Analysis of Atmospheric Attenuation at Different Weather Conditions for Various Wavelengths in FSO

Pinky Vishwakarma, Jayprakash Vijay
Department of Electronics and Communication Engineering
Swami Keshvanand Institute of Technology Management & Gramothan, Jaipur
Email- pinkyvishwakarma84@gmail.com
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Abstract: **Free space optics (FSO) has the great prospective for future communication. FSO link is a license free, secure and easily deployable and offers low bit error rate link. Over the last two decades free space optical communication (FSO) has becomes progressively interesting as an adjacent or alternative to radio frequency communication. In this paper analysis is performed for non return to zero (NRZ) and return to zero (RZ) line codes with various operating wavelengths using APD and PIN photodiodes receivers. The study comprises the effect of atmospheric attenuation due to scattering effects for different weather conditions and observes the pointing error and received signal power at different weather conditions.**

Keywords: **Free Space optics (FSO), pointing error, photo diode.**

1. INTRODUCTION

FREE SPACE OPTICS (FSO) is a latest technology in communication system that uses light beam propagating from the transmitter through Free Space to transmit data and received at the other side of the two point communication system. FSO is frequently referred to as Fibreless Optics or Optical Wireless Communication [1]. The high carrier rate of FSO in the range of 20THz to 375THz, gives it to provide high data rates. It can be considered as an Optical Fiber replacement especially when the physical connections are impractical due to several considerations.

In case of increased applications of wireless communication, it has many drawbacks such as Bandwidth regulations, power limiting, high data rates etc. While FSO may show as its main advantages are no licensing requirements or tariffs for link utilization, absence of radio frequency radiation hazards, no need of road digging as in the case of optical fiber, large bandwidth which enables high data rates and low power consumption[2] .

FSO link receiver powerfully affects the behavior of the link. Types of detectors like as sources of noise and error correction techniques are helpful to maintain the desired bit error rates at accepted levels that should be considered in the design of practical FSO receivers. For FSO links transmitters, different modulations techniques can be used [3]. Different types of light sources are used in FSO like LED, VSCEL laser. For FSO link channel, effect of scattering is evaluated through Kim's model, Kruse's Model, Al Naboulsi's advection fog model and Al Naboulsi's convection (radiation) fog model [4]. Phenomena of turbulence and scintillation are evaluated in the log normal channel model, negative exponential channel model and

Gamma-gamma model [5]. APD and PIN are introduced as FSO link receivers, where its performance is affected by thermal noise and shot noise. Different FSO implementation scenarios recently under research are ground-to-ground, satellite uplink/downlink, inter-satellite or deep space probes to ground terminal. FSO links are mainly affected by the local weather but the most unfavorable attenuation factor is fog. The performance of FSO links can be evaluated by forecasting the attenuation factor in terms of visibility [6].

In this paper we have used the Kruse models that forecast the specific attenuation in terms of visibility. It has been worked out in the different conditions like fog, haze and clear at different operating wavelengths.

Major challenge faced by FSO is that it uses the air as a transmitting media between transmitters and receivers where various weather conditions can affect the performance of FSO Link. Most likely known as weather phenomena are scattering and turbulence which causes attenuation in the transmitted Signal which results in high bit error rate or signal loss at the receiver end [4]. In this paper we have focused on the atmospheric effects on FSO in diverse conditions.

The FSO community is recently initiated the free space optics alliance to educate the communication for industry to the properly deployment in the telecom network and it will be justified that industry – wide education will facilitate to standard to materialize & growth of FSO technology. For better quantify the technical and scientific aspects of FSO, there is requirement of research in new laser sources, atmospheric spectroscopy, multi-beam and active alignment techniques and multi-detector averaging.

2. RESULTS AND DISCUSSIONS

Atmospheric weather conditions have a prominent effect on the performance of FSO links. Effect of different weather conditions is related to the size distribution of the scattering particles q and the visibility V.The specific attenuation in dB/km for Kim and Kruse model is given by the equation.

$$\text{ọ} = \frac{3.91}{V(km)}\left(\frac{\lambda}{\lambda_0}\right)^{-q}$$

Where,
V (km) = visibility
λ (nm) = wavelength
λ_0 = visibility reference wavelength
Size distribution of scattering particles for Kruse Model [8]

$$q = \begin{cases} 1.6 \; if \; V > 50km \\ 1.3 \; if \; 6km < V < 50 \; km, \\ 0.585 \;\; if \; V < 6km \end{cases}$$

Atmospheric attunation for FSO link in different whether condition is shown in table 1 and its affect on changing the visibility is shown in fig.1.

