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MATLAB Based Simulink Modelling and Performance Analysis of Free Space Optical Communication System

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Abstract— In the recent time free-space optical communication (FSO) systems have garnered significant recognition because of its higher capability it provides path for long distance applications. When FSO is being operated on illegal optical spectrum, it may yield the LOS optical transmission with the advantage of lower price and also better security system. FSO is defined as transference of harmonized visible or IR rays in the airspace for obtaining broadband communication. FSO can be operated over a long distance that can be up to many kilometres. In FSO systems, communication between transmitter and receiver can be done till the time the LOS. But the condition for this transference is that the transmitted power should be so much high that it can overcome the atmospheric losses till the time it reaches to the receiver. There are several factors which have a great effect on the data transmission rate are analysed like climatic attenuation, track loss and pointing error. In this research work, BER is investigated against various parameters for example atmospheric turbulence, distance, path loss factor and transmitter power. To execute the desired task MATLAB Simulink model is designed

Keywords— FSO, BER, Path Loss Factor, LOS, Turbulence

I. INTRODUCTION

FSO communication is the transmission of information/data over long distances using harmonized optical signals in unguided network system. The random communication system can be free space, water, atmosphere or an integration of these Medias. Since the research focuses on terrene transmissions, the main interest is atmosphere. The data to be transmitted can be modulated in its frequency, phase or intensity of the optical signal [2]. An FSO link is a line-of-sight technology.

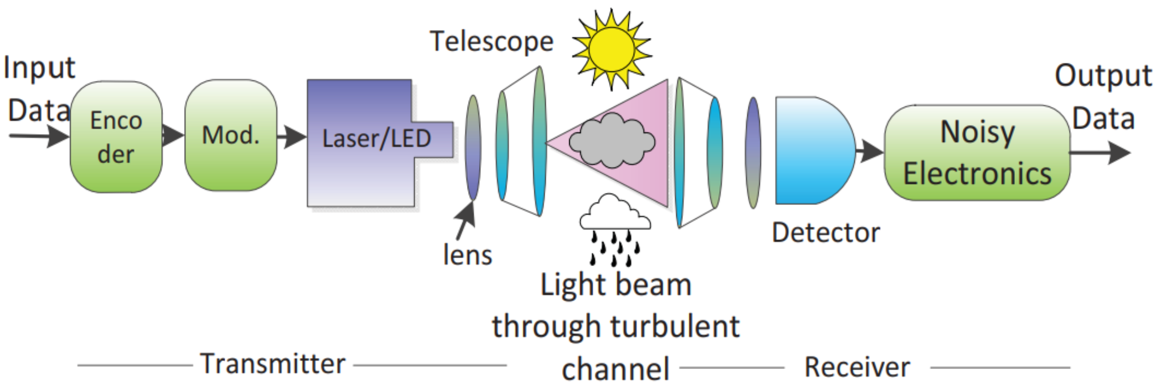

Fig.1: Fiber space optics Setup [2].

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It therefore requires the transceiver to point straight to each other without any hinderance in the path. It is for p2p communication along with two transmitters and receiver system all together. It permits information transfer in parallel between these transceivers. Free Space Optical communication systems dependent on WDM technology can provide a speed as high as 1 Terabit/s and much higher capacity according to user requirement. It has some other advantages like they use small size transmitter and receivers, the cost required for their installation and development is not much as compared to other techniques also they are not affected by electromagnetic interference FSO systems came into existence because of higher traffic requirement and security of the communication systems. The links that are involved in satellites, interstellar probes, ground stations, UAVs, long height platform, aircrafts are practically interesting.

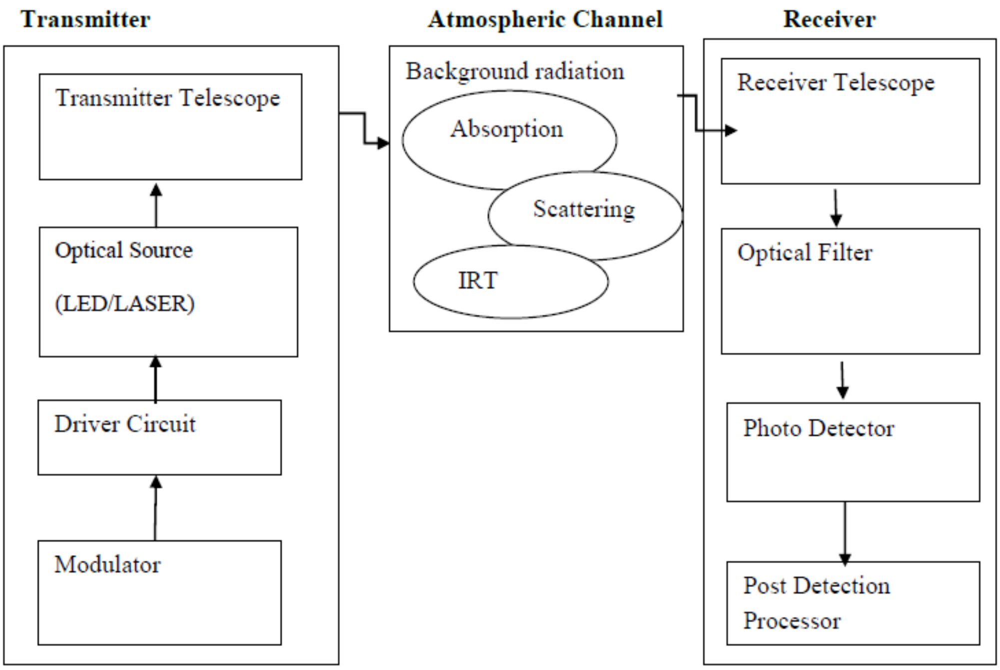

Fig.2: Block Diagram of FSO

Challenges Encountered in FSO: With advancement in technology FSO is one of the prime techniques to transmit data at high speed and it is also safe to use in comparison with electromagnetic interference. Every technique has its pros and cons therefore some of the challenges in FSO communication system are highlighted below:

