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The Attenuation of Free Space Optical Communication under Dusty Conditions in Lahore

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Abstract: FSO (free space optical) communication is one of the most advanced modes of wireless communication. FSO is a line of sight communication which is used to convey data from an optical transmitter to an optical receiver through atmosphere. FSO offers higher data rates but fading level due to atmospheric effects (like sand, dust, fog, rain, snow etc.) are higher than RF (radio frequency) technology. The atmosphere affects the laser beam passing through it. The atmospheric turbulence and scattering results in the degradation of the signal. In this research paper is focused and analyzes the variations in the visibility and attenuation with respect to the concentration of aerosol particles (suspended elemental particles) is done. This research work is conducted and dust model is designed in the atmosphere of urban area of Lahore city. The model deals the effect of the size of the dust particles on the visibility of FSO link and suggests a formula for the calculation of attenuation generated in the link.

Keywords: Free Space Optical (FSO) Communication System, Concentration, Visibility, Attenuation

1. INTRODUCTION

FSO is a line of sight (LOS) communication technology which is used to transmit data in atmosphere (Sheikh Muhammad *et al,* 2005). FSO uses LASER beam to transmit data. LASER stands for light amplification by stimulated emission of radiation. It works in visible and near infrared electromagnetic spectrum (Jassim *et al,* 2013). FSO transmits very narrow and directed beam of light from an optical transmitter to an optical receiver. It contains no side lobes (Trivedi, *et al,* 2013). FSO has large advantages like large bandwidth, being license free, being light weight, secure, insensitivity to interference and having easy installation (Khaleel *et al,* 2010). FSO is lower in cost as compared to other technologies (Abdul *et al,* 2014). The strength of the signal weakens when propagates through the free atmosphere. The atmosphere interacts with light due to the presence of aerosol particles in the air (Ali *et al,* 2013). The Lahore is an urban and busiest city of Pakistan. The population of the city is more than 10 million and is increasing day by day. In recent years, a group of Pakistani and USA scientists analyzed the outdoor suspended particles by taking the samples of air from different locations of Lahore. The elemental concentration in microgram/cubic meter of different elements (like Zn, Pb, Ni etc.) was found by the help of Atomic Absorption Spectroscopy method (Ahmad *et al,* 2014). The concentration of suspended particles reduces the visibility when the visibility of signal reduces, the attenuation of the signal increases of the signal. Due to Due to increase in attenuation the strength of signal weakens and transmission affects.

In this paper, the relationship between concentration of suspended elemental particles in air and visibility of a signal is found and analyzed. In simulation analysis, the concentration and visibility relation of different locations is analyzed. Similarly, visibility and attenuation relation while concentration of a particle and attenuation relationship is also analyzed and discussed. Further, the variation of optical attenuation of a signal with respect to visibility is also discussed. This research paper is subdivided in to 3 sections.1st section have introduction and related literature reviewed. In section 2 research methodology is discussed. Section 3 deals with Simulation charts and analysis. In the end conclusion and future work is mentioned.

2. MATERIALS ANDMETHODS

In FSO communication, the optical signal propagating through a free space channel is very sensitive to atmospheric conditions such as dust, sand, fog, snow and rain etc. The interaction between photon and the molecular constituents because some of photons to extinguished whereas the particulate constitute of the scattered photons. This process describes two phenomena: a. Absorption. Scattering.

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2.1 Absorption:

The absorption takes place when an interaction between a propagating photon and molecules present along its path occurs. A higher photon is absorbed when quantum state of molecule is excited to high energy state.

2.2 Scattering:

This phenomenon occurs when a light photon strikes the photon and re-radiate. This process depends upon the radius of particle encountered during propagation. The size parameter $X_0=2\pi r_p/\lambda$ where λ=wavelength, r_p= radius of particle.

Rayleigh scattering: If $X_0 << 1$, the scattering process is Rayleigh scattering.

Mie-Scattering: If $X_0 >> 1$, the scattering process is Mie-scattering.

2.3 Dust and Visibility:

The largest concentration of dust above 1-2 km above the surface of ground is of prime importance. In this paper, the urban model of dust is considered in which dust is produced due to industrial application.

