Performance Evaluation of 32×40 Gbps (1.28 Tbps) FSO Link using RZ and NRZ Line Codes

Jasvir Singh
Assistant Professor
EC Department
ITM Universe, Vadodara

Pushpa Gilawat

Balkrishna Shah
Assistant Professor
Physics Department
M.S.University of Baroda

ABSTRACT

In this paper, the implementation of 32×40 Gbps free space optical (FSO) communication system is developed. Analysis is performed for return to zero (RZ) and non return to zero (NRZ) line codes for 1 km free space optic length. Motivation to the current analysis is to compare RZ and NRZ lines codes in wavelength division multiplex communication system in free space optic channel and it is found that the NRZ line code is better than RZ code. A 1.28 Tbps wavelength division multiplexed communication system for free space optic channel workplace has been discovered in which 32 channel each of 40 Gbps data streams are combined using wavelength division multiplexed. The study includes the attenuation caused by atmospheric effect and beam divergence. Bit error rate (BER), quality factor (Q) and eye diagram are indicator of performance evaluation. By comparing one can get a promising system to the high capacity access network with more bandwidth, cost effective and good flexibility.

General Terms

Free Space Optics, Line Codes

Keywords

Free Space Optics; Wavelength Division Multiplexing; Return to Zero; Non Return to Zero.

1. INTRODUCTION

The main features of free space optics transmission is high directivity which provides high power efficiency and isolation from other potential interferences, unlicensed bandwidth, easy installation and it promises multi Gbps applications in next generation network [1]. On the other hand, signal fading and signal attenuation because of atmospheric effects limit practically attainable data rates and transmission distance in FSO systems [1]. Today most common type of communication system are using optical fibers and dense wavelength division multiplexing (DWDM). However deployment of FSO is still in progress. FSO technology is used in space communications (e.g., inter-satellite and deep space) and terrestrial communications (e.g., enterprise connectivity, last mile access network and backup links).

FSO is not being considered a suitable and practical solution for very high-speed communications, such as those of terrestrial WDM optical networks although it has no limitation in bandwidth. FSO limitation is its lack of reliability, difficult light collimation and beam tracking. Current FSO systems have much lower capacity than the current fiber systems and, generally, they show error bursts in long-time operation, i.e. high average bit error ratio (BER) [2], [3], [4], [5]. E. Ciaramella et. al first developed 1.28 Tbps (32×40 Gbps) FSO link [6].

In this paper we have developed 1.28 Tbps (32×40 Gbps) FSO link using RZ and NRZ line codes. Here we have used

dense wavelength division multiplexing in free space optics link using RZ and NRZ line codes. The results of NRZ and RZ line codes are compared on the basis of BER and Q. In section II, system configuration and in section III, results and discussion are discussed and in section IV, conclusion is outlined.

2. SYSTEM CONFIGURATION

Simulation set up of 1.28 Tbps (32 × 40 Gbps) communication system over free space optics using RZ and NRZ line codes is shown in Fig.1.

This system is designed using optisystem version 11, which is used as platform for many optical communication design and simulation. In Fig.1 we have used WDM transmitter at input. WDM Transmitter encapsulates different components, allowing users to select different modulation formats and schemes for multiple channels in one single component. It is a transmitter array that allows for different modulation types and schemes. Initial frequency is 190 THz and frequency spacing is 200 GHz. Modulation type are NRZ and RZ. We have taken 32 channels each one of 40 Gbps. These channels are then multiplexed using ideal multiplexer. At multiplexer, total data rate is 1.28 Tbps. After ideal multiplexer there is FSO component.

This component allows for simulation of free space optical links. The component is a subsystem of transmitter telescope, free space and receiver telescope. Parameter Range defines the propagation distance between transmitter and receiver telescope. The attenuation of the laser power in depends on two main parameters: Attenuation and Geometrical loss. The first parameter describes the attenuation of the laser power in the atmosphere. The second parameter, Geometrical loss, occurs due to the spreading of the transmitted beam between the transmitter and the receiver.

The link equation is

$$P_{Received} = P_{transmitted} \frac{d_r^2}{(d_T + \theta R)^2} 10^{-\alpha \frac{R}{10}} \quad (1)$$

Where:

d_R : Receiver aperture diameter (m)

d_T : Transmitter aperture diameter (m)

θ : Beam divergence (mrad)

Fig 1: Simulation set up of 1.28 Tbps free space optic link using RZ and NRZ line codes.

