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Performance Comparison between PIN and APD Photodiodes for use in Free Space Optical Communication Link

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Abstract-: In this paper investigation has been done on two different photodiodes PIN and APD for use as a receiver in free space fiber optical link. Eye Diagrams have been used to evaluate value of Q- factor in each and every case. Gaussian pulse modulation format has been used in this analysis work. It is clear from the findings of this analysis that value of Q-factor is maximum when APD has been used as the receiving photodiode at 1550nm wavelength and minimum when PIN diode has been used as receiving photodiode at 1550nm wavelength.

***Keywords-**: PIN, APD, Gaussian pulse modulation, free space optical link, Q- factor*

1. INTRODUCTION

Free Space Optics (FSO) is a technology that is used for telecommunication and can be used to transmit optical signals over the air. Free Space Optical communication can be considered as wireless transmission system [1-9]. FSO is capable of handling data at very high data rates of order of hundreds of Gbps. In Free Space Optical communication system licensing is not required as in case of radio communication and could be realized as a very low cost as compared to other telecommunication systems such as wireless communication. Also the narrow beams used for the purpose of transmission of information signals in FSO system are very difficult to intercept, and are resistant to interference or jamming [9-13]. Free Space Optical Communication can also be viewed as optical wireless communication. In Free Space Optical communication system different transmission medium can be used such as Light Emitting Diodes (LED) and Lasers. FSO can be used to establish a link between transmitter and receiver at very high data rate of the order of about tens of Gbps [1]. FSO depends on Line of Sight communication and there should not be any obstacle between transmitter and receiver in FSO [6]. FSO is very advantageous over other methods of data transmission system in many aspects for example t does not require any licensed frequency band for communication. It is very easy and relatively cheaper to install and price required for maintenance of FSO link is considerably quiet low as compared to other data transmission systems. Data transfer rate are very high in Free Space Optical transmission system. Because of the high security of information that can be transferred using FSO transmission system, it can also find its applications in military services. There are many parameters which decide the overall performance of a Free Space Optical transmission system. These performance parameters can be grouped as either internal parameters or external parameters [3-7]. Internal parameters consists of types of Laser used, the central wavelength used in transmission of data, amount of divergence of beam etc. Appropriate values of inner parameters are to be substituted in order to get desirable results from the data transmission system. The performance of a FSO has to encounter many challenges. The first and the most important is the loss incurred due to Free Space Path loss [5-12]. Second challenge is the dependence of performance on the current weather condition at different place and at different time of afternoon and night. The above mentioned challenges hinder the performance of the FSO transmission system and cause scattering [6], turbulence [5], and scintillation [10].

The performance of FSO system is also dependant on the elements that have been used in the link between transmitter and receiver. There are numerous types of modulation formats for example NRZ, RZ, Gaussian modulation formats that can be used in modulation of the information signal. Also different types of Lasers such as VSCEL laser, Gain guided Laser, Index guided Laser, Light Emitting Diode (LED) etc. can be used to transmit the data. After deciding the appropriate optical light source and method for modulation the wavelength used to carry information signal is evaluated. There are three optical transmission windows namely 850nm. 1310nm, and 1550 nm which is the most widely used transmission windows used these days. There are many factors which negatively affect the performance of FSO transmission system such as atmospheric attenuation. In atmospheric attenuation either whole signal or a part of signal can be lost. In this way signal degrades and becomes weak signal. Other factors which are responsible for signal degradation are absorption, scattering and scintillation [4-6, 11].

1.1 GEOMETRIC LOSSES

The spreading of light pulse as it travels through the optical channel causes the pulse to spread in time domain and frequency domain and hence result in geometric losses.

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The amount of beam spread in FSO transmission system is bigger in measurement than that of receiver antenna and this overfill of energy is bound to be lost. In general, large aperture of receiving antenna or small divergence of transmitted signal result in less geometric loss for a certain range. For a standard FSO transmission system, with a low obscured transmitter and receiver, geometric losses could be calculated with this formula [15] :

$$GL(db)= 10*\log\ \left(\frac{R \times Aper\ Dia\ (m)}{T \times Aper(m) + [\ Range(Km)*Div(mrad)\}}\right) \quad (1)$$

Equation (1) can be used to evaluate the values of the amount of geometric losses for a system using gaussian distribution by the use of 1/e value of divergence but with minutely low accuracy. It should be noted that equation (1) is to be used only for purpose of evaluating geometrical losses in FSO transmission system and not in microwave communication systems.

1.2 METHODOLOGY

FSO transmission system design has been proposed for performance evaluation and for simulation purpose Optisystem 7.0 tool has been used. The diagram for FSO link used in the simulations is shown in Fig. 1

