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Performance Analysis of Modulation Techniques for Indoor Free Space Optics

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Abstract: This paper deals with designing and analyzing the performance of indoor Free Space Optics (FSO) link for various modulation techniques in diffused channel conditions. At the present time, FSO is widely adopted because of its features; high speed, security, low power consumption and unlicensed spectrum. LEDs and LASERs are optimum choice to cater the dynamic range of requirements for optical communication system. The indoor FSO system has been simulated in Optisystem 14 software using various modulation schemes under different attenuation factors which may influence the performance of the system. In this paper, we have analyzed the performance of different modulation schemes such as Return to Zero, Non-Return to Zero, Phase Shift Keying, Pulse Amplitude Modulation, Quadrature Amplitude Modulation and Minimum Shift Keying. This work mainly focuses on the parameters; Bit Error Rate, Q-factor and power corresponding to transmission distance achieve minimum attenuation.

Keywords: Indoor Free Space Optics (IFSO), Q-factor, BER, Modulation Schemes, Optisystem

1. Introduction

Growing demand of high speed internet and high security of the users has persuaded recent interest in indoor optical communication. The primary and main features of optical wireless communication are unlimited license-free bandwidth, low power consumption, cheaper devices, and light weight, free from harmful radiations concerned with hospitals and airplanes, easy to implement and high speed communication. In addition, light signals cannot pass walls, in this way; it is difficult for interlopers to get the signals from outside of the room [1, 2]. This enhances the security of optical communication and can be used as a part of spots where high security is needed or where radio band would not be used because of regulations on bandwidth and interferences of electromagnetic signals. IEEE has developed a standard for short range optical communication, especially for indoor environments such as offices, home and hospitals. Murat Uysal et.al [4] predicated that light emitting diodes (LEDs) are vital lighting source in the near future and normal lights can be replaced by more energy efficient light technologies. It opens the door of the visible light communication means

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communication through the LEDs. Abdeslam Behlouli et.al [5] addressed a simulation algorithm based on Markov Chain Monte Carlo method for optical communication, this method reduces the computational time as compared with previous developed algorithms. Bangjiang Lin et.al [6] proposed a system used for indoor communication as well as for positioning with the help of orthogonal frequency division multiplexing access (OFDMA) technique. The LEDs are used to predict the position and receive the maximum received signal strength based on trilateration algorithm. The authors have discussed the signaling technique to study the turbulence environment conditions in free space optics. The work presented is totally concerned with bit error rate of communication link [7]. The performance of FSO link was explored on Hybrid-SIM modulation scheme, it is concluded that the BER results demonstrated in the form of simulation but link was not investigates practically [8]. Flicker free modulation scheme is proposed to achieve a suitable spectral efficiency. The under sampled modulation would be practical approach studied in [9]. The performance of free space optics mortified due to atmospheric noises. The important factor for good quality of communication link is BER and power efficiency was discussed in [10]. FSO system experimented under different conditions and modulation schemes as elaborated in ref [11]. The modulation schemes improves the efficiency of communication links which is decreased through some environmental changes such as; Fog, rain. The analysis is based on Q-factor and Bit error rate to accommodate the requirement of FSO systems [12]. Filter Bank Multi carrier modulation was implemented for visible light communication, LED is chosen as a source in optical communication [13].

The outdoor link was established to study the channel response, weak to strong turbulence and determination of impacting factors in FSO system. The limiting factors are beam divergence angle, transceiver antenna aperture diameter and modulation schemes [14-15]. The Filter approach is introduced to cater better results of the system which uses ASK and PSK modulations [16]. The underwater RGB optical link discusses the characteristics of modulation schemes. LEDs were used to test the link but possibly same RGB color of laser would perform better in network scenario [17]. The noise study and protocol design had been discussed in [18-19]. In order ensure secure data transfer of wireless body area networks through optical communication. The analysis and review of different modulation schemes in terms of BER, SNR and power is discussed in [20-21]. [23] provides detailed review of contemporary research in FSO, focusing on both outdoor and indoor applications. [24] proposed to use erbium doped fiber amplifier (EDFA) when using FSO link. [25] provides insights to NLOS FSO communication using scattering or multipath propagation.

The objective of this work is to investigate the comparative analysis of modulation schemes in indoor optical communication. The further details of paper are organized as follows, Sect. 2 determines the indoor optical simulation design, and then Sect. 3 presents a channel mathematical modeling has been elaborated. The result explained in Sect. 4 in the last Sect. 5 concludes and suggest future work.