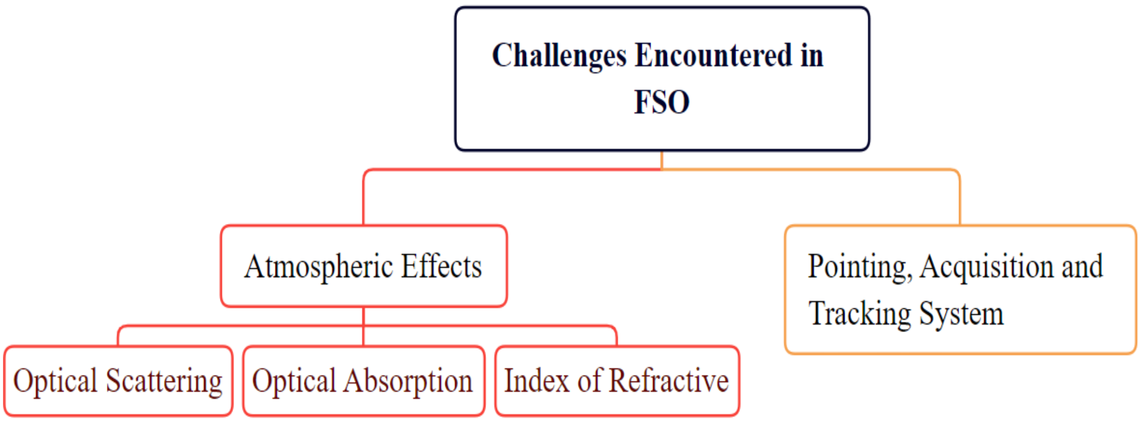

Fig.3: Challenges encountered in FSO.

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II. PLANNING OF WORK/METHODOLOGY

In this chapter Simulink model is depicted which is our proposed research work and these prototypes involve prototype for the transfer of optical data in atmosphere and prototype for studying the aftermath of scintillation. For studying these effects, the lognormal statistical model is utilized. Geometrical loss in FSO systems will be discussed. The transference of optical data via atmosphere is modelled by using Beer-Lamberts law. As given below:

$$\tau(\lambda, L) = \frac{Pt(\lambda,0)}{Pr(\lambda,L)} = \exp(-\gamma(\lambda)L) \text{......... Eq (1)}$$

$\tau(\lambda, L)$= Transmittance of the atmosphere
$Pt(\lambda, 0)$ = The emitted power from transmitter
$Pr(\lambda, 0)$ = The received power after a distance of propagation
$\Upsilon(\lambda)$ = Atmospheric attenuation coefficient(km^{-1})

Atmospheric attenuation coefficient is a function of optical wavelength and it consists both atmospheric assimilation and scattering and as given below:

$$\gamma(\lambda) = \alpha_m(\lambda) + \beta_a(\lambda) + \beta_m(\lambda) + \beta_a(\lambda) \text{........ Eq (2)}$$