Table 1
Atmospheric Attenuation at Different Weather Conditions for Various Wavelengths

Weather Condition	Visibility (km)	Attenuation (db/km) λ=780 nm	λ= 950 nm	λ= 1330 nm	λ =1550 nm
Clear air	25	0.4	0.3	0.2	0.1
	10	0.7	0.5	0.3	0.2
Haze	3	3.2	2.7	2.3	1.8
	2	5.8	4.3	3.8	2.1
	1	9.7	7.9	4.2	3.7
Fog	0.8	14.7	13.5	12.7	11.8
	0.6	20.9	20.5	20.1	19.5
	0.2	31.3	29.8	28.2	27.9

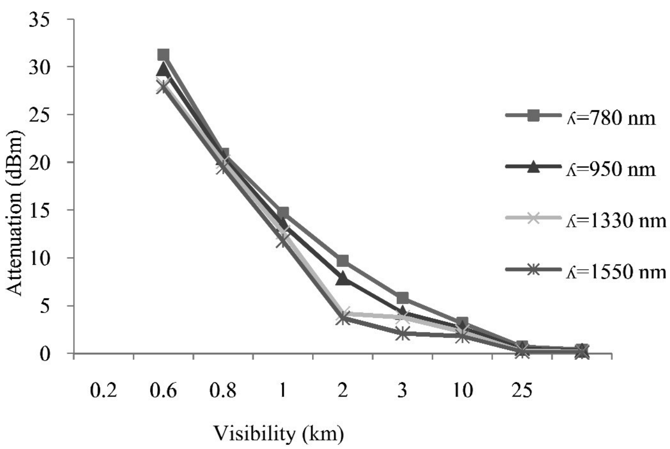

Fig.1. Atmospheric Attenuation Vs Visibility at different weather condition for various wavelengths

For clear air and high visibility (V = 10 km, 25 km), the effect of atmosphere on the signal power levels is almost negligible for all wavelength. The situation changes at haze and fog conditions. For haze (V = 1 km, 2 km, 3 km), and for a fog (V=0.2 km, 0.6 km, 0.8km) the visibility starts to decrease and the effect of the scattering particles appears. From observation it can be seen that wanelength 1550 nm gives the least attenuation so it is most suitable for use of FSO for data transmission.

Performance Analysis for FSO Link at 1550 nm

Performance evaluation of the proposed link at 1550 nm with NRZ-RZ line codes and APD-PIN receivers under various weather conditions .show in table 2 find the maximum pointing errors and signal power at different weather condition for NRZ line code and APD-PIN receiver at the wavelength 1550 nm.

Table 2
Maximum Pointing Errors and Received Signal Power at Different Weather Conditions for NRZ Line Codes and APD-PIN Receivers λ=1550nm

Modulation Technique Receiver Type		NRZ			
		APD		PIN	
	Visibility	Max. Pointing error (µrad)	Received power (dBm)	Max. Pointing error (µrad)	Received power (dBm)
Clear air	25	12.55	-24.28	11.75	-20.81
	10	12.45	-24.36	11.69	-20.97
Haze	3	12.32	-24.47	11.51	-21.02
	2	12.18	-24.56	11.42	-21.31
	1	12.02	-24.72	11.3	-21.48
Fog	0.8	12.94	-24.92	11.19	-21.67
	0.6	11.78	-25.3	11.1	-21.73
	0.2	11.62	-25.21	10.55	-21.89

