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Impact of Various Weather Conditions on Free Space Optics using 4X4 Transmitter/Receiver Combination Integrated with Different Ways of Amplification

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Abstract: Due to consistently growing demand for high data rate and high speed wireless access, free space optics has emerged as a next generation high speed wireless communication technology.FSO system using multiple transceivers has several advantages such large link distance and better bit error performance. In this paper, FSO system using spatial diversity technique and three ways of optical amplifications are proposed. Performance Analysis of different amplification systems for various weather conditions is carried out. Parameters such as received power, BER and maximum achievable range are analysed. Multiple transmitter/receiver combination integrated with various amplification types enhances the performance of FSO system.

Keywords: Free Space Optics (FSO) link, Multiple TX/RX FSO, Bit error rate (BER), Preamplifier, Optical amplification

I. INTRODUCTION

Free Space Optical Communication has attracted considerable attention recently as it is a technology which offers speed of fiber and flexibility of wireless technology. Free space optics also known as fibreless optics has many advantages such as high speed, unregulated bandwidth and protocol independent. [1] It is a cost effective, secure and rapidly deployable last mile wireless access technology which provides data rate up to tens of Gbps [2]. This technology is least effected by interference and is immune to fading which results in less power loss [3]. Despite of many advantages there are various challenges which limits the system performance. Local weather conditions such as fog, haze and rain severely effects the performance [4][5]. Atmospheric turbulence, Building sway, aerosol scattering effects and mechanical vibrations are also various causes of performance degradation [6]. FSO system can function over several kilometres as long as there is clear line of sight and thus can be effected by various obstructions. Atmospheric losses in the system occur due to absorption, scattering, scintillation and refraction [7]. Beam divergence and pointing error leads to free space losses. [8][9]

Spatial diversity techniques which uses multiple transmitter/receiver combination improves the link performance by reducing fading induced by atmospheric turbulence [10]. This further improves the received power at the receiver. This works focuses on spatial diversity [11] integrated with various ways of amplification systems analysis of performance is done under various weather conditions. Three systems are used. First system has the optical amplifier used at the transmitter known as the preamplifier. Post-Amplification use amplifier at the receiver. Third system is analysed with optical amplifier at the transmitter as well as the receiver. Comparative study over these systems is done. By using the feasible parameters for 4X4 TX/RX combination [12] integrated with various ways of amplification, performance of FSO system can be improved. Performance is analysed on the basis of maximum achievable distance and bit error rate. Section II describes the simulation set up and system parameters. The section III discusses the results and the paper is concluded in the section IV.

II. SIMULATION SETUP

The software platform uses optical communication package optisystem 7.0 of Optiwave Company. A 20Gbps high speed atmospheric optical communication model is established based on multiple transceivers integrated with various ways of optical amplification. This FSO system uses 4X4 transmitter/receiver combination which improves the received power and further it is integrated with three types of amplification. Three types of amplifications are used preamplification (system1), post-amplification (system 2) and pre-post amplification (system 3).System 1 consists optical transmitter connected to fork. A fork is a component used to duplicate the number of output ports so that each of the signals coming out from fork's output has the same value with the output signal from the previous component connected to it.The first fork produces the multiple beam and this fork is connected to another set of forks which also produces multiple laser beams .These laser beams are combined by the power combiner. An optical amplifier is applied before

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output is given to FSO channel. At the receiver side power coming from the FSO channel is again combined by power combiner and then fed to the optical receiver. Optical power meter, optical spectrum analyser and BER analyser are the three visualizers used in the simulation .[12]The power meter at the transmitter is used to measure the transmit power signal coming out from the transmitter output port and the receiver power meter is used to calculate average received power at the receiver. BER analyzer calculates the bit error rate and displays the eye diagram. System 2 setup is similar with system 1 but amplifier is applied after the FSO channel instead of before FSO channel. In system 3 amplifier are used at receiver as well as the transmitter. Table I shows attenuation offered by various weather conditions at 1550nm.Table II shows the various system parameters. Figure 1, 2 and 3 shows the block diagram of system 1, 2 and 3 respectively.

