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Performance Comparison of APD and PIN Photodiodes using Different Modulation and Different Wavelengths

Priyanka Sharma[1] and Himali Sarangal[2]

[1]*Student at G.N.D.U*
[2]*Assistant professor at G.N.D.U*
[1]*s.priyanka1191@gmail.com,*[2]*himali.sarangal@gmail.com*

Abstract

Free Space Optical communication systems to meet the growing need for high speed and tap proof communication systems. Free space optics causes the spatial and temporal fluctuation of light intensity. FSO is used to reduce the cost as well as in such places where physical optical wire usage is not possible. In this paper we study the quality factor of widely used modulation formats and compare the bit-error-rate performance. Analysis is performed for NRZ and RZ line codes with various different wavelengths using APD and PIN photodiodes receivers. Interpretation and explanation of simulation results implemented by the Optisystem through the optical high debit communication system chosen to evaluate the APD and PIN photodiodes performances in function of SNR in order to provide new perspectives for the future transmission axes.

Keywords*: PIN, NRZ, RZ, APD, FSO, Q- factor*

1. Introduction

Free Space Optics is a wireless (line-of-sight) technology that transmits data in the form of optical signals in the air. FSO is a very cheap technology with a data rate at Gbps level which does not even require license. The narrow beams of FSO signals are very difficult to be affected by interception, jamming or interference . FSO is also called as optical wireless (OW). Different optical sources can be used in FSO communication link such as Lasers and LED. Free space optics can enable a link at a data rate more than 1Gbps between transmitter and receiver placed at some distance [1]. FSO is based on line of sight therefore we should be careful about any obstacle between receiver and transmitter. It has many advantages like it is very cost effective, it does not need licensed frequency band allocation, very high data rate, easy to install, less interference due to secure transmission of data and is very useful in military application. Number of parameters affects the performance of FSO link. These parameters can be internal as well as external parameters. Internal parameters includes wavelength used, lasers types, beam divergence *etc.* [3]. There are certain challenges which affect the performance of FSO. First challenge is free space path loss phenomenon. Second challenge is due to the weather conditions such as rain, fog *etc.* of different places at different time of the day and night. These conditions create problem in Free Space Optics performance and appears in dealing with scattering, turbulence and scintillation. The performance of Free space optics link also depends upon the link elements. There are number of modulation schemes such as RZ, NRZ, CSRZ, BPSK, PPM, and DQPSK. We have various light sources like LED, APD, PIN, VSCEL lasers diodes [5-7]. There are three optical windows, from 780 nm to 850 nm is considered to be first window; Second window is 1310 nm wavelength whereas the third window is the 1550 nm wavelength. Third window is most widely used window know a days. There are number of losses due to which the FSO system can be further degraded. Atmospheric attenuation, when some part of the signal lost in the channel, is at

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the top of them. In the atmospheric attenuation, the signal degrades and become weaker in the channel. There are some other reasons which degrade the signal strength such as scattering, absorption and scintillation. Absorption is caused due to the presence of water droplets in the form of fog, rain and water vapors. Scattering can be of two types such as Rayleigh scattering and mie scattering. In Rayleigh scattering size of the wavelength is greater than particles. Mie scattering affects the signal when the size of wavelength and water particle is comparable. Scattering and absorption give worse effect in long distance communication and in low visibility [6].

2. Photodetectors

2.1.PIN Photodiode

The PIN photodiode consists of three zones: the first zone in order to create a hole excess is called as P-doped, the second zone has an intrinsic region called absorption zone and the third zone is N-doped which creates an electron excess. PIN photodiode has wide width of the intrinsic zone maximizes it's performances [1-2].

2.2.APD Photodiode

Avalanche effect is used to multiply the electrons in the APD photodiode. Multiplication effect occurs in the intrinsic zone in order to obtain an effective SNR. This avalanche effect is used to increase the electrical signal power by generating several photoelectrons[2,11]. The APD photodiode is same as a PIN photodiode because in order to gain a multiplication effect it also considered from a physical ionization by impact process.

