A Radio Over Free Space Optical (RO-FSO) System by Mixing Radio Frequency (RF) Waves in Advance Modulation Formats

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Abstract - *In this work, a radio frequency based free space optical system is presented at 40 Gbps data speed. An advanced modulation format and two linecodings such as NRZ and RZ are investigated in the system with radio frequency mixing. Investigation has been carried out for different distances, launched power sin terms of Q factor. Also a comparison has been made among CSRZ, RZ and NRZ to find out best modulation format in RO-FSO system. Results revealed that CSRZ exhibits best performance as compared to NRZ and RZ modulation formats.*

***Key Words*: FSO, CSRZ, RF, NRZ, RZ**

1. INTRODUCTION

Next Generation communication systems aim significantly boost the wireless transmission capacity i.e., bit rate per user by number of users, in cellular networks compared to 4G communication systems [1]. Near the beginning existence of telecommunication, applications such as global systems for mobile and GPRS can support less data rates [2]. On the other hand, in the today's world, to fulfil the demands of user, high capacity systems are needed i.e. WiMax and WiMAN, that uses capacity up to 1-10 Gbps with broad coverage region [3]. However, rising figure of users will enforce boundaries to the information transfer. Way for subjects is by dipping the cell dimension to put up additional users. This refers to as micro-cells or pico-cells concept [4]. Free Space Optical Communication is the technology in optical communication system in which light travelling in free space is used to transmit data wirelessly for computer networking or telecommunication. Free space can be air, outer space, vacuum, atmosphere or environment [5]. The atmosphere is often used for the transmission and reception of the information signal wirelessly. The presence of water molecules, particles and gases in the atmosphere, which can degrades the performance of Free Space Optics. This can cause the signal to scatter, disperse and even the signal can be absorbed [6]. The atmosphere consists of different types of gases and particles which absorbs and scatter the signal to different levels at the various wavelengths [7]. FSO systems are popular for the high degree of security which is virtually impossible to intercept by any of the eavesdropper and jammer. Optical fiber is good communication medium but it adds the cost due to trenching and splicing [8]. Applications of free space links are endless and majorly use in the inter satellite optical links. Laser and optical communications used for the wideband and high communication [8]. RO-FSO is a mixture of wireless and optical systems that will take to elevated ability. RO-FSO refers to a technique in which light is modulated by a RF signal and transmitted above an optical connection to make wireless access easy [9]. In general the RO-FSO systems are the analog signals mixed with the light signal or the formation of the analog signal into the light. Numerous research works has been reported so far in the free space optical communication. However, RO-FSO systems are very less reported in literature. Methods that are used till now to support high data rate and number of end users are such as polarization interleaving [10], linearly polarized modes along with RF [11] etc. However, these methods either are complex or limit the distance of transmission.

In this work, comparative analysis among various parameters including input power, aperture diameter and cost has been presented over FSO. Comparative analysis has been done in RO-FSO system using return to zero (RZ),non return to zero(NRZ) and compressed spectrum return to zero(CSRZ). Use of CSRZ considered because this scheme is less affected by dispersion effect and other nonlinear effects and has several more advantages such as constant power, high security etc.

2. SYSTEM DESIGN

In this system CW laser with frequency 193.1 THz has been used in different modulators drivers RZ, NRZ and CSRZ. A PRBS is used to transmit random data and followed by modulator driver i.e NRZ or RZ and a radio signal is mixed with NRZ/RZ/CSRZ signal to convert it into radio signal. This signal is fed in to mach-zehnder modulator for optical output. A FSO channel with 0.1dB/Km attenuation and beam divergence of 0.1 mrad is considered. At receiver side pin photodetector with 1A/W responsivity and 10nA dark current is used. A cosine roll of filter is used followed by a 3-R regenerator and BER visualizer. Operation principle of modulation formats given as Intensity modulation is the procedure to transmit information on the amplitude of the optical signal by the MZM, and demodulate the transmitted information at the receiving side by detects the changes in the amplitude. It includes NRZ, RZ and CSRZ.NRZ also includes carrier-suppressed zero CSRZ, zero chirp CRZ and so on. There are three principles for the modulation format that follow: firstly, the compact modulation signal spectrum is good and the dispersive tolerance: secondly, a high non-linearity tolerance; thirdly, the structure of the transmitter and receiver is simple. NRZ as in Fig.1 use the Mach–Zehnder modulator (MZM) and the consecutive wave (CW) laser in the modulation system.