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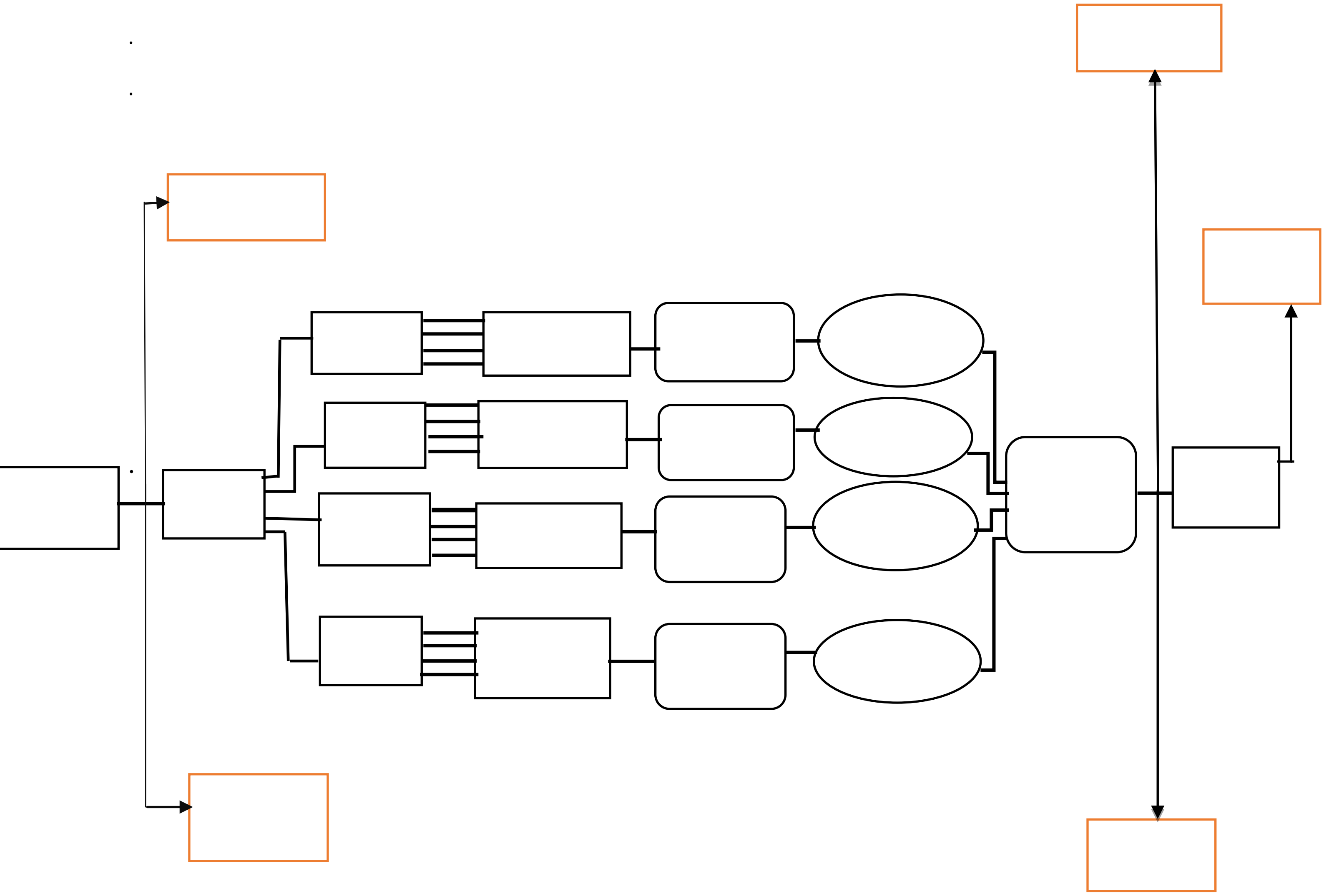

