

# Effect of Ternary Optical Linecode in Free Space Optics under Atmospheric Disturbances

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**ABSTRACT:** Free-space optics (FSO) or free space communication has been used for more than three decades to provide very fast and high capacity communication links in remote locations. FSO provides tap proof communication by using light carrying information between multiple points. Even though FSO system suffers due to various limitations and affected by geometrical factor like fog, snow, haze and rain etc. Quality of service of FSO link is strongly influenced by weather phenomenon like scattering and turbulence leads attenuation in the transmitted signal. These result shows significant changes in bit error rate at receiver. This paper analyzed the effects of ternary line code to mitigate the noise by using 2-Binary 2-Ternary RZ/NRZ code under different weather conditions based on the mathematical relationships of weather factors which affecting the transmission of laser beam carries the information with in different ranges.

**KEYWORDS:** Attenuation, Bit Error Rate, Free Space Optics (FSO), Line Codes, Link Range, Quality Factor.

## I. INTRODUCTION

Free space optical communication has emerged as a viable technology for next generation indoor and outdoor broadband wireless applications. Over the last 3 decades advancement in communication technology leads a drastic increase in bandwidth and capacity. This growing demand arise a need to shift from RF carriers to optical carriers and it gained worldwide acceptance in the telecommunication industry. The principal advantage of FSO technology is its very high bandwidth flexibility, which could provide wireless optical extension from portable computer to last-mile bridging gaps between end link users. In addition, FSO permits the use of narrow divergence, directional laser beams, which provide essentially more secure channels with low probability of interception or detection (LPI/LPD) in a non-licensed spectrum. Narrow optical beams which propagating through the free space which also have considerable obscuration penetrating capability and allows considerable spatial re-use with highly scalable.

FSO system suffers various limitations and handicapped due to degradation phenomena of different geometrical factors like fog, snow, haze and rain etc. Quality of service of FSO link is strongly influenced by weather phenomenon like scattering and turbulence leads attenuation in the transmitted signal. These results in significant changes in bit error rate at receiver. The FSO system is similar to the fiber optic communication, which operate near the spectral range 780-850 nm and 1450-1550nm. But optical devices using the 850 nm spectral range cannot operate above 2.5 Gbps because of the power limitations imposed for the eye safety. The system operating at 1500 nm can transmit more than 10 times power than system operating at shorter wavelengths and it more safe because cornea, the outer layer of eye absorb the energy of light which does not allow it to focus on retina.

In the literature, various papers covers the issues related to the free space communication and suggested various techniques like adaptive optics, FSO-RF hybrid combinations etc. to mitigate the atmospheric noises. In this paper, the effect of modulation while varying the distance is analysed. And the effect of Q-factor and Bit Error Rate for various atmospheric conditions namely clear air, fog and rain are investigated.

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The work in this paper is divided in two stages. 1) Simulation of Free space communication system with binary line code 2) Simulation of Free space communication system with ternary line code. First stage is done by applying basic binary NRZ code for modulating the optical signal and propagating signal through free space medium. Thereafter, APD photo detector is applied to detect the signal which undergoes significant degradation due to environmental factors. Then measuring components uses to measure min BER and Quality factor to analyse the efficiency of communication. And in the second stage is done by applying the ternary code with the same system instead of NRZ code.

Paper is organized as follows. Section II describes the block diagram of free space communication system model. Proposed system model with ternary and binary codes is given in Section III. Section IV presents experimental results with graphs and plots. Finally, Section V presents conclusion.

## II. FREE SPACE COMMUNICATION SYSTEM MODEL

FSO system design has been proposed for performance evaluation by optical simulation software and MATLAB. The block diagram for FSO system link used in the simulations is shown in Fig. 1.