When transmitted the code "1" in the NRZ, optical signal impulse occupies a whole bit-time; when there is no optical pulse, the signal is code"0".

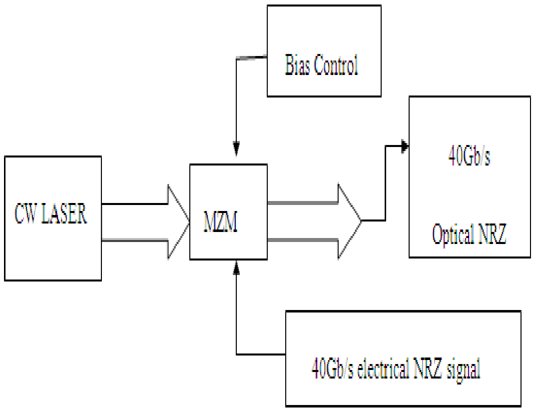


Fig- 1 Block diagram of non-return to zero modulation (NRZ)

Fig.2 represent about the principle of the generation of RZ and CS-RZ, which is composed of the two MZMs. The technology of RZ code is depicted which is used in the high speed 40 Gbps system. In the pulse sequence of RZ code, the transition area which connects "1" amplitude of has the independent time envelope. The benefit of RZ is the low average of optical power, higher ability on anti-non-linearity effect and anti polarization mode dispersion. The CSRZ code is based on the RZ code, and joins the phase separation of each adjacent sign bit.

The phase separation of the carrier can be regards as the signal with a minus but the carrier is invariable. In the CS-RZ, because the sign about successive code of amplitude of electric field is reversed, we can get the low width of spectrum. With the high power, it is not only increases the dispersive capacity, but also enhances the resistance of the non-linearity of self-phase modulation and four-wave-mixing and so on.

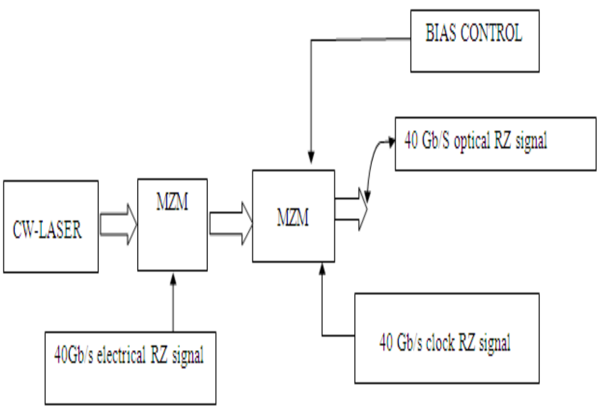
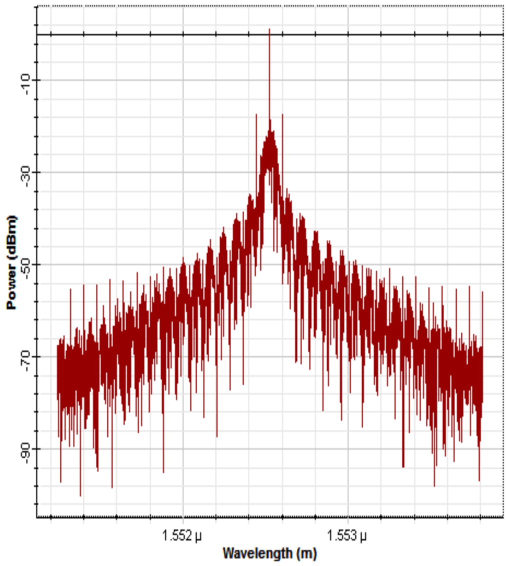


Fig- 2 Block Diagram of return to zero and compressed spectrum return to zero modulation



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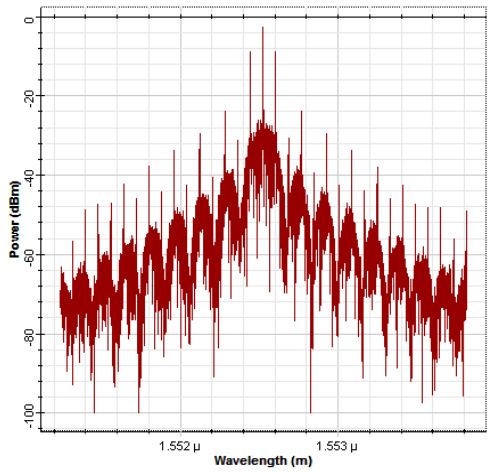

