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Performance Analysis of RZ and NRZ Modulation Format for Moderate Weather Conditions for 2.5 Gb/s PolSK-FSO

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ABSTRACT: In recent years, free space optical (FSO) communication has gained momentous importance owing to its unique features: huge bandwidth, license free spectrum, high data rate, easy and quick installation ability, less power consumption. FSO communication uses optical carrier in the near infrared (IR) and visible band to set up either terrestrial links within the earth's atmosphere or inter-satellite or ground-to-satellite or satellite-to-ground links. In this research paper, comparison of modulation format NRZ and RZ with different duty cycles (33%, 50% and 60%) on polarization shift keying-free space optical communication system has been investigated for moderate weather conditions. It has been observed that NRZ modulation format outperforms RZ format.

KEYWORDS: FSO, FOC, IR, NRZ, PolSK, RZ

I.INTRODUCTION

Free Space Optics (FSO) is an optical communication technology that uses light propagating in free space to transmit data between two points. This technology is useful where a fiber optic cable is impractical [1]. The basic principle of FSO transmission is similar to fiber optic communication (FOC) except that unlike fiber transmission, in this case the modulated data is transmitted through unguided channel instead of guided optical fiber.Mazin Ali et al. [2] in their paper describes that in FOC pulses of light through an optical or glass fiber carry information from one point to another whereas FSO system uses sources of light to transfer data through the clear air, space or atmospheric channel. As light travels faster in air than it does in glass, so FSO can also be called as communicationat the speed of light. Jitendra Singh et al. [3] in their paper observed that external modulation gives better performance in comparison to direct modulation because direct NRZ spectrum has a strong carrier component as compared to the external modulated NRZ.

However, FSO uses the atmosphere as a propagation medium, optical links in the propagation channel are considerably influenced by different weather conditions and scintillations resulting in the increasing signal losses and fades, which critically affect the communication performance. To improve reliability of communication, various schemes have been proposed but always the system complexities increase drastically and the cost and volume is multiplied in the schemes. Considering that the properties of simple structure and low cost are necessary in practical FSO systems, an excellent modulation technique is undoubtedly an effective way to enhance system performance.

Polarization shift keying (PolSK) technique has been studied for more than 12 years and it is researched to be used in wireless optical communication at present. As state of polarization (SOP) for the optical signal is hardly affected by atmosphere turbulence during the transmission in the atmosphere, PolSK has an advantage to achievea low bit error rate (BER) transmission over long distances. S. Trisno et al. [4] in their paper studiedPolSK modulation based on linear polarization and their results show a 3.4dB performance improvement of the PolSK modulation over On-Off Keying (OOK) system. Compared to the Linear PolSK (LPolSK), Circular PolSK (CPolSK) has further advantages: (1) it no longer requires the alignment of polarization coordinates of the transmitter and the receiver. (2) distribution of light intensity will be more uniform through particle scattering. Therefore, CPolSK modulation is manifested to be a good choice for FSO system.

K. Prabu et al. [5] compared channel capacity, BER and outage performance of the FSO system using various modulation formats and concluded that PolSK offers the best outage probabilityperformance for the FSO system.

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Benshuang Yu, Yong Yao et al. [6] showed that the system with optical amplifier at thetransmitter hasoptimum performance than the system with optical amplifier at the both ends with the same total gain, it is worst for the system with optical amplifier at the receiver.X. Zhao et al. [7]showed thatthe state of polarization remains unchanged and thedegree of polarization slightly increases due to propagationin a turbulent atmosphere.Mahdieh et al. [8] proved from their simulation results that laser beam size and wavelength have also significant effects in the BER values and laser beam with wavelength 1550nm provides lower BER as compared to 850nm.Prabhdeep Kaur et al. [9] analyzed the performance of Inter Satellite Optical Wireless Communication system link using DWDM multiplexingtechnique for long distance transmission and compared NRZ and RZ modulation formats by varying the input powers.