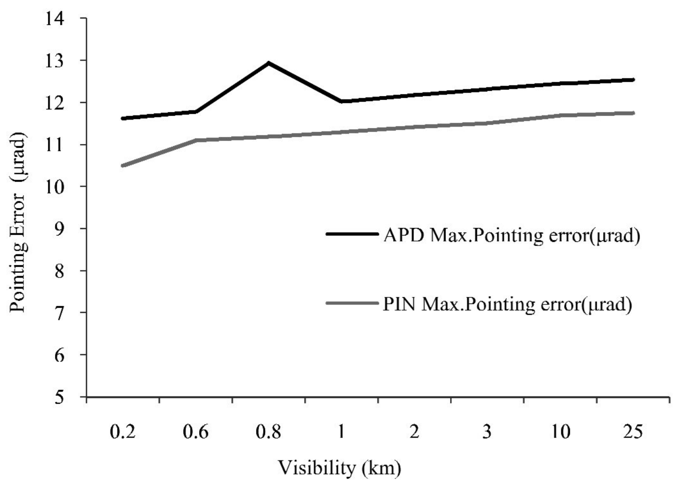

Fig.2. Visibility Vs Pointing Error at 1550nm for APD and PIN receiver

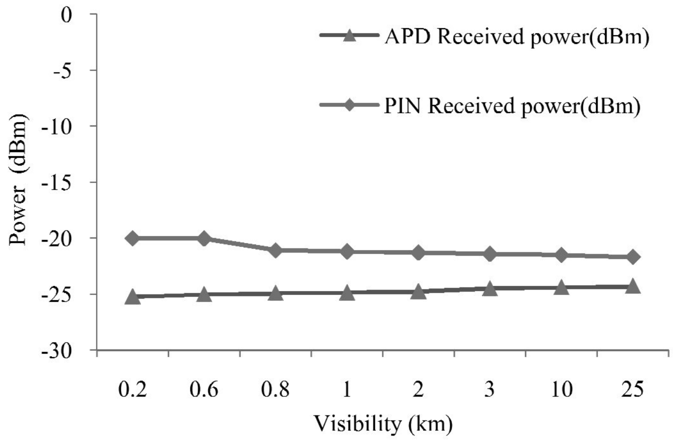

Fig.3. Visibility Vs receiving Power at 1550nm

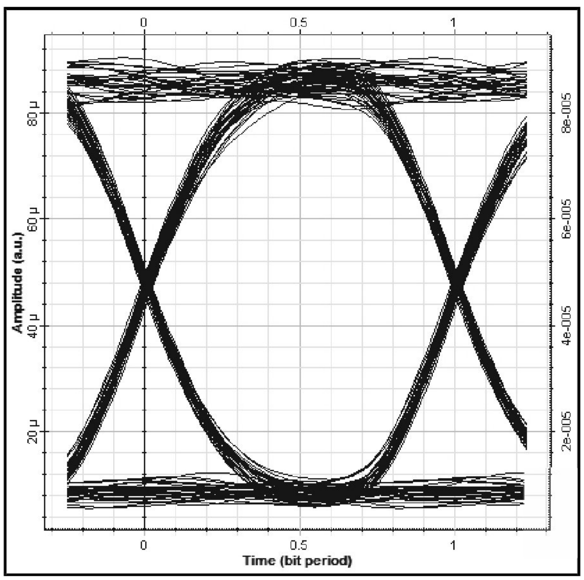

Fig.4. Eye diagram for bit error rate for at the 1550nm

Table 3
Maximum Pointing Errors and Received Signal Power at Different Weather Conditions for RZ Line Codes and APD-PIN Receivers, λ=1550nm

Modulation Technique Receiver Type		RZ			
		APD		PIN	
	Visibility	Max. Pointing error (µrad)	Received power (dBm)	Max. Pointing error (µrad)	Received power (dBm)
Clear air	25	12.20	-25.01	11.65	-22.46
	10	12.07	-25.21	11.50	-22.57
Haze	3	11.95	-25.32	11.33	-22.62
	2	11.73	-25.46	11.21	-22.75
	1	11.68	-25.57	11.18	-22.91
Fog	0.8	11.47	-25.68	11.07	-23.02
	0.6	11.36	-25.82	10.92	-23.20
	0.2	11.22	-25.91	10.42	-23.31