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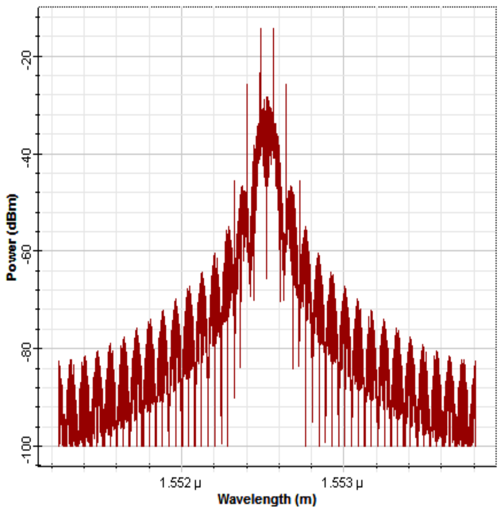


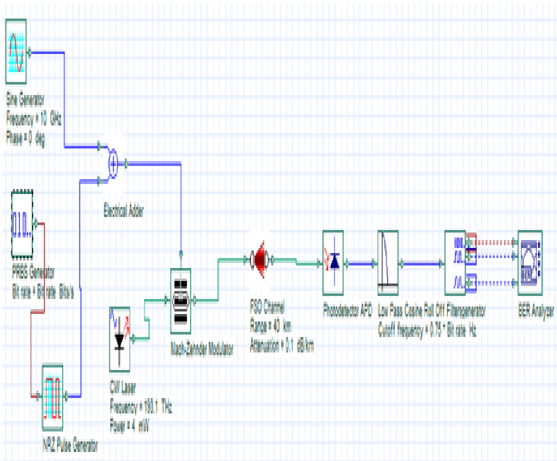
(c)

Fig- 3 Power Spectrum analyzers of (a) NRZ (b) RZ (c) CSRZ

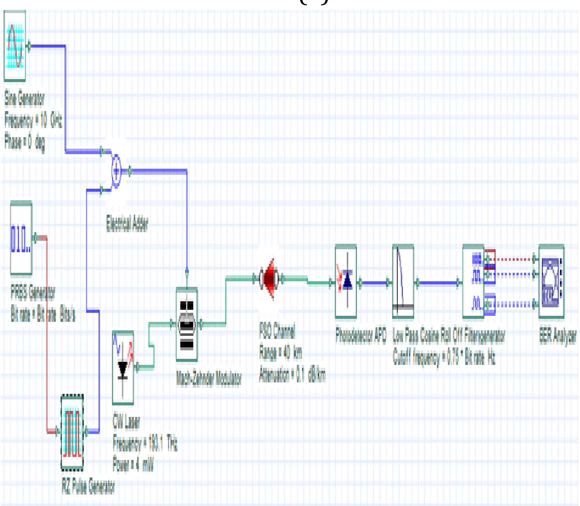
Table.1 System Parameters

Parameters	Values
Laser Frequency	193.1THz
Data Rate	10Gbps
RF signal	10GHz
FSO Attenuation	0.1dB/Km
Beam Divergence	0.1mrad

System Diagram for NRZ, RZ and CSRZ RO-FSO system has been shown in Fig. 3(a), Fig. 3(b) and Fig. 3(c). All the three system using different modulation formats has been studies at varied parameters like input power, aperture diameter in terms of Q-factor and BER.