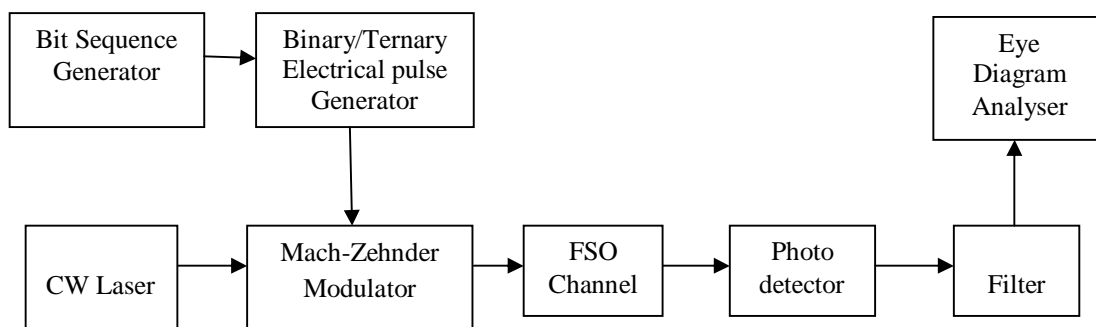


Fig.1. Block diagram of free space communication

It consists of a transmitter at one end with laser diode as a optical source and Mach-Zehnder Modulator using as external modulator for intensity modulation of laser diode, followed by FSO channel and receiver part. Wavelength of laser diode was set up at 1550nm. Modulator in transmitter part was assigned to randomly generated bits by pseudo random bit sequence (PRBS) generator transmit through the channel to the receiver. A photo detector functioned as converting the received optical signal into an equivalent electrical signal. For high amplification purpose Avalanche photodiode (APD) some time used in free space optical data transmission in larger distance application. Measuring tools like eye diagram and BER analyser used for the measurement of Q-factor and bit error rate.

The power received at the photo detector can be explained by [4],

$$P_R = P_T * \left( \frac{d_R^2}{(d_T + \theta_R)^2} \right) * 10^{-\frac{\alpha R}{10}} \quad (1)$$

The equation 1 represents the power received at the output end with the effects of geometrical loss. Where  $P_R$  is the power received at the output (W),  $P_T$  is the power transmitted from the input (W),  $d_T$  and  $d_R$  are antenna aperture diameters of transmitter and receiver section respectively (m).  $\theta_R$  is the divergence angle (mrad),  $\alpha$  is the attenuation factor (dB/km) and R is the link range ranges from transmitter to receiver (km).

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## III. PROPOSED FSO SYSTEM MODELS

### A. NRZ-FSO SYSTEM MODEL

The NRZ-FSO design model is shown in Fig. 2. In our proposed design; the output of a PRBS is given to the NRZ driver. This driver encodes the data using NRZ encoding technique in which “1” is represented by a significant bit and “0” is represented by another significant bit in entire bit period. The output of a NRZ driver is given to an optical intensity Mach-Zehnder modulator which has two input ports, one is electrical input and other is optical input from CW laser, and resulting modulated signal passes through the channel area.

