New Technologies of Optical Wireless Communications and their Applications

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Abstract: To enhance the experience of mobile phones, new data services has been emerged. With increasing demand of network infrastructure, it is difficult to handle the data services. The technology used to solve the issue is OWC. In this paper, various technologies like FSO, VLC, Inter-Satellite OWC has been discussed. Various modulation methods like CSRZ, MDRZ and DRZ of Inter-Satellite OWC has been compared at bit rates of 40 and 50 Gbps. The comparative results show that on increasing bit rate, quality factor degrades and BER increases. The challenges and various applications have also been explained..

Keywords: VLC, Inter-satellite OWC, FSO, gamma radiation, BPSK, DPSK, QAM and OOK.

Introduction

As we know that 4th generation as well as 5th generation techniques are evolving in wireless fields, there has been rigorous progress in IT field like accessing internet, applications in multimedia and HD services of television etc. With huge evolution in wireless access, there has been tremendous growth in multimedia and data services. Thus these data services enhance the life capacity of mobile phones but it will be a challenge to deal with data services. Thus, on the other hand, by comparing OWC with the available RF wireless technology, OWC has band of wavelength which lies from 350 to 1550 nm along with tremendous data rateis becoming more and more encouraging competitor for future generation access[1].

Optical wireless communications (OWC) contains certain merits such as it has the ability to operate at high bit rate, low loss, high bandwidth, the small size of the antenna and high efficiency of power. It has the ability to operate in several electromagnetic bands like ultraviolet communication (200-280 nm) and infrared wavelength (750-1560 nm) [4, 5].

An optical communication system comprise of transmitter part, transmission channel, and receiver part. There will be a merging of Wavelength-Division multiplexing (WDM) using OWC system which would result in providing excellent bit-rate, less bit-errors and high speed which can travel across long distances [3]. Free space optical communication is technology of optical transmission which is helpful for transmission of data and signals [2].One of the most important applications of FSO is IS-OWC. IS-OWC systems usually promote exchanging of informationbetween two satellites. It has been helpful to carry an optical signal with the help of wireless links resulting in the combination of optical as well as wireless technology [4]. The schematic diagram of OWC has been shown in Fig. 1.

Various modulation methods like CSRZ, MDRZ and DRZ are used in inter-satellite OWC. OWC systems usually prefer LOS propagation. These systems can be helpful in inside and outside environment because of less BER [5].The techniques like on-off keying, binary-phase shift keying, Quadrature Amplitude Modulation and differential-phase shift keying are used in inter-satellite systems and the ionizing radiation effects of gamma rays have been demonstrated [11,12].

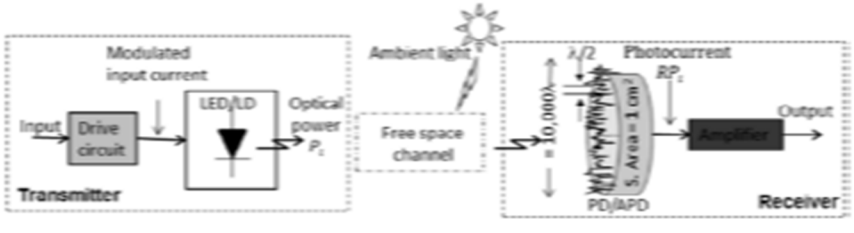

Fig. 1 Schematic Diagram of Optical Wireless Communication [1]

Literature Review

OWC includes visible light communication, Inter-satellite OWC, underwater OWC and FSO [1]. In reported studies, optical communication techniques like NRZ and RZ has been preferred to transmit signals and data [4].The techniques like on-off keying, Binary Phase-shift keying , Quadrature Amplitude Modulation and differential –phase shift keying had been used in inter-satellite systems and the ionizing radiation effects of gamma rays had been demonstrated in[11,12].An OWC system with 32 channels was designed in which NRZ and RZ modulation methods were preferred by authors.In paper [4],the use of 64 channels DWDM by different modulation formats had been described by authors and the system was analyzed at various bit rates of 10, 20 and 40 Gbps.

