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ANALYSIS OF MULTIBEAM BASED SCINTILLATION EFFECTS REDUCTION IN WDM-FSO SYSTEM

A.Devisri[1] B. Rajesh Kanna[2]

[1]PG Scholar,[2]Associate Professor

[1]Electronics and Communication Engineering,

[1]Alagappa Chettiyar College of Engineering and Technology, Karaikudi, India

Abstract: Free space optical communication has engrossed a large section of researchers in recent times due its wide bandwidth, effortless deployment and immune links making it appropriate for communication purposes. Free space optics to be an exalted technique for fast and cost-effective information exchange. As communication happens through air, FSO transmission is much faster than its fiber counter parts where glass is used as the medium for transmission. This wireless optical technique requires clear and non turbulent atmospheric conditions for efficient transmission. Multi beam technique which uses spatially diverse transmitters for transmission has been used for increasing the achievable link distance of the FSO system. Atmospheric-effects like scintillation, fog, haze, rain, absorption by water vapors, scattering of beam, fading, etc., have to be considered while designing an FSO network. Multibeam technique which uses spatially diverse transmitters for transmission, has been used for increasing the achievable link distance of the FSO system. Parameters like quality factor and bit error rate have been used to check the received signal quality.

Index Terms - **FSO, bit error rate (BER), Attenuation, Multibeam, Scintillation, Link Length, WDM –FSO**

I. Introduction

Free Space Optical communication (FSO) or sometimes addressed as laser communication is a technology that uses laser beams through free space to reach the receiver. This technology owes its growing importance to the incredible increase in the volume of data transfer all over the world and the resultant increase in bandwidth requirements. FSO's key attributes like rapid data transfer, quicker deployment, cost effective infrastructure and data rates as high as tens of gigabytes per 1 second make it a viable alternative for the short-range radio frequency (RF) links Licensed frequency bands, spectrum congestion and lesser data rates as compared to FSO, are some of the demerits of RF.Nowadays, FSO is finding its application in almost every stratum of daily life, ranging from ship to ship communication to enterprise connectivity.

Like every other technology FSO also has some limitations and some design considerations which need to be contemplated. Light beam carrying the information travels through air and is encumbered by the atmospheric effects, like rain, fog, snow, haze, and the atmospheric turbulences due to temperature and pressure fluctuations in the atmosphere Absorption, scattering and scintillation of light are consequences of turbulent atmospheric conditions Line of sight (LOS) is an imperative requirement in FSO communication, but sometimes physical objects like birds or poles temporarily obstruct it, making the link unachievable. A brief description of the harm caused by scintillation on the light beam is given below.

Scintillation Effect

Scintillation refers to the turbulence caused by thermal in- homogeneities along the path of light beam. Wind velocity is always variable, which transfers heat and water vapors in the form of eddies. Temperature changes in the atmosphere caused by these eddies lead to heating up of air pockets called Fresnel zones having different temperatures and different densities, which lead to refractive index differences. Turbulences are random, which means that these pockets are continuously being created and destroyed. Fluctuations in the refractive index of air deform the laser beam causing "beam dancing" at the receiver. Figure 1 shows the scintillation effect with air pockets having different refractive indices. Randomly formed pockets refract the optical wave front of the incoming beam due to which the signal cannot be received properly. The refractive index structure parameter Cn^2 accounts for the strength of fluctuations Cn^2 varies from 10^{-16} $m^{[-2/3]}$ (weak scintillation) to 10^{-12} $m^{[-2/3]}$ (strong).

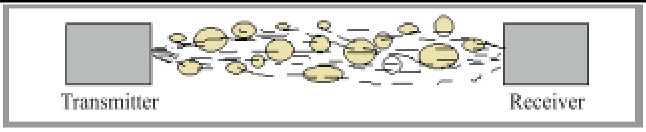


Fig. 1 . Heated air pockets which lead to scintillation of light

Two common effects of scintillation on the optical beam are:

- Beam Wander, the refractive index fluctuations are due to turbulent eddies of size varying from few millimeters to hundred meters. Beam wander means that the beam is deflected from its original path and loses its los. It happens when the size of refractive index in homogeneity is greater than the beam diameter;
- Beam Spreading, when the homogeneities are lower than the size of beam diameter, they tend to broaden the beam but do not deflect it. This is called beam spreading. It defocuses the beam reducing its intensity. In communication systems, bandwidth is always a factor that needs deliberation, so only the mitigation of channel turbulence like scintillation effect does not solve the purpose. It should be combined with efficient bandwidth utilization in order to make it a quintessential system. One of the best techniques used here is Wavelength Division Multiplexing (WDM).