(a)



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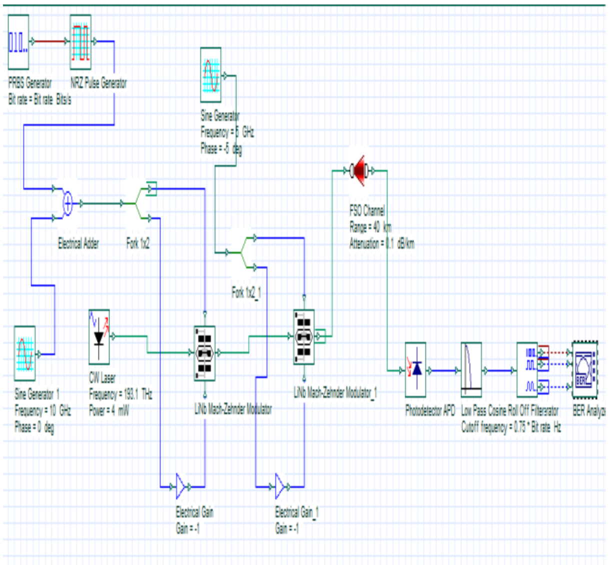


(c)

Fig- 4 System diagram of RO-FSO system (a) NRZ (b) RZ (c) CSRZ

3. RESULTS AND DISCUSSIONS

Performance analysis of all the three modulation parameters has been studied on different FSO link distance i.e. 1 Km, 10 Km, 20 Km, 30 Km and 40 Km as shown in Fig.5. It is prominently displayed in results that CSRZ performs better than RZ and NRZ at low distance and effects of degradation increase as distance increase. Table 2 represents the values of Q-factor and BER at different link distance.

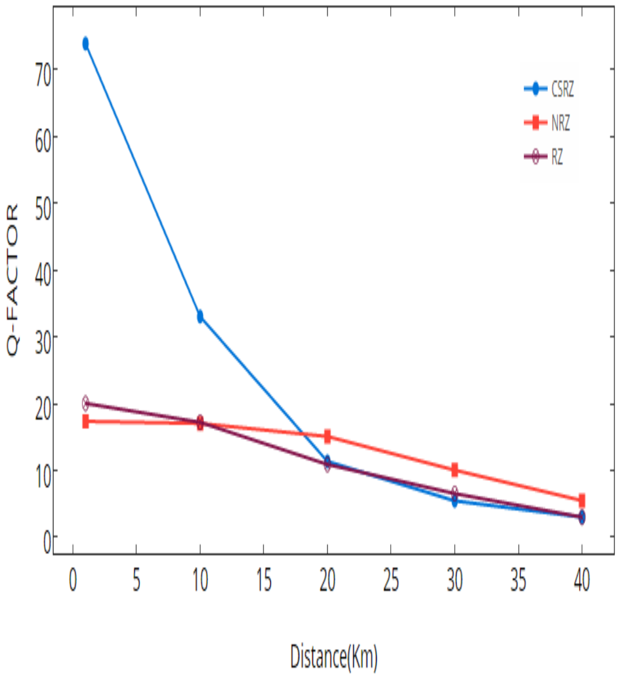


Fig- 5 Performance of different modulation formats at varied distance in terms of Q-factor

Table- 2 Values of Q-factor and BER at different FSO link distance

Distance	Q-factor			BER		
	CSRZ	NRZ	RZ	CSRZ	NRZ	RZ
1Km	73.91	17.34	20.03	0	9.94*10^-68	1.3*10^-89
10Km	33.04	17.03	17.20	9.50*10^-240	2.16*10^-65	1.14*10^-66
20Km	11.35	15.08	10.89	3.29*10^-30	9.53*10^-52	6.26*10^-28
30Km	5.44	10.04	6.53	2.6*10^-10	4.79*10^-24	3.41*10^-11
40Km	4	4.02	3	1.3*10^--4	2.04*10^-8	5.17*10^-5