The air is composed of dust, sand, elemental loading and mineral particulates. The minerals particulates (Silica and Quartz etc.). The particulates are majorly of two categories:

A. Coarse Particulates (2.5-10 micrometer),

B. Fine Particulates (less than 2.5 micrometer)

Coarse aerosol particulate is determined by crustal sources like dust.

The Fine particulates were dominated by carbonaceous aerosol (organic matter and elemental carbon). The climate of Lahore is semi-arid. The elemental analysis shows that it contains extremely high concentration of Pb, Zn, Cd and several other toxic metals. The elemental concentration in Microgram /cubic meter was found by a group of scientists.

The Atomic Absorption Spectroscopy technique was used by the scientists to find out the elemental concentration. The samples were collected at different locations in Lahore and the result of the experiments are collected.

Table:1 Different Environmental Concentrations in different locations in Lahore.

Location	Concentration (micro gram per cubic meter)			
	Cu	Zn	Cd	Pb
Walton	0.1	0.2	N.D	0.7
Shadman	0.07	0.4	N.D	2.5
Township	0.2	1	0.02	3
Misrishah	0.4	1.4	0.02	6.1
Charing Cross	0.1	1.1	N.D	4.5
Ichra	ND	1	N.D	1.3
Bhatti Chowk	0.1	0.9	0.07	5
Mazang Chungi	0.06	0.3	N.D	3.8
Bund Road	0.4	1	N.D	3.7
Cheburji Chowk	0.3	0.8	N.D	4

N.D = Not detected

2.4 Visibility:

The visibility is the greatest distance at which an observer can just see a black object viewed against the horizon sky. An object considered as threshold contrast when difference between brightness of sky and brightness of object is reduced to such a degree that an observer can just barely see object (William 1999). The visibility and dust concentration relationship was found by CHEPIL and WOODRUFF (1957) at height 6 feet above the surface of ground (Hagen, and Woodruff *et al,* 1973).

For height 6 feet above from the surface of ground:

$$C_6 = 56/(V)^{1.25} \quad [mg/m^3] \quad \text{--------Eq.1}$$

Visibility and concentration of dust particles calculations:

$$V = (56/C)^{0.8} \quad [m] \quad \text{-------Eq.2}$$

Where:

V=Visibility in meters; C=Concentration of dust

The above said formula is valid for the case where particles are of uniform size and scattering alone accounts for visibility.

2.5 Attenuation:

Atmospheric attenuation is the process where some or all of electromagnetic wave energy is lost when traversing through atmosphere. According to research thesis of (Saleem 2009), the attenuation of signal decreases with increasing wavelength. The visibility of signal is related with the optical attenuation in the following way:

The CCIR formula 1990 gives expression for optical attenuation due to aerosols according to visibility. It applies particularly in the visible spectrum around 0.6 micro meter.

$$\text{Attenuation} = \frac{17}{V} \quad \text{----------Eq.3}$$

A= Attenuation in dB/km; V= Visibility in meters;

3. SIMULATION RESULTSANDDISSCUSSION

Table:2. Concentration of Cu (Copper), Visibility and Attenuation:

Sr.No.	Location	Concentration of Cu (mg/m^3)	Visibility (m)	Visibility (km)	Attenuation (dB/km)
1	Walton	0.0001	39.67	0.039	26.39
2	Shadman	0.00007	52.78	0.052	25.14
3	Township	0.0002	22.78	0.022	28.88
4	Misri shah	0.0004	13.08	0.013	31.16
5	Charing cross	0.0001	39.67	0.039	26.39
6	Bhatti chowk	0.0001	39.67	0.039	26.39
7	Mazang chungi	0.00006	59.7	0.059	24.59
8	Bund road	0.0004	13.08	0.013	31.16
9	Cheburji chowk	0.0003	16.47	0.016	30.26

The optical attenuation of dust particles should be increased by the decrease of visibility. The visibility should be increased by decreasing the concentration of dust particles.