FSO Model Simulation Block Diagram

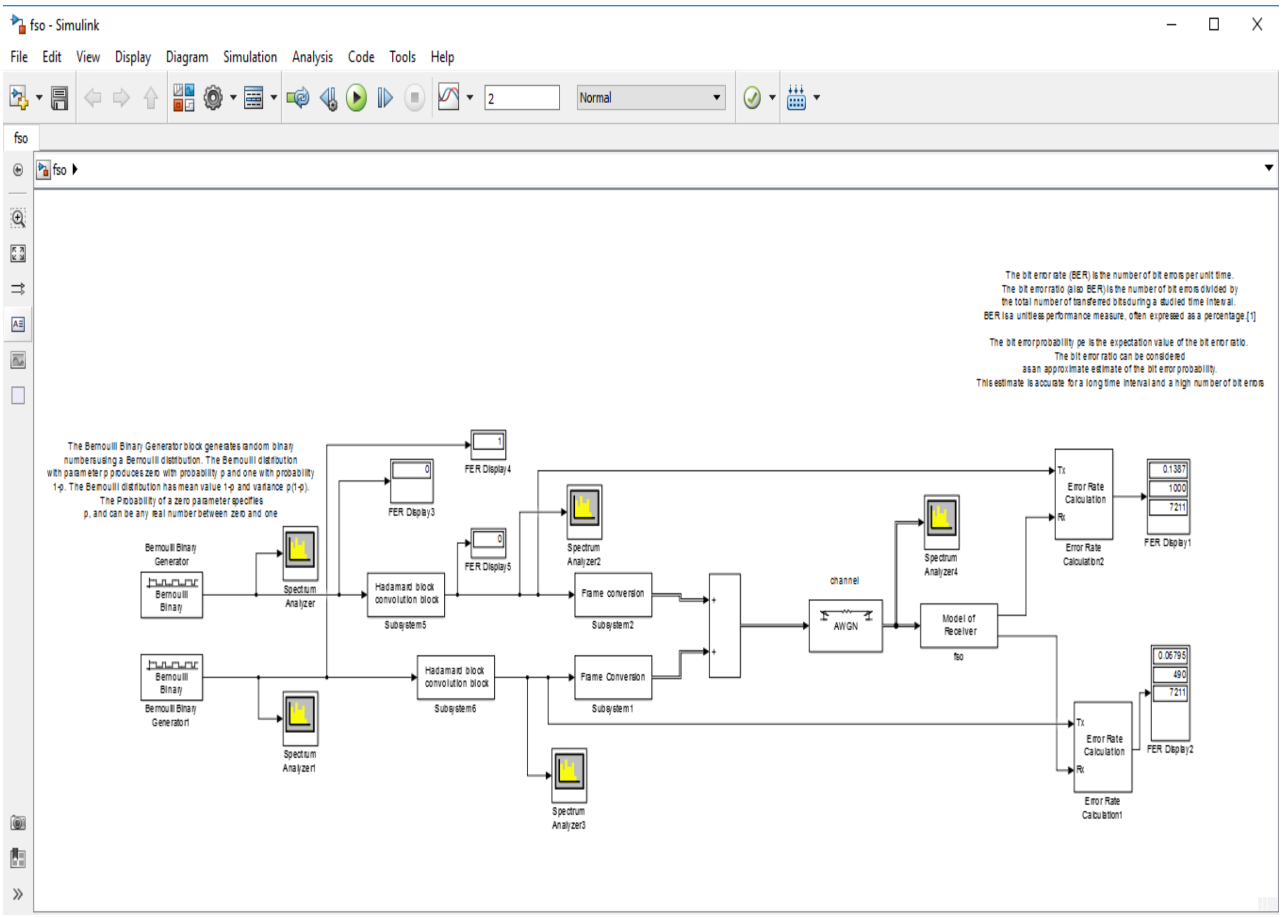

Fig.4: FSO Communication system Simulink Model using MATLAB

Figure 4 illustrating the FSO communication system block diagram developed in MATLAB Simulink environment. This simulation work carried out using two case studies in which code sequences are generated using Bernoulli Binary Generator having probability 0.5 and 0.4

