources together on an optical fiber, with each signal carried at the same time on its own separate light wavelength. Using DWDM, up to 96 wavelengths or channels of data can be multiplexed into a light stream. It is a technique for increasing the bandwidth of an optical network communication. The bandwidth is carved up into wavelength channels, each of which carries a data stream individually. There are different architectures used for implementing this technique.

### **5. CONCLUSION**

Optical wireless communication systems are among the most secure networking transmission technologies the future will require higher and higher bandwidth solutions to meet the needs of corporations and individuals. Free-Space Optics can meet these needs and will be used in an ever-increasing way to provide these solutions in the future. Cost effective alternatives for WAN required for providing secure and redundant links between different resources. FSO systems offer a viable solution toward building optical connectivity in a cost-effective, quick, and reliable manner in certain situations. With its cost effective and high bandwidth qualities optical wireless operates in the near infrared wavelength range as an alternative transport technology to interconnect high capacity networking segments. Optical wireless light beam is difficult to intercept because the information is not spread out in space but rather kept in a very narrow cone of light.

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