II. WDM SYSTEMS

WDM allows multiplying data streams over optical carriers having different wavelengths called channels and sent as a single signal. WDM FSO systems use a single light beam to transmit the multiplexed signal through free space. A multiplexer is used at the transmitter to combine different modulated carriers and a Demultiplexer at the receiver to restore each one WDM systems used in combination with FSO are called WDM FSO and can be classified into two types: single beam and multibeam systems. Single beam system uses one pair of transmitter and receiver. Only one beam carrying the information travels through the channel

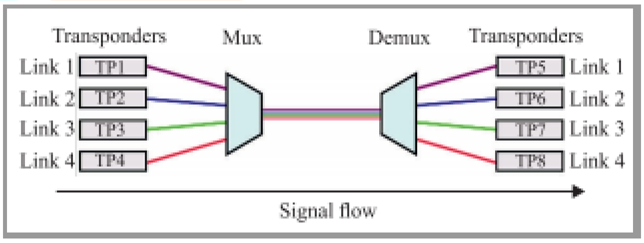


Fig. 2 ***WDM Technology***

In case of FSO systems, if the light beam is obstructed by an object, which prevents it from reaching the receiver, the signal is lost and communication stops. The multibeam WDM uses more than one beams of the multiplexed signal. Each beam travels a different path, and thus its attenuation is different. This technique uses spatially diverse transmitters and so it is also called Spatial Diversity Technique. At the receiver, the beam that has undergone least attenuation is selected and processed for data extraction. This technique serves as a solution for various FSO limitations like physical obstructions, scintillation effect, weather effects, etc. Multibeam system improves the link achievability and reduces the probability of link failure to a large extent. When WDM FSO system uses multiple beams for transmission, they are called "Hybrid multibeam WDM FSO systems".

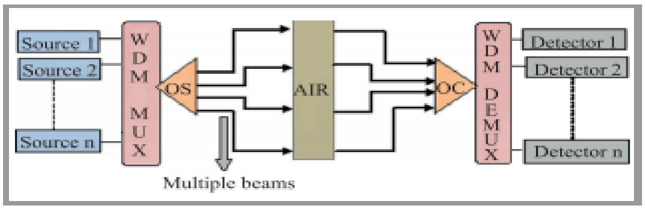


Fig. 3 Multibeam WDM FSO System Block Diagram

MULTIBEAM WDM FSO SYSTEM

Multibeam WDM-FSO is designed to reduce the effect of atmospheric attenuation and obstacles in the path of light beam. In this system, more than one beam of the multiplexed signal traverse through the free space and reach the receiver. As each beam travels a different path, each of them undergoes different amount of attenuation. The multiplexed signal is split using a power splitter at the transmitter and the received power of all the beams is combined using a power combiner at the receiver Among the different scintillation effects, play the major deterrents for the light beam; the following sections of this paper analyze the efficiency of a multibeam WDM-FSO system in enduring the scintillation effect. This MWDM-FSO increases the system capacity and the link reliability.

SYSTEM DESIGN

In this paper, there are two WDM FSO systems are used and analyzed under scintillation effect. First is WDM FSO, which uses single beam technology and system 2 uses the multibeam technology. Both systems have been designed with an aim to improve the efficiency under identical atmospheric conditions. Quality factor (Q) and bit error rate (BER) have been used as the measures of received signal quality. Comparative analysis of both systems has been done in terms of link distance and received power for best values of quality factor and BER. The software used for analysis is OptiSystem v7.

SYSTEM CONSIDERATIONS

WDM-FSO system consists of a transmitter, receiver, and free space channel. Transmitter has a single CW laser for carrier generation, a pseudorandom bit sequence generator for generation of information signal, NRZ pulse generator a Mach-Zehnder modulator, and a 32 channel WDM multiplexer. "Subsystem" has the transmitter module. On the other side, the receiver module is present in subsystem_1 which has a WDM Demultiplexer, followed by a selector, an APD detector, and a low pass Gaussian filter. A bit error rate (BER) analyzer is used at the reception which gives the Quality factor and the BER of the received signal.

DESIGN PARAMETERS

The analysis has been done by comparing a four beam WDM-FSO system with a single beam WDM-FSO. A single Continuous Wave Laser is used which operates at 1,550 nm, data rate used is 10 Gbps, lenses' aperture is set at 15 cm. Transmitter consists of a CW laser, a Demultiplexer and a Mach–Zehnder modulator. A 4:1 power splitter splits the output of the modulator into four beams which travel independently through air to reach the power combiner which combines the received power of all the four beams and gives it to the DEMUX. The analysis has been done by taking different attenuation values for different beams.