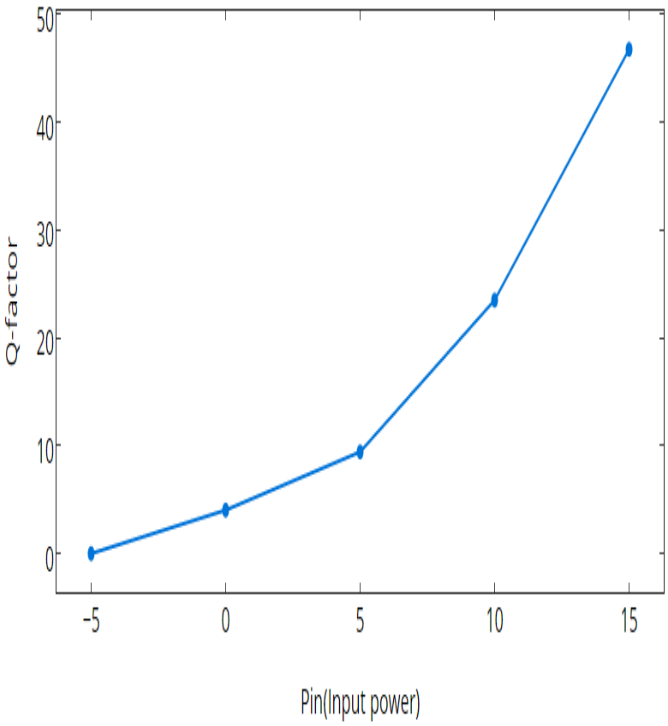


Fig- 6 Performance of CSRZ RO-FSO at varied input power in terms of Q-factor

Further CSRZ Ro-FSO system is analyzed at different input power e.g. -5 dBm, 0 dBm, 5 dBm,10 dBm and 10 dBm in terms of Q-factor. Fig 6 represents the performance of CSRZ at varied power. It has been concluded that the increase in power mitigates the effects of attenuation and provide better results. Distance of FSO link is kept constants at 20 Km. In FSO channel transmitter antenna as well as receiver antenna size play a vital role to transmit and receives signal efficiently.

Behavior of Ro-FSO system has been analyzed at different aperture antenna diameters on transmitter side and receiver side i.e.10 cm, 15 cm, 20 cm, 25 cm and 30 cm. It has been concluded that as aperture diameter of FSO channel increase-factor also increase and BER decrease.

Eye closer penalty at 30 cm diameter is less as compared to 20cm and 15 cm. Eye closer penalties is very high at 10 cm aperture dia. Fig.7. Shows the performance of CSRZ RO-FSO system at different aperture diameter on Rx and Tx side at 5 Km.

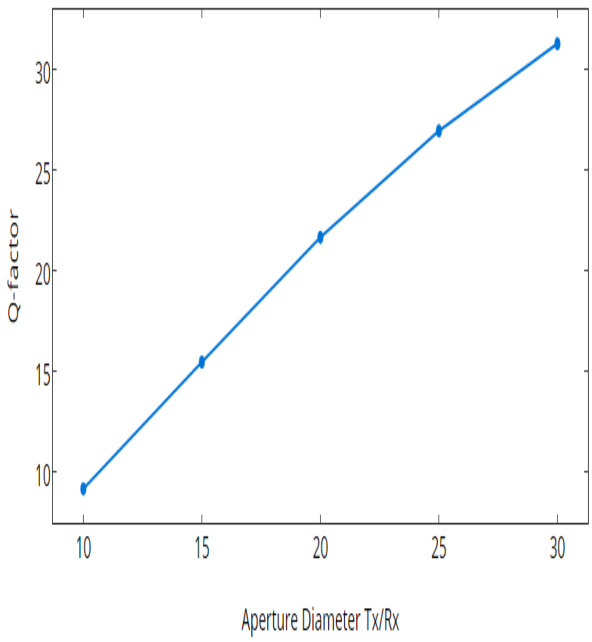
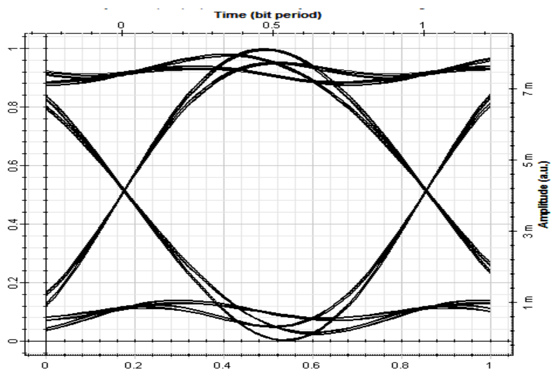
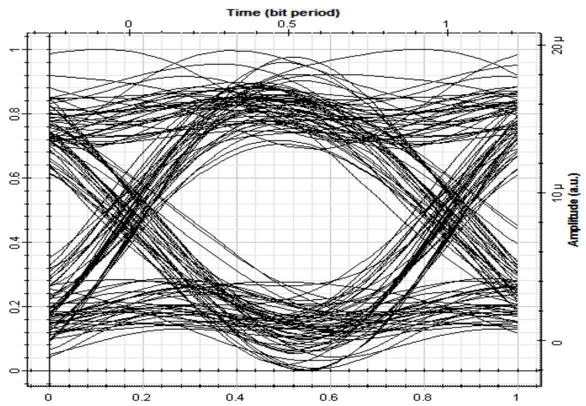