2 Methodology

2.1 Indoor Optical Wireless Modeling and Simulation

The Opti-system is an optical tool to design, test and optimize any type of optical communication links with real time parameters. According to the TCP/IP and OSI Model, simulation can be designed in this Simulator from physical to transport layer [22]. The indoor visible light link is scrutinized on 380 nm and 780 nm to check the dispersion characteristics of optical link [26-27]. The simulation package is consisting of sensible parametric values of optical communication utilizing drag and drop components and configurations. In our system three primary parts in diffused indoor optical communication system. First one is the transmitter, diffused channel and receiver. In this simulation, an external sequence generator is used to produce sequence and transmitter has a wavelength of 1310nm along with power of 11 w with different modulation schemes to analyze their effects in diffused channel. At the both ends optical amplifiers are used to increase the strength of modulated signal. At the receiver side, optical signal is converted back into digital data. The system components and parameters are mentioned in Table I. This model uses Mach Zehnder Modulator, wavelength of 1310nm, attenuation is kept variable. The transmitter and receiver aperture diameter are set to 16cm and 40cm respectively. In measuring the performance of diffused indoor channel with different modulation schemes, BER, Q-factor, and optical power meters are used to differentiate the power levels between transmitter and the receiver. BER and eye diagrams visualize the performance and quality of the system. Bits are in error can be predicated through eye diagrams and theoretical analysis. The minimum bit error rate for optical communication is 10^{-9} if the values are approximately nearer to it then data can be extracted to its original format. The simulated IOWC model in Opti-System 14 is shown in Figure 1.

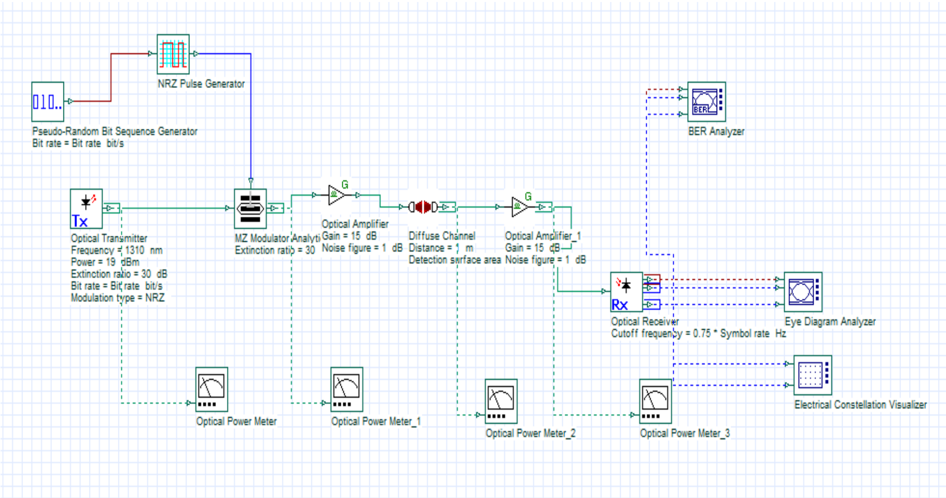

Fig 1: Simulation model of Indoor Optical Wireless Communication

Table 1 Components and parameters used in this work.

Parameters	Values
Modulator Type	Mach-Zehnder
Extinction Ratio	30dB
Optical Transmitter	1310 nm
Beam Divergence	3mrad
Attenuation	Variable
Bit Rate	Variable
Transmitter aperture diameter	16cm
Receiver aperture diameter	40cm
Ionization Ratio	0.9
Dark current	10nA

2.2 IFSO Mathematical Modeling

The channel is modeled, where y (t) denotes the instantaneous power received at the receiver. The transmitted power is denoted by x(t), h(t) is the impulse response, n(t) shows the AWGN noise, R is the responsitivity of receiver and the convolution is shown by ⊗ to check the efficiency of optical to electrical signal and transmitted power.

$$y(t) = h(t) \otimes R.x(t) + n(t) \qquad (1)$$

The optical diffused channel is interrupted by the reflected light from the surface of room and transceiver requires no interferer in line of sight scenario. The ambient light affects the indoor optical communication networks which mortifies the system performance.

$$F_r = \log_s(\beta)\Omega_r \tag{2}$$

Path loss of luminous can be expressed as

$$L_L = \frac{r_r}{F_s} \tag{3}$$

F_r and F_s are the received and transmitted luminous fluxes of optical transmitter. Lambertian source order is obtained by

$$m = \frac{-\ln(2)}{\ln(\cos\alpha \, ½)} \tag{4}$$

$\alpha ½$ in Eq.4 is transmitter semi angle. In Eq. 5 A_r is the detection area of receiver, the field of view (FoV). Channel coefficients depend on placement of transceiver system according to the scenarios.

