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Performance analysis of different modulation format on free space optical communication system

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ABSTRACT

In this article, different modulation format RZ, CRZ, CSRZ and NRZ on free space optical communication system has been investigated. It has been observed that external modulation gave us better performance in comparison to direct modulation because direct NRZ spectrum has a strong carrier component compared to external modulated NRZ. Simulation results show that RZ modulation format is best for long distance. Where NRZ is used for short distance and it is less complex, cheaper in comparison to RZ.

1. 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. It is similar to fiber optic communications in that data is transmitted by modulated laser light [1]. Instead of containing the pulses of light with in a glass fiber, these are transmitted in a narrow beam through the atmosphere. Light travels through air faster than glass, so FSO is communication at the speed of light in atmosphere. The stability and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat. FSO used in military systems because of their inherent benefits as most of the systems are rated for greater than 1 km in three or more lasers operating in parallel to mitigate distance-related issues. The quality of the transmission is characterized by the realized bit-error rate (BER) [2]. Free Space Optics (FSO) is a cost effective and attractive solution for high data rate and voice transmission [3]. FSO has received significant possible alternative to solve the bottleneck connectivity problem and as an alternative to more conventional RF/microwave links [4]. The three factors that affect the optical transmission are absorption, Scattering and scintillation [5,6]. All these can reduce the amount of energy received by receiver. Absorption is caused primarily by carbon dioxide and water vapor in the air along the transmission path. Their presence is a function of both humidity and altitude. This causes a decrease in the power density (attenuation) of the FSO beam and directly affects the availability of a system. However, the use of appropriate power based on atmospheric conditions and the use of spatial diversity (multiple beams within an FSO based unit) helps maintain the required level of network availability [7,8]. This focused the impact of transmission power and attenuation in free space optical communication system. It had shown BER of received data increases when transmission power is decreases and also increase when attenuation increases [9]. Here investigated the impact of with and without FEC in free space optics communication for different bit-rates. It had shown that forward error correction technique yields the highest Q^2 value and lowest BER in Free Space Optics (FSO) communication [10]. This [11] evaluated transmission in atmospheric concerning 650 nm laser beam, which it utilizing a low power and allowed maximum range of 300 m of data rate 100 Mbps experimentally. This allowed maximum range of 300 m at data rate 100 Mbps and evaluated low power used in atmospherics channel concern 650 nm laser beam. Here [12] compared the maximum transmission distance with NRZ and RZ modulations for two different laser inter-satellite communication scenarios. Simulation results shown long-range laser inter-satellite communication system with a saturated booster optical amplifier, the RZ modulation scheme can offer a longer transmission distance than NRZ modulation scheme. This [13] gave comparative study of different modulation formats for single channel systems. In this article work, we have presented the simulation investigation of FSO transmission system at different modulation format of RZ, CRZ, CSRZ and NRZ. The simulative setup description of FSO system is reported in Section 2 followed by the simulation results discussion in Section 3. The conclusion drawn from our simulation results is presented in Section 4.

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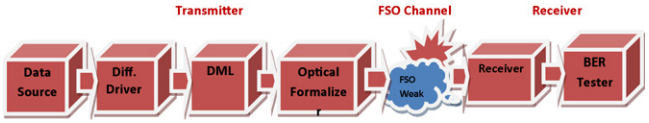

Fig. 1. Block diagram of FSO.

2. System modeling

FSO design has modeled and simulated for performance characterization by using Opt. Sim. 4.6. The FSO design model is illustrated in Fig. 1.

In our proposed design, the optical transmitter consists of three subsystems. The first subsystem is the Pseudo-Random Binary Sequence (PRBS) generator. This subsystem is to represent the information or data that wants to be transmitted. The output from a PRBS generator is a bit stream of binary pulses; a sequence of "1"s (ON) or "0"s (OFF), of a known and reproducible pattern. The second subsystem is the different modulation format (RZ, CRZ, CSRZ and NRZ) electrical pulse generator. This subsystem encodes the data from the PRBS generator by using the different modulation format (RZ, CRZ, CSRZ and NRZ) technique. The third subsystem in the optical transmitter is the direct modulated lasers. Direct modulated lasers based on InGaAs semiconductor technology with operating wavelengths around 1550 nm [14] were developed specifically for fiber optic communications systems because of the low attenuation characteristics of optical fiber in this wavelength range. The free space between transmitters and receiver is considered as FSO channel which is propagation medium for the transmitted light. The optical receiver consists of an avalanche photodiode (APD) followed by a front-end amplifier, a low pass filter. The receiver is use to regenerate electrical signal of the original bit sequence and the modulated electrical signal as in the optical transmitter to be used for BER analysis.