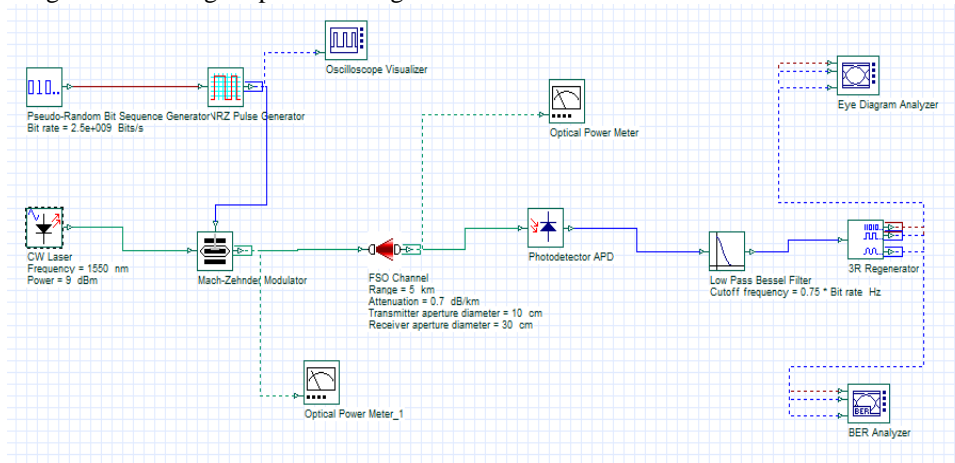


Fig.2. Simulation layout of NRZ-FSO model

At the receiver end APD used for the detection purpose. A Bessel filter which has cutoff frequency of  $0.75 \cdot \text{bit rate}$  is used for limiting the bandwidth of channel. For getting regenerative electrical output from original bit sequence, 3R generator is used. The output of 3R generator used as an input for eye diagram analyser.

### B. 2B2T RN- FSO SYSTEM MODEL

The purpose of coding data is to efficiently transport it through a particular channel medium. Each type of medium suffers from a group of impairments which may include signal reflection, attenuation distortion, harmonic distortion, phase distortion, intermodulation distortion, echo, crosstalk, delay distortion manifesting itself as inter symbol interference (ISI) etc. All these impairments in the medium affect the ability to transport data through it. When the channel is bandwidth limited, more efficient codes are available and it utilize multi-level symbols and alter the message data to allow the receiver to synchronize to it.

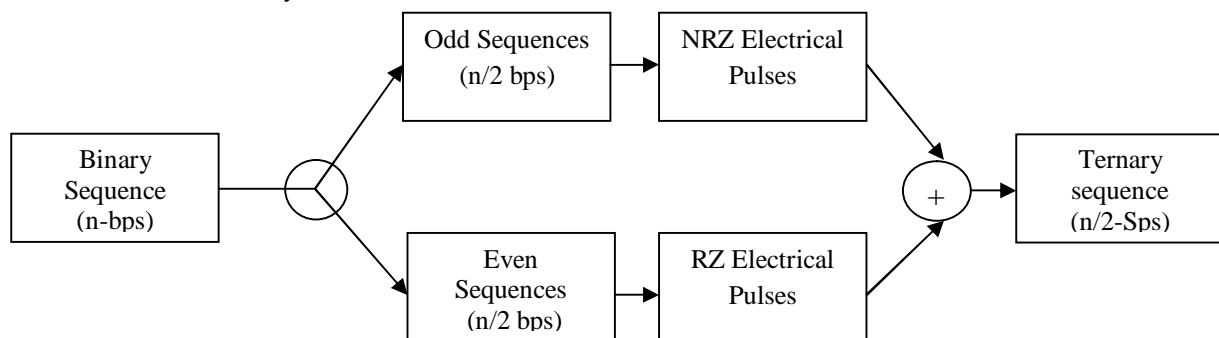


Fig.3. Schematic diagram of 2B2T RN code

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The principle of this code is adapted from the combination of the properties of NRZ and RZ codes which illustrated in Fig 3. The signal does not require much state memory state as in conventional bipolar codes like bipolar NRZ [5]. It convert n bit per second binary sequence to n/2 samples per second ternary sequences. The user defined sequences generated from the generator is multiplexed to two different sequences which consists odd and even sequences of input data and it converted to NRZ and RZ sequences respectively. An electrical adder is used to combine two electrical pulses to form ternary sequence. Fig 4 represents the simulation layout of ternary FSO system and the working is almost similar to NRZ-FSO system. Here we use ternary RZ code for the modulation of optical signal.