$$L_L \approx \frac{(m+1)}{2\pi D^2} A_r \mathrm{Cos}(\alpha)\,\mathrm{Cos}^m(\beta) \tag{5}$$

The Luminous path loss can be upgraded as shown in equation below

$$L_L = \frac{1}{D^2} \times \text{transmitted power} \tag{6}$$

The path loss can be calculated through the Eq.7, d represents the distance between transmitter and receiver, λ denotes the carrier wavelength.

$$PL = 22\text{dB} + 20\log\frac{d}{\lambda} \tag{7}$$

3 Simulation Results and Discussion

This segment discusses the results and analysis of diffused indoor optical communication. The system quality has been analyzed at various distances to get optimum signal strength for extracting the information. The performance evaluation parameters are BER, Q-factor and optical received power. It is observed that link working perfectly at a distance of 3m with different modulation schemes. Fig.2 shows the relationship between Q-factor and distance with various modulation schemes, it suggests that the NRZ has better results in comparison of rest of modulation schemes. The system degrades it Q-factor values as the distance increased, so that performance obtaining worst which is unwanted and the BER is inversely proportional to Q-factor so that both should be optimum for communication system.

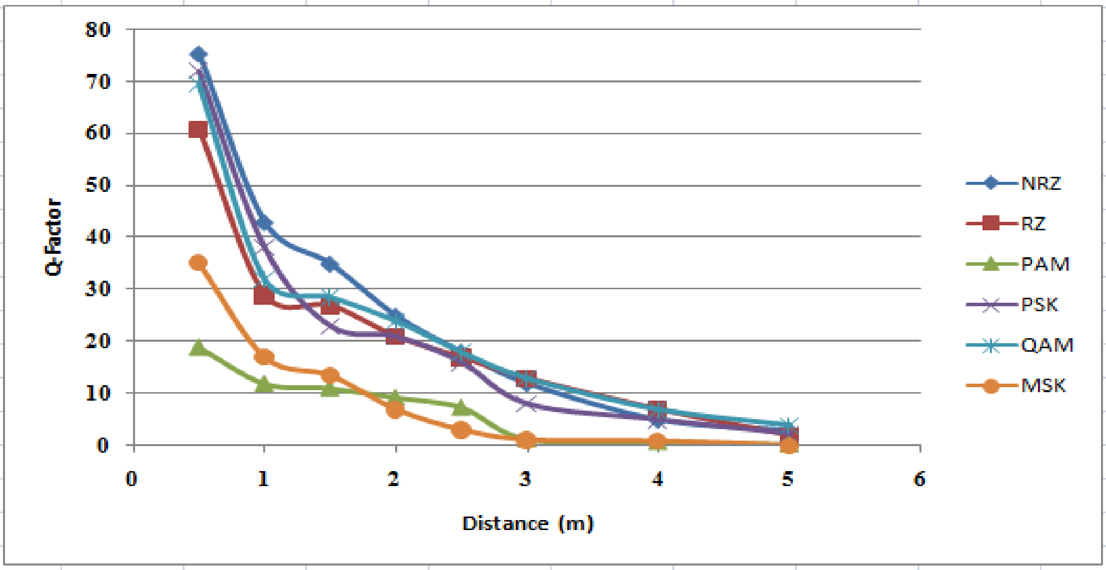

Fig 2: Simulated values of Q-factor versus link distance of various modulation schemes

