Performance Evaluation of Downlink Design Based on Free Space Optical System

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Abstract. In this paper, the performance of downlink design utilizing the free space optic (FSO) is presented. The permissible BER of 10^{-58} is achieved when the system utilized 40 cm aperture diameter. The highest system sensitivity will lead to less error and enable more transmission output. The result revealed, at a bit rate 155Mbps and effective received power -27.5 dBm, FSO downlink system at bit rate 155 Mbps improved by 13% as compared to 1.5 Gbps and 2.5 Gbps in single transmission line. It is truly shown that, the FSO system utilized 155 Mbp/s with 40 cm aperture diameter shown good performance of a reliable FSO downlink system.

1 Introduction

Free space optical (FSO) has to be included in the set of answers for qualifying the bandwidth requirements of the modern internet. FSO system is an incredible alternative to overcome the bottleneck broadband connectivity problem. Recently, FSO is very active with numerous fundamental and technological problems to enhance its performance in a wide situations range. The swift continuity in the increasing of data rate transmission by FSO communication system in both long- and short-range applications implementing the rapid development of the system performance. Figure 1 shows a basic scheme of the FSO communication system with optical wireless and diverse user connectivity.
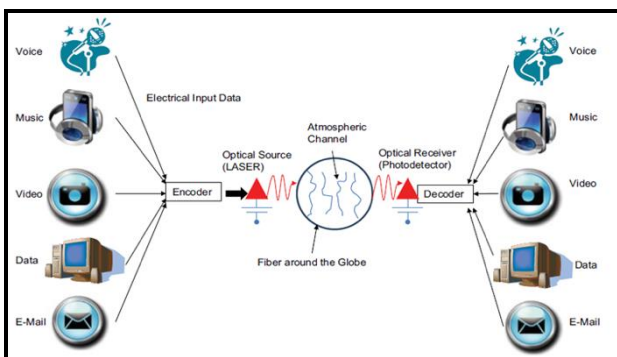

Fig. 1. A basic scheme of the FSO communication system with optical wireless and diverse user connectivity [1]

Various FSO link conditions must fulfil multiple system needs. These involve various propagation channel characteristics, different technique of

transmission, and detection methods. The advantage of indoor applications of FSO communications such as secure communications and sensor networking over short ranges is drawing attention globally. It is made as a non-interfering replacement to RF communications [1]. Speeds usually up to 2.5 Gbps are achievable and ranges up to a few km, depends on technology and conditions of the atmosphere [2]. In a FSO link the transmitters transmit high power light. The power light however appears as low power light at the receiver after transferring through the air.. The link margin of the connection shows the light amount received by an optical terminal over the lowest value crucial to maintain the link active. Fig. 2 displays the basic communication system which is consisting of a transmitter, a receiver, and a communication channel.
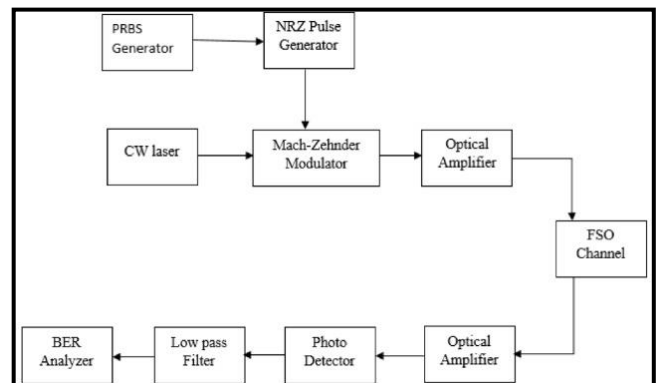

Fig. 2. The basic communication system [3]

There are some parameters related to the performance degradation of a FSO link. They are the

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link range between optical transceiver, line of sight, alignment of optical transceiver, atmospheric conditions, water vapour and hot air, strong electromagnetic interference, and optical signal wavelength [4]. An expendable microwave link is inevitably crucial, as the laser link can stop working under various changing conditions. Numerous investigations and applications of FSO have been reported [5-6]. A laser beam faces power loss due to various factors as it propagates through the air. One of them is absorption and scattering loss as defined in Beer's Law [7]. Absorption happens due to the photons of the beam bumping with haze particles. This phenomenon can reduce the link margin, distance and the availability of the link [8]. Scattering is the dispersion of a radiation beam due to physical interactions.