The concentration of Cu(Copper) is maximum in Misrishah (0.0004 milligram/cubicmeter) and Bund road regions. Therefore, the visibility is minimum (0.013 dB/km) in both areas. The attenuation of signal is of maximum value (31.16 dB/km) accordingly. The visibility is maximum in Mazang and Shadman areas. So, the attenuation of signal has minimum values respectively. This means that the strength of signal did not lose too much.

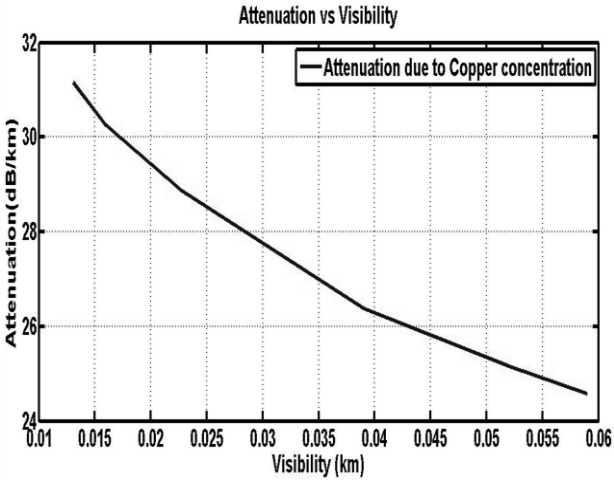

Fig. 1: Illustration of Visibility verses Attenuation due to Cu.

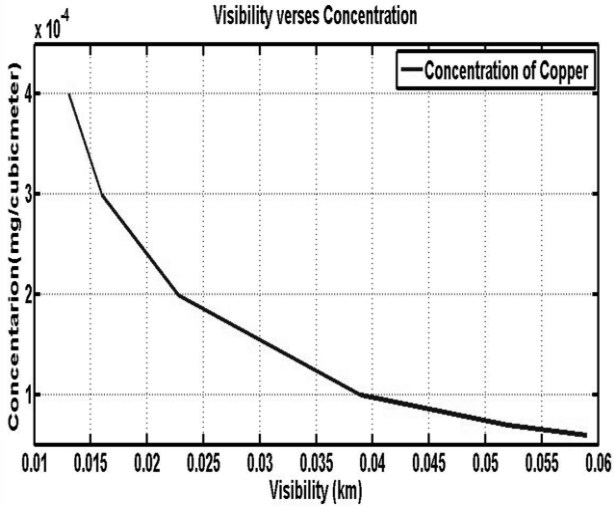

Fig 2: Illustration of Concentration of Cu verses Visibility

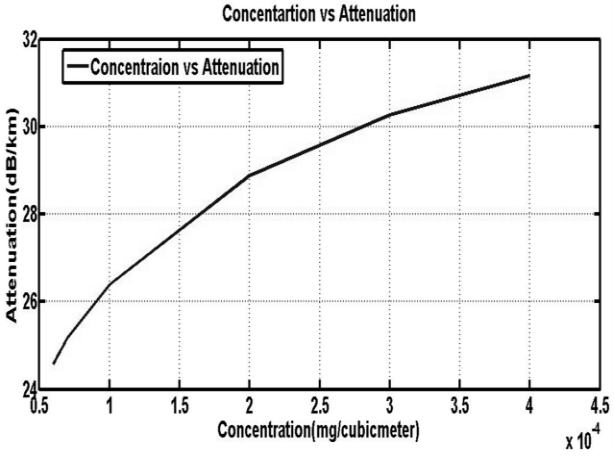

Fig 3: Illustration of Attenuation verses Concentration of Cu.

Table No.3: Concentration of Zn (Zinc), Visibility and Attenuation.

Sr.No.	Location	Concentration of Zn (mg/m^3)	Visibility (m)	Visibility (km)	Attenuation (dB/km)
1	Walton	0.0002	22.78	0.027	27.99
2	Shadman	0.0004	13.08	0.013	31.16
3	Township	0.001	6.28	0.006	34.52
4	Misri shah	0.0014	4.8	0.004	36.28
5	Charing cross	0.0011	5.82	0.005	35.31
6	Icchra	0.001	6.28	0.006	34.52
7	Bhatti chowk	0.0009	6.84	0.006	34.52
8	Mazang chungi	0.0003	16.47	0.016	30.26
9	Bund road	0.001	6.28	0.006	34.52
10	Choburji chowk	0.0008	7.51	0.007	33.85