In this paper, the performance analysis of an FSO system under the impact of various weather conditions like haze, moderate fog and light fog is done by varying the transmission distance and attenuation using RZ modulation format at different duty cycles and NRZ modulation format. The paper is organized as follows: Section II gives the description of FSO system. Section III discusses the results and finally conclusions are drawn in section IV.

II.CPolSK BASED FSO SYSTEM DESCRIPTION

PolSK modulation utilizes the vector character of light wave and codes digital bits as the states of polarization and the intensities of pulses stay constant over time, thus, the complete utilization of the output power of a laser transmitter is obtained. CPolSK implements binary modulation based on the two rotation states of circular polarization. There are three functional elements contained in a FSO system, transmitter, free space as channel and receiver. The schematic diagramof CPolSK modulated optical communication system is shown in Fig. 1. The transmitter is used to produce a left or right-hand polarization light and launch it into the atmospheric channel. CPolSK modulation can be achieved by combination of polarization beam splitter (PBS), phase modulator (PM) and polarization beam combiner (PBC). The transmitter includes PRBS (pseudo random bit sequence generator) which generates the logical signals in the form of random 1s and 0s and transmits logical signal to the pulse generator. Laser emits the light signal at a wavelength of 1550nm and passes it to PC (polarization controller). It rotates the signal at 45° and transmits it to polarization beam splitter. Further, the signal is divided into two linearly polarized orthogonal beams along the x and y direction.

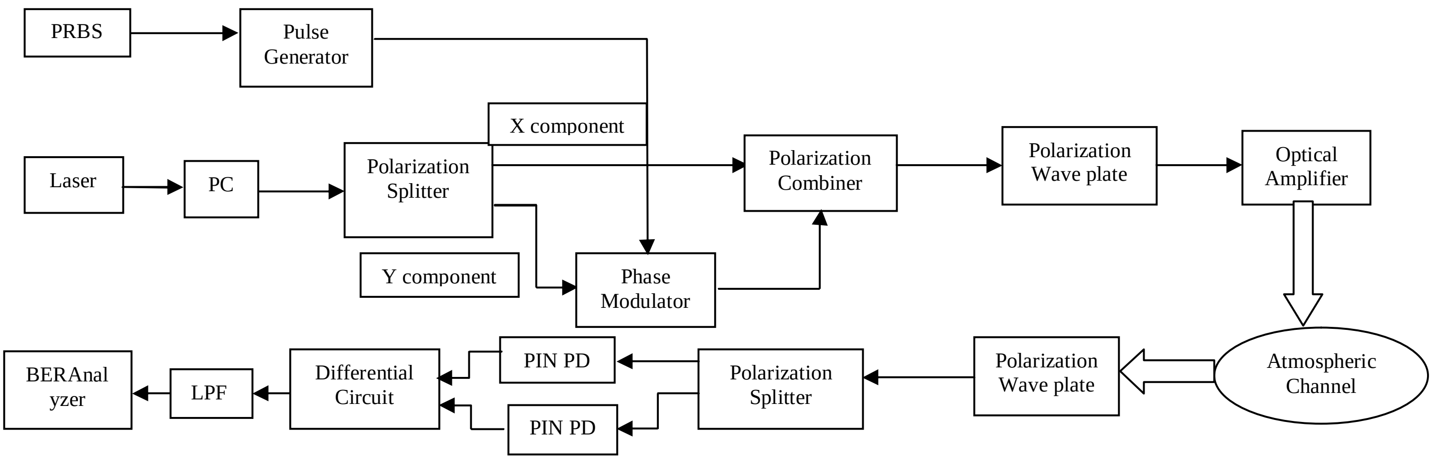

Fig. 1 Simulation Setup of CPolSK FSO

Depending on the input data stream, phase modulation is applied to the y-component of the signal. Output signal from the phase modulator is given by

$$E_{out}(t) = E_{in}(t)[j\,\Delta\phi data(t)]$$

Where E_{in} denotes the input light signals of phase controller, ϕ= *180*$^{\circ}$denotes the phase difference between the marks and spaces, *data(t)* denotes digital signal ‘0’ or ‘1’. Then PBC combines x and phase modulated y component into a bunch of light. Then ‘0’ bits are transmitted via left-hand circular polarized light and ‘1’ bits via right-hand circular

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polarized light. The receiver play a role to extract and detect the circular polarized light, composed of a quarter-wave plate, a PBS, two photo detectors and the differential circuit [6].

