Multiple Transmitters & Receivers for Free Space Optical Communication Link Performance Analysis

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***Abstract*—FSO is a line-of-sight communication technology able to provide quick and simple optical communication connections and excellent in sending and receiving information data. This paper investigated FSO utilising multiple transmitters and receivers, and revealed better and effective performance at various distances between the transmitters and receivers. While maintaining the quality of received signals, the analysis also showed improvement in terms of received power, eye diagram, gain and noise power and Q–factor.**

***Index Terms*—Distance; Free Space Optic; Transmitter; Receiver.**

I. INTRODUCTION

Free space optics (FSO), likewise free–space photonics (FSP) refers to the transmission of infrared (IR) bars through the air to get broadband correspondences. Most of the time, laser shafts are utilized, albeit non-lasing sources, for example light–emanating diodes (LEDs) or IR–discharging diodes (IREDs). The hypothesis of FSO is that it is basically the same as that of fibre optic transmission. The distinction is that the vitality shaft is collimated and sent through clear air or space from the source to the destination, as opposed to guiding through an optical fibre. On the off chance that the vitality source does not deliver an adequately parallel shaft to venture to every part of the obliged separation, collimation should be possible with lenses. At the source, the unmistakable or IR vitality is regulated with the information to be transmitted. At the destination, the bar is captured by a photo detector, the information is extricated from the obvious or IR bar (demodulated), and the subsequent sign is intensified and sent to the equipment.

FSO frameworks can work over separations of a few kilometres. At the length of an unmistakable viewable pathway between the source and the destination, correspondence is hypothetically conceivable. Regardless of the possibility that there is no immediate observable pathway, deliberately situated mirrors can be utilized to mirror the vitality.

Free Space Optics has emerged as a distinct option to perform such transmission and it needs high velocity correspondence framework. It uses the idea of transmitting high data transmission data by utilising the optical shaft, and starting with one point then onto the next in the free space. Subsequently, the reasonable observable pathway between both the transmission and getting to terminals is crucial to build up a consistent correspondence. This observable pathway innovation offers various points of interest to both telecom clients and suppliers. Specifically, it gives high information rates up to a few Gbps, is invulnerable to radio recurrence obstructions, obliges no authorising, gives a profoundly secured correspondence interface because of the utilisation of an exceptionally thin pillar edge, and offers a modest, quick and simple organisation when contrasted with fibre optic establishment [1, 2]. It offers different execution on diverse separations in the middle of the transmitter and beneficiary by utilizing numerous transmitters and recipients with the expectation of complimentary space optic connection. Analysis of system performance is based on four parameters, which are the received power, gain, noise figure and Q–factor.

The unsettling influences will essentially influence the FSO transmission exhibitions since this innovation exclusively utilises the air as the medium of transmission. Further, the defencelessness towards environmental phenomena is inexorable. The environmental turbulences will bring about the fast change of received power and inevitably will diminish the framework quality. In addition, the interference of the laser bar, for example, the feathered creature fold will likewise exasperate the correspondence channel [3]. Subsequently, there are studies [4–6] proposing different options for alleviate these weaknesses. Various transmitters/receivers (Tx/Rx), i.e. multiple beam of laser are utilised to enhance the nature of Free Space Optics (FSO) correspondence frameworks. With the present needs of this innovation for more separation correspondence, the subjective investigation of the framework has to be fundamental. This work will utilise different Tx/Rx.

In light of the business FSO hardware that are on a trial site, Tx/Rx FSO connection measures the FSO received power. The execution examination will be as far as the measured received power, eye diagram and re–enacted BER. The drive to outline the model is activated by the limitation that the BER analyser does not furnish a direct association with the BER. Basically, it merely shows a pass/come up short relationship without passing on anything. Along these lines, it would be valuable to know the amount of blunder the framework can endure before the BER increments altogether and the quantity of transmitters and recipients is utilised. With respect to the eye diagram, it will serve as an extra pointer in deciding the nature of the FSO connection. In the advanced transmission, the quantity of bit lapses is the quantity of received bits of an information stream that is more than the correspondence channel that has been changed because of commotion, obstruction, contortion or bit synchronisation mistakes.

FSO that utilises multiple TXs/RXs potentially has the ability to reduce geometrical losses [5, 9, 10]. Geometrical losses are also known as optical beam attenuation that results in the reduction of optical power due to the spreading of laser beam while propagating from one end to another. Also, a multiple TXs/RXs FSO reduces the possibilities of the laser beam being blocked as it may provide laser path redundancy. Adding to that, attenuation due to scintillation and heavy rain can be reduced by making the receiver aperture larger [10, 11, 12].