FIG 1: Block diagram of system 1

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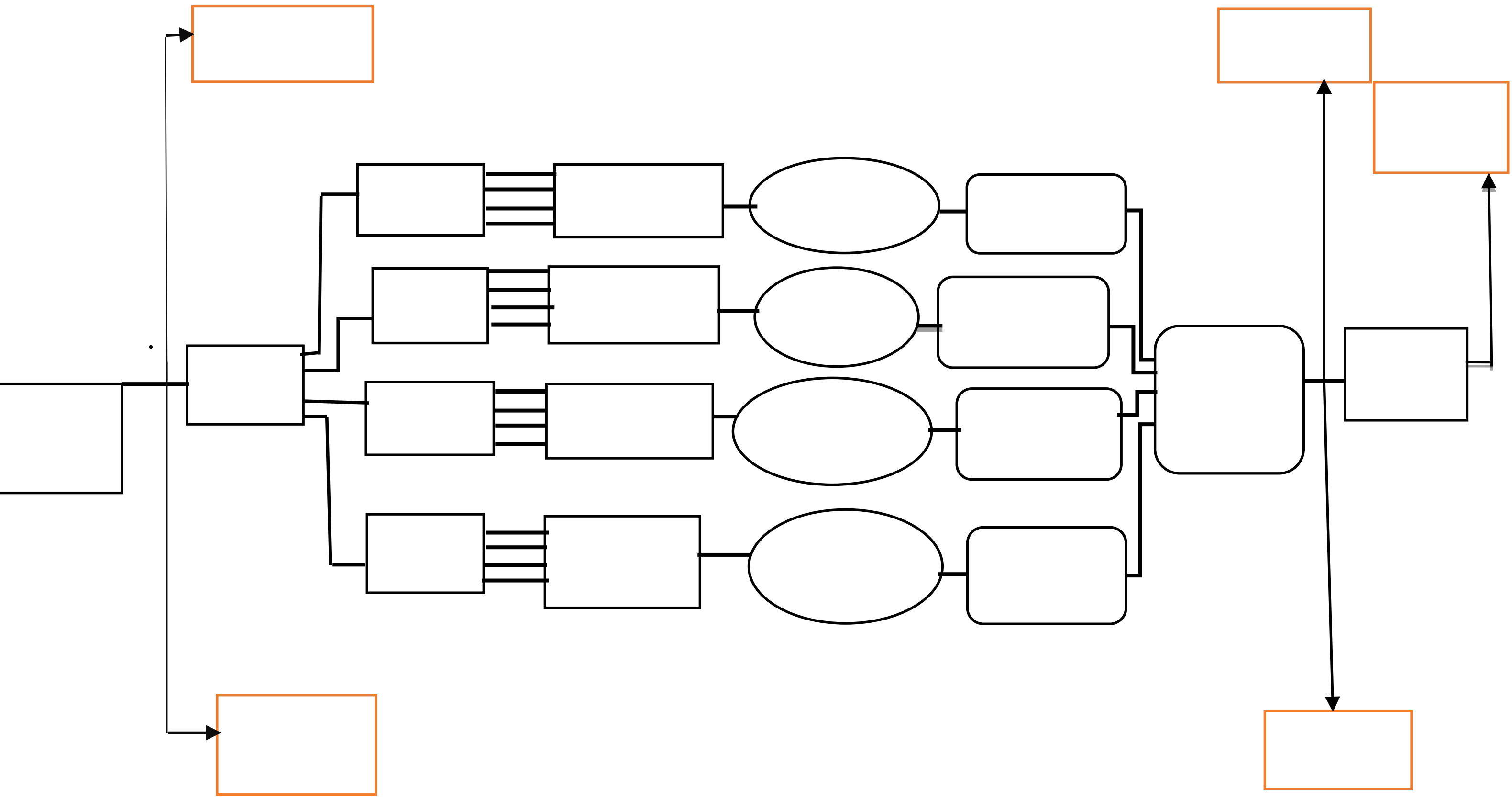

Fig. 2: Block diagram of system 2

TABLE I: Atmospheric attenuation at different weather conditions for 1550 nm wavelength

Weather Conditions	**Visibility (km)**	**Attenuation(dB/Km)**
Clear air	23	0.1
Haze	2	4.2
Light Fog	0.8	15.5
Moderate Fog	0.6	25.5