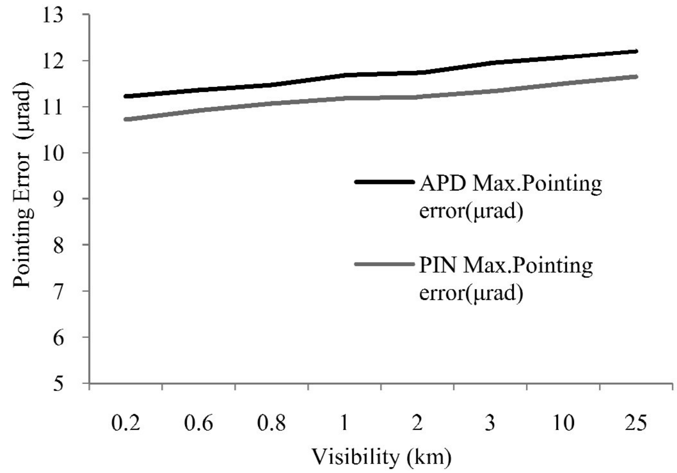

Fig .5. Visibility Vs Pointing Error at 1550nm Wavelength for a RZ line codes

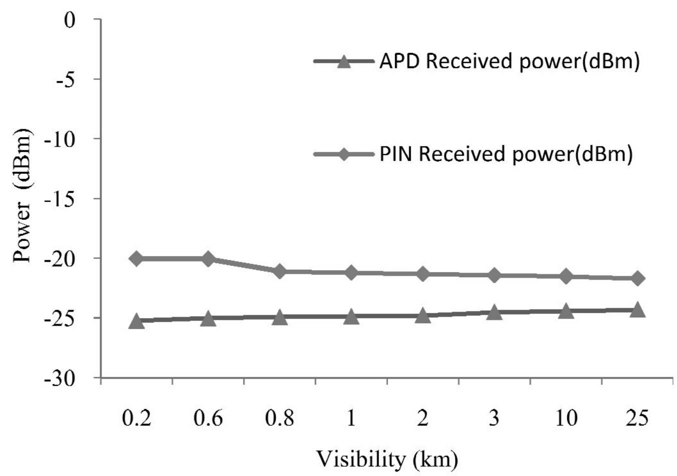

Fig 6.Visibility Vs receivimg Power at 1550nm Wavelength for a RZ line codes

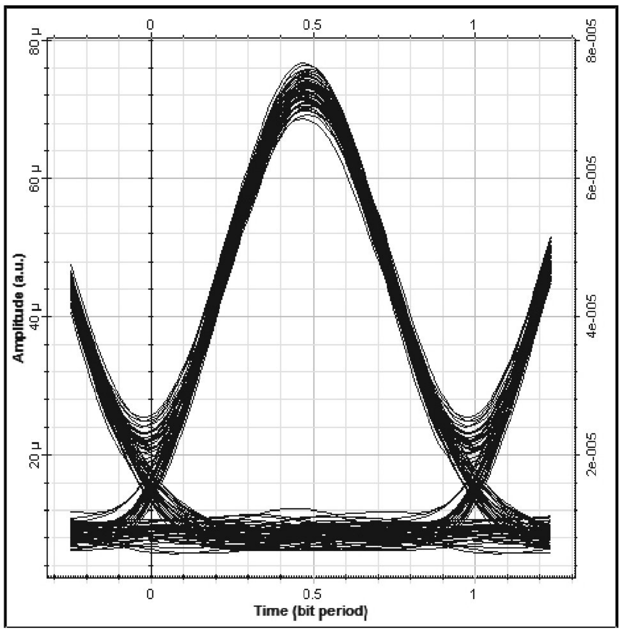

Fig7. Eye diagram for RZ line code at1550nm

3. CONCLUSION

In this paper, study for FSO link show that for NRZ-APD maximum pointing error is 11.62 μrad where RZ-APD maximum pointing error is 11.22 μrad. RZ-APD received signal is more attenuated than NRZ-APD in all weather conditions. Performance study for PIN receiver shows, in the presence of fog, the maximum pointing error for NRZ-PIN and RZ-PIN is 10.55 μrad and 10.42 μrad, respectively. Thus result for 1550 nm, NRZ-PIN is better to use for all the weather condition.

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