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Simulative Performance Evaluation of a Free Space Optical Communication Link Operating at 1550 nm using Different Modulation Formats

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ABSTRACT

FSO enables to provide last mile transmission reach with some advantages such as inherent security and no electrical hazards without laying any fiber or cable. In this paper we have analyzed the performance of free space optics communication system by employing five transmitters (CSNRZ CSRZ DBNRZ MDBNRZ and MDBRZ) for different attenuation values at 10Gbps up to the transmission distance of 1100m. The effect of beam divergence, transmitter losses, receiver losses and receiver aperture diameter is also calculated on the performance of proposed hybrid modulation format based free space optical communication system.

Key words: FSO; CSNRZ; CSRZ; DBNRZ; MDBNRZ; MDBRZ;

I. INTRODUCTION

Free space optics is a wireless communication technology which utilizes light for transmission of data through the air in the similar manner as the fiber optics uses a fiber cable. Free space optics is having the same capabilities as that of fiber optics, but at a very lower cost and very fast deployment speed [1]. It has advantages high speed, low cost, high bandwidth, quick installation high security and also license-free longer range spectrum [2]. But in fiber case have problem that is dispersion, nonlinear impacts in a transmission line but not in the FSO channel [3-5-6] and FSO system is also severely limited by the four wav mixing effect [4]. Free space optics work on the principal of laser driven technology which use light source and detectors to transmit and receive information, through the atmosphere same as the Fiber Optic communication cable [2]. The motivation for FSO is to eliminate the cost, time, and effort of installing fiber optic cable, yet to retain the benefit of high data rates for transmission of voice, data, images and video. FSO communication can be used in building to building, ship to ship, aircraft to ground and satellite to ground. The stability quality of the link is highly dependent on atmospheric factors such as Fog, Rain, Haze and Heat [7]. FSO system consists of an optical transceiver at the both ends to provide full duplex capability. FSO communication is not a new technology. FSO is a LOS (Line of sight) technology, where data, video and voice communication is achieved with maximum 10Gbps of data rate by full duplex [8]. An effective FSO system should have the following characteristics [8]:

(a) FSO system should have the ability to operate at higher power levels for longer distance.
(b) For high speed FSO systems, high speed modulation is important.
(c) An overall system design should have small footprint and low power consumption.
(d) FSO should have the ability to operate over wide temperature range and the performance degradation would be less for outdoor system.
(e) Mean time between failures of system should be more than 10 years.

An effective FSO system usually has the following Merits [9]

(a) FSO is a flexible network that delivers better speed than Broadband.
(b) Installation is very easy and it takes less than 30mintues to install normal locations.
(c) It has very low initial investment.
(d) It is a secure system because of line of sight operations and so no security system up gradations is needed.
(e) There is relatively high bandwidth.

The advantages of an effective FSO system are linked below [9]:

(a) Physical obstructions: -flying birds, tree and tall building can temporary block a single beam, when it appears in the LOS of transmission of FSO system.
(b) Geometric losses: - Geometric losses which can be called optical beam attenuation are induced due to the spreading of beam.
(c) Atmospheric turbulence: - It is caused by weather and environment structure.
(d) Atmospheric Attenuation: - It is the result of Fog and haze normally.
(e) Scattering: - Scattering phenomena happen when the optical beam and scatter collide.

In the section 2, literature survey is discussed. In the section 3, different modulation formats along with their optical spectrum are described. In section 4, explains simulation setup and parameters. In section 5, results have been reported for various formats. In section 6 conclusions are made.

II. LITERATURE SURVEY

Ajay K. Sharma et al. (2009) studied robustness of various modulation formats at 40Gbps. The performance is categorized using Q-factor. They investigated non linearity and noise show robustness up to 450 km at 40Gbos. At high rate, CRZ show better results than NRZ, RZ and CSRZ [10].

Jagjit Singh Malhotra et al., (2010) investigate the Performance analysis of NRZ, RZ, CRZ and CSRZ data formats in 10Gbps. In this paper investigate the performance of NRZ, RZ, CRZ and CSRZ data formats analyzed on the basis of bit error rate (BER), Q2 (dB), OSNR, eye opening performance metrics. The results show that CRZ and CSRZ modulation format is perform better as compared to NRZ and RZ. The CSRZ has optimal performance according to performance metrics [11].

Malti et al. (2012) studied advance modulation format at different bit rates and observed that MDBRZ show better performance as compared to DBRZ and CSRZ at high bit rates but at 2.5Gbps CSRZ is better than DBRZ and MDBRZ [12].

