Optimizing Different Parameters of Inter-Satellite Optical Wireless Communication (Is-OWC) System by Incorporating Mach Zehnder Interferometer (MZI) with Duobinary Modulation Technique

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Abstract - *High speed data transmission for long distance is the main motive of today's as well as for next generation communication system. Inter-satellite communication provides the superior result with Optical Wireless Communication (OWC) technology. Duobinary encoding technique provides the highly efficient result for long distance communication with data security. In this paper, we designed a system to communicate two or more satellites using Duobinary modulation technique with Mach Zehnder Interferometer (MZI). The performance of system is analyzed by OPTISYSTEM 7.0 software for bit rate up to 100 Gbps for 8000-kilometer distance with transmitting power of 20 dBm and result shown in the form of BER, Q-factor and eye diagram obtained.*

Keyword: *Is-OWC, ISL, duobinary encoding technique, Q-factor, BER*

1. INTRODUCTION

High data rates with large coverage area is achieved by optical wireless communication (OWC) system. In 1945, Arthur C. Clarke was first author who gave the idea of satellites. In March 2003, Artemis and SPOT4 was the first Inter-satellite communication using optical link [1]. For global coverage link established between satellites to reduce recurrence. NRZ, AMI, Duobinary are the modulation technique. In 1990s, duobinary encoding technique was applied with optical signal. There are many benefits to use duobinary encoding technique like high spectral efficiency with improving channel capacity utilization. As we, analyzed in previous paper, duobinary encoding technique provides the superior result with diversity technique at high pointing error. Thus, duobinary encoding technique is also used for long haul communication. Radio frequency (RF) waves used as conventional technique for communication purpose which having some limiting issues like interference, fixed bandwidth, license requirement and so on. Thus, for high speed data transmission between different satellites which revolve either in the same orbit or in different orbits OWC provides the superior result. To improve the Is-OWC system performance with global coverage different types of techniques have been studied and analyzed by researchers. To reduce the degrading issues beacon signal which is transmitted from transmitter and receiver antenna for getting the proper position of transmitter and receiver satellites. Thus, optical beacon signal is one of the important factors to reduce the limiting factor and for getting the proper line of sight (LOS) [2]. Similarly, spatial channel-based diversity technique also provides the excellent result at 100 Gbps for 10000 km distance at large pointing error up to 3 μrad with duobinary encoding technique [3]. While, space and polarization-based diversity provide result at 6000 km for transmitting 7.63 data rate [4]. So, channel diversity technique is also used for transmitting high speed data at large distance to mitigate the degrading issues [5]. Polarization interleaving (PI) with AMI and NRZ modulation technique also effective technique for transmitting large data [6]. In this paper, we analyzed the performance of duobinary encoding technique with Mach Zehnder Interferometer (MZI) at different parameters of system. Duobinary encoding technique is the method for high speed data transmission at large distance. It provides effective and efficient signal in compare to NRZ encoding technique [7]. Similarly, Mach Zehnder Interferometric devices like switching, multiplexing, modulators, or as optical filters used in different applications purposes [8]. In this, MZI filter transmits the high-speed information by removing unwanted optical domain signal and enhance the performance of system. MZI optical filter defined their frequency response in terms of magnitude and phase of incoming signal which is modified by filter [9].

This paper further defined the section as follows: section II defined the proposed system, section III discussed the result at different parameters by using proposed model and section IV conclude the paper.

2. SYSTEM DESCRIPTION

In proposed model fig.1 which is based on duobinary encoding technique by integrating Mach Zehnder Interferometer (MZI) in OPTISYSTEM 7.0 software. In Is-OWC system designing, up to 100 Gbps data is transmitted with 1550 nm wavelength at 20 dBm power level. In fig.1 designing is free from component complexity and based on single channel of OWC at large distance up to 8000 kilometer and 1.1 μrad pointing error.

