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INTER SATELLITE OPTICAL WIRELESS COMMUNICATION SYSTEM DESIGN USING WDM

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Abstract - Integration of WDM in optical wireless communication has undoubtedly enhanced performance of the satellite communication system for use in the coming future. The unique performance of OWC system like long distance communication with high data rate makes it more popular now a days. In this paper, we designed a high speed data communication system for inter satellite O.W.C. by using 8-channel WDM, which uses amplifier and loop control method. The system has a link distance of 6000 km with no. of loops 3 and by simulation we analyze achievable bit rate 10 Gbps. The system performance is based on Q factor, eye opening and BER.

Keywords - Inter satellite optical wireless communication system, BER, Q Factor, WDM, EDFA, line of sight (LOS).

I. INTRODUCTION

The increasing demand in cellular and wireless devices has caused network congestion. Hence in RF spectrum there is no room exists for the further development of application and services. Optical wireless communication is invented to overcome the limitation of existing RF technology. The advantages of next generations of lightwave systems over RF technology are such as, high data rate capability so it can support large number of user capacity with minimum power consumption and it minimize the size of antenna hence reducing the weight of satellite [1]-[2]. Optical wireless communication uses optoelectronic components for exchanging signals between transmitter and receiver. The main purpose of OWC is to achieve intersatellite link between the satellites situated in different orbit or in same orbit to the earth station to establish the communication between different places of the earth. Thus the intersatellite linking plays an important role in global communication [3]. OWC uses unlicensed spectrum in the range of 750-1550 nm. This is lead to be an important factor for realizing a high speed, high security, low cost format and large bandwidth space communication [4]. The IS-OWC system uses the operating wavelength of 1550 nm because of human eye safety and according to Raleigh scattering phenomenon at this wavelength we have maximum transmission with minimum loss.

The advantages of using narrow beam for inter satellite link also introduces some disadvantages such as small misalignment or beam divergence can cause large pointing, acquisition and tracking (PAT) error. Pointing error is caused due to satellite vibration while orbiting and typical value is 1 µrad [5]. A pointing error can cause signal loss which must be removed to get better error free system performance. System performance depends on several other parameters like as distance between the both ends of the link, transmitted laser power, and transceiver antenna aperture. For a highly accurate tracking system two types of technique is used one is quadrant detector and another one is servo motor which lock the beacon signal of the satellite in a close loop. These techniques also provide proper coordination and proper line of sight (LOS) between the linked satellites [6]-[8].

However in wireless communication highly directional laser beam is use for security but it also causes difficult interception of laser beam. Even if a section of beam is intercepted, significant power dissipation occurs at receiver. For removing the problem of power dissipation and achieving highest power level at the receiver side amplifier is used. Hashim et. al. proposed a system for a link distance of 5000 Km with a data rate of 1 Mbps and verified that NRZ modulation is best for Is-OWC system [13]. Aggarwall et. al. designed a system which uses multiple transmitter and multiple receivers between two FSO linked satellites and achieve data rate 5.6 Gbps at link distance of 5000 Km with operation wavelength of 1550 nm [14]. Prabhdeep kaur et. al. designed a WDM based OWC system for a link distance of 5000 km with achievable bit rate 10 Gbps and also show the comparative analysis of NRZ and RZ modulation techniques [15]. Guddan kumari et. al. proposed WDM based Is-OWC system with EDFA amplifier to achieve data rate of 80 Gbps for the coverage distance of 5000 km [16].

Considering these works, we designed a 8-channel WDM based Is-OWC system with optical amplification using EDFA and loop control methodology, system operating at 1550 nm wavelength. This design offers dedicated high bandwidth and increased transmission speed to every user. The performance of the designed system is analyzed on the basis of Q factor and BER, which is should not be less than to 6.8 and 10^{-9} respectively.

This paper has arranged in different sections: section II discusses the inter satellite optical wireless communication system design consideration; section III gives the system design , section IV discusses the result discussion.