Jitendra Singh et al., (2013) investigate different modulation format based on the performance analysis of free space optical communication system. In the FSO network some factor play important role i.e. bit error rate (BER), Q factor, forward error correction (FEC), attenuation, absorption, Scattering and scintillation. In this paper investigate the impact of different direct and external modulation formats i.e. RZ, CRZ, CSRZ and NRZ on free space optical communication system. The external modulation has better performance as compare to direct modulation because direct NRZ spectrum has a strong carrier component compared to external modulated NRZ. The simulation results prove 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 [13].

Jun He et al., (2014) discussed the survey on recent advances in optical communications. The FSO is used in various applications. In this paper investigate the overview of recent research in optical communications and focus on the topics of modulation, switching, add-drop multiplexer, coding schemes, detection schemes, orthogonal frequency-division multiplexing, system analysis, cross-layer design, control and management, free space optics, and optics in data center network. The author aim is provide the knowledge about the advances in optical communications. Hence from this survey conclude that optical communication plays important role in telecommunication and data center communications [14].

Mazin Ali et al. (2014) analyzed data rate for FSO system and showed that the data rate decreases with increasing divergence angle and link distance [15].

Ajay K. Sharma et al. (2009) studied robustness of various modulation formats at 40Gbps. At high rate, CRZ show better results than NRZ, RZ and CSRZ. Jagjit Singh Malhotra et al., (2010) investigate the Performance analysis of NRZ, RZ, CRZ and CSRZ data formats in 10Gbps. The results show that CRZ and CSRZ modulation format is perform better as compared to NRZ and RZ. The CSRZ has optimal performance according to performance metrics. Malti et al. (2012) studied advance modulation format at different bit rates and observed that MDBRZ show better performance as compared to DBRZ and CSRZ at high bit rates but at 2.5Gbps CSRZ is better than DBRZ and MDBRZ. Jitendra Singh et al., (2013) investigate different modulation format based on the performance analysis of free space optical communication system. The simulation results prove 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. Jun He et al., (2014) discussed the survey on recent advances in optical communications. The FSO is used in various applications. Hence from this survey conclude that optical communication plays important role in telecommunication and data center communications. Mazin Ali et al. (2014) analyzed data rate for FSO system and showed that the data rate decreases with increasing divergence angle and link distance. It has been observed from the study of available literature that most of researchers have contributed towards enhancement of fiber optic communication links by different modulation formats, whereas none of the precision researchers have investigated the performance of free space optical communication link by employing different modulation formats.

III. DIFFERENT MODULATION FORMATS

1) **Carrier Suppressed Non return to Zero (CSNRZ) Format: -** CSNRZ format has narrower pedestal shape of the optical spectrum than the conventional RZ format. Fig-(1a) shows the schematic diagram of CSNRZ transmitter. In it the NRZ signal after MZ modulator goes through the phase modulator driven by analog sine wave generator at the frequency equal to half the

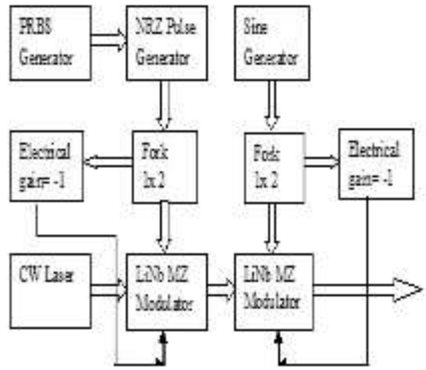
bit rate. That will introduce zero phase-shift between the two adjacent bits and the spectrum will be modified such that the central peak at the carrier frequency is suppressed as shown in the Fig-(1b).

2) **Carrier Suppressed Return to Zero (CSRZ) Format: -** Fig-(2a) shows the schematic diagram of CSRZ transmitter. In it the RZ signal after MZ modulator goes through the phase modulator driven by analog sine wave generator at the frequency equal to half the bit rate. That will introduce zero phase shift between the two adjacent bits and the spectrum will be modified such that the central peak at the carrier frequency is suppressed as shown in the Fig-(2b) [16].