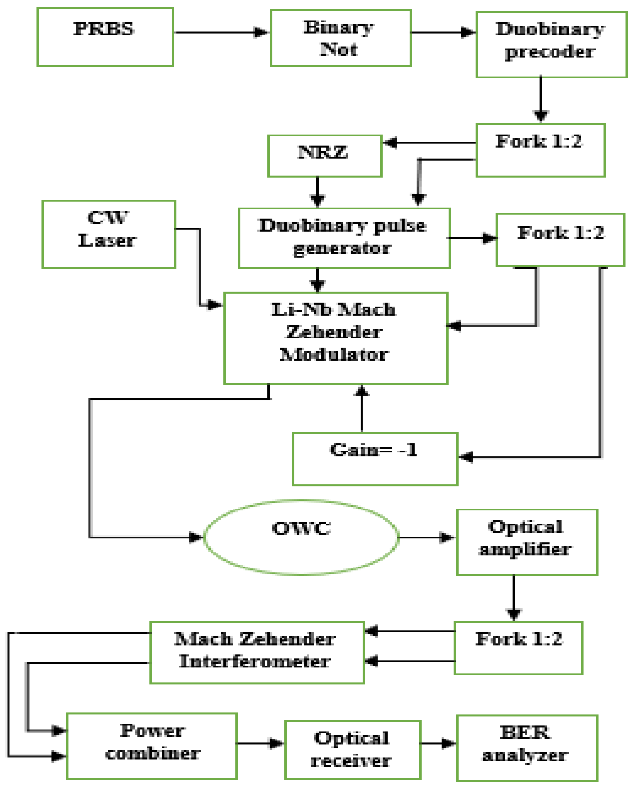

Fig. 1 Duobinary encoding technique by incorporating MZI in Is-OWC system

100 Gbps of message signal is transmitted to duobinary precoder which provide the error free data by using pseudo random bit sequence (PRBS). The binary signal is converted into electrical domain pulse with the help of NRZ based duobinary pulse generator which generates the duobinary electrical pulse. Optical signal of 1550 nm laser light with 20 dBm power level is transmitted as optical carrier which is modulated by LiNb Mach Zehnder modulator. Optical Wireless Channel (OWC) with transmitting and receiving antenna of aperture size 25 cm, pointing error of 1.5 μrad. The output of OWC is based on optical domain which having some irregular and unwanted signal which can be remove by Mach Zehnder Interferometer (MZI) with coupling coefficient of 0.5 and couples the optical signal to transmits at receiver side. At receiver side, APD photo detector converts optical signal into electrical signal and further electrical domain unwanted signal removed by Low Pass Bessel Filter (LPBF). Output of the system is analyzed using BER analyzer by eye diagram and Q-factor value.

The received power at receiver satellite of an Is-OWC system is defined by Friis transmission equation [10]:

$$P_r = P_t \eta_t \eta_r G_t G_r L_t L_r (\lambda / 4\pi Z)^2$$

Where,

P_r = received power of the system

P_t = transmitted power of the system

G_t = telescope gain of the transmitter

G_r = telescope gain of the receiver

L_t =pointing loss factor of the transmitter

Laser transmits 1550 nm optical beam with narrow divergence for long haul communication with Z distance between transmitter and receiver satellite. The parameters used in system designing are given in table 1

Table -1: parameters of proposed system

Parameters	Value
Modulation type	Duobinary NRZ
Bit rate	40-120 Gbps
Transmitted power	15-25 dBm
Tx. / Rx. Efficiency	0.8
Tx. / Rx. Antenna aperture size	20-30 cm
Tx. /Rx. Pointing error	0.75-1.5 μrad
Distance range	10000 kilometer
Laser light wavelength	1550 nm
Sequence length	128 bits
Laser linewidth	0.1 MHz
Number of samples	8192

3. RESULT AND DISCUSSION

In recent researches various parameters have defined which affects the Is-OWC system. In this paper, we show the result by plotting graph between Q- factor and distance range at different parameters. Pointing error is one of the disadvantages of inter satellite link which occur due to misalignment of signal when transmitting from one satellite to another. Duobinary is one of the modulation techniques which provides the result up to 3 μrad using diversity technique [2].