According to the theory of polarization optics, no matter what the included angle between the polarization axis of the transmitter and the receivers, after the quarter-wave plate, the circular polarization (left-hand or right-hand) is converted into linear polarization (+45°linearpolarized or −45°linear polarized), and then detected by the corresponding detector (detector1 or detector2) [7]. So, the polarization coordinates of the receiver no longer requires alignment with the transmitter.Table 1 shows the input parameters of the system that are being used in the setup. The power attenuation value is shown in table 2 for different weather conditions of PolSK FSO system.

Table 1: Input Parameters that are used in the Setup [6]

Parameter	Value
Transmitter Power	0 dBm
Wavelength	1550 nm
Transmitter Aperture Diameter	5 cm
Receiver Aperture Diameter	20 cm
Beam Divergence	2mrad
Receiver Responsivity	1A/W
Voltage Gain	30 dB
Data Rate	2.5 Gbps

Table 2: Attenuation Coefficient for Different Weather Conditions [10]

Weather Condition	Attenuation (dB/km)
Haze	0.736
Light Fog	4.285
Moderate Fog	25.5160

As shown in table 2, the impact of haze is less on FSO system as compared to fog. The visibility for haze, light fog and moderate fog is 6km, 2km and 500m respectively. Haze particles can stay longer time in the air andlead to the atmospheric attenuation. So, attenuation valuesdepend upon the visibility level at that time. Attenuation can be calculated by using Kim and Kruse model. For fog, the attenuation is mainly because of Mie scattering effect.

III.RESULTS AND DISCUSSIONS

Performance of three weather conditions haze, light fog and moderate fog with NRZ and RZ modulation formats is analyzed in this section. In Figure 2, it is shown that the power received for haze is maximum (25.108dB) in case of NRZ modulation format at a distance of 2000meters and is reduced to 21.715, 20.577 and 17.628dBm for RZ with 60%, 50% and 33% duty cycle respectively at same transmission distance. Also, the transmission distance can be increased up to 6000meters for haze in case of NRZ, RZ (60%) and RZ (50%) but in case of RZ (33%) the transmission distance is reduced by 500meters. So, NRZ performs better than RZ [9].

Figure 3 shows the variation of received power with the transmission distance for light fog and it has been observed that till 1200meters of transmission distance the signal received is without any error beyond which signal is deteriorated as the distance between transmitter and receiver is increased. The received power at 1200meters distance is recorded as 26.499, 23.106, 21.968 and 19.017dBm for NRZ, RZ (60%, 50% and 33%) respectively.

After 1200meters distance, decrease in received power is observed and at 2600meters distance the received power is observed as 1.545, -1.534, -2.507 and -4.826dBm for NRZ, RZ (60%), RZ (50%) and RZ (33%) respectively. It is observed that more negative value of received power is obtained for RZ (33%) format.

The performance of received power with distance for moderate fog is shown in figure 4. In case of NRZ the highest value of received power observed is 25.986dBm at a distance of 500meters which decreases for RZ (60%), RZ (50%) and RZ (33%). The transmission distance can be increased upto 900meters for NRZ, RZ (60%) and RZ (50%) but for

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RZ (33%) the distance can be increased upto 800meters only. At 800 meters distance, the value of received power corresponds to 3.024, -0.143, -1.161 and -3.640dBm for NRZ, RZ (60%), RZ (50%) and RZ (33%).