TABLE II: FSO system parameters

Parameter	**Value**
Transmitted Wavelength	1550 nm
Data Rate	20 Gbps
Transmitter Aperture	2.5 cm
Receiver Aperture	45 cm
Transmitted Power	25 dBm
PIN Responsivity	1 A/W
Each Amplifier Gain	30 dB
Transmitter loss	1.8 dB
Receiver loss	1.8 dB
Receiver Sensitivity	-45 dBm
Beam Divergence	2 mrad

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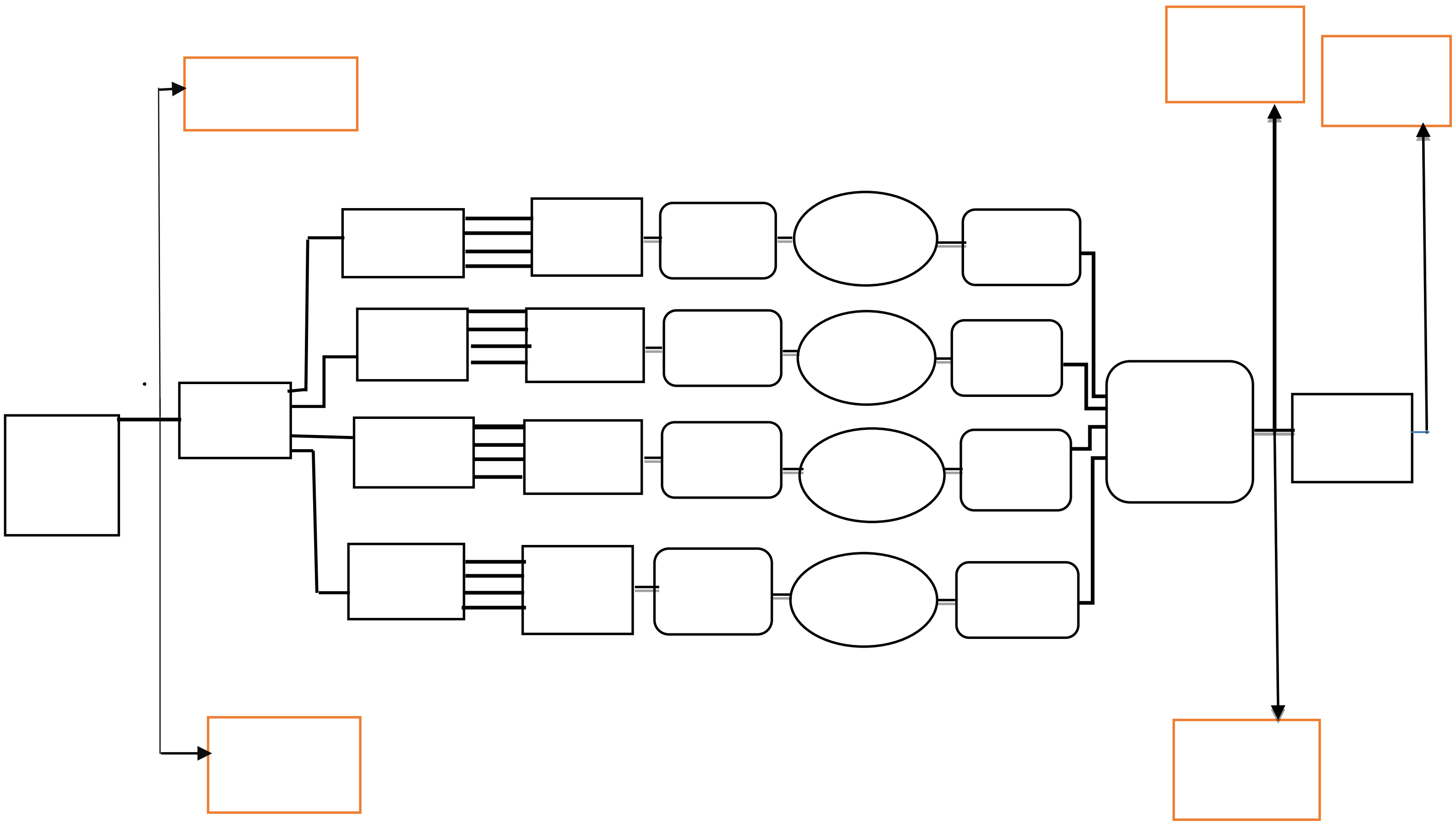