Table 1 System Parameters

PARAMETERS	VALUE
Data rate	2.5Gb/s
Wavelength	1550nm
Power	5 dBm
Gain	35dB
No. of input ports	32
No. of output ports	32
Bandwidth	10GHZ

SIMULATION SETUP

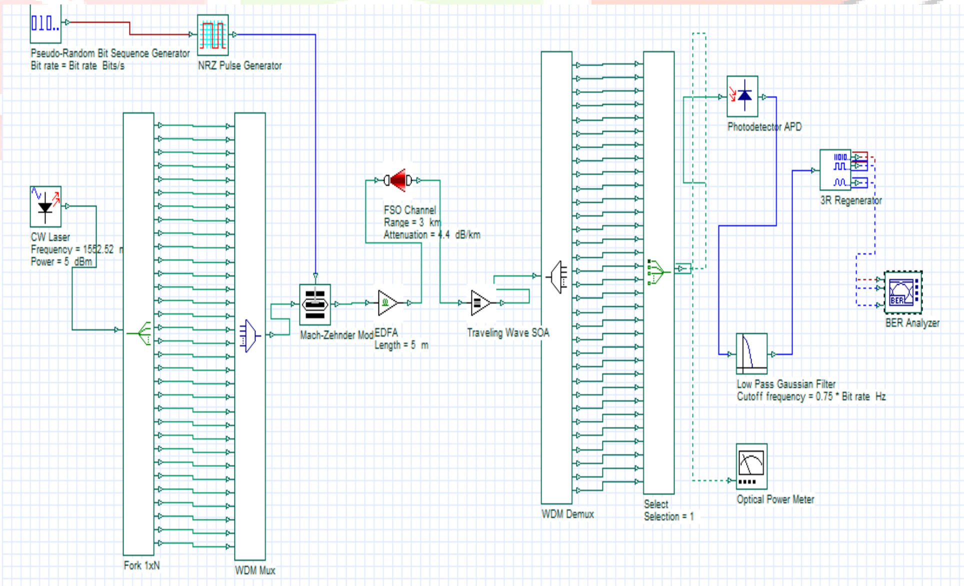


Fig. 4 Simulation setup for single beam FSO system using NRZ pulse generator