II. Theoretical Analysis

The FSO join exhibitions can be controlled by a few parameters, including the geometrical misfortune, join edge, influences and BER. This work concentrates on two parameters to assess the FSO join exhibitions, which are the received force and the BER. Hypothetically, the fundamental correspondence guideline that expresses the received power must not be exactly to the transmitted force, $P_R \leq P_T$ as indicated by [4]:

$$P_R = P_T - total\, losses \tag{1}$$

where P_R(dBm) is the received power, P_T(dBm) is the transmitted force. As indicated by [5], all of the misfortunes in a FSO correspondence framework would cover all the misfortunes brought about by the environmental phenomena, L_{ATM} (dB) which can be formulated as in Equation (3), geometrical misfortune, L_{GEO}(dB) and framework misfortune, L_{SYS} (dB). The new mathematical statement for FSO received force is as in Equation (2):

$$P_R = P_{TCOMB} - L_{ATM} - L_{GEO} - L_{SYS} \tag{2}$$

In every correspondence framework, misfortunes because of the gear wastefulness cannot be disregarded. As per Beers–Lambert Law [6], the barometrical misfortunes for any laser influence is in a type of exponential comparison of:

$$L_{ATM} = e^{-a\ell} \tag{3}$$

Since the work included the use of multiple TX/RX building design, the aggregate transmitted force indicated by P_{TCOMB} (dBm) from each of the transmitters has been seriously thought. The aggregate transmitted force can be calculated as in Equation (4):

$$P_{TCOMB} = P_T + 10\log N_T \tag{4}$$

Where N_T is the quantity of transmitter lenses on a solitary FSO unit. Geometrical misfortune and framework misfortune are the inner misfortunes happened inside of the FSO handset. Both misfortunes are settled on all FSO join and cannot be disregarded. Once the L_{SYS} as a producer is characterised, then in [5] L_{GEO} can be computed as in Equation (5):

$$L_{GEO} = -10\log\left[\frac{4A_{Rtotal}}{\pi(\ell\theta)^2}\right] \tag{5}$$

Length (km) is the separation of the optical way where the laser pillars travel and θ (mrad) is the unique point which is the edge of the cone of light radiated from the transmitter. In the meantime, $4A_{Rtotal}$ (m^2) is the aggregate region of the collector openings on a solitary FSO unit. Bit slip rate is the proportion of the quantity of blunders to the aggregate number of bits. BER is another fundamental subjective parameter of FSO connection. In this work, it measures the nature of the different TX/RX framework [3], which has characterised BER as the estimation of Equation (6) where, n_e is the quantity of got lapse bits and n_B is the quantity of every single transmitted bit for a long stretch.

$$BER = \frac{n_e}{n_B} \tag{6}$$

III. Experimental Design

For multiple TXS/RXS system performance analysis, we used model of FSO link as shown in Figure 1 that comprises the layout model for the multiple TXS/RXS combinations. A typical FSO system consists of FSO transmitter, FSO channel and the FSO receiver. The wavelength used for the simulation was set to 850 nm with the power of 8.66 dBm [5, 7]. The output of the TX was branched so as to duplicate the number of output so that each of the signals emits the same value of wavelength and power. The fork was connected to the TX to produce multiple laser beams from one source. Then, each of the output signals was connected to FSO channels.

The apertures of the TXS and RXS were set to 2.5 cm and 8 cm respectively [5]. The beam divergence was 2 mrad and the distance of the channel was set from 1 km to 5km. Hence, the work involved the modification of the single TX and single RX layout design to enable the simulation of the multiple TXS/RXS.

In every communication system, losses due to the equipment inefficiency cannot be ignored. Since there were multiple FSO terminals involved, each terminal had a loss of 1.8 dB according to FSO equipment installed on the practical site. For the simulation, we considered a clear weather condition; therefore, the attenuation was set to be 0.43 dB/km [5, 10–12]. All multiple signals coming out from the FSO channel were then once again combined using the power combiner before they were received by the RX units.

The sensitivity of the RX was set to be –45 dBm. The two visualisers used in the simulation are the optical power meter and the BER analyser. The first power meter was used to measure the transmit power signal coming out from the TXS output port and the second power meter was used to calculate and display the average received power at the RXS. As for the Ber analyser, it automatically calculated the BER value and display the eye diagram of the designed system. The bit rate used in this setup was 1 Gbps.