Fig. 3: Block diagram of system 3

III.RESULTS AND DISCUSSION

In this work, a novel FSO system is modelled in which 4X4 multiple transmitter/receiver combined with different ways of amplification. Weather conditions such as fog, haze and rain severely effects the FSO system. High data rate of 20Gbps and wavelength of 1550nm is used. Optical amplification applied enhances the performance of system. Table III shows the maximum achievable distance at an acceptable BER and received power for various weather conditions for system 1.For clear weather condition the maximum range of 338 km can be achieved for system 1.As attenuation increases the maximum achievable distance for light fog is 4.56 km.System 2 uses post amplification which has an inferior performance than system 1.System 3 uses optical amplification both at receiver as well as at the transmitter. Table IV and table V shows the performance of system 2 and system 3 for various weather conditions. System 3 provide us with maximum range up to 310 km under clear weather condition. System 3 shows the higher received power but BER performance of system 3 is inferior to system 1.System 3 also become little costlier and complex because of extra optical amplifiers required. Figure 4, figure 5 and figure 6 shows the graph for BER vs range for system 1, 2, 3 respectively under clear weather condition. System 1 shows the best BER performance as the optical signal is amplified at the transmitter, so it avoids being merged by noise in transmission. For system 2 strong noise is added in transmission before the signal is amplified, so its BER performance is worst. System 3 is the combination of both system 1 and 2 hence its BER performance is better than system 2 but not superior than system 1.

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TABLE III: Results of system 1 for different weather conditions

Weather Condition	Maximum Range	Received Power(dBm)	Received BER
Clear Air	338 km	-36.546 dBm	$2.95e^{-009}$
Haze	14.5 km	-36.302 dBm	$1.001e^{-009}$
Light Fog	4.56 km	-36.05 dBm	$3.07e^{-010}$
Moderate Fog	2.92 km	-35.97 dBm	$2.101e^{-010}$

TABLE IV: Results of system 2 for different weather conditions

Weather Condition	Maximum Range	Received Power	Received BER
Clear Air	105 km	6.692 dBm	$4.613e^{-009}$
Haze	7.8 km	6.725 dBm	$9.66e^{-010}$
Light Fog	2.7 km	6.736 dBm	$5.734e^{-010}$
Moderate Fog	1.78 km	6.743 dBm	$4.18e^{-010}$

TABLE V: Results of system 3 for different weather conditions

Weather Condition	Maximum Range	Received Power	Received BER
Clear Air	310 km	6.701 dBm	$2.85e^{-009}$
Haze	13.8 km	6.709 dBm	$2.09e^{-009}$
Light Fog	4.36 km	6.75 dBm	$2.93e^{-010}$
Moderate Fog	2.8 km	6.75 dBm	$2.737e^{-010}$