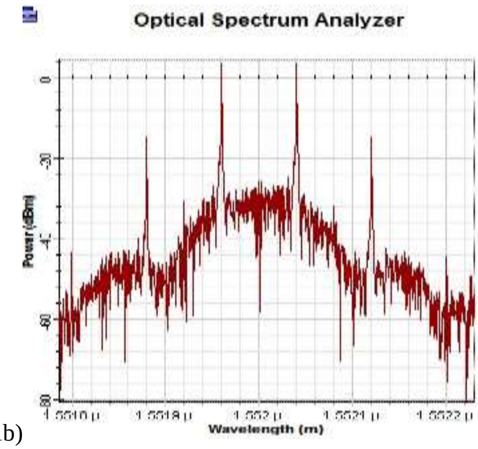
3) **Duo Binary Non-return to Zero (DBNRZ) Format: -** Fig-(3a) shows the diagram of DBNRZ transmitter. The Duo binary was generated by first creating NRZ duo binary signal using a duo binary precoder, NRZ generator and a duo binary pulse generator. The generator drives the first MZM and then the cascades this modulator with a second modulator that is driven by a sinusoidal electrical signal with the frequency on bit rate and phase= -90. The duo binary precoder used here is composed of an exclusive-or gate with a delayed feedback path and frequency spectrum shown in Fig-(3b) [15].

4) **Modified Duo-Binary Non return to Zero (MDBNRZ) Format: -** Fig-(4a) show the schematic diagram of MDBNRZ transmitter are called carrier suppressed duo binary format. MDBNRZ was generated by first creating an NRZ duo binary signal using a delay and subtract circuit that drives the first MZM and then concentrating this modulator with a second modulator that driven by a sinusoidal electrical signal with the frequency equal to the bit rate and phase equal to -90. The generation of MDBNRZ signal is same as the DBNRZ signal except the delay-and-add circuit is replaced by a delay-and-subtract circuit. In the duo binary signal used earlier where the phase of bits ‘1’ are modified only after a bit ‘0’ appear where as in the modified duo binary signal the phase is alternated 0 and 180 for the bits ‘1’. Also optical signal spectrum shown in Fig-(4b) that carrier of the duo binary signal has been-suppressed.

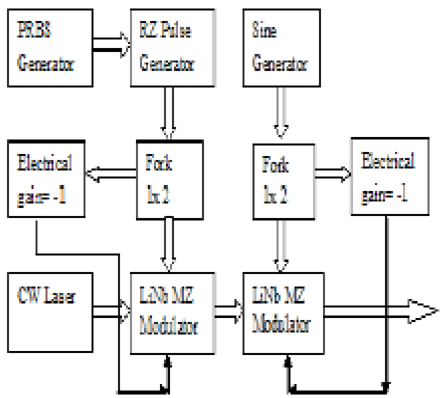
5) **Modified Duo-Binary Return-to-Zero (MDBRZ) Format:-**Fig-(5a) show the schematic diagram of MDBRZ transmitter format. MDBRZ was generated by first creating an RZ duo binary signal using a delay and subtract circuit that drives the first MZM and then concentrating this modulator with a second modulator that driven by a sinusoidal electrical signal with the frequency equal to the bit rate and phase equal to -90. The generation of MDBRZ signal is same as the DBNRZ signal except the delay-and-add circuit is replaced by a delay-and-subtract circuit. In the duo binary signal used earlier where the phase of bits ‘1’ are modified only after a bit ‘0’ appear where as in the modified duo binary signal the phase is alternated 0 and 180 for the bits ‘1’ frequency spectrum shown in Fig-(5b) [16].



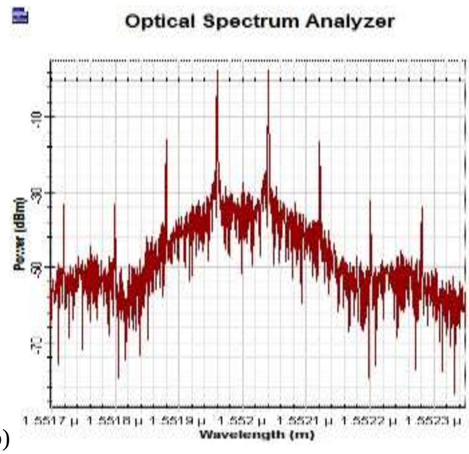
1a)



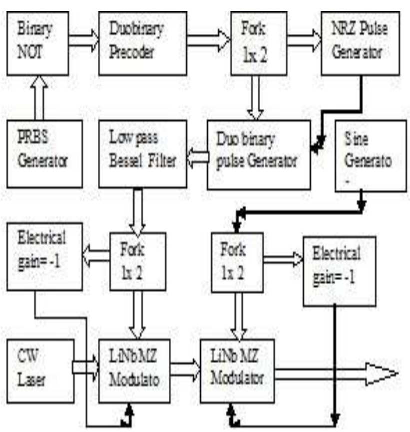
1b)