II. INTER-SATELLITE OPTICAL WIRELESS COMMUNICATION SYSTEM DESIGN CONSIDERATION

The Is-OWC system performance depends on the appropriate selection of component parameters used at the both ends of the link. The power received at the receiver can be explained by friis transmission equation [11].

$$PR = PT\ GT\ GR\ \eta T\ \eta R\ LT\ LR\ (\lambda/4\pi R)^2 \quad (1)$$

Where:
PT = Power of transmitting antenna,
PR = Power of receiving antenna,
GT = Gain of transmitting antenna,
GR =Gain of receiving antenna,
ηT = Efficiency of transmitting antenna,
ηR = Efficiency of receiving antenna,
λ = Operating wavelength
R= Distance between the two ends of the link

Here the gain of transmitter antenna can be expressed as [16]

$$GT = (\pi\ DT / \lambda)^2 \quad (2)$$

And the gain of receiver antenna can be expressed as,

$$GR = (\pi\ DR / \lambda)^2 \quad (3)$$

Here the LT transmitting pointing loss factor can be expressed as

$$LT = \exp(-\ GT\Theta T^2) \quad (4)$$

And the receiver pointing loss factor can be expressed as [16]

$$LR = \exp(-\ GR\Theta R^2) \quad (5)$$

Where ϴT and ϴR are transmitter and receiver pointing losses respectively.

While choosing system parameters equations (1) to (5) are taken into consideration. By carefully choosing these parameters laser transmitter can send sufficient signal which reaches at photo detector receiver with negligible error [9].

III. SYSTEM DESIGN

Figure 1 shows the block diagram of designed system using various components. A 8-channel WDM system has been designed for a distance of 6000 km using inter satellite OWC channel for different power levels. The IS-OWC system consists of the following main components: 1. WDM transmitter, 2. WDM receiver, 3. Loop control, 4. EDFA amplifier, 5. OWC channel. At transmitter side to send a signal pseudo random bit sequence (PRBS) generator, NRZ pulse generator, MZ modulator and laser are used. Laser is an optoelectronic component, it act as a light source and generates narrow laser beam carrying information which is transmitted in free space. At receiver side photo detector, low pass filter and other electronic processing system are used to intercept the transmitted information. At receiver side APD is used, it has a avalanche multiplication process and it multiplies photo current before experiencing the thermal noise associated with receiver so it provides distinctive current gain and improves receiver sensitivity.

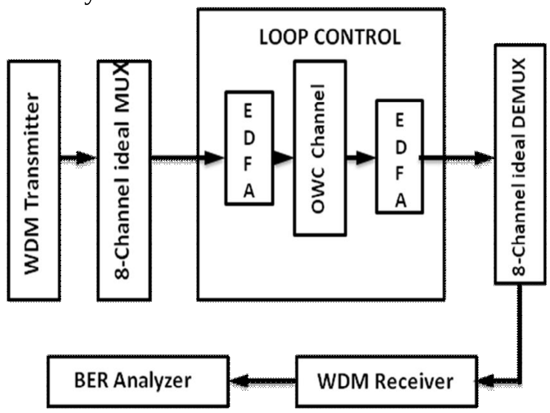

Fig.1 Proposed Is-OWC system based on WDM

The free space acts as propagation medium between the transmitter and the receiver. The OWC channel is designed at a distance of 6000 kilometers using loop control and EDFA amplifier. Loop control methodology can be used for increasing the distance of optical communication system. The number of loop decides the distance between the transmitter and receiver. As the number of loop increases, the link distance multiplies and hence results in optical signal transmit for a long distance communication. By using EDFA for pre and post amplification gain and BER of the system is improve. EDFA has a property which directly and simultaneously amplifies a wide wavelength band in 1550 nm region, with a relatively flat gain. Hence by using EDFA amplifier system becomes highly efficient in terms of its low noise gain and higher bandwidth.

The modulation format used for this setup is NRZ. This technique is used to achieve long distance and high bit rate communication. NRZ provides minimum optical bandwidth and minimum optical peak per bit interval for given power.

The designed system has been configured for a specific set of parameters. According to simulation system requirements these parameters are selected either on the basis of their type or mathematical value.

The proposed system is designed using optisystem 15 and the parameters used in system are listed in table 1.

Parameters	Values
Modulation Type	NRZ
Transmitting power	10-30 dBm
Capacity	8-Channel
Frequency Spacing	100 GHz
Bit rate	10 Gbps
Tx/Rx antenna aperture	15 cm
Distance	6000 km
No. of loops	3
Tx/Rx error	0.5-1.1 μrad
Dark current	10 nA
Gain of APD	3
Responsitivity	1 A/W
Line width of laser	0.10 MHz
Operating wavelength	1550 nm
Frequency	193.1 THz
Sequence length	128 Bits
Sample per bit	64
Addition losses	1 dB

TABLE 1
SIMULATION PARAMETERS OF IS-OWC SYSTEM

IV. RESULTS

This proposed system designed for link distance 6000 km with bit rate 10 Gbps at 20 dB of input power. The system performance is analyzed on the basis of quality factor and bit error rate. System performance can improved by varying parameters like input power, bit rate, link distance, antenna size and modulation format.