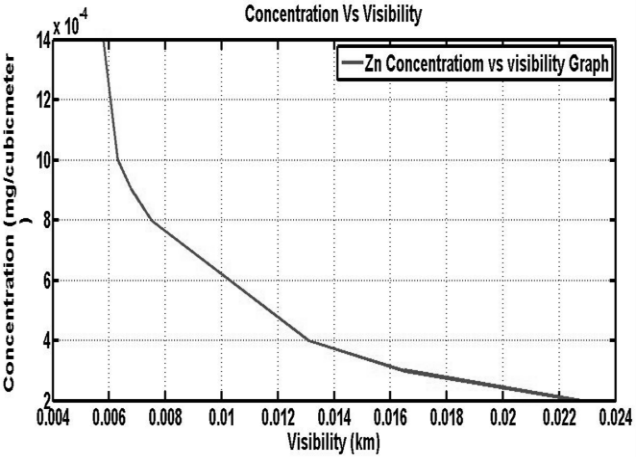

Fig:4 Illustration of Concentration of Zn verses Visibility.

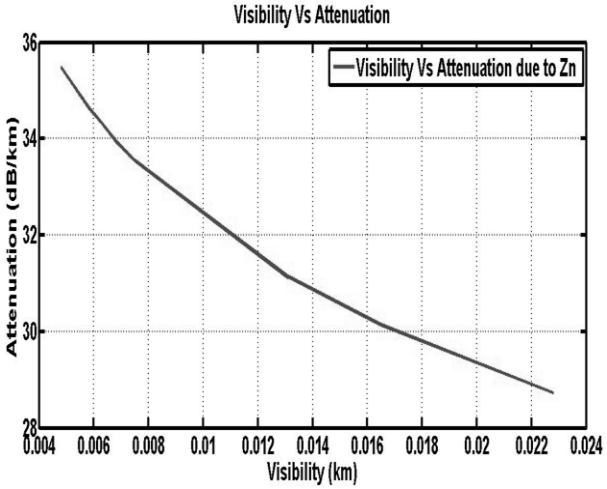

Fig:5 Illustration of Attenuation verses Visibility due to Zn.

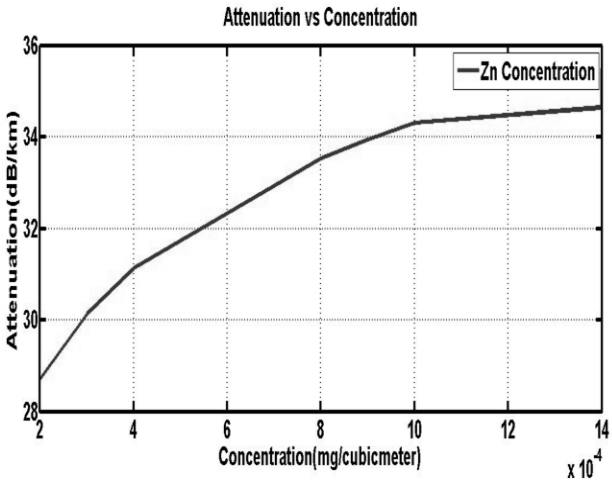

Fig: 6 Illustration of Attenuation verses Concentration of Zn.

The concentration of Zn (Zinc) in Misrishah and Charring-cross areas is maximum (0.0014 milligram/cubic meter and 0.0011 mg/cubic meter). Therefore, the visibility is minimum (0.004 km and 0.005 km) and attenuation is maximum (36.28 dB/km and 35.31 dB/km), accordingly.