Fig- 7 Performance of CSRZ RO-FSO with varied Tx/Rx aperture diameter in terms of Q-factor

Evaluation of eye diagrams at 1Km and 40Km has been shown in Fig.8. It is clearly observed that at 1 Km eye diagram is better in terms of eye height with low eye closer penalty but at 40 Km system performance is below acceptable BER and eye height is minimum.



(a)



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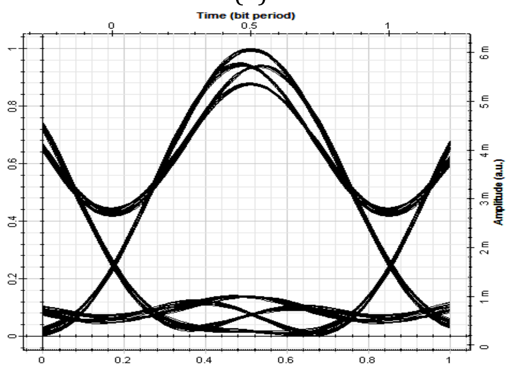

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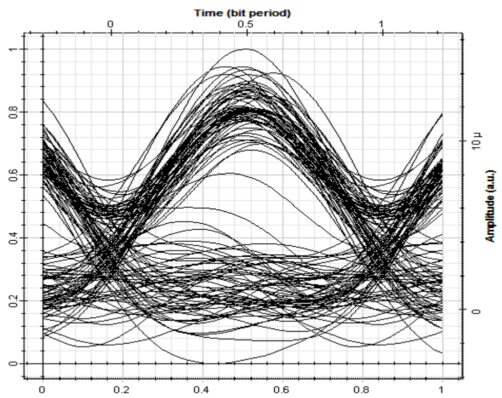

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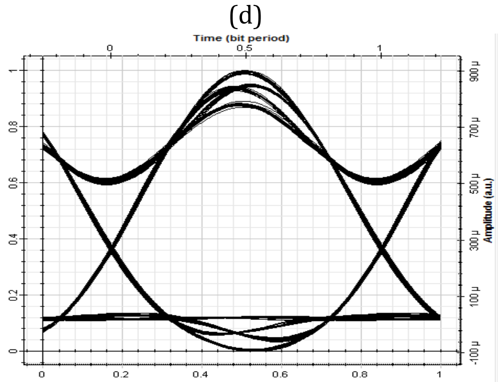

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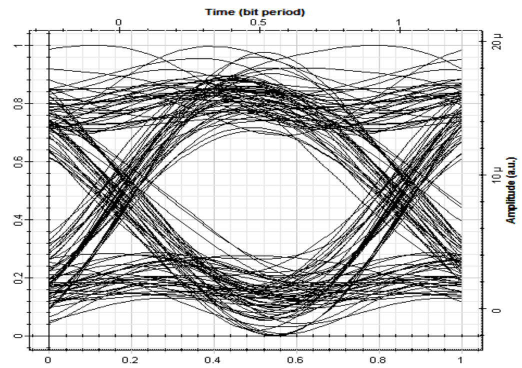

(f)

Fig- 8 Evaluation of Eye diagram at 1Km and 40Km for (a) (b) NRZ (c) (d) RZ (e) (f) CSRZ respectively

4. CONCLUSIONS

In this work, the RO-FSO system has been analyzed for different modulation formats. It is observed that CSRZ performs superior at lower powers to NRZ and RZ. Further CSRZ RO-FSO system has studied for varied power and aperture diameter. Power of system is varied from -5dBm to 15dBm to analyze the effects on Q-factor. It is reported that with the increase of power, system performance increase due to the mitigation the effects of power losses caused by attenuation of free space optical link. In further enhancement of CSRZ system transmitter and receiver aperture are taken into account and varied from 10 cm to 30 cm. With the increase in aperture diameter, system performance also increases. It is also observed that at 1 Km eye diagram is better in terms of eye height with low eye closer penalty but at 40 Km system performance is below acceptable BER and eye height is minimum.

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