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# Basic Concept of Free Space Optics Communication (FSO): An Overview

Piyush Singhal, Priyanka Gupta, Prashant Rana

***Abstract*—Now a days the wireless technology has become popular in the wireless system. FSO is a technology that uses the visible to near infrared (NIR) light propagating through the atmosphere to transmit information. FSO communications are attracting attention as the contemporary engineering science to resolve the last mile bottleneck issues in local area access networks due to their high bandwidth, low cost implementation in a non-licensed spectrum, relatively low power using up and security compared with RF technologies. Equally we know that the free space optical communication is extremely impressed by the various atmospheric conditions which cause the degradation of the carrying out of FSO link. This report introduces the study of the issue of the various atmospheric conditions on the FSO link. This report includes the result of the fog by analysis the various fog models such as Kim Model, Kruse Model. And also analysis the wet and dry snow over the FSO links.**

***Index Terms*— APD, FSO (Free space optics), LED, LD, PIN.**

## I. INTRODUCTION

The Free Space Optical (FSO) communication also known as Wireless Optical Communication. During recent years, there has been faster growing interest in free- space optical (FSO) communication. FSO is a technology that uses the visible to near infrared (NIR) light propagating through the atmosphere to transmit information. The FSO communications are attracting attention as the contemporary engineering science to resolve the last mile bottleneck issues in local area access networks due to their high bandwidth, low cost implementation in a non-licensed spectrum, relatively low power consumption and immunity and security compared with RF technologies. FSO is basically the same as fiber optic transmission. The conflict is that the laser beam has been applied and shipped through the aura from the sender, rather than run through optical fiber [1]. The chief cause of FSO attenuation is due to the alterations in the atmosphere because atmospheric channel is non stable. Still, the composition of the ambiance, particularly, aerosols (fog, fume, debris) has Similar particle size distributions when compared to optical wavelengths in FSO. This can potentially result in breaking up and absorption of visible and NIR optical beams, therefore degrading the FSO link performance and its availability [2-3]. In lodge to provide solution to last mile problem we can use free space laser communication in mesh nets to bring higher bandwidth quickly to the clients.

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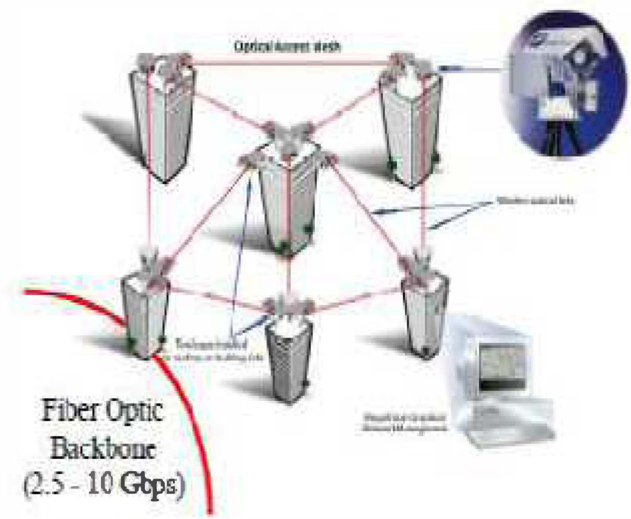


Fig 1: FSO laser Communication Link

Section II denotes FSO Communication system. Section III describe various FOG attenuation models of FSO. Section IV explain snow attenuation in FSO. Section V mentioned rain attenuation in FSO and conclusion is followed by Section VI.

## II. FSO COMMUNICATION SYSTEM

FSO communication works on line of sight technology that utilizes a laser beam by sending the very high bandwidth data from one level to another through atmospheric channel. This can be accomplished by applying a modulated narrow laser beam by transmitted through the transmitting antenna in the atmosphere and subsequently received at the receiver antenna. FSO system is illustrated as:

### A. *Transmitter*

Transmitter transforms the electrical signal to an optical signal and it regulates the laser beam to transmit data signals to the recipient through the atmospheric channel. The transmitter consists of four characters as indicated in Fig.: 2

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laser modulator, driver, and optical source and transmit telescope.