3. Results and discussion

In our proposed design, performance of different modulation format has been evaluated on free space Optical Communication. A comparative study has been carried out for free space optical communication at different modulation format of RZ, CRZ, CSRZ and NRZ. Here, the results have been mentioned for FSO system at different modulation format by taking values of the various parameters like: Data rate 2.50 Gbps, transmitter Wavelength 1550 nm, aperture area 180 cm^2, transmitted power 8 dBm, Sigma Add 1.9, Aperture area 180 cm^2, Divergence angle 3 mrad, Geometrical loss 20 dB, and propagation loss 5 dB.

From Fig. 2 we can see that the direct NRZ spectrum has a strong carrier component compared to external modulated NRZ and there are dip null at multiples of the bit rate. This is the reason that external NRZ modulation format is preferred compared to direct NRZ format.

Fig. 3 shows the BER versus transmission distance having some parameter of direct and external modulation. From Fig. 3 it has been observed that there is significant increase in BER which lies within [10^{-15} to 10^{-4}] and [10^{-98} to 10^{-4}] for transmission distance of 3 km in case of direct and 6 km in case of external modulation respectively.

Fig. 4 shows the Q value versus transmission distance having some parameter of direct and external modulation. From Fig. 4 it has been observed that there is significant decrease in Q value which lies within [18,11] to [64,12] for transmission distance of 3 km and 6 km in case of direct and external modulation respectively. From above discussion it is clear that external modulation

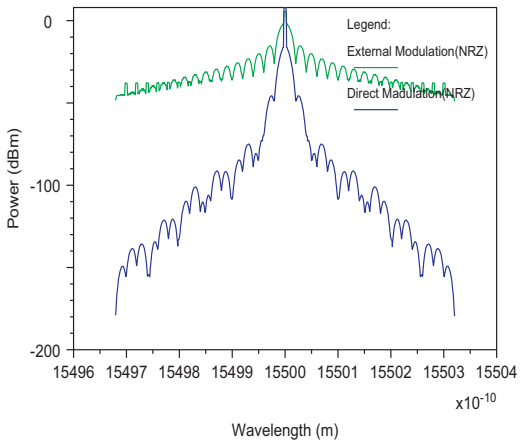

Fig. 2. Spectrum comparision of direct and external modulatation using NRZ modulation format.

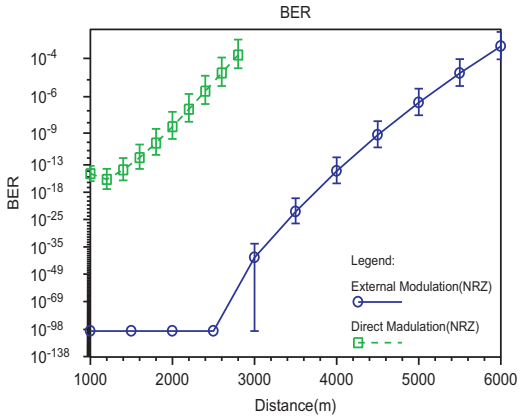

Fig. 3. BER versus transmission distance using direct and external modulation.

give better performance compared to direct modulation. So there is need to analyze external modulation.

From Fig. 5 we can see that reduction in power content of the RZ modulated carrier is disappearing compare to NRZ modulation. However, the carrier frequency still contains much power but no information. The RZ performs better than NRZ for 2.50 Gbps FSO because the energy is confined in the center of each bit-slot in the case of RZ case and that more differential group delay (DGD) is required before the energy leaks out the bit-slot to result in inter-symbol interference. This is the reason that RZ modulation format give better result.