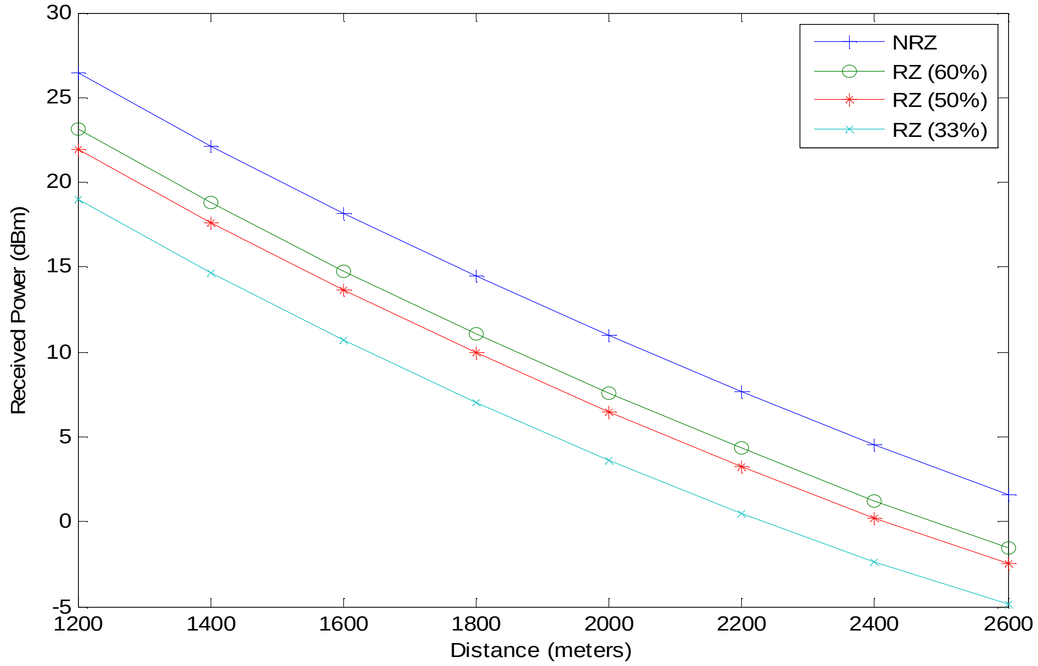

Fig. 2 Received Power versus Transmission Distance for Haze at NRZ and RZ (60%, 50% and 33%) Modulation Format