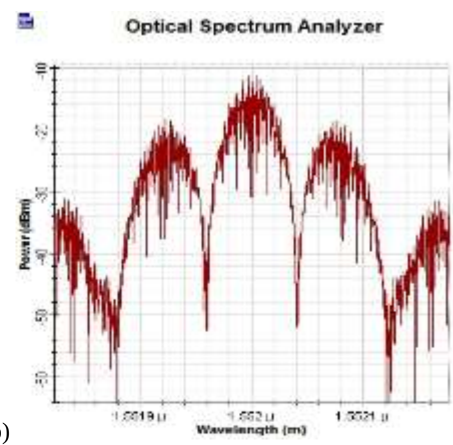
2a)



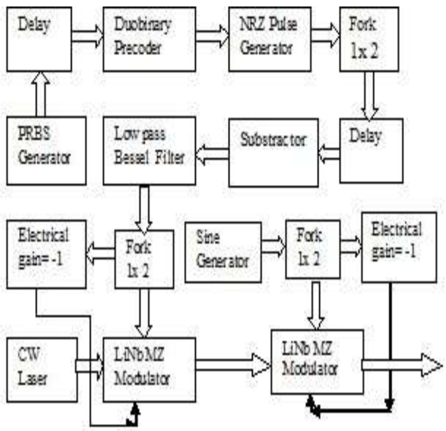
2b)



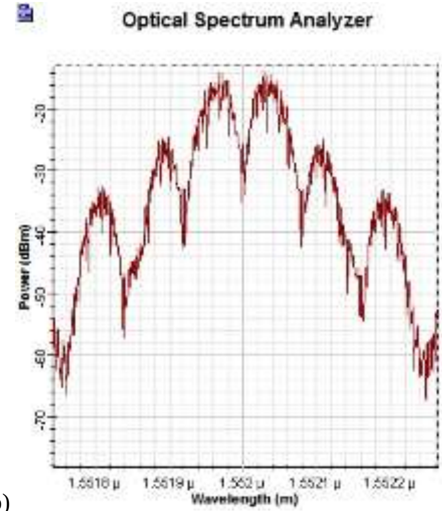
3a)



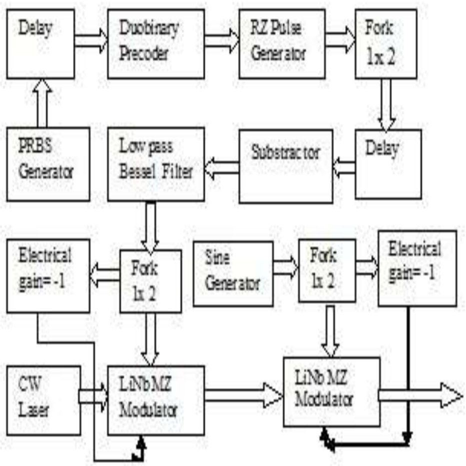
3b)



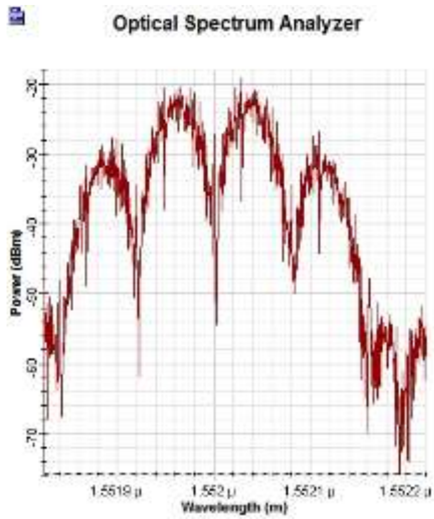
4a)



4b)



5a)



5b)

Fig.1. (1a) schematic of CSNRZ transmitter, (1b) frequency spectrum of CSNRZ transmitter, (2a) schematic of CSRZ transmitter, (2b) frequency spectrum of CSRZ transmitter, (3a) schematic of DBNRZ transmitter, (3b) frequency spectrum of DBNRZ transmitter, (4a) schematic of MDBNRZ transmitter, (4b) frequency spectrum of MDBNRZ transmitter, (5a) schematic of MDBRZ transmitter, (5b) frequency spectrum MDBRZ transmitter.

IV. SIMULATION SETUP

Fig-2 shows a schematic setup of a single channel optical free space communication system operating at 10Gbps with the central frequency 1552nm.