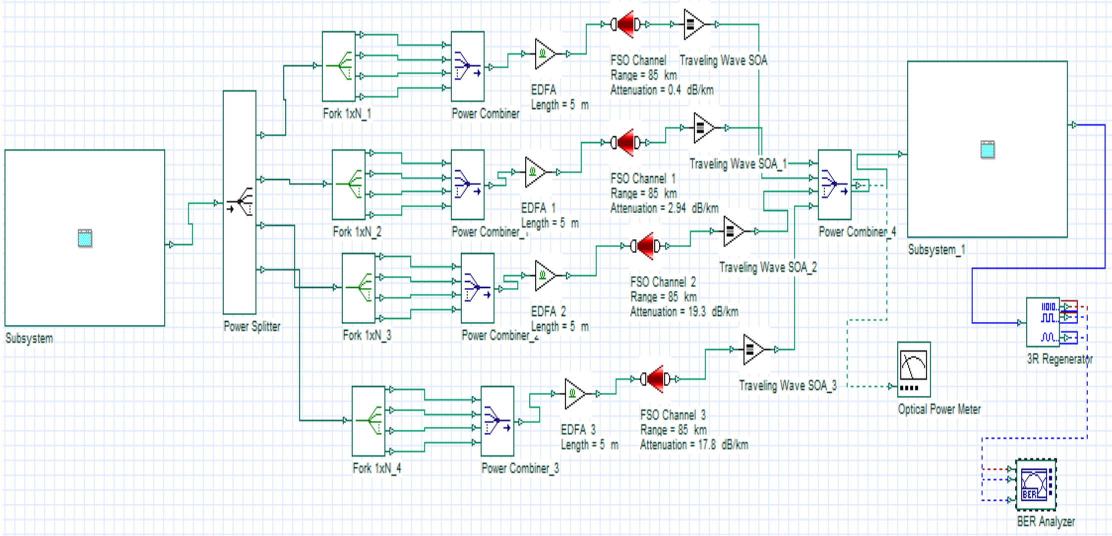


Fig. 5 ***Simulation setup for Multibeam FSO system using NRZ pulse generator***

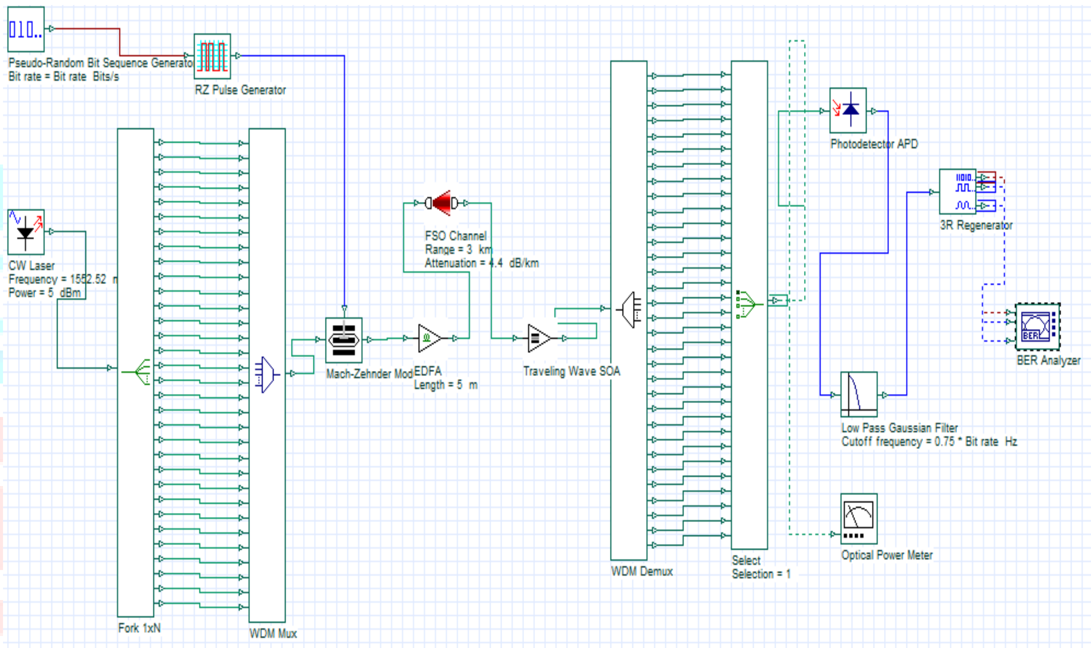


Fig. 6 ***Simulation setup for single beam FSO system using RZ pulse generator***