3.1 Effect of antenna aperture

LiNb Mach Zehnder modulator modulates the optical carrier signal with duobinary pulse for transmitting the message signal at transmitter antenna. Transmitter and receiver antenna aperture size is important parameter to define the system performance. As we increase the aperture size of antenna, quality of signal is also improving. Due to optical beam strike without any loss as the size of antenna aperture increases. In fig.2 aperture size with 30cm provides the best result at 100 Gbps data rate, 20 dBm power level at 1.1 μrad pointing error.

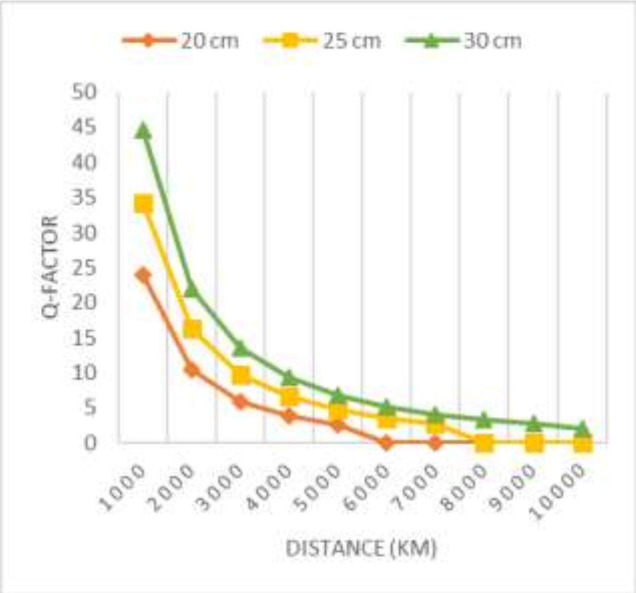

Fig.2 Q-factor v/s distance range at different aperture size with 100 Gbps data rate at 20 dBm power level

3.2 Effect of power level

As we increase the transmitted power of optical source the cost of the system is also increases. Thus, modern communication system needs such a technique which can work at low power by transmitting high speed data and distance range.

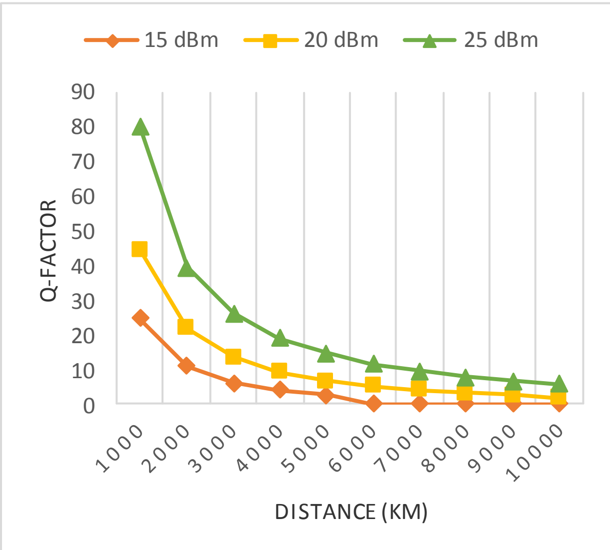

Fig.3 Q-factor v/s distance range at different power level with 100 Gbps data rate at 30 cm transmitter and receiver antenna size

3.3 Effect of data rate

Today's communication system needs high speed data transmission with large coverage. As the distance between transmitter and receiver satellite increases quality of signal degrading for large data transmission. From the fig. 1 designing we observed that Q-factor for low bit rate is high while for high bit rate up to 100 Gbps bit error rate (BER) is also increases. In fig. 4 we observed the system performance at different bit rate data for 1.1 μrad pointing error at 20 dBm.