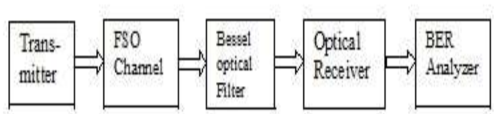


Fig-2-Block-Diagram-of-Fso

The simulation parameters used in the system model are given in Table 1.

Table-1 Simulation parameters of FSO

Parameter	**value**
Bit rate	10Gbps
Sequence length	128
Samples/bit	64
Central Frequency of channel	1552nm
Range	1100m

The simulation setup is composed of transmitter, free space optical channel and receiver. The transmitter consists of a CW laser, data modulator as shown in Fig-1 and to each output port of the CW laser a data modulator has been connected. The optical Transmitter consists of three subsystems. The first subsystem is the Pseudo-Random Binary Sequence generator. This subsystem is representing the information or data that want to be transmitted. The output from a PRBS generator is a bit stream of a binary pulse; a sequence of “1”s (ON) or “0”s (OFF), of a known and reproducible pattern. The second subsystem is very different modulation format (CSNRZ CSRZ DBNRZ MDBNRZ MDBRZ) electrical pulse generator as discussed in section3. The third subsystem in the optical transmitter is the direct modulation lasers. Laser operating wavelengths around 1550nm were developed specially for fiber optic communication because of low attenuation characteristics on this range. The free space between transmitter and receiver is considered as FSO channel which is propagation medium for transmitted light. 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.

V. RESULTS AND DISCUSSION

The five different modulation formats have been numerically compared for 10Gbps FSO system in terms of received maximum Q value. To analyze the system, the result of the channel has been taken. As shown in Fig-3 here in this simulation, we are varying the power from 11dbm to 20dbm at the transmitter side and Attenuation is 20dB/km and Beam divergence is 0.5mrad.With increase in the power at transmitter side, it has been observed that DBNRZ system response good as compared to other system. Also MDBNRZ have shown less-variations as we have increased the power. DBNRZ system is better response than CSNRZ, CSRZ, MDBRZ and MDBNRZ systems.

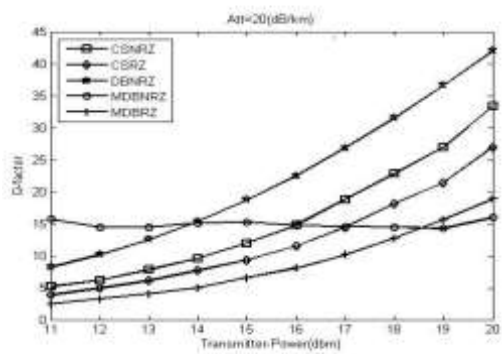


Fig-3 Plot between Q-Factor and Power

Further in order to validate the precision result that performance of DBNRZ is better, further investigation have been carried out for different value of the Beam divergence. The power is also set to 20dbm and attenuation is 20dB/km and beam-divergence varying form 0.1mrad to 1mrad; the performance of the five systems degrades as shown in the Fig-4. The performance of the DBNRZ system is better than the other systems. For beam divergence=1mrad, DBNRZ system have Q factor is up to 16.47, whereas MDBRZ system have Q factor= 5.59 and CSNRZ system have Q factor = 10.46

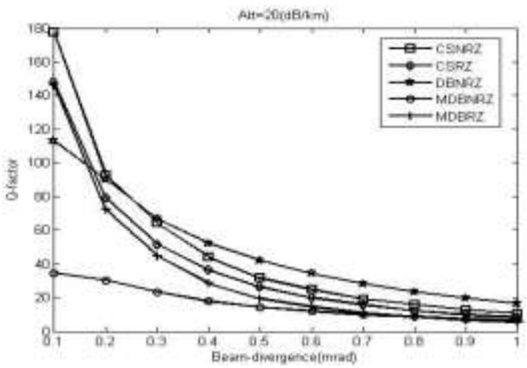


Fig-4 Plot between Q-factor and Beam divergence

For evaluating the performance, we have analyzed five transmitters for free space optics communication by using the different attenuation values.