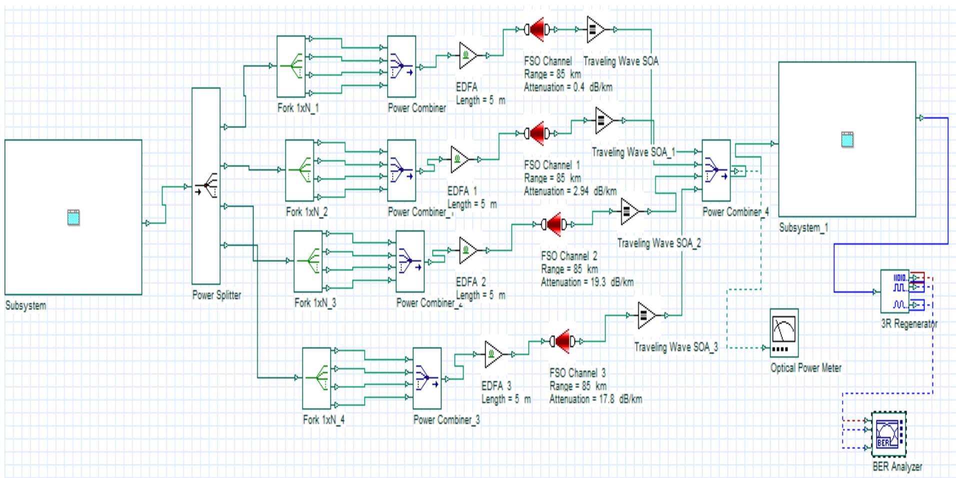


Fig. 7 ***Simulation setup for multibeam FSO system using RZ pulse generator***

III. RESULTS AND DISCUSSION

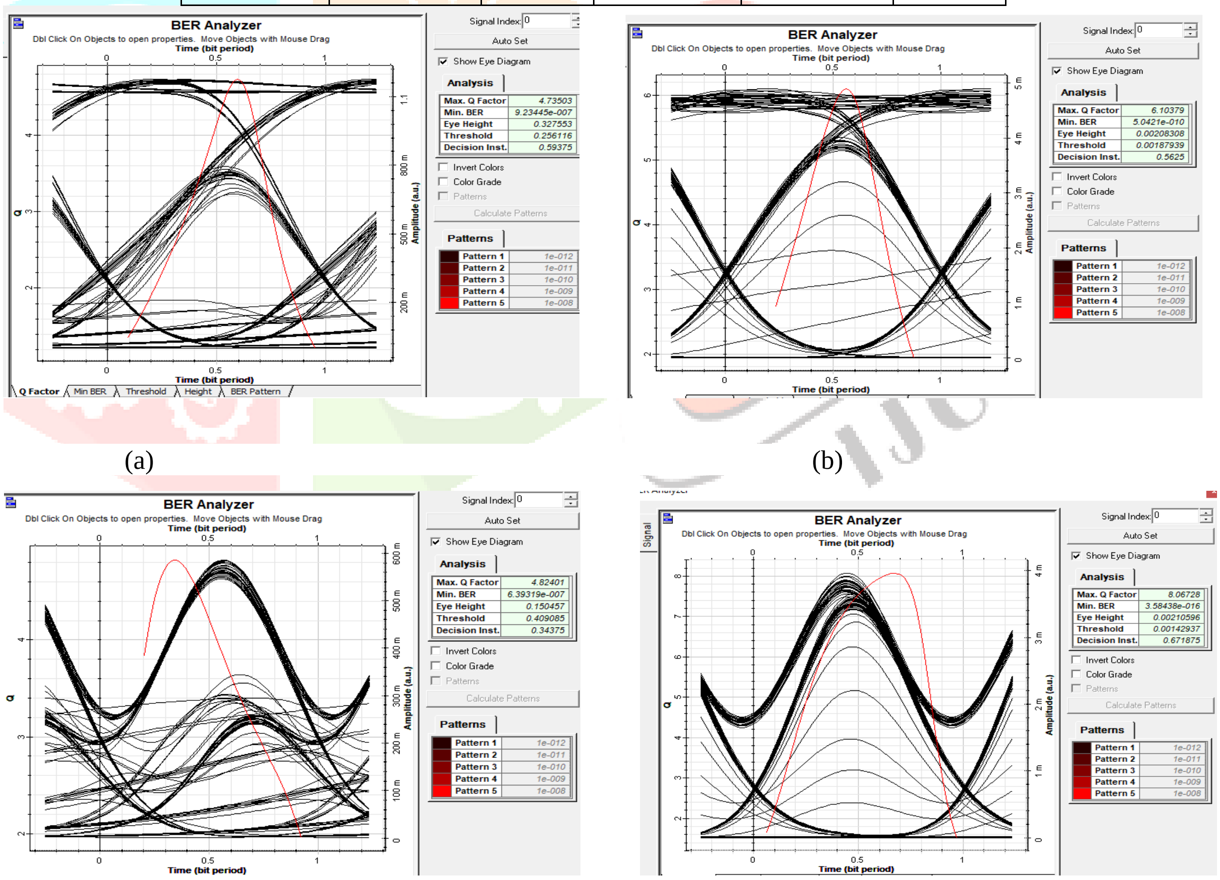
Both the systems have been compared in terms of achievable link distance using same system parameters. The analysis has been done up to the acceptable values of Quality factor (Q) and minimum BER for successful communication. Results for under scintillation effect as given below:

Table 2 Achievable link distance for single beam FSO system and Multi beam FSO system under scintillation

The comparison of and Multibeam FSO scintillation effect for quality factor 5.94 with diagram using RZ and generator.

SINGLE BEAM FSO SYSTEM			MULTI BEAM FSO SYSTEM		
Amount of scintillation Cn^2 [$m^{-2/3}$]	Attenuation for scintillation (dB/Km)	Link distance (km)	Amount of scintillation Cn^2 [$m^{-2/3}$]	Attenuation for scintillation (dB/Km)	Link distance (Km)
10^{-10}	4.4	3.0	10^{-12}	0.4	85
			10^{-13}	2.94	85
			10^{-14}	19.8	85
			10^{-15}	17.8	85