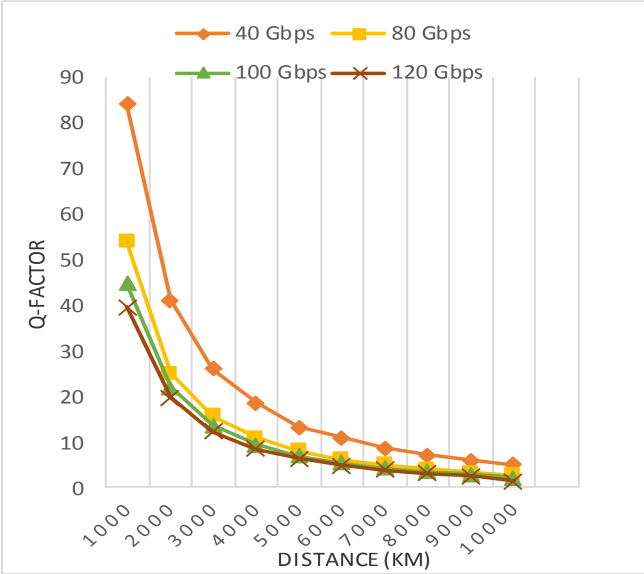

Fig.4 Q-factor v/s distance range at different data rate with 20dBm power level at 1.1 μrad transmitter and receiver pointing error

3.4 Effect of pointing error

Pointing error increases when beacon signal not observed accurately by transmitter and receiver satellites. It causes misalignment of signal due to large divergence angle of transmitted laser beam. Thus, system required proper line of sight (LOS) with accurate tracking. The proposed designing fig.1 observed the system up to 1.5 μrad pointing error by transmitting 100 Gbps data rate, 20 dBm power level at 30 cm transmitter and receiver antenna aperture size. In fig. 5 performance of system analyzed at different pointing error.

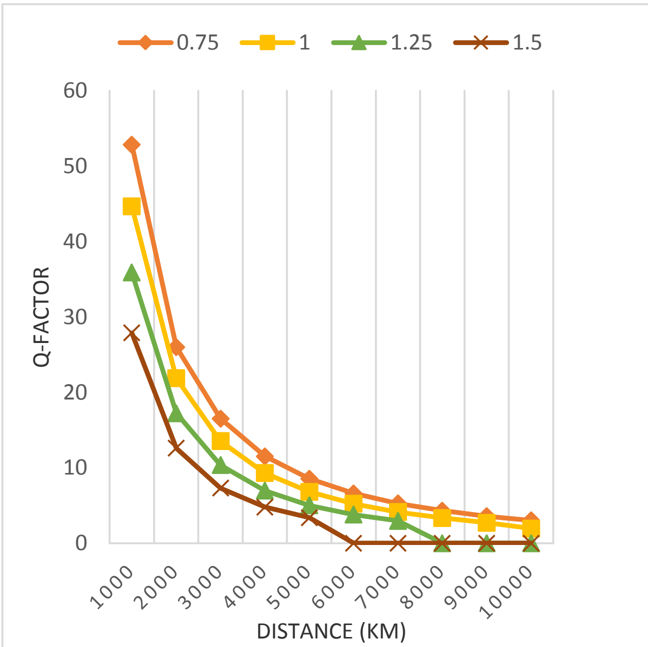

Fig.5 Q-factor v/s distance range at different pointing error with 20dBm power level at 100 Gbps data rates

4. CONCLUSION

In this paper, we analyzed and optimized the different parameters of Is-OWC system by using duobinary encoding technique with Mach Zehnder Interferometer (MZI). As we already prove that duobinary encoding technique provides the best result for high data transmission. The performance of system evaluated the best result for large distance up to 10000 km. MZI is also having an important role in this paper. MZI improves the system performance in comparison simple duobinary encoding technique. Thus, this proposed model defines the different parameters to give the superior result for high speed transmission of data with large coverage area.

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