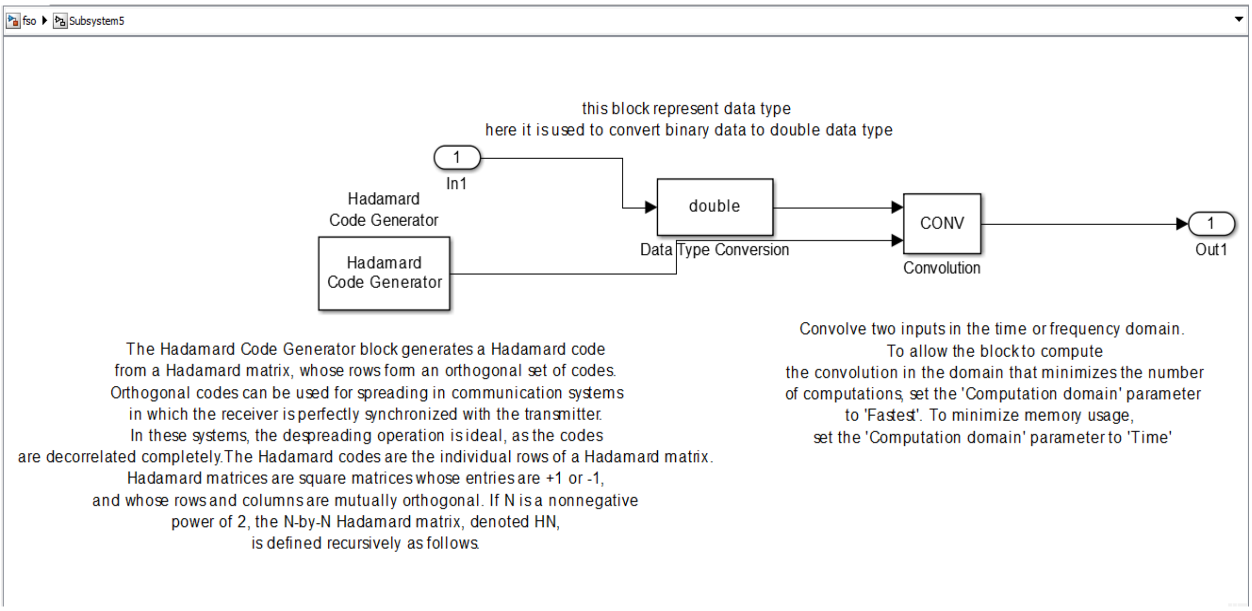

Fig.5: Hadmard Code Generator in FSO communication system

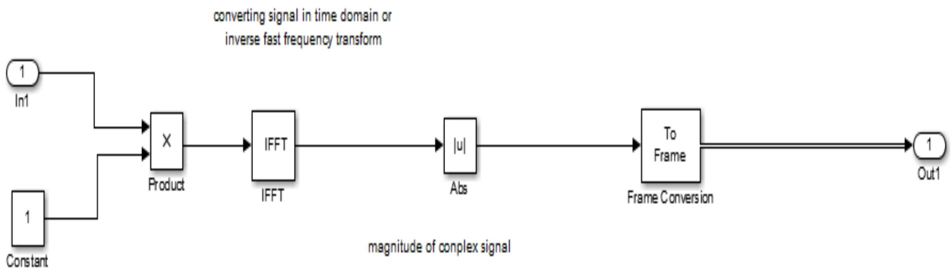

Fig.6: Time to frequency domain conversion

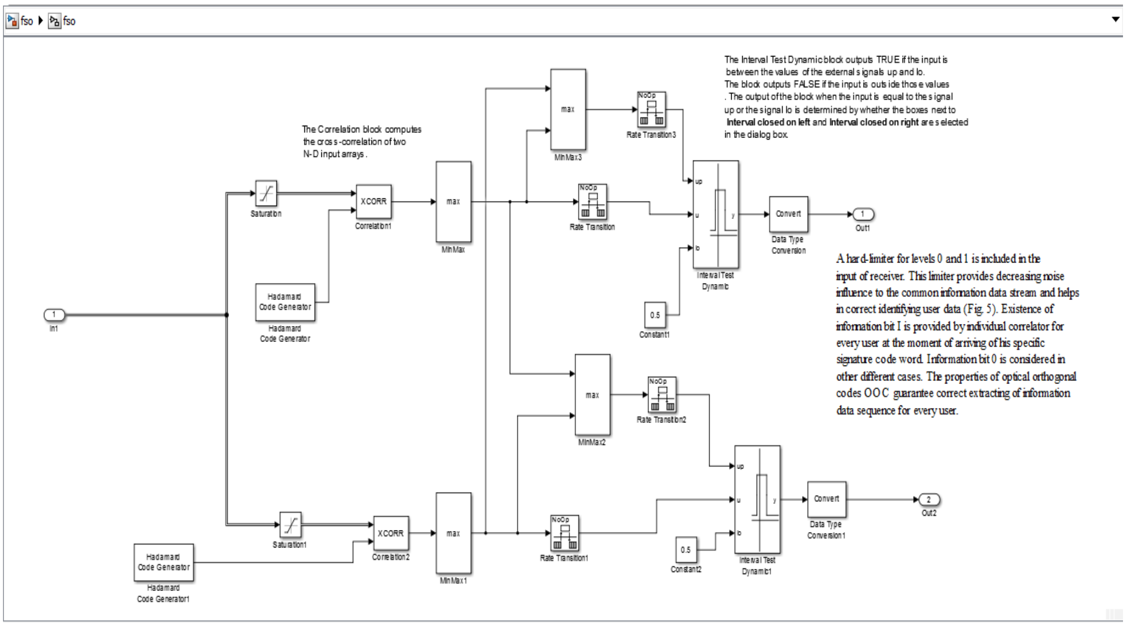

Fig.7: FSO internal circuit

SNR plays vital part in any communication systems weather RF communication or FSO communication. Fundamental definition of SNR is total power of signal to total power of noise. There are various noises exist in FSO unit like

- Shot Noise (SN)
- Thermal Noise (TN)
- Background Noise etc.

These disturbances accumulate more noise at FSO receiver system. The final output of FSO examined with help of BER which rely on SNR value and types of modulation used [1]. Let us assume Gaussian distribution of noise and also assume that there is no atmospheric turbulence condition in that case output of photo detector is evaluated by

$$SNR_0 = \frac{P_s}{\sqrt{\left(\frac{2h\upsilon B}{\eta}\right)(P_s+P_B)+\left(\frac{h\upsilon}{\eta e}\right)^2\left(\frac{4kT_nB}{R}\right)}}$$

……… Eq (3)

where Ps is power of signal (W), P_B background noise (W), e charge of electron (C), h plank's constant, v represent optical frequency (Hz), k Boltzman's constant, B - bandwidth, TN represent noise temperature and effective input resistance given by R. SNR becomes a fluctuating term when turbulence is there therefore average value of it can be given as

$$\langle SNR\rangle = \frac{SNR_0}{\sqrt{\left(\frac{P_{SO}}{\langle P_S\rangle}\right)+\sigma_I^2(D)(SNR_0)^2}}$$

……………… Eq (4)

III. SOFTWARE USED AND SIMULATION RESULT

Software: MATLAB R2021b: These days MATLAB is one of the fabulous software through which anyone can computer his/her problem as it gives numerous computation techniques in diversity domains. The work carried out in MATLAB Simulink environment and models is designed. To execute this task there are different simulation parameters are required so that desired task can be easily executed. Some of the important parameters are listed below:

- Signal to Noise Ratio
- Sampling Time
- Bernouli Binary Generator
- Hadmard Code Generator
- Channel Type

There is a block of Bernoulli Binary Generator (BBG) in simulation library which generate digital numbers using a Bernoulli distribution. In this system, p (parameter) generates 0 having probability p. On another hand 1 having probability 1-p.

- Mean value of Bernoulli distribution = 1-p
- Variance value = p (1-p).

Our simulation work carried out using two case studies. In this paper, code sequences are generated using generators. As shown below in figure 8 first code sequence produced with help of Bernoulli Binary Generator having probability 0.5

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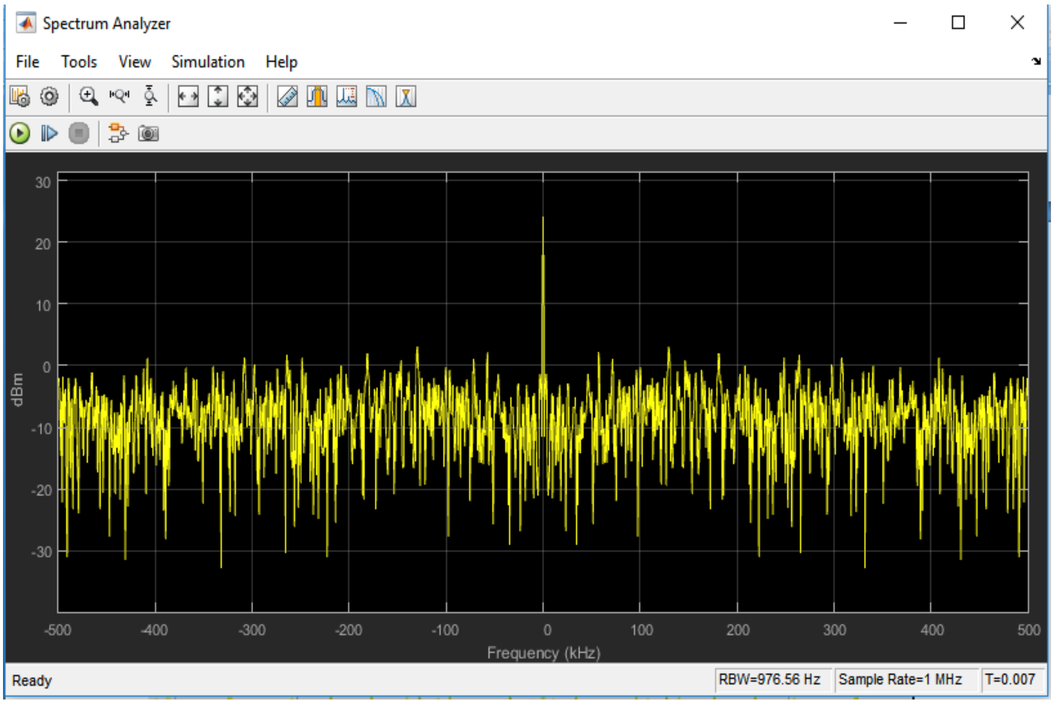

Fig.8: Sequence generated using Bernoulli Binary Generator (Probability=0.5)

Figure 9 represents second code sequence produced with help of BBG. Convolutional code (CC) plays very important role in telecommunication for error-correction in code with help of parity symbols. In convolution two input signal are convolved to get desired output in time or frequency domain. With help of this complexity becomes simpler and easy to calculate.