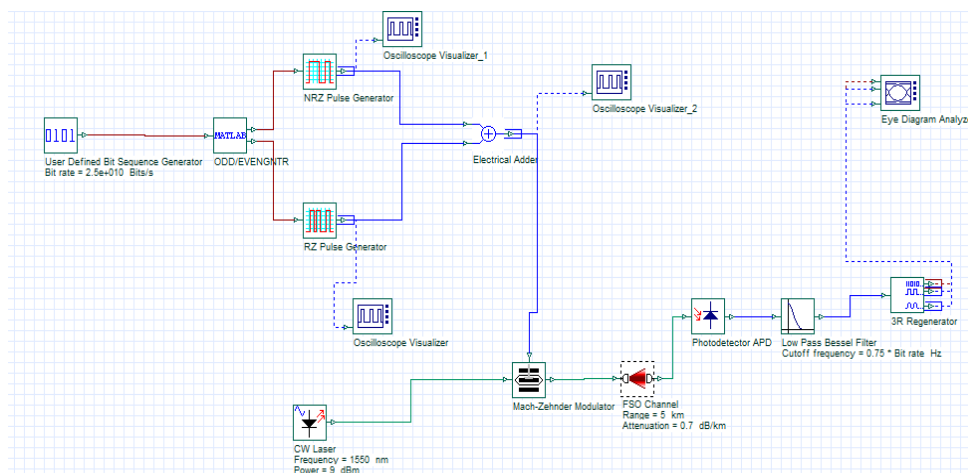


Fig.4. Simulation layout of 2B2T RN-FSO model

## IV. SIMULATION RESULTS AND DISCUSSION

Simulations of both systems with binary and ternary code with a power of 9 dBm, range upto 15 km and bit rate of 2.5 Gbps are analysed under three conditions clear, haze and fog. The atmospheric conditions can be possible to set the attenuation losses in the FSO channel. According to the international visibility values of atmospheric conditions, the attenuation values of clear, strong rain and thick fog are 0.7db/km, 6.9db/km and 75db/km respectively. Simulation parameters are listed in Table 1.

Table 1: Design parameters for optsystem simulation

DESIGN PARAMETERS	VALUES
Bit Rate	2.5 Gbps
Sequence length	128 bits
Power	9dbm
Frequency	1550nm
Transmitter aperture diameter	10cm
Receiver aperture diameter	30cm
Attenuation	Sweep
Link range	0-15km
Beam divergence	0.2mrad
Detector gain	10
Responsivity	9

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Figure 5 represents the FSO system under clear condition. Ternary line code shows better performance than binary codes with high Q-factor and low BER. From the eye diagram we can clearly observe that the Q-factor of FSO under ternary code condition is 34 and the minimum BER in the rate of  $10^{-257}$ . But in the case of FSO with binary NRZ code, we can only achieve the Q-factor up to 27 and BER in the rate  $10^{-167}$ . Prior to the performance analysis, higher Q-factor and min BER represents a good, high quality communication system.