2 Bit Error Rate Simulation Analysis

The structural design of FSO can be categorized into three types of connections. They Point-to-Point connections, Point-to-Multipoint connections, and Multipoint-to-Multipoint connections. Point-to-Point connections consist of one transmitter and one receiver. This type of connection provides greater bandwidth although their availability is lower. The second connection is Point-to-Multipoint connections. They consist of one transmitter and multiple receivers. This second design provides low cost connections. Its advantage is that it facilitates node addition of the network. Even so, this type of connection provides poor bandwidth level compared to the former. The third design of FSO connection is Multipoint- to- Multipoint connections. This connections utilize multiple receivers and transmitters. They are also called as Mesh Network which provides redundancy and better reliability with easy node addition. Nonetheless, these connections have a significant disadvantage which shorter is distance limitation than other FSO designs. The FSO networks are shown in Figure 3, Figure 4 and Figure 5.
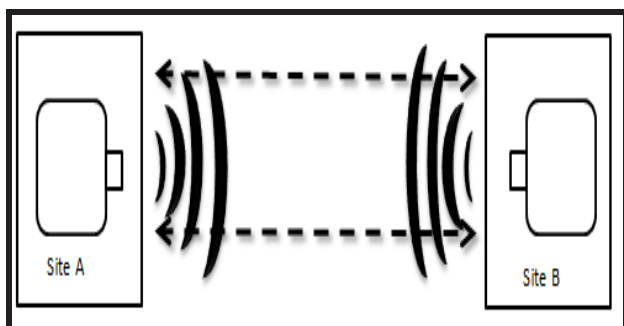

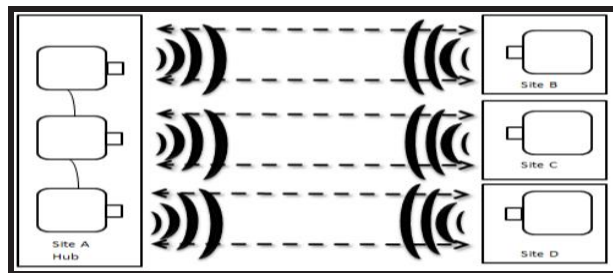**Fig. 3.** Point-to-Point Connection
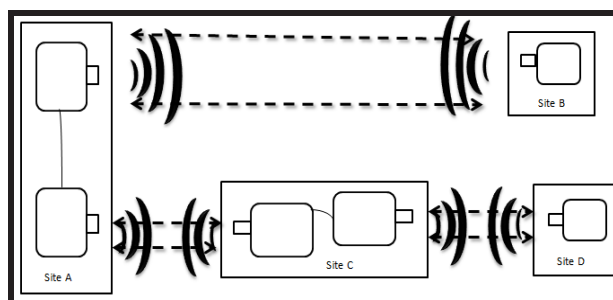

Fig. 4. Point-to-Multipoint Connection

Fig. 5. Multipoint-to-Multipoint Connection

FSO systems provide numerous advantages to the users. Examples are being low start-up and economical, swift deployment, and high bandwidths due to the technology optical nature[9]. The optical bandwidth can reach up to 1 Gbps or more. It is primarily to assist wide bandwidth range over a long distance communication [10]. Although at high bandwidth, long distance cost efficient communication the environmental factors such as weather linked factors continue as major challenges to minimize and may limit the data rate and link availability via LOS (Line of Sight) [11]. Recent studies suggest ways to solve LOS line of sight problems with minimal bit-error-rate (BER) performance in FSO communication system under worst interference conditions [12]. But the increasing of laser power can resolve this problem up to some point [13]. As the transmitter reaching maximum power limit, the bandwidth or transmission distance of the physical links which are under severe weather conditions such as heavy haze has to be reduced. This will cause some alterations in the structures of FSO networks. Thus, the effectiveness and performance of Free Space Optical network will be affected.

3 Bit Error Rate Simulation Analysis

Bit error rate (BER) is one of the main elements of FSO communication system. BER can be estimated using equation 1

$$BER \approx \frac{Ne}{Nb}$$

where,
Ne=received error bits number
Nb=transmitted bits for a period

Generally, the BER values for a digital transmission system are usually specified and influenced on the Signal-to-Noise-Ratio (SNR) of the optical receiver.