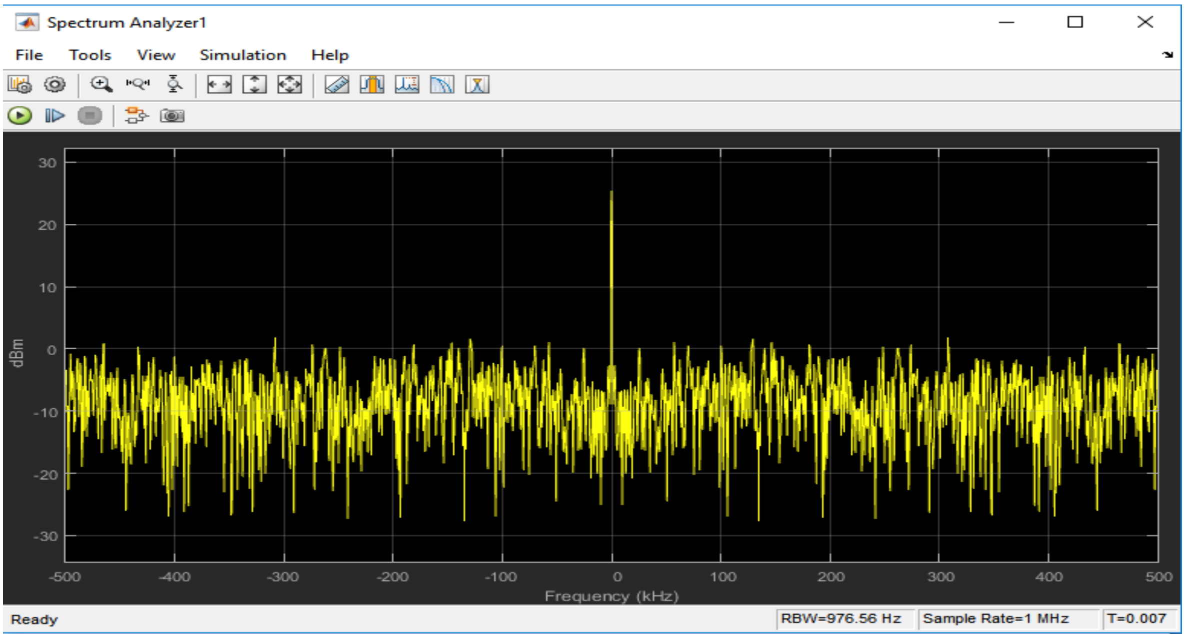

Fig.9: Sequence generated using Bernoulli Binary Generator (Probability=0.4)

Sequence generated by Bernoulli Binary Generator with different probability are convolved and after that information transmitted using free space. In communication process noise came into existence and authentic data may be lost due to noise therefore at receiver end there must be robust mechanism so that data can be restore precisely. Normally AWGN channel is used for transmission data. As the signals are convolved, then

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information is transferred for further processing through FSO. In this procedure atmospheric attenuation take place that should be remove at destination side to get desired output.