3.System Modeling

Free space optics communication system design has been formulated for performance characterization and Optisystem 14.0 software has been used for simulation purpose. The block diagram of FSO link is shown in Figure. 1. In the proposed design the complete link can be divided into three parts, optical transmitter, FSO channel and the optical receiver. The first block in optical transmitter is the Pseudo-Random Binary Sequence generator which generates the random sequence of ones and zeros. The second block is the Non Return to Zero and Return to Zero pulse generators. The output of Pseudo-Random Binary Sequence is fed to the Non Return to Zero pulse generators which generates the zero coded signals. The next block in transmitter block is the directly modulated lasers measured. These lasers allow us to specify various parameters such as side mode, line width, relative intensity noise, chirp, and suppression [11]. Then this signal is transmitted in the atmosphere (free space) called channel. Channel is distance between transmitter and receiver telescope. The parameters which affect the FSO link in the channel are beam divergence , link distance, transmitter loss, attenuation, geometric losses, receiver loss, additional losses *etc.*[7]. The second part of the optical link, optical receiver, consists of an APD and PIN photodiodes. The optical receiver is used to regenerate the electrical signal. It consists of a 3R regenerator, photodiode, and a low pass filter. The regenerated signal is fed to Bit-error-rate analyzer and displays the Q factor and eye diagrams of the signal [10].

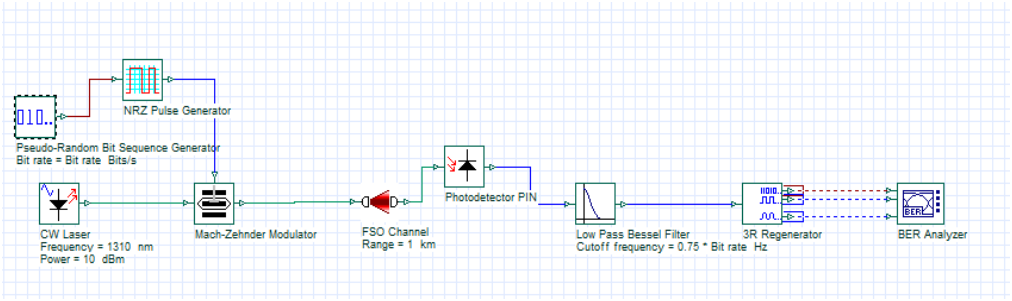


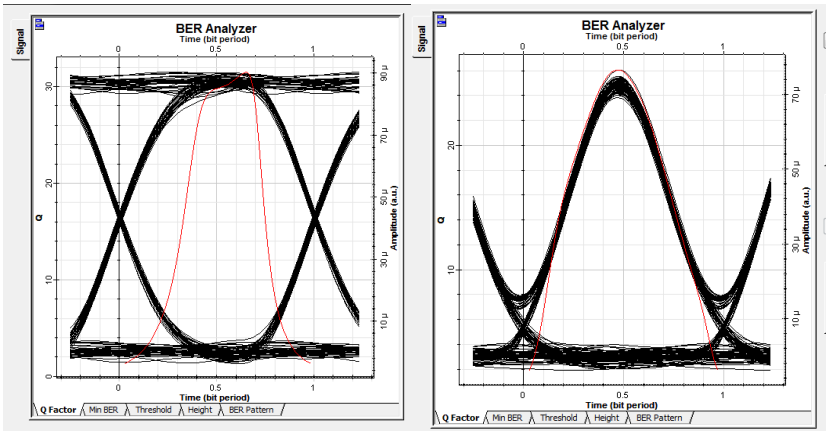
Figure 1. Block Diagram of FSO links Design

Table 1. **Parameters Chosen**

PARAMETER	SYMBOL	VALUE
Transmission Rate	Bit rate	1.25 Gbps
Link Distance	Z	1km
Transmitter and Receiver Apertures	DT , DR	10 cm
APD Responsivity	R	0.8-52 A/w
PIN Responsivity	R	0.55-0.85 A/w
Power	Pt	10 dB
Attenuation	a	0.4dB/km
Low Pass Filter Cutoff Frequency (at receiver)	Bit rate	0.75*