This feature determined the probability of errors when one bit of data is being transmitted. The internal noise of the optical receiver affects the value of BER [14]. The value of BER can be calculated using the following formula.

$$BER = \frac{1}{2} erfcQ$$

However in this paper, the results for tht BER are obtained from simulation using OptiSys^{TM} simulation tool. The data collected are analysed in the form of graph and evaluated in the section below.
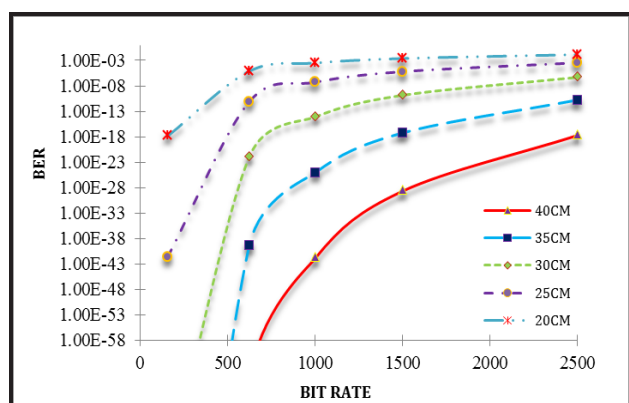
4 Results and Discussion

Fig. 6. Graph of bit rate against bit error rate (BER) with different receiver aperture diameter

Figure 6 demonstrate the relationship between bit error rate (BER) and bit rate using apertures diameter which ranges from 20 to 40 cm. From the graph, it can be seen that the bit error rate increases when there is bit rate increment. It is observed that the receiver aperture diameter of 40 cm has achieved the lowest bit error rate throughout the investigation (from bit rate 155 mbps to 2.5 gbps) compared to aperture diameter of 20, 25, 30, and 35 cm respectively. The FSO with receiver aperture diameter 40 cm has the lowest BER of 10^{-58} at 155 mbps. Then it finishes at BER 10^{-18} with bit rate of 2.5 Gbps. For receiver aperture diameter of 20 cm, the BER is 10^{-18} at the bit rate 155 mbps until BER 10^{-2} at bit rate of 2.5 Gbps. From the figure, it can be concluded that by increasing the receiver aperture diameter, the receiver's sensitivity is also increased. Higher sensitivity will allow more outputs and reduce the error received by the system. This will directly improve the system at high performance.
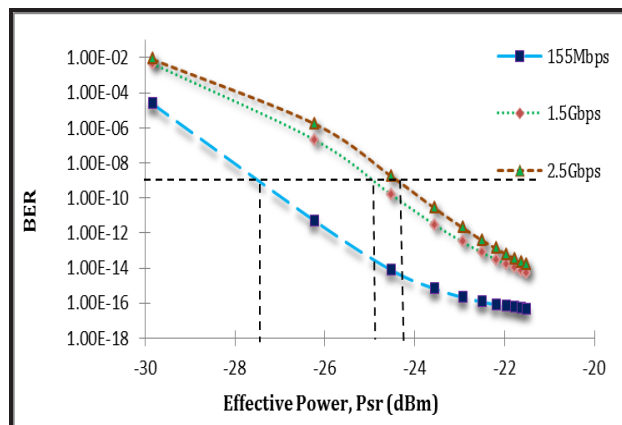

Fig. 7. Graph of bit error rate (BER) versus effective power with different bit rate

Figure 7 shows plot a BER versus effective power for bit rate 155 Mbps, 1.5 Gbps and 2.5 Gbps, respectively by considering all at range 1km and receiver aperture diameter at 20cm. the value caused of effective power P_{sr} varies from -30 dBm to -20 dBm. It can be seen that, the bit rate 155Mbps have a better performance contrast with the bit rate 1.5 Gbps and 2.5 Gbp, respectively, when the effective receives power P_{sr} for bit rate 1.5 Gbps and 2.5 Gbps are larger (i.e. when P_{sr} >-25 dBm). The effective receives power for bit rate 155 Mbps is -27.5 dBm at BER= 10^{-9} better than bit rate 1.5 Gbps and 2.5 Gbps are -24.8 dBm and -24.4 dBm respectively. The effective receiver power for bit rate 155 Mbps is the lower receiver power that can be reached to the receiver as compared with the bit rate 1.5 Gbps and 2.5 Gbps. The bit rate 155 Mbps proved that high bit rate can enhance the transmission link by 13% compared to bit rate 1.5 Gbps and 2.5 Gbps are 2% impeovement.

4 Conclusions

The downlink FSO communication system with 155 Mbps bit rate at BER 10^{-9} is best suited in comparison with a bit rate 1.5 Gbps and 2.5 Gbps, respectively. The result had shown the bit rate 155 Mbps with low BER 10^{-9} can obtain optical receive power P_{sr} -27.5 dBm. In addition, by using large aperture diameter, consequently, will improve system sensitivity.

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