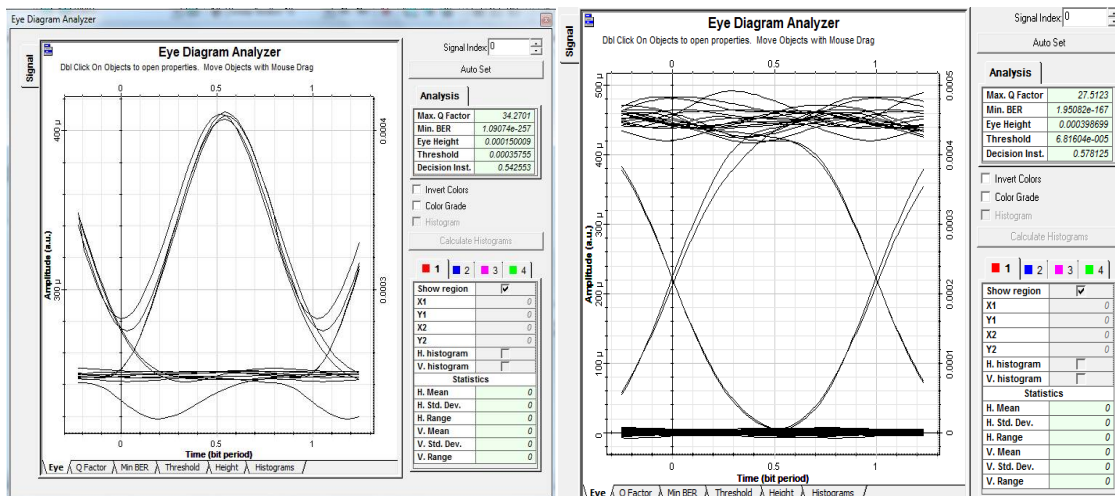


Fig.5. Eye diagram of (a) 2B2T RN-FSO (b) NRZ-FSO model under clear atmosphere at 10 km

Eye diagram of both FSO systems under rain condition are shown in Figure 6. Due to the high attenuation value Q-Factor decreases when compare with the clear atmospheric condition. Here the Q-factor of FSO with ternary code condition is 23 and the minimum BER in the rate of  $10^{-120}$ . But in the case of FSO with binary NRZ code, we can only achieve the Q-factor up to 8 and BER in the rate  $10^{-16}$ . Under the same atmospheric conditions, the FSO system with binary line codes severely affects the link availability than FSO system with multilevel line codes.

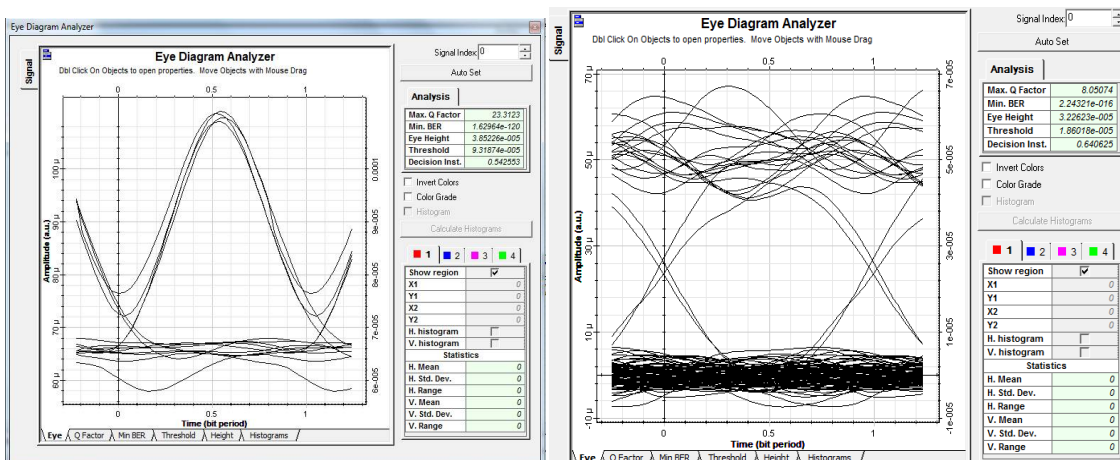


Fig.6. Eye diagram of (a) 2B2T RN-FSO (b) NRZ-FSO model under rainy atmosphere at 2km

Figure 7 represents the eye diagram of both systems under foggy atmosphere. Fog particles are the most photon scatters which causes high degradation in signals when it passes through the free space. The BER analysis from eye diagram shows that the binary coded signal more degraded than ternary code because ternary free space

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communication provides higher Q-factor and lower BER which shows more reliable communication. From clear to foggy atmospheric condition attenuation increases Q-factor decreases and link range between transmitters to receivers also decreases.