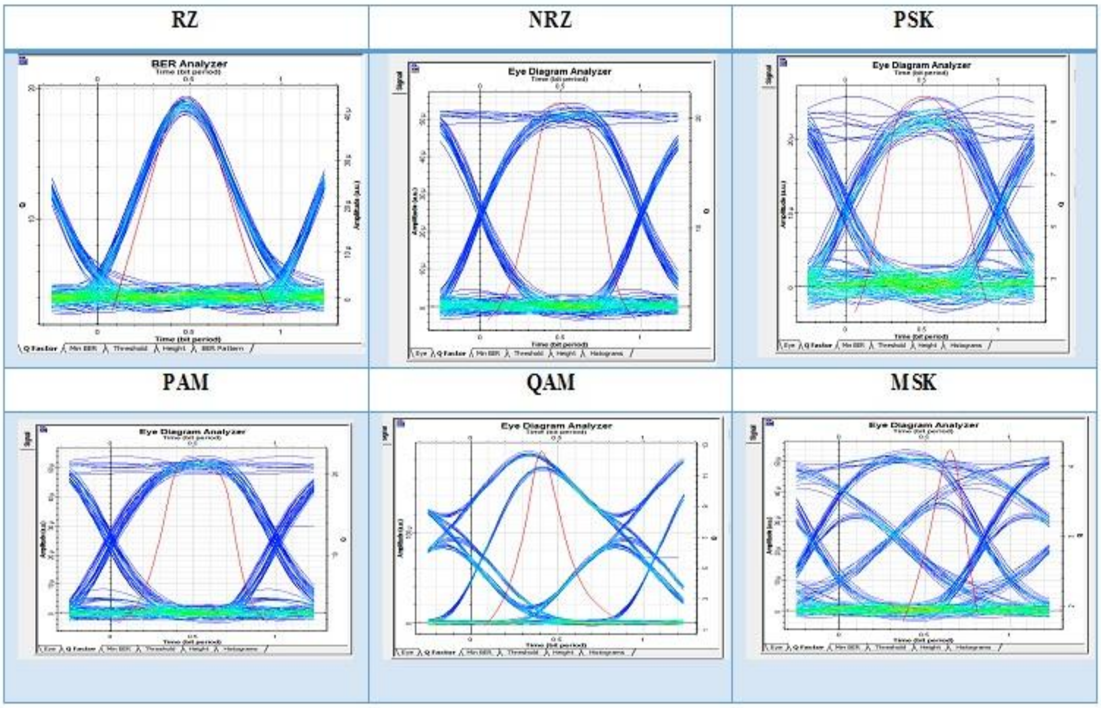

Fig 3:Comparison of Modulation schemes in terms of Q-factor represented in eye diagrams

Fig.3 represents the eye diagram; it can be visualized that the eye openings are clearly defined and faces attenuation throughout the transmission with minimum BER values required for optical communication. NRZ and QAM offers low bit error rate as compared to other modulation schemes. Fig.4 shows the 3D BER curves depicts the red area suggest that it has lower error in the transmission at the distance of 1 to 3m of distance. The graphs have been plotted by Optisystem.

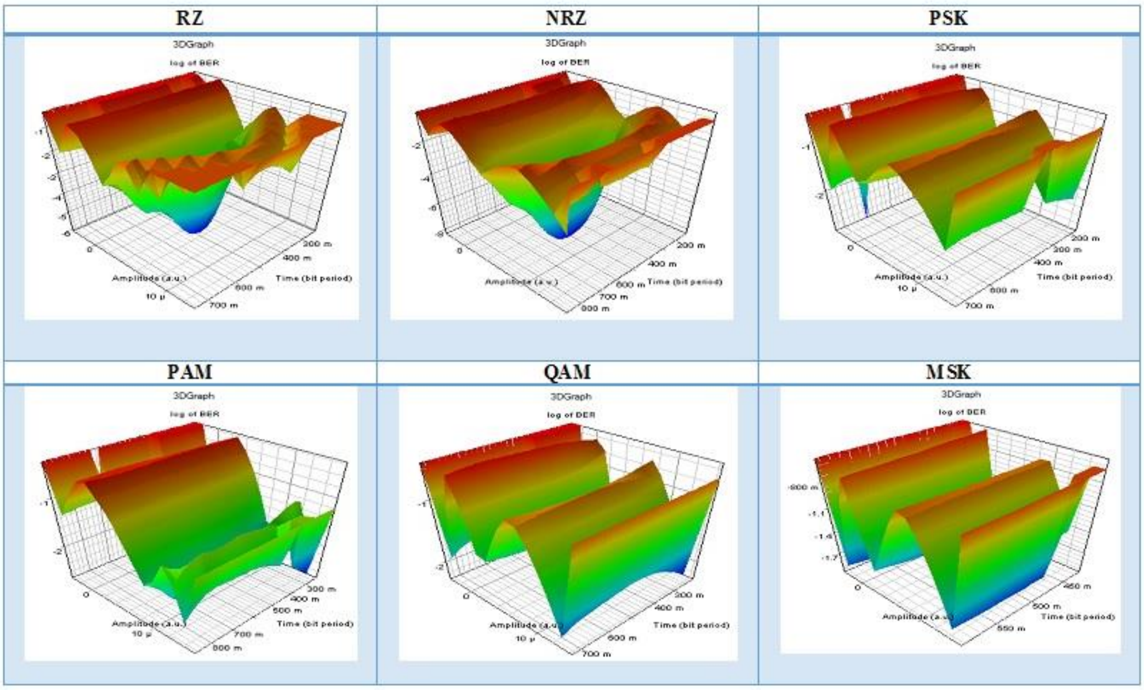

Fig 4: 3D BER diagrams of different modulation schemes for indoor optical communication