Table No.4: Concentration of Cd, Visibility and Attenuation

Sr.No.	Location	Concentration of Cd (mg/m3)	Visibility (m)	Visibility (km)	Attenuation (dB/km)
1	Bhatti chowk	0.00007	52.28	0.052	25.14
2	Misri shah	0.00002	143.78	0.143	20.74
3	Township	0.00002	143.78	0.143	20.74

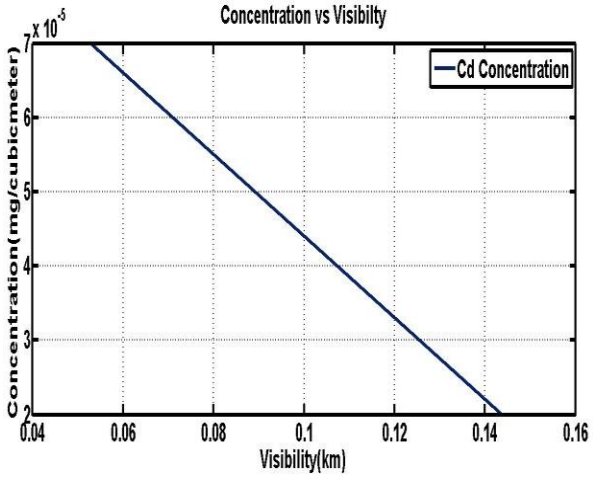

Fig:7 Illustration of Concentration of Cd verses Visibility.

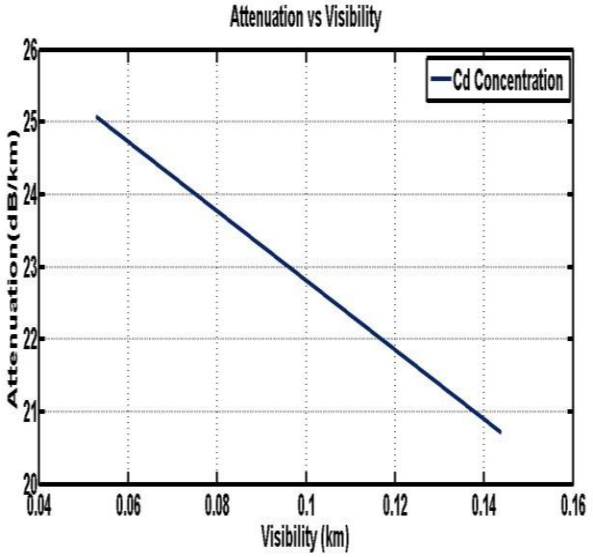

Fig 8:Illustration of Attenuation verse Visibility due to Cd.

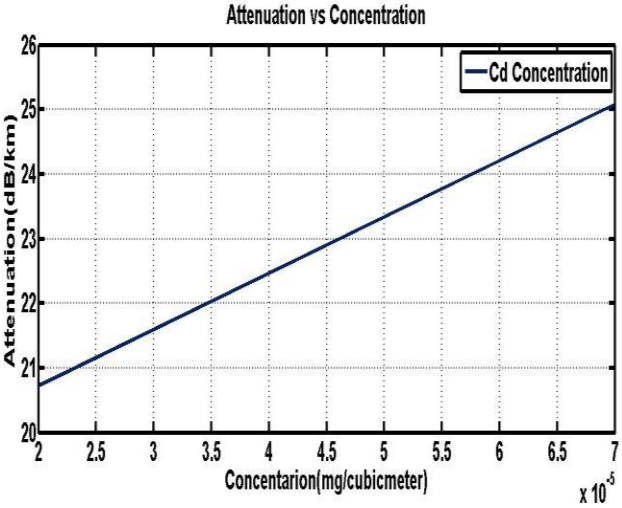

Fig 9: Illustration of Attenuation verses Concentration due to Cd.

Table No. 5: Concentration of Pb (Lead), Visibility and Attenuation in different locations in Lahore.

Sr.No.	Location	Concentration of Pb (mg/m3)	Visibility (m)	Visibility (km)	Attenuation (dB/km)
1	Walton	0.0007	8.36	0.008	33.11
2	Shadman	0.0025	3.02	0.003	37.53
3	Township	0.003	2.6	0.002	39.29
4	Misrishah	0.0061	1.48	0.001	42.3
5	Charing cross	0.0045	1.88	0.001	42.3
6	Icchra	0.0013	5.09	0.005	35.31
7	Bhatti chowk	0.005	1.73	0.001	42.3
8	Mazang chungi	0.0038	2.16	0.002	39.29
9	Bund road	0.0037	2.2	0.002	39.29
10	Chohurji chowk	0.004	2.07	0.002	39.29