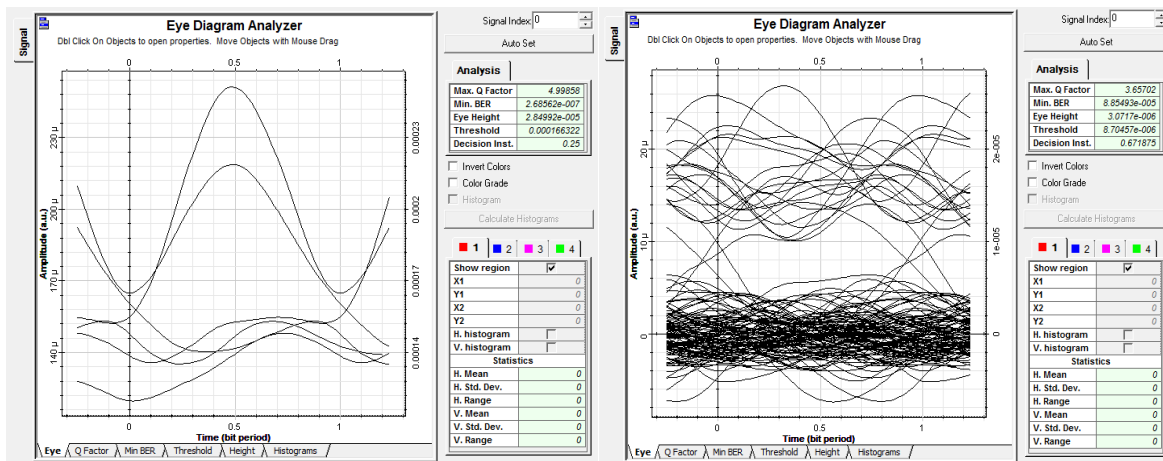


Fig.7. Eye diagram of (a) 2B2T RN-FSO (b) NRZ-FSO model under foggy atmosphere at 500m

Figure 8 represents the graphical comparison of both systems under clear atmospheric conditions. Due to the higher attenuation value Q-factor decreases due to the degradation of signal. From the graph we can analyse that the Q-factor decreases with increase in the link range. Here the link range varies from 1 km to 15 km and RN-FSO system provides higher Q-factor in the entire link range than the NRZ-FSO system.

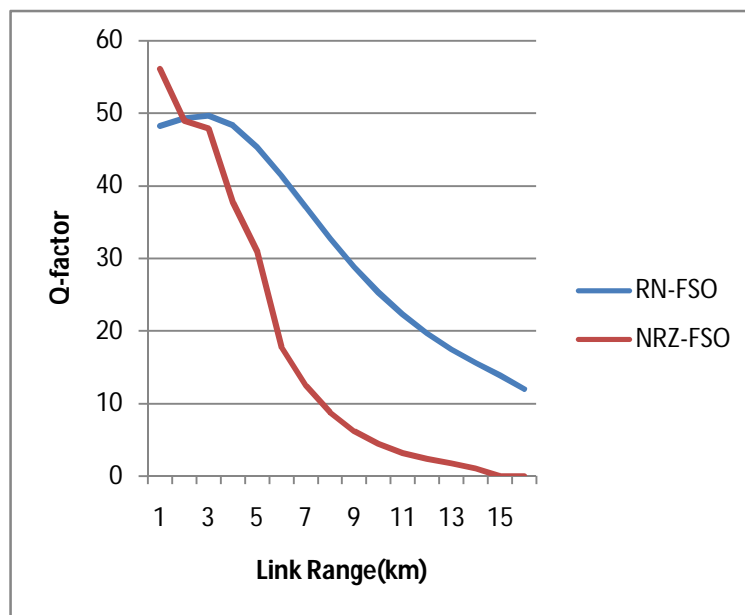


Fig.8.Comparison of 2B2T RN-FSO and NRZ-FSO model under clear atmosphere

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## V. CONCLUSION

FSO communication system were modelled and simulated and the system performances were analysed when several parameters of the system were varied. In this work, we have analysed the Free Space optical communication System using intensity modulation techniques and with different line codes under channel conditions like Fog, Rain and clear. The ternary code has a better performance than binary codes in atmosphere disturbances. It can also be said that an appropriate coding technique can be further improve the performance for the free space optical transmission system.

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