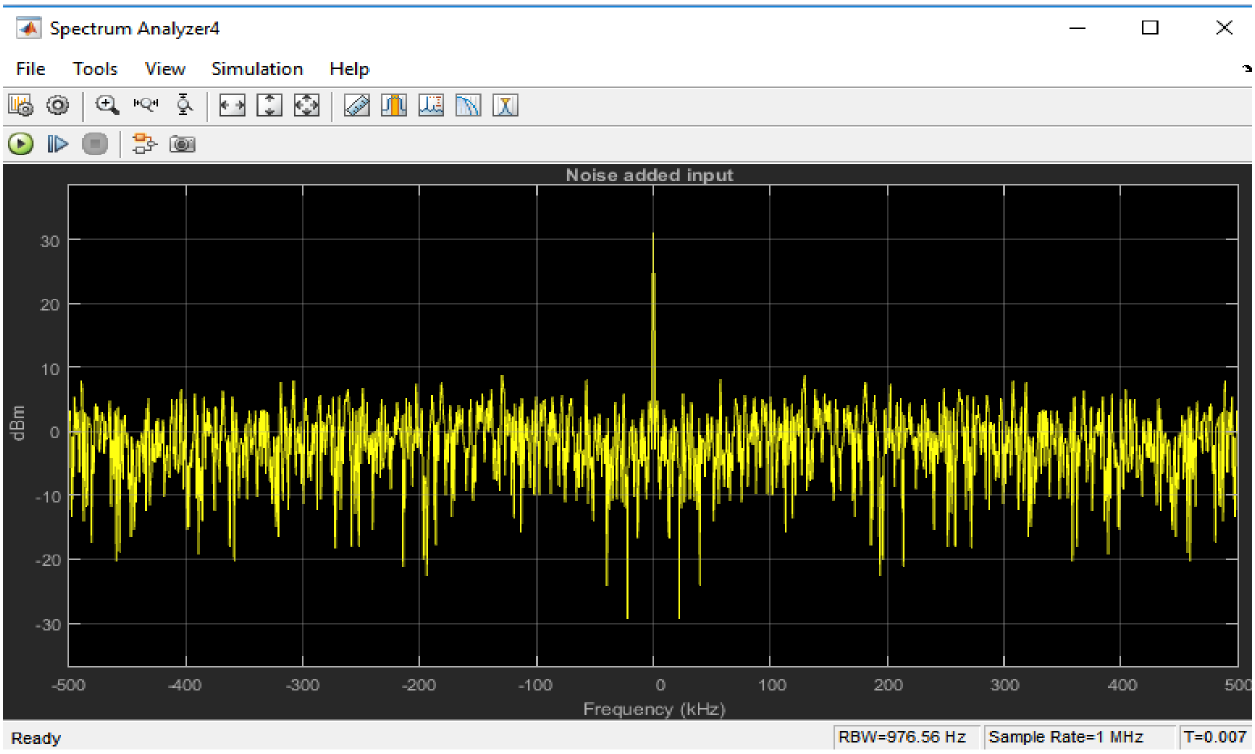

Fig.10: Signal quality after passing through AWGN channel

Figure 11 depicts energy signal for diverse technique in time as well as in frequency domain. Frequency domain demonstrate signal in very effective way and important analysis can be done accurately.