Fig. 6 shows the graph between BER versus transmission distance at different modulation formats. From Fig. 6 it has been

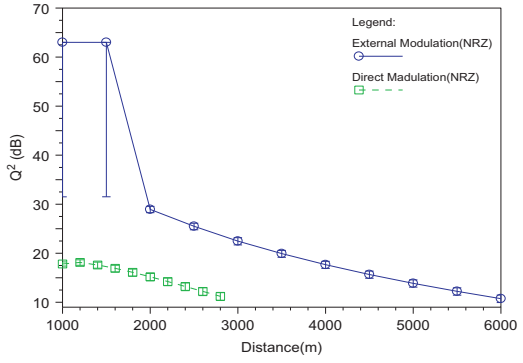

Fig. 4. Q factor versus transmission lengths using direct and external modulator.

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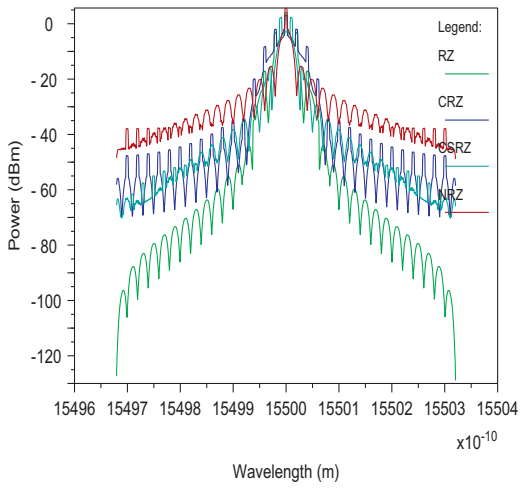

Fig. 5. Spectrum of external modulation using different modulation format.

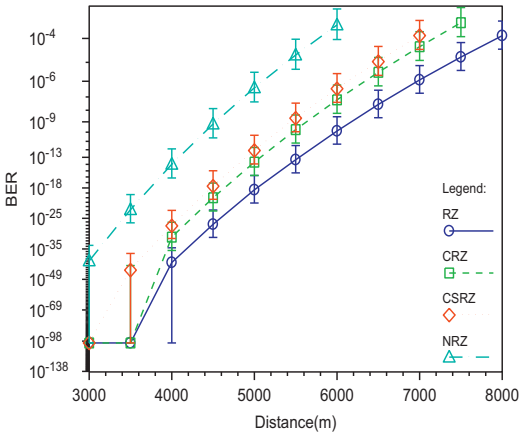

Fig. 6. BER versus transmission length at different modulation format.

observed that there is significant increase in BER which lies within [10^{-98} to 10^{-4}], [10^{-98} to 10^{-3}], [10^{-98} to 10^{-4}] and [10^{-42} to 10^{-3}] for transmission distance 8 km, 7.5 km, 7 km and 6 km in case of RZ, CRZ, CSRZ and NRZ modulation format respectively.

Fig. 7 shows the graph between *Q* value versus transmission distance at different modulation format. From Fig. 7 it has been observed that there is significant decrease in *Q* value which lies within [27–11], [26–10.5], [25.5–10.5] and [22.5–10] for

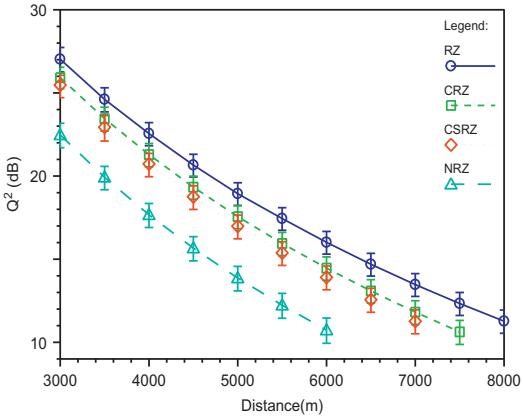

Fig. 7. *Q* factor versus transmission distance at different modulation format.