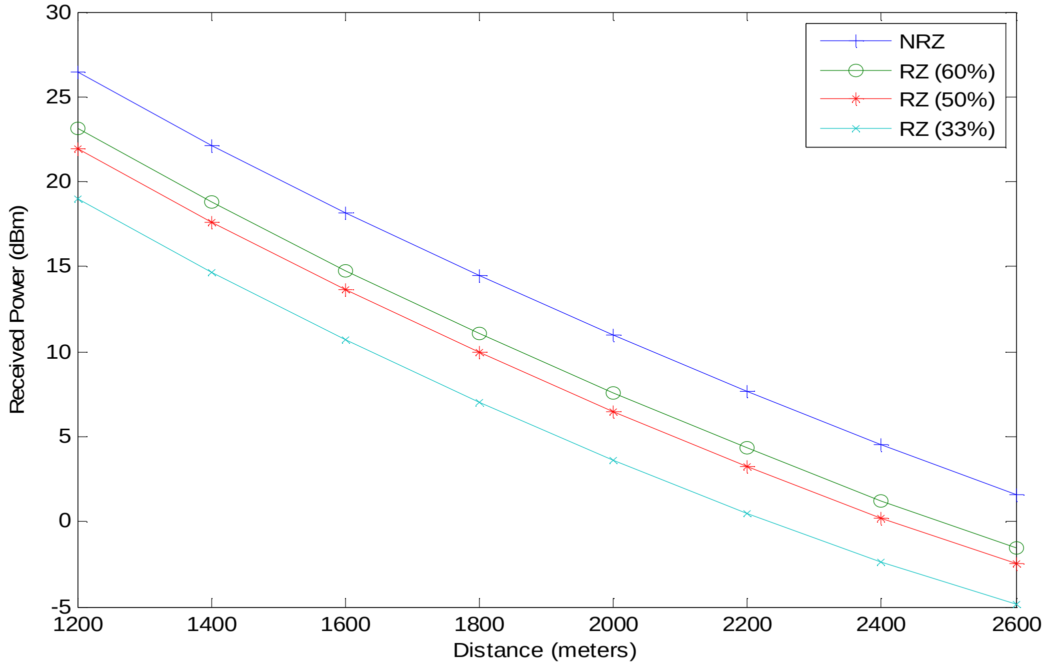

Fig. 3 Received Power versus Transmission Distance for Light fog at NRZ and RZ (60%, 50% and 33%) Modulation Format

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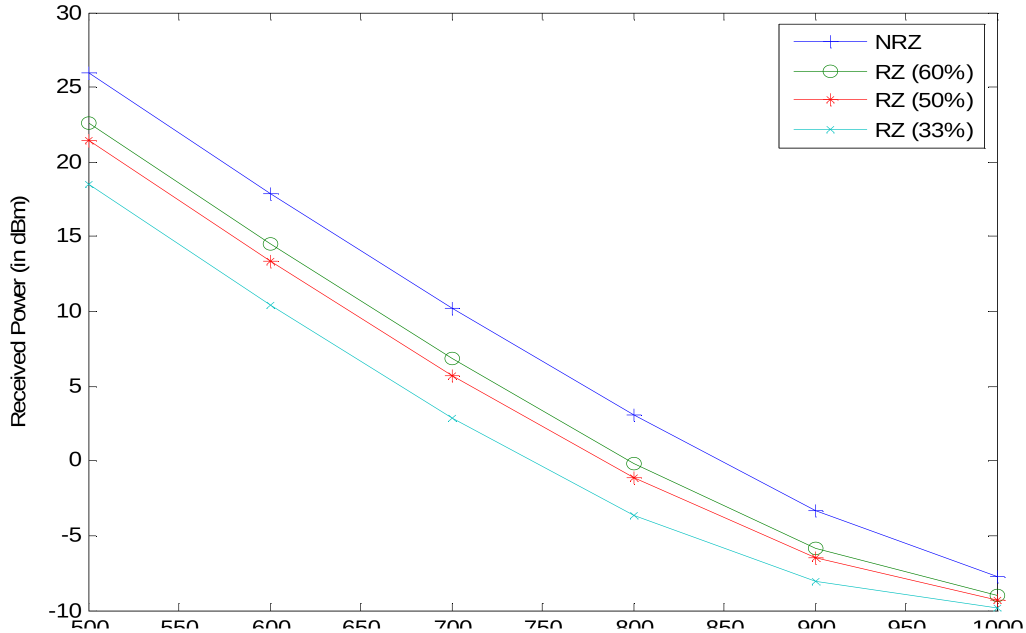

Fig. 4: Received Power versus Transmission Distance for Moderate fog at NRZ and RZ (60%, 50% and 33%) Modulation Format

IV.CONCLUSION

Free-space optics (FSO) has become one of the outstanding solutions to the bandwidth limitation of radio frequency links. But, the FSO system performance is purely dependent on atmospheric conditions. In this paper, the comparison of NRZ and RZ modulation format is analyzed for weather conditions haze, light fog and moderate fog for the free space optical system using polarization shift keying at 2.5 Gbps bit rate. It has been concluded that lesser received power is obtained for RZ (33%) when compared to NRZ, RZ (60%) and RZ (50%) at the same transmission distance for all weather conditions. The highest value of received power is obtained for NRZ modulation format (25.108, 26.499 and 25.986dBm for haze, light fog and moderate fog correspondingly) and it decreases for different duty cycles of RZ modulation format. Furthermore, it is observed that use of NRZ modulation format in PolSK-FSO system increases the transmission distance. As a result, NRZ can also be used for long haul communication in FSO system when polarization shift keying modulation technique is being used. The transmission distance can further be enhanced by increasing the input power of the laser source.

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