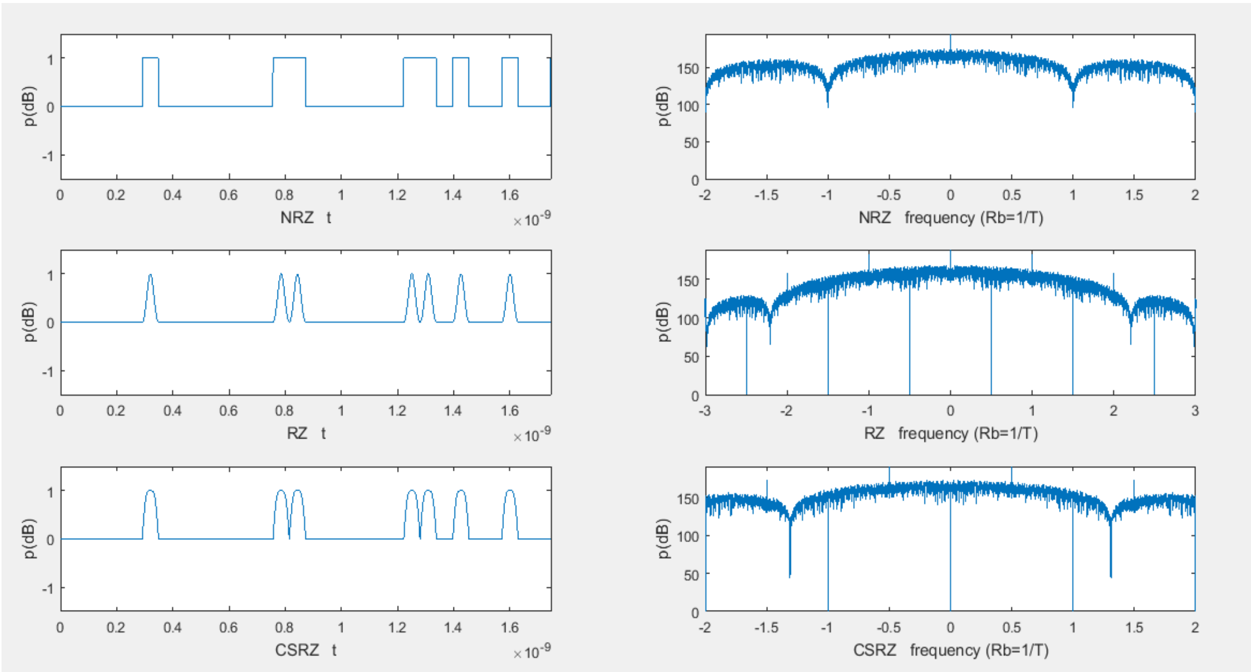

Fig.11: Signal strength for various schemes in frequency as well in time domain

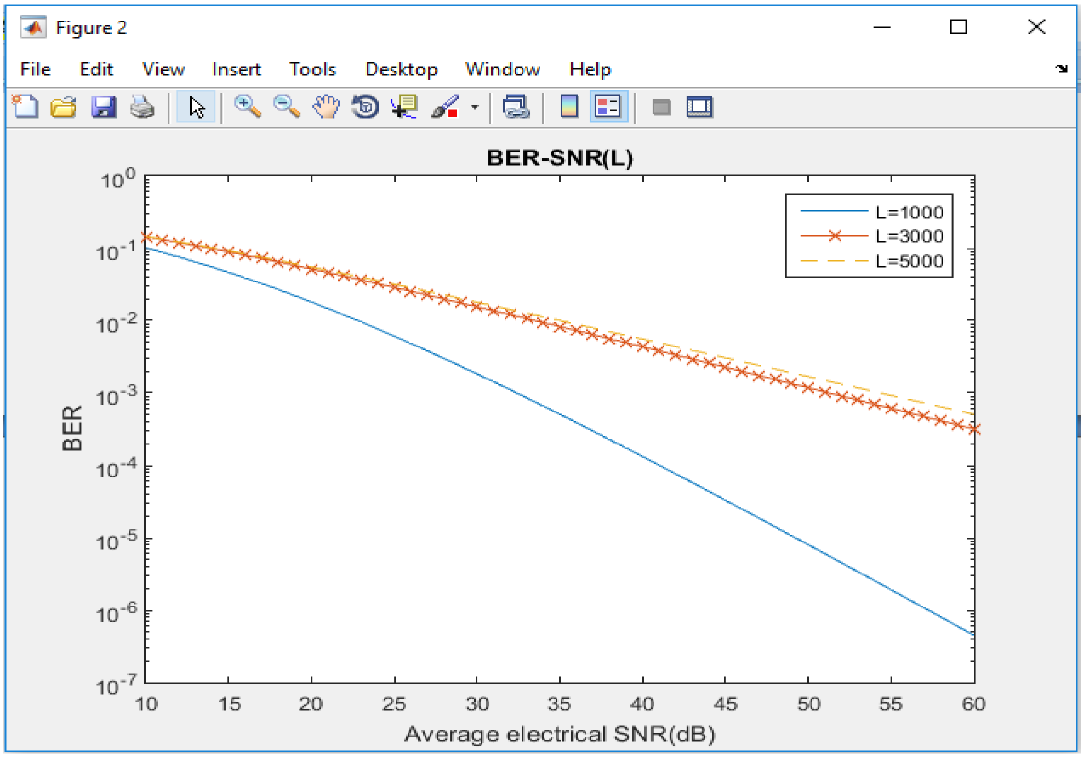

Fig.12: Comparative analysis of BER and SNR for different range

Figure 12 represent BER analysis with SNR for various range. From figure 4.13 it is very clear that as BER decreases SNR increases. Value of BER will be minimum for 1000 meter with respect to 3000 and 5000 meters.

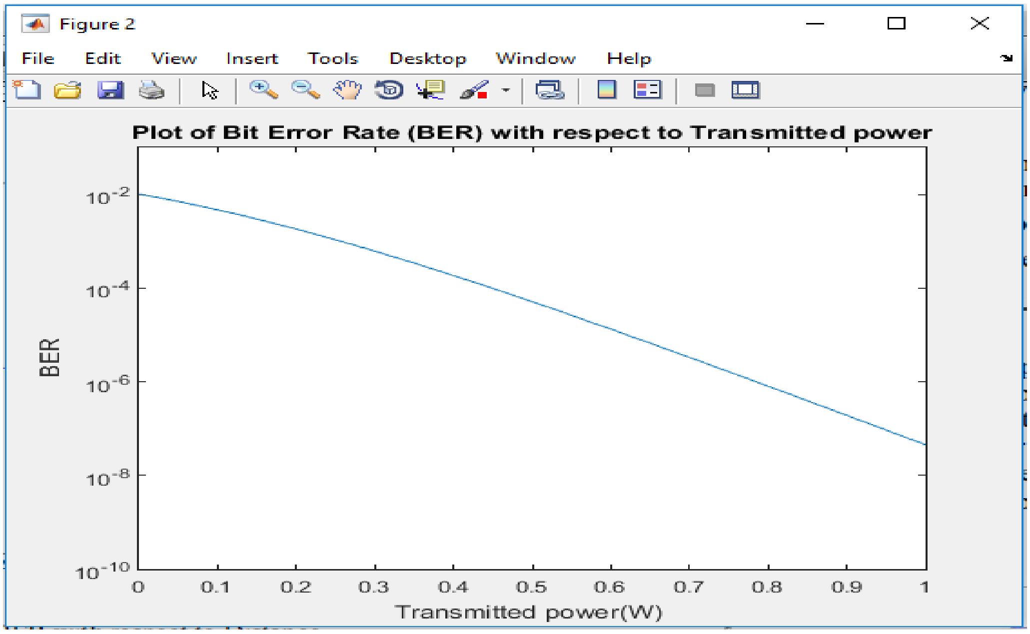

Fig.13: BER and Transmitted power representation

Figure 13 represent that as the power increasing from 0 to 1 watt and then bit error rate also decreasing. This is common phenomenon that if power will be more then BER will be come but design must be realistic means to easy to understand by observer.

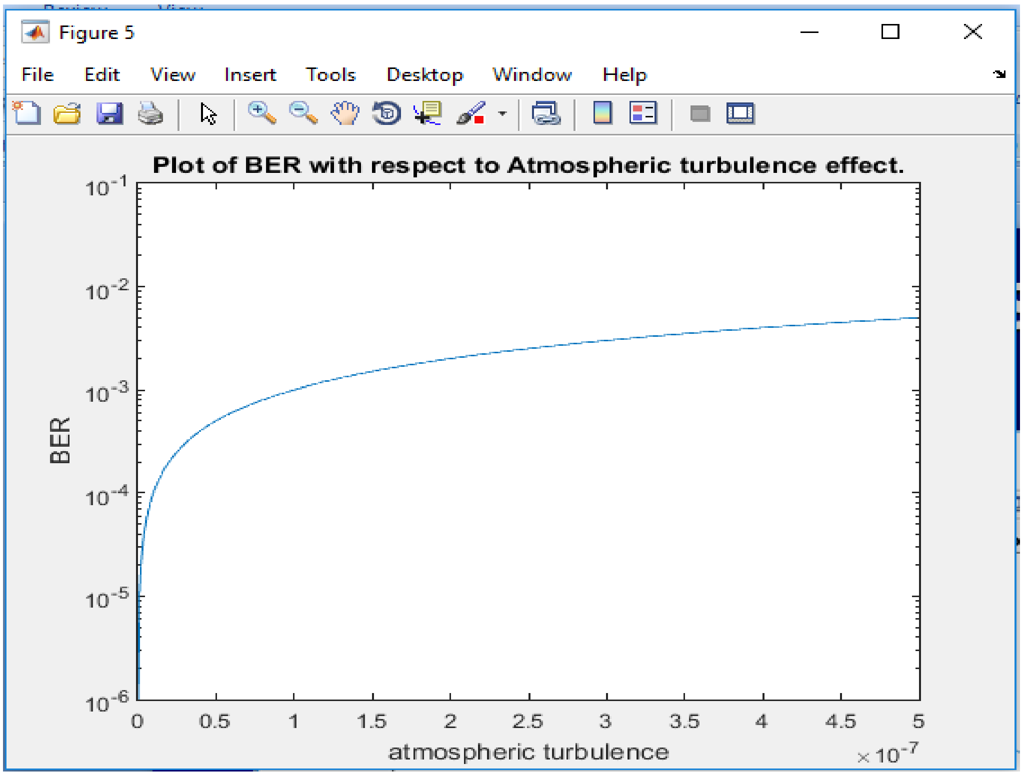

Fig.4.14: BER V/S Atmospheric Turbulence Effect

Figure 14 depicts the relationship between BER and Atmospheric Turbulence Effect. Our main focus's is to minimize BER very low so achieve this various factor are considered because when we transmit data through free space lot of atmospheric condition are available which are hazardous for our communication so we have to make our system so robust so that BER will be minimum