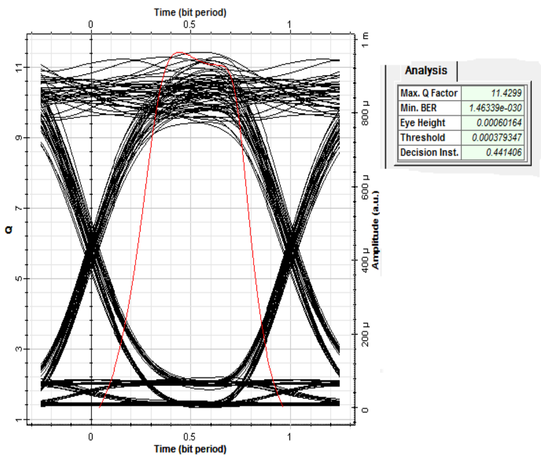

Fig.2 Eye diagram for NRZ modulation at 10 dBm input power

Figure 2 shows the eye diagram for an input power of 10 dBm at a distance of 6000 km using NRZ modulation format. It has been observed that a Q factor of 11.4299 and a bit error rate of 1.46339e^{-30} has been obtained which is acceptable for such a long distance transmission.

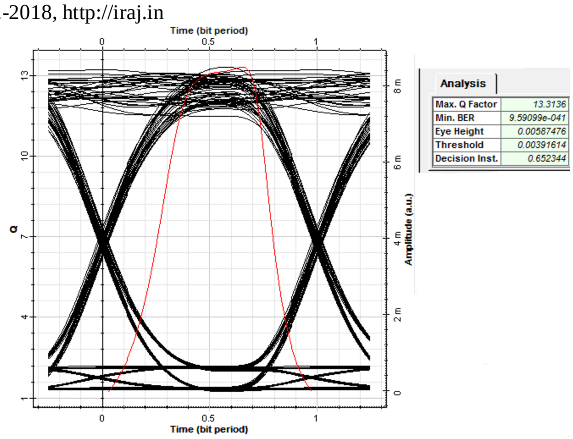

Fig.3 Eye diagram for NRZ modulation at 20 dBm input power

Figure 3 shows the eye diagram for an input power of 20 dBm at a distance of 6000 km using the same NRZ modulation format. It has been observed that if we increase the input power by 10 dBm to the previously used power, the Q factor increases to 13.3136 and the bit error rate decreases to 9.59099e^{-41} which are also acceptable but at the cost of increased input power. So results are better at 20 dBm input power.

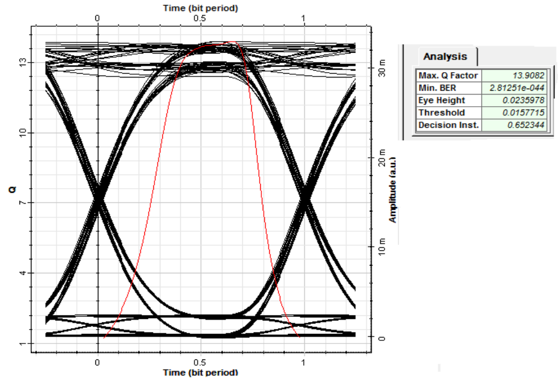

Fig.4 Eye diagram for NRZ modulation at 30 dBm input power

Figure 4 shows the eye diagram for an input power of 30 dBm at a distance of 6000 km using the same NRZ modulation format. It has been revealed that if we increase the input power to 30 dBm for the same system configuration, the Q factor diminutive increases to 13.9082 and the bit error rate diminutive decreases to 2.81251e^{-044} in its value. A minor increase in the Q factor and a minute decrease in the value of BER have been observed for an input power of 30 dBm So it is preferable to operate the system at 20 dBm input power rather than 30 dBm for best performance of the system.

S.No	Power (dBm)	Modulation formats	Q factor	BER
1.	10	NRZ	11.4299	1.46339 e^{-30}
2.	20	NRZ	13.3136	9.59099 e^{-41}
2.	30	NRZ	13.9082	2.81251 e^{-044}

TABLE 2. Performance analysis of the optimized link by varying input power.

CONCLUSION

A 8- channel WDM based ISOWC system with loop and amplifier is proposed. For the input power 20 dBm, transmitter & receiver antenna aperture 15 cm, a data rate of 10 Gbps is achieved at link length of 6000 km. The performance analysis shows system works better at 20 dBm input power in terms of system efficiency due to attainment of a high Quality factor and a low BER. The system may be analyzed for further improving the link distance and data-rate.

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