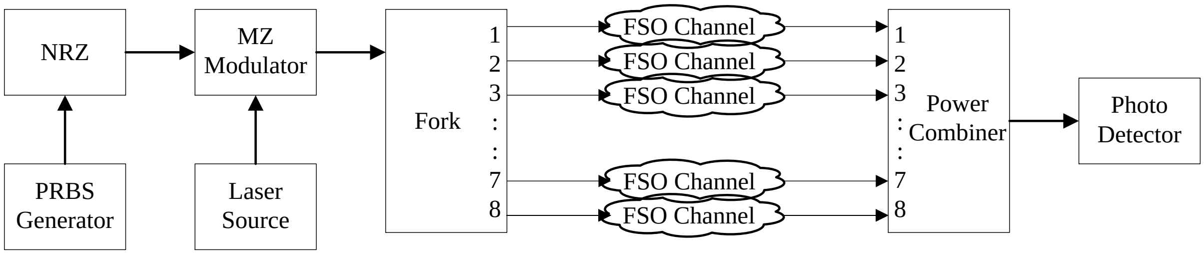

Figure 1: TXs/RXs FSO link simulation layout.

IV. Results & Discussion

Referring to Table 1, the size of eye opening was the best when 8X8 TXs and RXs were used. This condition resulted in the production of less jitters of the signal; thus, reducing the potential occurrence of data errors. Although at 1 km distance, all configurations showed good performance, an excellent performance indicated for RXS and TXS were at 2 km and above distances for the 8X8 configurations. Better system performance was achieved as indicated in the results of having wide eye opening. As the distance between TXS and RXS increased, more noise was introduced to the system and more laser light was spread; thus, affecting the eye diagram. However, this problem was overcome by increasing the number of TXS and RXS, especially for long distance data transmission.

Table 1
Eye diagram results for various TXS & RXS units at various distances

No. of transmitter & receiver / Distances	4x4	5x5	6x6	7x7	8x8
1km					
2km					
3km					
4km					
5km					

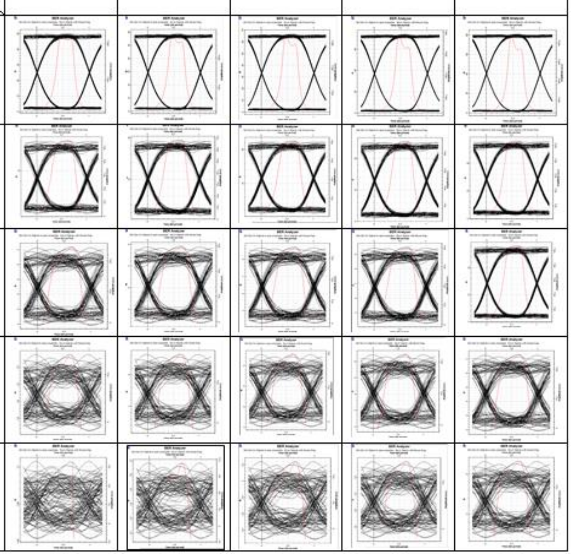

Figure 2 shows that the received power decreases when the distances between TXS and RXS units increase. The increase number of TXS and RXS units increases the received power.

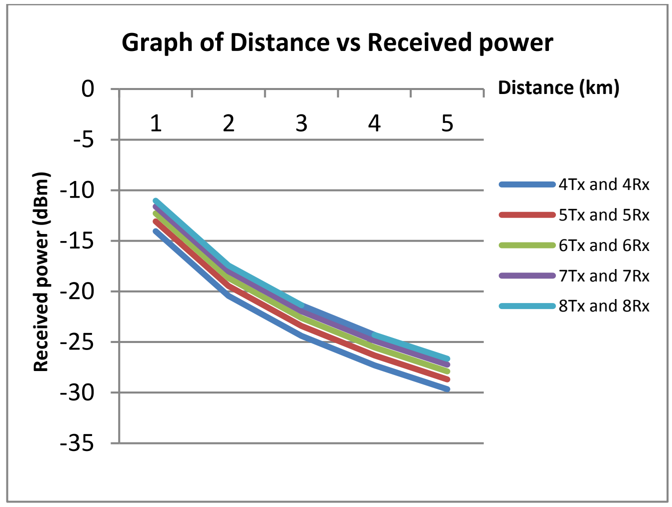

Figure 2: Graph of distance versus received power.