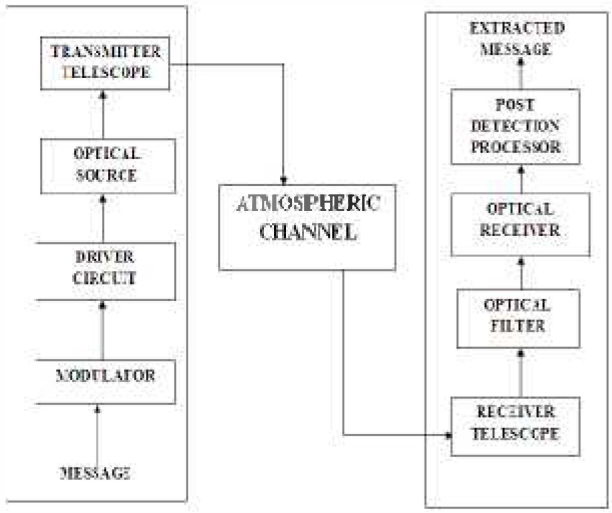


Fig 2: FSO Communication Subsystem

1) In Laser modulations the data were extended by a laser source. This technique implemented in two common methods first internal modulation and second external modulation [4]. The procedure which passes in the laser resonator is known as internal modulation and it depends on the change the additive components and intensity of the laser beam according to the data signal. In the external modulation occurs outside the laser resonator and it depends on the refractive dual phenomenon and polarization phenomena.
2) Driver circuit is used to convert the electrical signal to optical signal by varying the current which goes through the light source.
3) Optical source converts the electrical signal to an optical signal. It may a laser diode or light emitting diode in which a laser diode produces optical radiation by the stimulated emission and also laser diode emits light that is highly non-chromatic and very directional i.e. The laser diode has a narrow spectral width and small beam divergence angle. There are II cases of laser diode ND: YAG solid state laser and Fabry- Perot and distributed-feedback laser (FP and DFB) [5]. The selection for laser diode in FSO communication depends on various matters. These include [6].
   - Price and availability of ingredients.
   - Transmit power, lifetime.
   - Modulation capabilities.
   - Eye safety.
4) Transmitter telescope is used to collect and climates, directs the optical signal in the direction of the receiver telescope i.e. at the opposite end of the channel.

### B. *FSO channel*

In FSO links to collect is the climates, on medium. The aura consists of serial publication of numerous gas layers surrounding the globe. The atmospheric layers are the homosphere, troposphere, stratosphere and mesosphere [7]. These layers are separated by their temperature gradient with respect to the height. In FSO communication, we are concerned in the troposphere because this is where most weather phenomena occur and FSO links operate at the lower portion of this layer [7]. The troposphere is primarily composed of nitrogen (N2, 78%), oxygen (O, 21%), and argon (Ar, 1%), but there are a number of other factors also such as water (H2O, 0 to 7%) and carbon dioxide (CO, 0.01 to 0.1%), present in diminished measure. Besides these there are other small particles also such as haze, fog, dust, and soil [8] that contributed to the constitution of the air. The propagation characteristics of FSO through atmosphere drastically change due to the communication environment, especially, the effect of weather condition is substantial. The principal effects on optical wireless communication are absorbed, breaking up, and scintillation [9].

### C. *Receiver*

The receiver optics consist of five sections as indicated in Fig. 2: receiver telescope, optical filter, detector, amplifier and demodulator.

*1)* In the receiver telescope, it collects and focuses the incoming optical signal along the photo sensor. Larger the receiver telescope, then it takes in more multiple uncorrelated radiation and focuses their average on the photo detector [10].
*2)* By inserting the optical filters that will allow mainly energy at the wavelength of interest to impinge on the detector and reject energy of unwanted wavelengths, the essence of solar illumination can be significantly minimized.
*3)* The sensor is a semiconductor device which changes the light energy into an electrical signal. The diodes are generally capacitive charged and turn back-biased [11]. The two most commonly used photodiodes are the pin photodiode and the avalanche photodiode (APD) because they have good quantum efficiency and are made of semiconductors that are widely and easily available at commercially [12].

## III. VARIOUS FOG ATTENUATION MODELS OF FSO

### *A. Basics of Fog Formation*

Fog can be depicted as a swarm of little molecules of water, smoke, glass or a combination of these near the earth's surface, thereby scattering the incident light and thus bringing down the visibility [13]. Fog forms when the difference between temperature and dew point are (5 °F) 3 °C, or less and water vapour in the air start to condense into liquid water while relative humidity reaches to 100%. The establishment of a fog layer occurs when a moist air mass is cooled to its saturation point (dew point). This cooling can be the result of Advection fog), radiation fog, frontal fog and upslope fog. Valley fog forms as an outcome of air being radioactively cooled thereby becoming denser than its surroundings and starts running down the slope creating a puddle of cold air at the valley floor, resulting in fog formation, if the air becomes cold enough to progress to its dew point. The most commonly encountered fog types in nature are Advection and Radiation fogs.