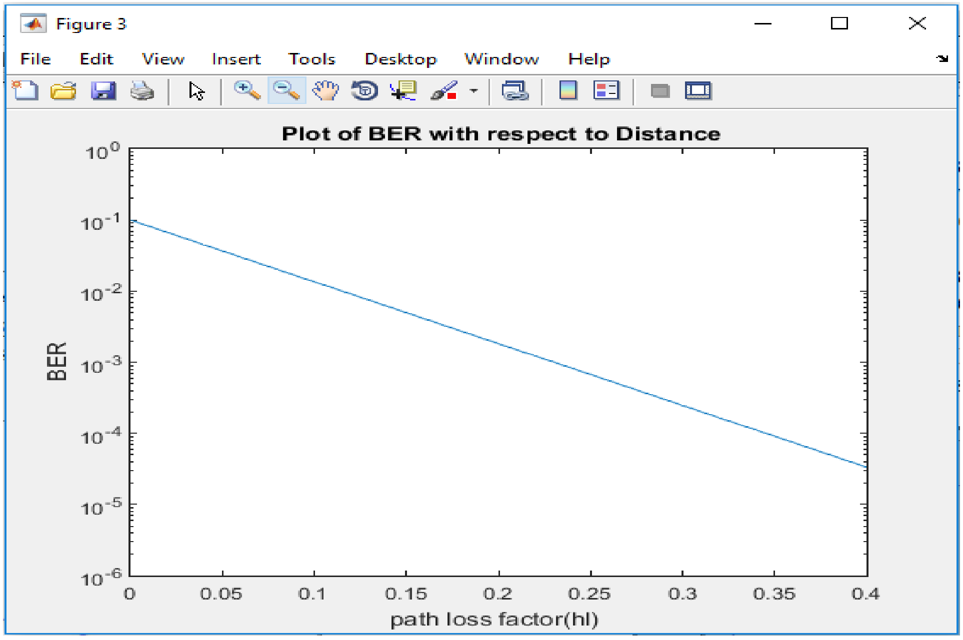

Fig.15: BER V/S Path Loss Factor for proposed scheme

In this work, main objective is to minimize bit error rate with respect to various factor which is used during communication for example path loss factor, atmospheric turbulence, power and many more. Figure 15 represent path loss factor with respect to bit error rate for proposed work and during analysis of graph, it was found that path loss factor increasing BER also decreasing. When we compare our result like BER w.r,t.

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power transmission, path loss factor and atmospheric turbulence condition with base paper then we analyse that our result are far superior to base paper.

Table 1: Performance Comparison between existed and Proposed Technique

Sr. No	Parameter	Existed Technique	Proposed Technique
1	BER vs Distance	$BER=10^{-2.4}$ Distance= 500m	$BER=10^{-2.6}$ Distance= 500m
2	BER vs Transmitting Power	$BER=10^{-3}$ Transmitted Power=1W	$BER=10^{-7}$ Transmitted Power=1W
3	BER vs Path Loss Factor	$BER=10^{-2.7}$ Path Loss Factor=0.4	$BER=10^{-4}$ Path Loss Factor=0.4
4	BER vs Atmospheric Turbulence	$BER=10^{-3}$ Atmospheric Turbulence=$10.5*10^{-8}$	$BER=10^{-2}$ Atmospheric Turbulence=$5*10^{-7}$

Table 1 illustrates the comparative analysis of various parameters between existed scheme and proposed scheme. In this table bit error rate was investigated with respect to various parameters for example distance, transmitting power, path loss factor and Atmospheric Turbulence.

Table 2: BER vs SNR with respect to length (in meter)

Sr. No	Parameter	Range	Proposed Technique
1	BER vs SNR	L=1000m	$BER=10^{-6}$ SNR=60 dB
2	BER vs SNR	L=3000m	$BER=10^{-3}$ SNR=60 dB
3	BER vs SNR	L=5000m	$BER=10^{-2}$ SNR=60 dB

Table 2 depicts the BER vs SNR relation for different range lies between 1000m to 3000m for proposed scheme. From the data it is very clear that as range increases bit error rate also increasing.

IV. CONCLUSION

Few years back RF communication system was used for transferring information among various devices. After that adhoc network came into existence but this system unable to meet the demand of industry and people. Today, FSO communication is replacing RF communication system. FSO communication has been simulated with the MATLAB software in this work. When in FSO system information is transferred in the transceivers system several problems are encountered for the successful transmission of the data. There are several factors which have a great effect on the data transmission rate are analysed like climatic attenuation, track loss and pointing error. In this research work BER is evaluated by varying the several parameters such as distance, transmitter power, path loss factor and atmospheric turbulence. Besides this SNR also examined with different range 1000m, 3000m and 5000m. From simulation results it is clear that proposed model performed better with respect to existed one in term of BER vs Distance, Transmitting Power, Path Loss Factor. But in case of Atmospheric Turbulence model is just competing with existed one. Besides this proposed model also evaluated the BER vs SNR with different range. For range 1000m BER is 10^{-6} whereas SNR is 60dB but when range is increased from 1000m to 5000m then BER becomes 10^{-2} for same SNR. It means with increasing distance BER also increasing.

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