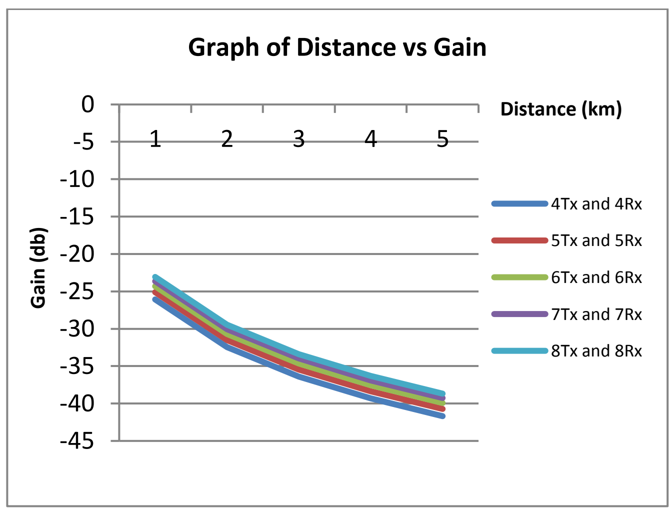

Figure 3: Graph of distance versus gain

Figure 3 shows that the gain of the FSO system is decreased when the distances between TXS and RXS increase. The gain for this FSO system analysis is low due to no amplifier being used.

Figure 4 shows that the noise figure increases when the distances between TXS and RXS units increase. With more numbers TXS and RXS units utilised, noise figure is reduced.

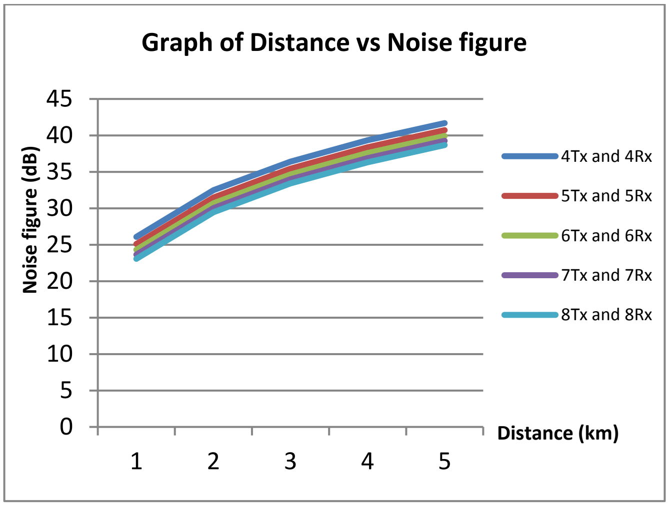

Figure 4: Graph of distance versus noise figure

Figure 5 shows that the Q factor decreases when the distance between the TXS and RXS units increase. The 8X8 configurations had never failed in producing the best results. As indicated, it produced the highest Q factor compared to other sets of configurations of TXS and TXS units. Every set of TXS and RXS configurations showed high rate of Q–factor reduction for distances of 1 km and 2 km but for the 8x8 configurations, it achieved a Q–factor of 7 for distance of 5 km.

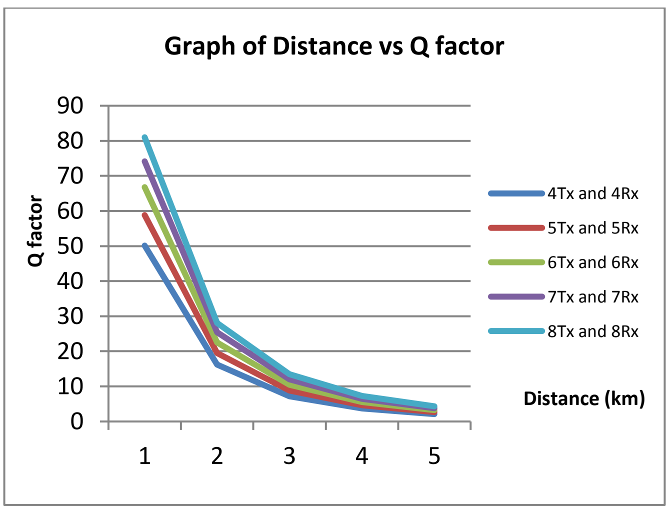

Figure 5: Graph of distance versus Q factor

V. CONCLUSION

We conducted the BER and eye diagram analysis at various distances. It can be concluded that a lot of improvements have been achieved using higher number of TXS and RXS, as the best performance indicated by the 8X8 configurations. At the distance of 5 km between TXS and RXS, the 8x8 configuration simulation results showed a better performance in terms of received power, gain, noise figure and Q–factor as compared to the 4x4, 5x5, 6x6 and 7x7 configurations. Thus, it is proven from theoretical and references that increasing the number of TXS–RXS pairs will improve the performance of FSO communication system.

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