R: Range (km)

α : Atmospheric attenuation (dB/km)

The user can also specify the transmitter and receiver losses due to fiber-telescope interface and coupling efficiencies (parameters Transmitter loss and Receiver loss).

Additional losses due to scintillation, mispointing, and others can be specified by the parameter Additional losses. Parameter Propagation delay allows for calculation of the delay between transmitter and receiver.

If parameter Intensity scintillation is enabled, a Gamma-Gamma distribution [4][5][6] is used to model atmospheric fading. In this case the probability of a given intensity is:

$$P(I) = \frac{2(\alpha\beta)^{\frac{\alpha+\beta}{2}}}{\Gamma(\alpha)\Gamma(\beta)} I^{\frac{\alpha+\beta}{2}-1} K_{\alpha-\beta}(2\sqrt{\alpha\beta}I) \quad (2)$$

Where $1/\alpha$ and $1/\beta$ are the variances of the small and large scale eddies, respectively [4], $\Gamma(\dots)$ is the Gamma function and $K_{\alpha-\beta}(\dots)$ is the modified Bessel function of the second kind.

$$\alpha = \exp \left[\frac{0.49 \sigma_R^2}{(1+1.11\sigma_R^{12/5})^{5/6}} \right] - 1 \quad (3)$$

$$\beta = \exp \left[\frac{0.51 \sigma_R^2}{(1+0.69\sigma_R^{12/5})^{5/6}} \right] - 1 \quad (4)$$

The Rytov variance is calculated from:

$$\sigma_R^2 = 1.23 C_n^2 k^{7/6} z^{11/6} \quad (5)$$

Where C_n^2 is the parameter Index refraction structure, k is the optical wave number and z is the parameter Range. Channel time variations are considered according to the theoretical quasi-static model, also called the frozen channel model. By this model, channel fading is considered to be constant over the duration of a frame of symbols (Coherence time), changing to a new independent value from one frame to next.

We have used single mode fiber (SMF) of 1 km length and EDFA amplifier of gain 30 dB; we have used WDM analyzer for analyzing every channel signal power, noise power and

OSNR.

At the receiving end, demux is used. This component is an optical receiver subsystem. The subsystem was built using two different types of photo detectors, one Bessel filter and the 3R regenerator. The component properties allow the user to select the internal component parameters. Depending on the choice between PIN and APD, the Switch/Select components will redirect the signal into the proper photo detector type.

After optical receiver, bit error rate (BER) analyzer is used. From BER analyzer ber, Q factor and eye diagram are used for indicator for performance evaluation.

Table 1. Simulation parameters

Component	Parameter	Value/unit
Free Space Optics channel	Distance	1 km
	Attenuation	25 dB/km
	Transmitter aperture diameter	5 cm
	Receiver aperture diameter	20 cm
	Beam divergence	2 mrad
	Wavelength	1550 nm
EDFA	Index refraction structure	5e-015
	Gain	30 dB
WDM Transmitter	Initial Frequency	190 THz
	Frequency spacing	200 GHz
	Power	30 dBm
	Bit Rate	40 Gbps
	Modulation type	RZ, NRZ

3. RESULTS AND DISCUSSIONS

Distortion of signal due to inter symbol interference and noise appear as closure of eye diagram. In fig 2, eye diagram for channel no 1st, 10th, 20th and 32nd for NRZ line coding for 1 km free space optics link is shown. In fig 3, eye diagram for channel no 1st, 10th, 20th and 32nd for RZ line coding for 1 km free space optics link is shown.

Fig 2: Simulation Eye diagram for 1 km free space optics link using NRZ line codes.

Fig 3: Simulation Eye diagram for 1 km free space optics link using RZ line codes.

Statistical characteristics of the amplitude noise are determined for finding the relationship between BER and eye-opening at data decision. Figure of merit, Q-factor is used for determining BER. If the ISI distribution does not exist and the dominant amplitude noise has Gaussian distribution, the signal Q-factor is defined as:

$$Q = \frac{v_1 - v_0}{\sigma_1 - \sigma_0}$$

Here v_1 , v_0 are the mean values for $v(t)$ amplitude high and low without ISI, whereas σ_1 , σ_0 are the root mean square

(RMS) of the additive white noise for each Gaussian distribution.