single beam FSO System under acceptable the help of Eye NRZ pulse



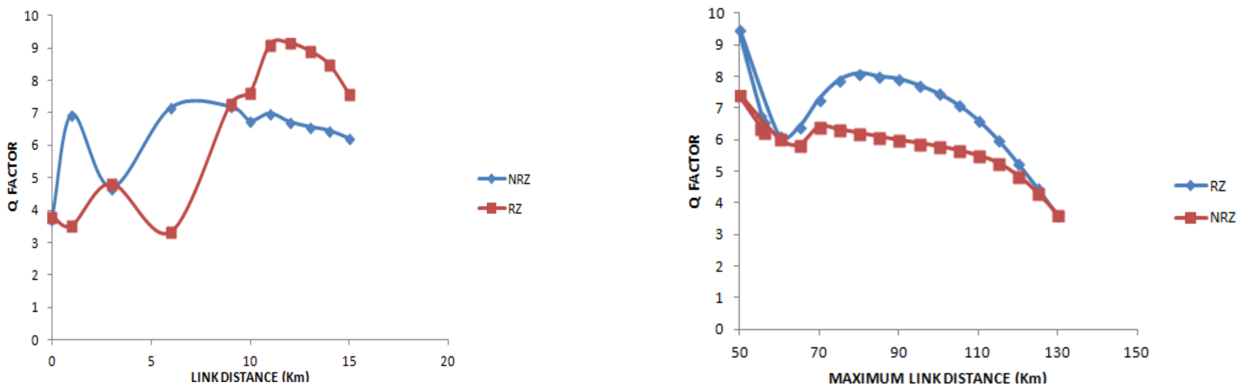
(a) (b)

(c) (d)

Fig. 8 (a) Single Beam FSO Using NRZ (b) Multi beam FSO using NRZ (c) Single beam FSO using RZ (d) Multi beam FSO using RZ

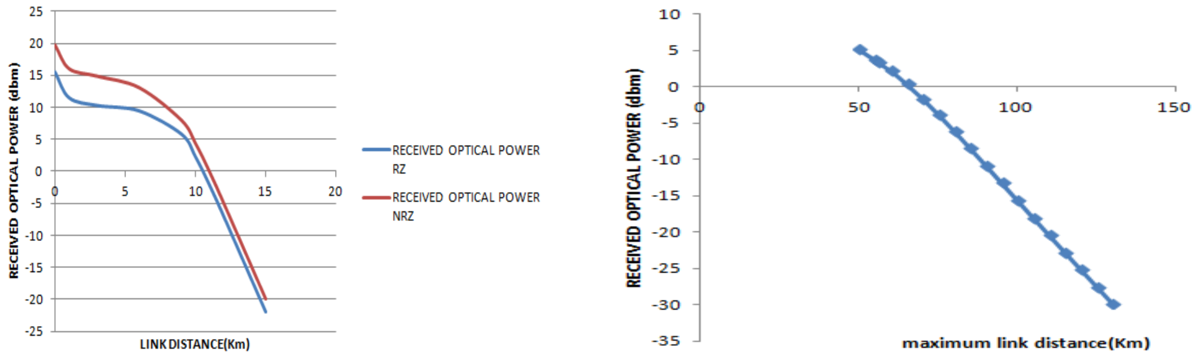
Performance analysis for single beam and multibeam FSO system

To Obtain Quality Factor for Minimum Link Distance in Single Beam Fso System both RZ and NRZ



(a) (b)

Fig. 9 Comparison of NRZ and RZ under Scintillation Effect in terms of Q factor: (a) Single beam FSO (b) Multi beam FSO



(c) (d)

Fig. 10 Comparison of NRZ AND RZ under Scintillation Effect in terms of Received Optical Power: (a) Single beam FSO (b) multibeam FSO

Q factor:

Q factor measures the quality of an transmission signal in terms of its signal-to- noise ratio (SNR).Q factor is the difference between the mean values of the signal levels for a "1" and a "0" divided by the sum of the noise values at those two signal levels assuming Gaussian noise and the probability of a '1' and '0' mission being equal (P(1) = P(0) = ½)).The greater that difference is, the higher the Q-Factor and the better the BER performance.

BER:

It is the number of bit errors per unit time. It is the number of bit errors divided by the total number of transferred bits during a studied time interval.

IV.CONCLUSION

There is a big similarity between results given by both software. Thus, it can be inferred, that the analysis done is a valid one in this paper, the method for the simulation under the scintillation effect was studied in which multibeam system successfully transmits up to 85 km which is much greater than that achieved by the single beam system that transmits only 3 km, under same atmospheric conditions. Multibeam system outperforms single beam system by taking scintillation effect into account. Thus, it can be used in the FSO applications where the signal reliability is important.

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