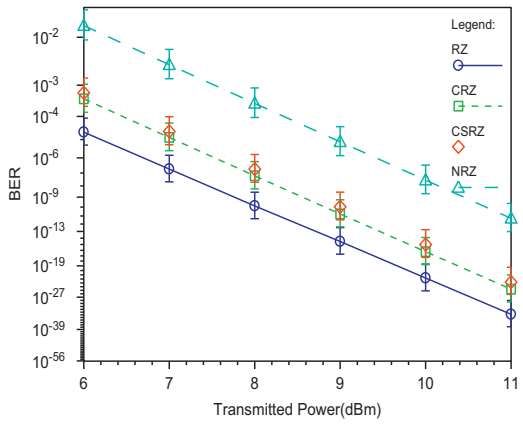

Fig. 8. BER versus transmitted power at different modulation format.

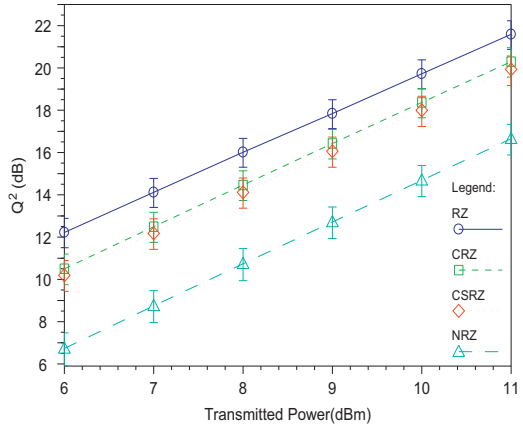

Fig. 9. *Q* factor versus transmission power at different modulation format.

transmission distance 8 km, 7.5 km, 7 km and 6 km in case of RZ, CRZ, CSRZ and NRZ modulation format respectively.

Fig. 8 shows the graph between BER verses transmission power at different modulation format. From Fig. 8 it has been observed that there is significant decrease in BER which lies within [10^{-2} to 10^{-9}], [10^{-3} to 10^{-19}], [10^{-4} to 10^{-22}] and [10^{-5} to 10^{-29}] for transmission distance 6 km, in case of RZ, CRZ, CSRZ and NRZ modulation format respectively as transmission power vary from 6 to 11 dBm.

Fig. 9 indicates the graph between BER verses transmission power at different modulation formats. From Fig. 9 it has been observed that there is significant increase in *Q* value which lies within [7–17], [10–20], [10.5–20.5] and [12–22] for transmission distance of 6 km in case of RZ, CRZ, CSRZ and NRZ modulation format respectively as transmission power vary from 6 to 11 dBm.

4. Conclusion

This article targets the impact of direct and external modulation with different modulation formats. It has been observed that external modulation gave us better performance in comparison to direct modulation because direct NRZ spectrum has a strong carrier component compared to external modulated NRZ and there are dip null at multiples of the bit rate. Further, external modulation has also been investigated with different modulation format (NRZ, CSRZ, CRZ and RZ). It has been observed that there is significant decrease in *Q* value which lies within [27–11], [26–10.5], [25.5–10.5] and [22.5–10] for transmission distance 8 km, 7.5 km, 7 km and 6 km in case of RZ, CRZ, CSRZ and NRZ modulation format respectively and in the BER case, it is observed that there is increase in BER which lies

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within [10^{-98} to 10^{-4}], [10^{-98} to 10^{-3}], [10^{-98} to 10^{-4}] and [10^{-42} to 10^{-3}] for transmission distance of 8 km, 7.5 km, 7 km and 6 km in case of RZ, CRZ, CSRZ and NRZ modulation format respectively.

In other case it has been observed that there is significant increase in Q value which lies within [7–17], [10–20], [10.5–20.5] and [12–22] for transmission distance of 6 km in case of RZ, CRZ, CSRZ and NRZ modulation format respectively and in the BER case, it is observed that there is decrease in BER lies within [10^{-2} to 10^{-9}], [10^{-3} to 10^{-19}], [10^{-4} to 10^{-22}] and [10^{-5} to 10^{-29}] for transmission distance 6 km, in case of RZ, CRZ, CSRZ and NRZ modulation format respectively at transmission power vary from 6 to 11 dBm.

It is concluded that RZ modulation format is best for long distance, but is complex and costly. Where NRZ is used for short distance and it is less complex, cheaper in comparison to RZ.

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