Bit error ratio (BER) can be given as:

$$BER = \frac{1}{2} \operatorname{erfc} \left(\frac{Q_{BER}}{\sqrt{2}} \right)$$

Where

$$\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-v^2} dv$$

Q_{BER} is the minimum required Q-factor for a given BER.

In Fig 4 BER for 1 km free space optics channel using NRZ line coding and in Fig. 5 BER for 1 km free space optics using RZ line coding for channel no 1st, 10th, 20th and 32nd is shown. It can be observed from the Fig. 4 that for NRZ line coding when input signal power is less than 8 dBm BER is very high, but when we increase input signal power more than 8 dBm BER starts decreasing rapidly whereas for RZ line coding when input signal power is less than 10 dBm BER is very high, but when we increase input signal power more than 10 dBm BER starts decreasing rapidly.

Fig 4: BER for 1 km free space optics link using NRZ line codes

Fig 5: BER for 1 km free space optics link using RZ line codes

In Fig 6 Q-factor for 1 km free space optics channel using NRZ line coding and in Fig. 7 Q-factor for 1 km free space optics using RZ line coding for channel no. 1st, 10th, 20th and 32nd is shown. It can be observed from the Fig. 5 that for NRZ line coding when input signal power is less than 8 dBm Q-factor is very low, but when we increase input signal power more than 8 dBm Q-factor starts increasing rapidly whereas for RZ line coding when input signal power is less than 10 dBm Q-factor is very low, but when we increase input signal power more than 10 dBm Q-factor starts increasing rapidly.

Fig 6: Q for 1 km free space optics link using NRZ line codes.

Fig 7: Q for 1 km free space optics link using RZ line codes.

We can observe from Fig.5 that Q-factor is more than 6 for all channels when input power is more than 17 dBm in NRZ line coding whereas Q-factor is more than 6 for all channels when input power is more than 19 dBm in RZ line coding. From the comparison of Eye Diagram, BER and Q-factor we can observe that performance of 1.28 Tbps capacity free space optics channel of length 1 km using NRZ line coding is better than free space optics channel of 1 km using RZ line coding. We can also observe that as we increase input signal power Q-factor increases.

4. CONCLUSION

The paper illustrates the simulation and analysis of 1.28 Tbps (32×40 Gbps) free space optics link of 1 km length using NRZ and RZ line coding and it describes NRZ line coding is superior. In simulation results, it is found that as the power increases, the bit error rate decreases and Q-factor increases. We can see using wave length division multiplexing how capacity of free space optics channel can be increased.

5. REFERENCES

- [1] H. Willebrand and B.S. Ghuman. 2002, Free Space Optics: Enabling Optical Connectivity in Today's Networks, Sams Publishing.
- [2] D. Song, Y. Hurh, J. Cho, J. Lim, D. Lee, J. Lee, and Y. Chung. 2000, 4 x 10 Gb/s terrestrial optical free space transmission over 1.2 km using an EDFA preamplifier with 100 GHz channel spacing. Optics express, vol. 7, no. 8, p. 280.
- [3] M. Jeong, J. Lee, S. Kim, S. Namgung, J. Lee, M. Cho, S. Huh, Y. Ahn, J. Cho, and J. Lee, 2003. 8× 10-Gb/s terrestrial optical free-space transmission over 3.4 km

using an optical repeater IEEE Photon. Technol. Lett, vol. 15, no. 1, pp. 171–173.

- [4] R. Sova, J. Sluz, D. Young, J. Juarez, A. Dwivedi, N. Demidovich III, J. Graves, M. Northcott, J. Douglass, J. Phillips, et al., 80 Gb/s free space optical communication demonstration between an aerostat and a ground terminal. Proc. SPIE, vol. 6304, p. 630414.
- [5] P. Chen, S. Chang, S. Shuen-Te Ji, H. Lin, H. Tsay, P. Huang, W. Chiang, W. Lin, S. Lee, H. Tsao, et al, 2008. Demonstration of 16 channels 10 Gb/s WDM free space transmission over 2.16 km IEEE/LEOS Summer Topical Meetings, 2008 Digest of the, pp. 235–236.
- [6] E. Ciamarella, Y. Arimoto, G. Contestabile, M. Presi, A. D’Errico, V. Guarino, 2009. 1.28 Terabit/s (32x40 Gbit/s) wdm transmission system for free space optical communication. IEEE journal on selected areas in communications, vol. 27, no. 9.