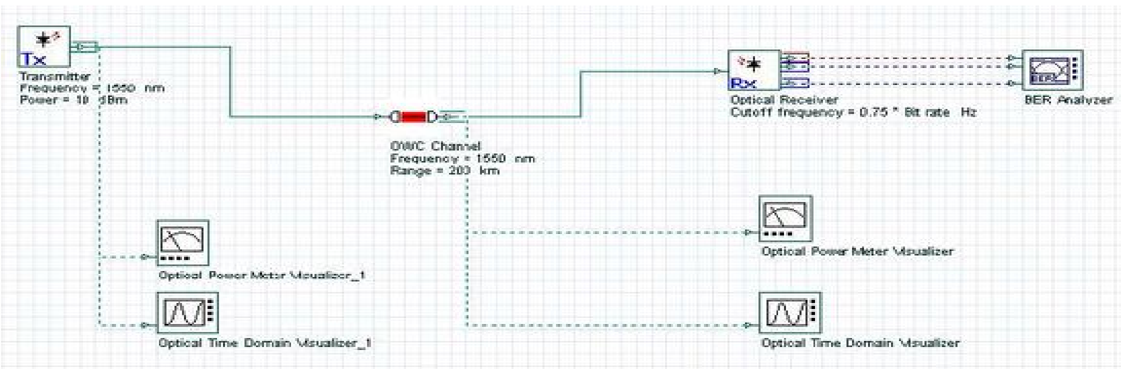

Fig. 1: Block Diagram of FSO link design

In the optical transmitter block, first we have the Pseudo Random Bit Generator (PRBS) which is used to generate sequence of zeroes and ones randomly. Then next in the transmitter section we have Gaussian pulse generator. The output of PRBS is fed as input to Gaussian pulse generator. Gaussian pulse generator is used to generate Gaussian signals. Then the third block is directly modulated laser. This laser can be used to decide different parameters such as for instance line width, chirp, side mode, suppression and relative intensity noise. After this the signal is transmitted in the free space. This free space is also named as channel. It's distance between transmitter telescope and receiver telescope. There are many parameters which affect the performance of FSO link in the channel namely link distance, attenuation, geometric losses, transmitter loss, receiver loss, beam divergence, additional losses etc. In the receiver side we can either use APD or PIN photodiode to receive signal. This receiver is capable of regenerating the electrical signal. The optical receiver consists of a photodiode followed by a LPF, and at last a 3R generator is used. The output of 3R generator is fed as input to BER analyzer. This BER analyzer is used to calculate value of Q-Factor of system, and also calculates the Bit Error Rate (BER) of the system. It can also be used to determine eye diagrams of the received signal.

2. RESULTS AND DISCUSSIONS

In this proposed system, the evaluation has been done of performance of FSO communication system on the basis of type of photodiode used at the receiver side namely PIN and APD photodiode. The simulation link on optisystem 7.0 has been designed for different modulation formats such as for example gaussian pulse generator. Various parameter utilized in this simulation for FSO link are: Link length 200 km, Data rate 2.5 Gbps, transmitter Wavelength 1550 nm , transmitter aperture diameter 5 cm, transmitted power 10 dBm, receiver aperture area 17cm, Divergence angle 0.3 mrad, Geometrical loss 23.69 dB, and additional losses 1 dB and attenuation 4 dB/km.

These parameters are kept constant for both PIN and APD photodiode. Fig. 2 shows eye diagram of a system having wavelength 1550 nm. The modulation format utilized in this technique is gaussian pulse and APD photodiode is employed to detect the optical signal. From eye diagram it's clear that the Q element in this design is 64.037. The Q element in this system is highest among another system discussed in this paper. Fig. 3 shows eye diagram of something having wavelength 1550 nm. The modulation format utilized in this technique is gaussian pulse and PIN photodiode is employed to detect the optical signal. From eye diagram it's clear that the Q element in this design is 34.4519. The Q factor has been decreased from 64.037 to 34.4519. This decline in Q factor is because of the utilization of PIN photodiode.

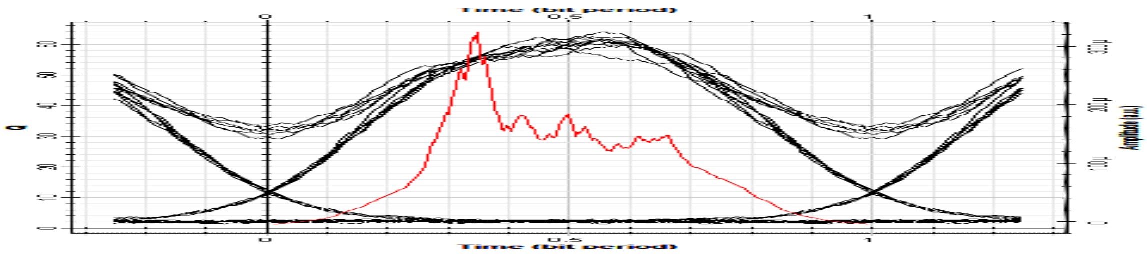

Fig. 2: Eye Diagram (APD photodiode used system at 1550 nm wavelength)

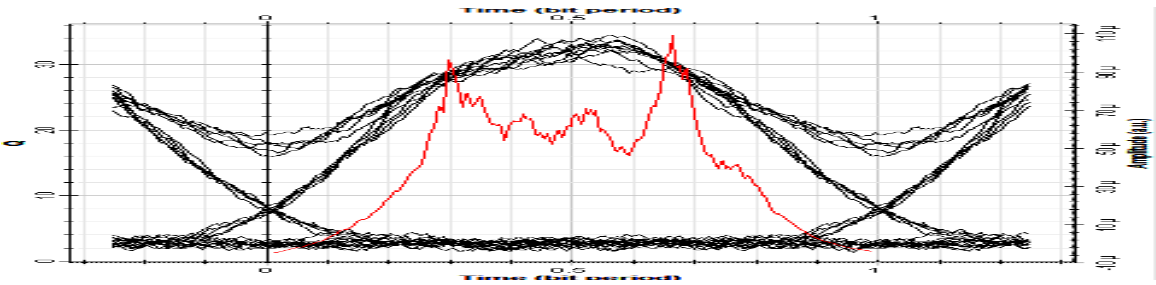

Fig. 3: Eye Diagram (PIN photodiode used system at 1550 nm wavelength)

3. CONCLUSIONS

This informative article targets the impact of different photodiodes at receiver end namely PIN photodiode and APD photodiode on the performance of FSO transmission system. It's concluded from the above mentioned discussion that there is considerable decline in Q factor which lies within (64.037 – 34.4519) for 1550 nm. In the event of photodiodes APD gives better Q factor then PIN photodiodes. As a result of above carried out analysis it is concluded that APD photodiode gives a better performance as a receiver in FSO transmission system as compared to PIN photodiode.

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