### *B. Fog Attenuation Model*

Fog is the most critical attenuation factor among all atmospheric attenuation factors of FSO. Mie scattering is used to calculate attenuation in case of fog droplets. Nevertheless, it requires information of various fog parameters such as particle size distribution, refractive index, particle size, etc., which may not be readily usable at a special location of facility. Moreover, it involves complex computations [14]. Another path is to use visibility data to predict specific attenuation. This model Kruse, Kim, [15-17] use this approach and predict specific attenuation using visibility. The specific attenuation for Kruse is made by:

$$\gamma(\lambda) = \frac{3.912}{V}\left(\frac{\lambda(nm)}{550(nm)}\right)^{-q} \tag{1}$$

The coefficient q depends on

$$q = \begin{cases} 1.6 & V > 50\,km \\ 1.3 & 6\,km < V < 50\,km \\ 0.585V^{1/3} & V < 6\,km \end{cases} \tag{2}$$

Where V is visibility in km and λ is wavelength in nm and $(\lambda)$ represents specific attenuation. Kim et al rejects such wavelength dependent attenuation for low visibility in dense fog. The q variable in eq. (1) For Kim model is made by:

$$q = \begin{cases} 1.6 & V > 50\,km \\ 1.3 & 6\,km < V < 50\,km \\ 1.6V + .34 & 1\,km < V < 6\,km \\ 0.5 & 0.5\,km < V < 1\,km \\ 0 & V < 0.5\,km \end{cases} \tag{3}$$

## IV. SNOW ATTENUATION IN FSO

Snow effect the FSO by scattering of the light wave and the laser beam power which is attenuated due to loss in receiving signal strength level. When the received signal level decreases either bit errors occurs or complete link failure [18]. The quantity of light attenuation is proportional to the figure and size of fog, rainfall and snow particles [19-20]. Since the size of snowflakes is generally larger than rain drops, the received signal strength fluctuation will be larger [21] and can cause link failure [22-23]. Whenever the laser ray of light goes on through the nose candy, then the received signal power will depend upon the expanse of the snow particle and separation from the transmitter as good as on the location of snow particle relative to the beams cross section. The FSO attenuation due to snow is calculated for both dry and wet snow. If snow rate in mm/hr is represented by S then specific attenuation in dB/km is given by [24].

$$\alpha_{snow} = a.S^{b} \tag{4}$$

If λ is the wavelength, a and b are as follows for dry snow

$$a = 5.42\times 10^{-5}\times\lambda + 5.4958776,\ b = 1.38 \tag{5}$$

The same parameters for wet snow is given by as Follows

$$a = 1.023\times 10^{-4}\times\lambda + 3.7855466,\ b = 0.72 \tag{6}$$

## V. RAIN ATTENUATION IN FSO

Rain is formed by water vapour contained in the atmosphere. It consists of water droplets whose form and number are variable in time and place. Their form depends on their size: they are considered as spheres until a radius of 1 mm and beyond that as oblate spheroids: flattened ellipsoids of revolution [7]. Scattering due to rainfall is called non-selective scattering, this is because the radius of raindrops (100– 1000 μm) is significantly larger than the wavelength of typical FSO systems. The laser is able to go through the raindrop particle, with less scattering effect occurring. The haze particles are really low and stay longer in the air, but the rain particles are really great and stay shorter in the aura. This is the main reason that attenuation via rain is less than haze. An interesting detail to bank bill is that RF wireless technologies that use frequencies above approximately 10 GHz are adversely affected by rain and little affected by fog. This is because of the close match of RF wavelengths to the radius of raindrops, both being larger than the moisture droplets in the fog [6]. The rain scattering coefficient can be calculated using Stroke Law see Eq. (13) [26]:

$$\beta_{rainscat} = \pi a^{2} N_a Q_{scat}\left(\frac{a}{\lambda}\right) \tag{6}$$

Where:
a= is the radius of a rain drop, (cm).
$N_a$= is the rain drop distribution, $(cm^{-3})$.
$Q_{scat}$ = is the scattering efficiency.

The rain drop distribution $Na$ can be estimated utilizing the equivalence:

$$N_a = \frac{R}{1.33(\pi a^{3})v_a} \tag{7}$$

Where, R= is the rain fall rate, (cm/sec).
$v_a$= is the limit speed precipitation.

It is given as a shot:

$$v_a = \frac{2a^{2}\rho g}{9\eta} \tag{8}$$

Where: $\rho$ = is water density, ($\rho = 1g/cm^{3}$)

## VI. CONCLUSION

The work of various weather effects on the FSO link is very significant in parliamentary procedure to predict the efficiency of the FSO communication system. The study of these effects is caused along the ground of the attenuation coefficient. Attenuation is defined as the loss of signal in the received power as transmitted through space. Through the subject of fog effects more have been considered with the aid of the various good examples such as the Kim model, Kruse model. The consequence of snow is analysed by considering the dry and wet snow. It has been noticed that fog attenuation doesn't have the wavelength dependency for the visibility distance greater than 10 kilometre. For snow attenuation it has been resolved that it increases with the increase in the snow rate and the rain attenuation also increases with the increase in the rain rate... These studies have practical importance in designing of wireless mesh in diverse terrain and environment condition.

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