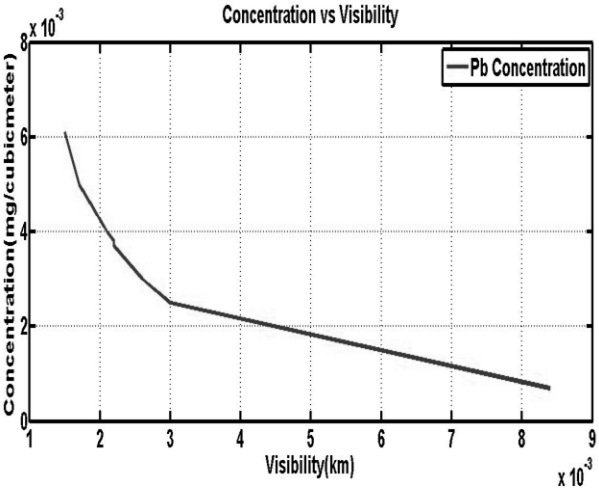

Fig:10. Illustration of Concentration of Pb verses Visibility

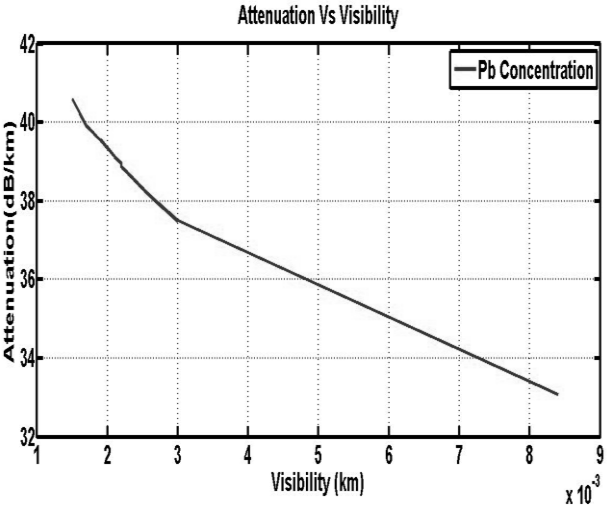

Fig:11. Illustration of Attenuation verses Visibility due to Pb.

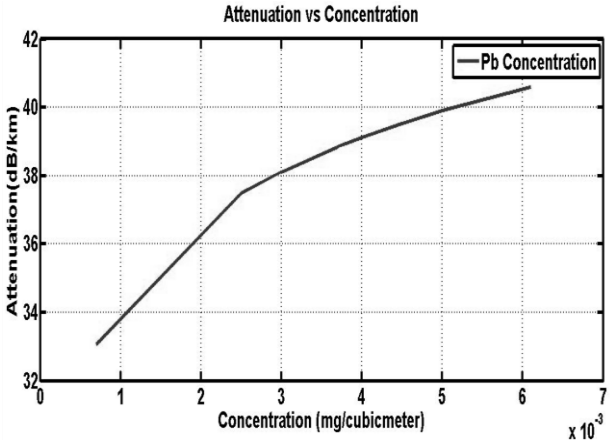

Fig: 12. Illustration of Attenuation verse Concentration due to Pb.

For Cd, the visibility is maximum (0.143 km) in Misrishah and Township. Therefore, the attenuation is minimum (20.74 dB/km) which means the signal is clear. The concentration of Pb is maximum in Misrishah (0.0061 milligram/cubic meter). So, the visibility is minimum (0.001 km) while attenuation is of maximum value (42.30 dB/km).

4 CONCLUSION

In FSO communication, the laser beam propagates through the atmosphere in the form of EM waves. The suspended particles in the air degrade its performance. The suspended elemental particles of high concentration reduce the visibility of the signal and enhance the attenuation of signal. The above results may be quite similar for the areas having same meteorological conditions like Lahore. The atmospheric conditions are location dependent and may vary from one place to another. The general solution should be sorted out for areas having same atmospheric conditions. We cannot change the conditions of atmosphere but transmitting parameters like wavelength of signal can be adjusted to get satisfactory result.

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