4.Results and Discussion

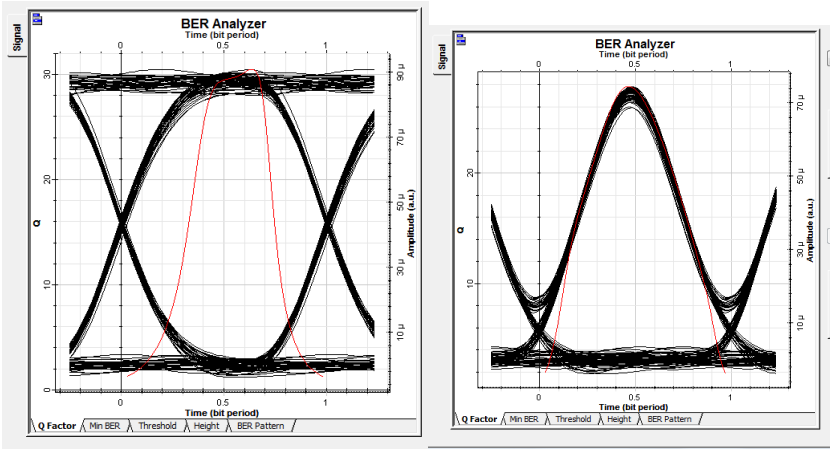
In this proposed system, the performance of free space optical link has been evaluated on the basis of different modulation formats, different types of photodiodes and different wavelengths. The simulation link on optisystem 14.0 has been made for different modulation formats such as RZ, and NRZ. A comparison has been performed between two photodiodes such as APD and PIN photodiodes. Another comparison between two wavelengths 1550 nm and 1310 nm has been performed.



NRZ RZ

Figure 2. Eye Diagram of PIN 1310 nm

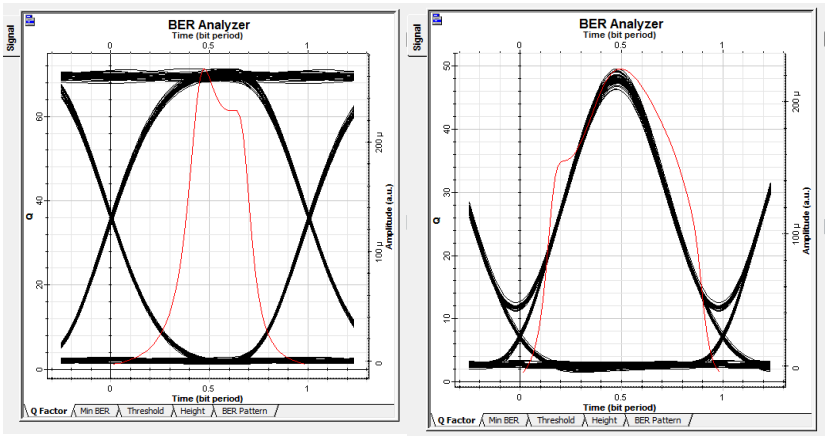
Figure 2. shows the eye diagram of a system having wavelength 1310 nm. The modulation formats NRZ and RZ with photodiode PIN is used to detect the optical signal. It is clear From the eye diagram that the Q factor in this design for NRZ is 33.60 and for RZ is 28.



NRZ RZ

Figure 3. Eye Diagram of PIN 1550 nm

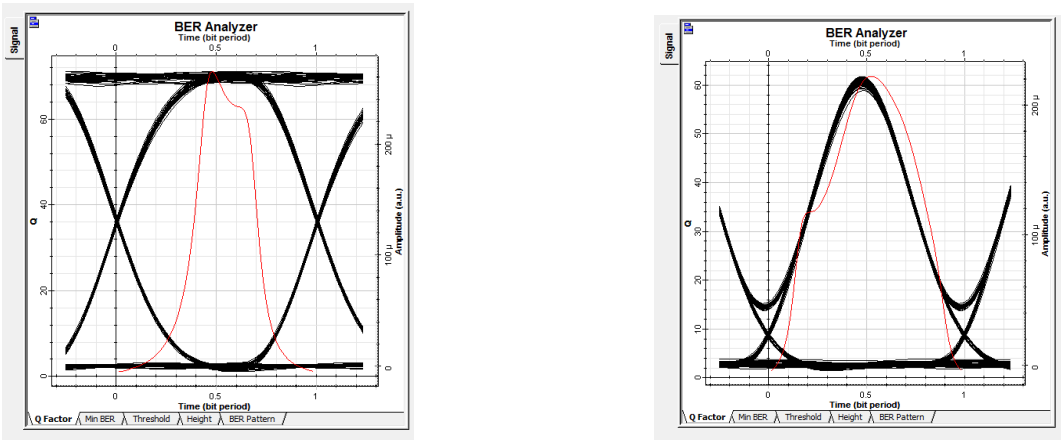
Figure 3. shows the eye diagram of a system having wavelength 1550 nm. The modulation formats NRZ and RZ with photodiode PIN is used to detect the optical signal. It is clear from the eye diagram that the Q factor in this design for NRZ is 31.82 and for RZ is 25. The Q factor in this system is lowest among the other system discussed in this paper.