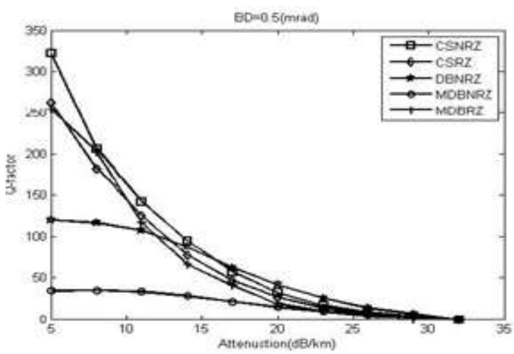


Fig-5 Plot between Q-Factor and Attenuation

Here we have taken attenuation values from 0 to 35dB/km and Beam-divergence is set to 0.5mrad. As the attenuation increases, the Q factor decreases for all system except MDBRZ system because there is very less variation. The overall performance for different values of attenuation is better in all case except MDBRZ system. In the CSNRZ system gives high Q factor value for low value of attenuation, but falls as attenuation increase as shown in the Fig-5.

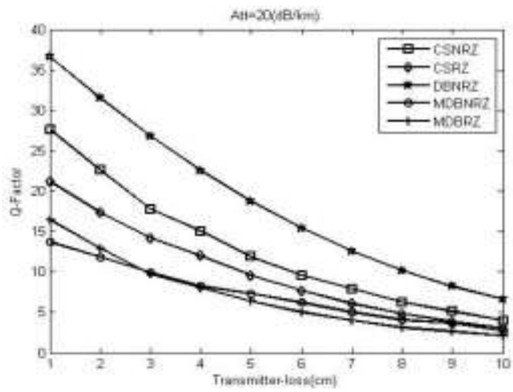


Fig-6 Plot between Q-Factor and Transmitter Loss

We have analyzed the five systems for the transmitter losses and the receiver losses as shown in Fig-6 and Fig-7.

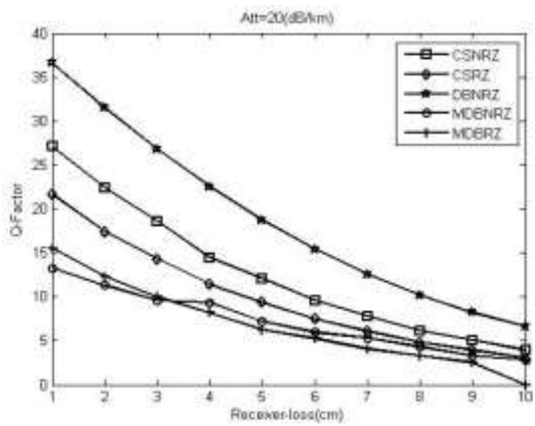


Fig-7 Plot between Q-Factor and Receiver Loss

From the results it is observed that the performance degrades for the increase in both transmitter and receiver losses. In the both case DBNRZ high Q factor, so DBNRZ system better performance as compare to the system.

We have also analyzed the system performance using receiver aperture diameter as shown in Fig-8. As we increase the receiver aperture diameter (from 25cm to 115cm and Beam-divergence is 0.5mrad) the Q factor value increases.

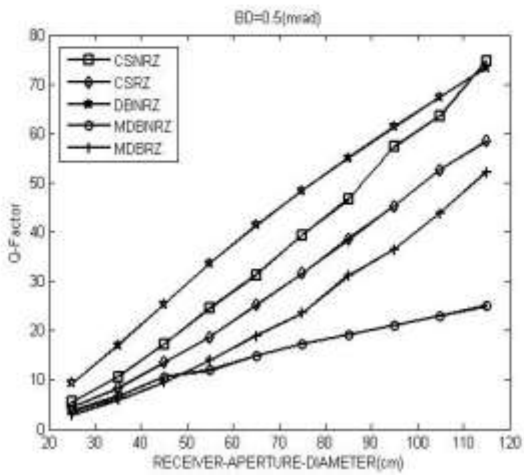


Fig-8 Plot between Q-Factor and RAD

This increased in Q factor value for DBNRZ system more than the other system. All system has almost similar response except MDBNRZ system because this system has very less variation in the Q-factor as compared to other system.

V. CONCLUSION

In this paper, we have studied the performance of five transmitters DBNRZ, CSNRZ, CSRZ, MDBNRZ and MDRZ for the free space optical communication by evaluating the performance using various parameters such as attenuation, Beam-divergence, Receiver aperture diameter, Transmitter Losses and Receiver Losses. From the simulation results, it is concluded that the DBNRZ transmitter gives the better performance for all the parameters except attenuation where CSNRZ has better results. Also it is analyzed that the performance of each transmitter degrades with the increase in Beam-divergence, Transmitter Losses and Receiver Losses as the Q factor also decreases. Finally it is concluded that the overall performance of the DBNRZ system is better than CSNRZ, CSRZ, MDBNRZ and MDBRZ transmitters.

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