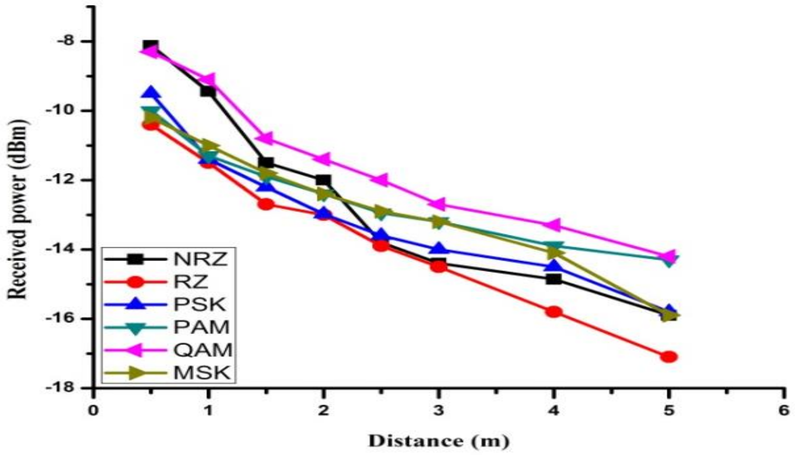

Fig 5: Computed received power of different modulation schemes

Received power depends upon several parameters such as distance, wavelength and atmosphere. In our system, we have used 1310 nm wavelength with distance range upto 5m. Fig. 5 represents the received power results at the receiver. From figures it can be concluded that as quality decrease the received power will be decreased and BER increases. Fig. 6 shows the BER is function of distance; as distance increase performance decreases and also quality of signal degraded.

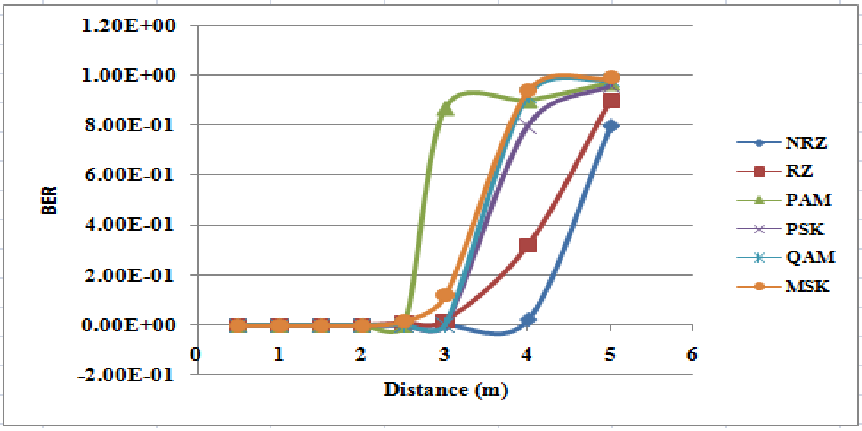

Fig 6: BER Vs distance with various modulation schemes distance range upto 5m

Due to the requirement for line-of-sight communication, FSO systems may only cover a limited area. Obtaining longer distances may require higher transmitter power, which impacts received signal intensity. The trade-off is in balancing the coverage area with received signal power [23].

4 Conclusions

In this work, we have simulated a diffused indoor optical wireless communication system in view of 1310 nm transmitter wavelength. The performance analysis of modulation schemes has been analyzed at fluctuating the distance. The amplifiers are used to increase the distance range and reduce the errors in the transmission. The simulation results are perfectly related to indoor diffused channel. Received optical power drops quickly form the distance of 3m and calculated in decibel mill watts (dBm), which is -14dBm, -13.5 dBm, BER values are 3.2×10^{-3} and 6.8×10^{-4} along with Q-factor values are 12 and 13 for NRZ and QAM respectively. The rest of modulation could not achieve a suitable quality of signal to resilience for communication. It has observed from result both schemes are feasible for indoor free space communication. This communication system can be utilized in applications like industrial monitory of IoT, or patient health monitoring devices etc. The reliability of indoor optical communication with the use of diffused channel conditions has been optimized by using light sources, amplifiers and to achieve high quality signal.

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