NRZ RZ

Figure 4. Eye Diagram of APD at 1310 nm

Figure 4. shows the eye diagram of a system having wavelength 1310 nm. The modulation formats NRZ and RZ with photodiode APD is used to detect the optical signal. It is clear from the eye diagram that the Q factor in this design for NRZ is 59.40 and for RZ is 53.28. The Q factor in this system is highest among the previous system discussed but lower than APD 1550.



NRZ RZ

Figure 5. Eye Diagram of APD at 1660 nm

Figure 5. shows the eye diagram of a system having wavelength 1550 nm. The modulation formats NRZ and RZ with APD photodiode is used to detect the optical signal. It is clear from the eye diagram that the Q factor in this design for NRZ is 63.85 and for RZ is 57.12. The Q factor in this system is highest among the other system discussed in this paper.

Table 2. Quality Factors of Photodiodes

RECEIVER TYPE	WAVELENGTH	MODULATION FORMAT	QUALITY FACTOR
PIN	1310	NRZ	33.60
		RZ	28.0
PIN	1550	NRZ	31.82
		RZ	25.0
APD	1310	NRZ	59.40
		RZ	53.28
APD	1550	NRZ	63.85
		RZ	57.12

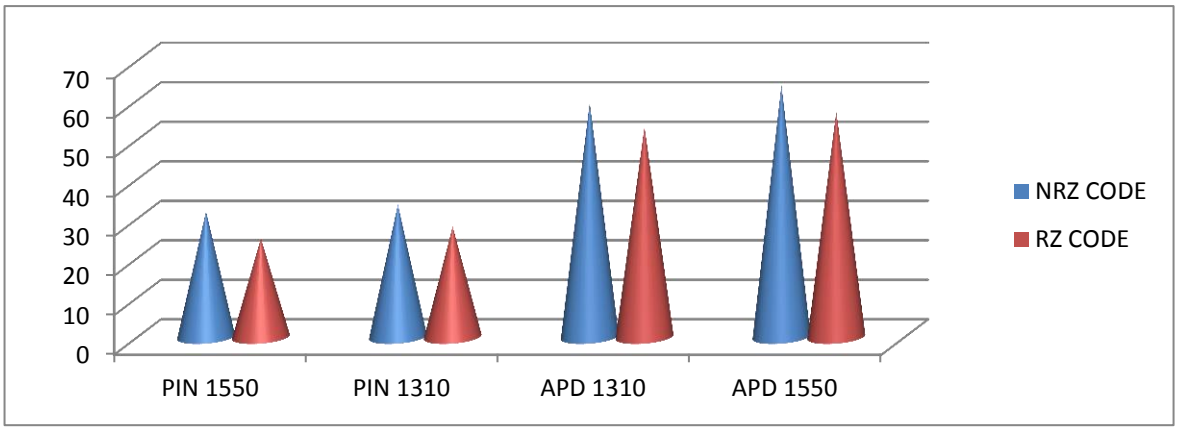


Figure 6. Shows the Graphical Comparison between Two Different Modulators using Different Wavelengths and Photodiodes

Conclusion

In the near future Free Space Optics is a promising communication technology. There is distortion of signals at the receiver due to the atmospheric disturbances. By using new techniques it is possible to reduce the distortion in the atmospheric effects on the optical signal. Free space optics provides very high bandwidth than RF technology. Information is transmitted through the free space on modulated optical beams therefore LOS links are needed. Free space optics operates on very high bit rate (up to 10 Gbps) and is highly immune to interference and interception. This technology has many telecommunications applications. This article targets the impact of different photodiodes PIN and APD, different modulation formats RZ and NRZ, and two different wavelengths 1310 nm and 1550 nm.

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Author

Priyanka sharma, student at Guru Nanak Dev University.