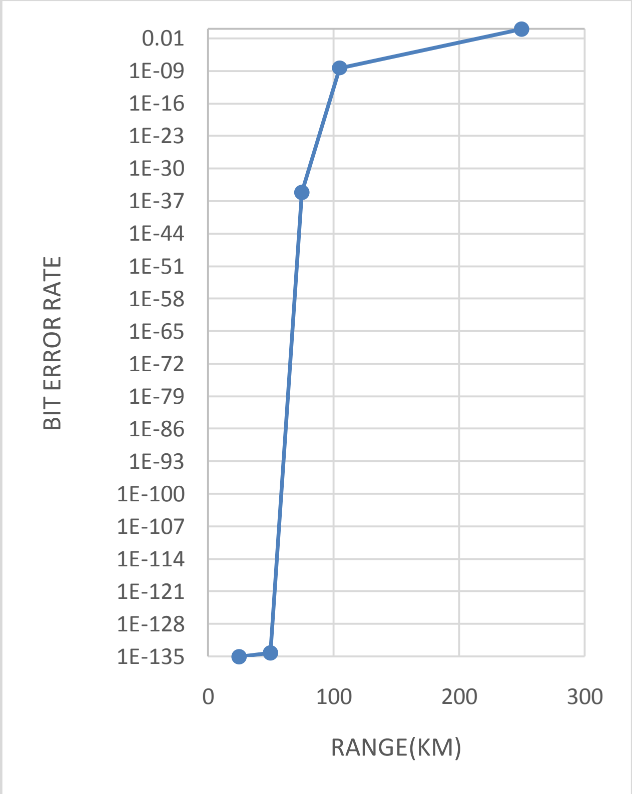

Fig. 5: bit error rate versus distance for system 2

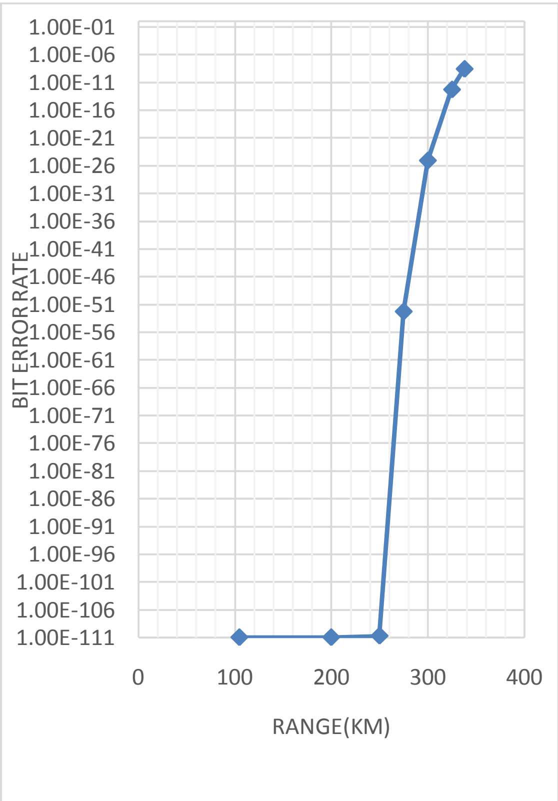

Fig. 4: bit error rate versus distance for system 1

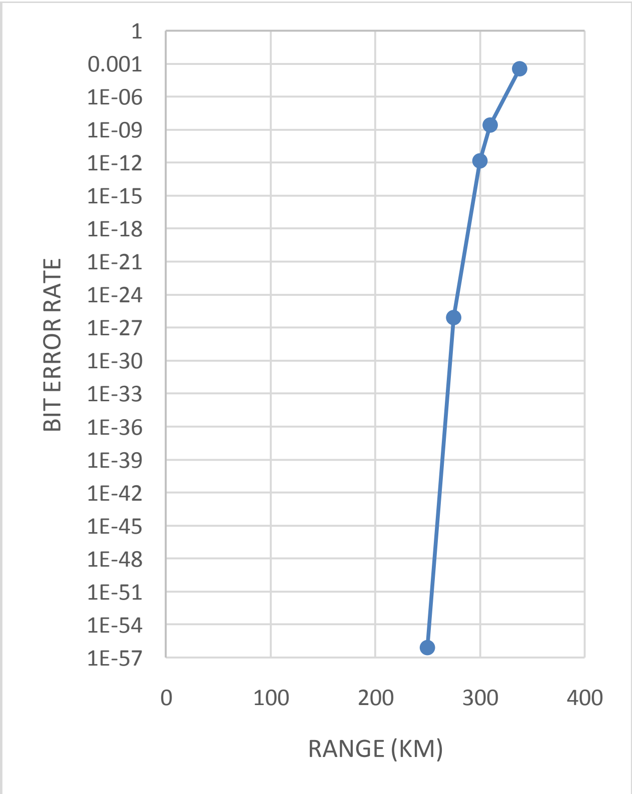

Fig. 6: bit error rate versus distance for system 3

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IV. CONCLUSION

The aim of this work is to investigate a multiple transmitter/receiver FSO link which is integrated with different types of amplifications. Three types of systems are studied in this work. System 1 shows the best BER performance and gives maximum range of 338 km within acceptable received power .System 2 using post amplification is not a good option as its BER is quite high and maximum range is just up to 100 km. System 3 uses both pre and post amplification shows superior performance than system 2 but its BER is higher than system 1 though its received power is good. So it can be concluded that preamplification is a better option as it has good BER performance within acceptable received power and is lesser costly and complex than system 3.

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