In [5], authors had shown that optical wireless communication is useful in many applications due to its capability to work in infrared,visible and ultraviolet bands.In paper [8], experiment description of VLC was made at bit rates of 50 Mb/s using MIMO system. The performance of different modulation formats was compared.The usage of optical beam which is modulated has been described to send the information as described in paper [2].In previous years, authors have implementedQPSK modulator and it has been designed for communication in Inter-satellite [11].

Proposed Work and Technologies used

VLC

Indoor visible light communication is latest technology which lies in the range of 380-780nm and it is a different substitute for indoor infrared technology [6]. Apart from illumination, Visible light provides communication of data and localization for indoor systems containing the present LED emitting light of white color. In this technique, light which is visible as well as infrared links can be utilized for up linking. As we know LEDs have proved to be more ecological as well as financial importance, these are becoming more and more attractive worldwide [7].

In various delicate environments like emergency rooms, industrial plants of production and aircrafts, this Visible Light Technology can be observed as a fully substitute technology. But whenever this VLC technology is incorporated in between the present technologies of wireless fields, this technology have to face certain challenges like:

1. We have to increase the throughput of data
2. There are high losses of path and increased artificial obstruction
3. ISI and light dimming

By using commercially available LEDs of high power, this technique is able to provide data rates above 210 Mbps. In original indoor communication using GPS, attenuation is high. But using VLC in indoor areas, it is a good option which provides high efficiency in navigation purposes [1].

Free-Space Optical communication

This terrestrial free space optics is a line of sight process that is managed at a wavelength of 850, 1300 and 1550nm [8].This technique is helpful in various fields and contains various applications like buildings providing high links of data rate, vehicles having connection with vehicles and trains, etc. and also in using leading broadband wireless access, recoveries in case of disasters and finally for data transmission from ground to satellite and vice-versa.The diagram of FSO has been shown in Fig. 2.

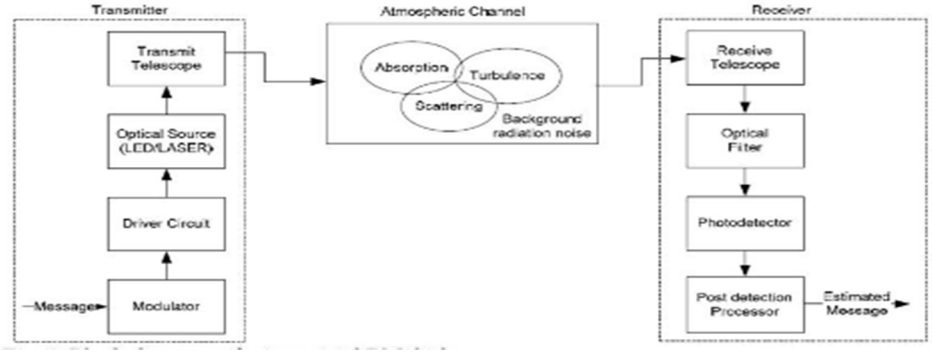

Fig. 2 FSO having terrestrial links [10]

This free space optics used with radio has been introduced which is a new criterion useful to provide connection to inappropriate areas [9]. The links of FSO with less range around 500 m has been able to be used in urban areas and these links has been providing tough competition for RF links in providing huge bandwidth. Full duplex free space optics has been operating in almost all weather conditions and FSO is very much fast, convenient and useful as compared to optical fiber.

Against the benefits, it has been affected by weather changes errors in pointing, dust and snow resulting in interference. Thus these factors degrade the performance of FSO which includes spreading of beam too. Due to rainfall, obstruction can cause up to 25 to 30dB. Now various models have been demonstrated like exponential negative and distribution of K [1]. But still fading and security problems are a major issue which is solved by inter-satellite OWC.

Advancements in Designing of Inter-Satellite OWC

The IS-OWC system has a number of benefits. First, no license is required in a communication link. Thesecond benefit is the immunity and power to the RF interference or level of saturation. Various modulation methods like CSRZ, MDRZ and DRZ have been used in inter-satellite communication.

The first technique is carrier-supression return to zero technique. It has been by specified by altering the direction of optical field at every change of bit. This modulation technique has high endurance to non-linear fiber and better resistance from the nature of dispersion. This type of modulation contains NRZ optical signal which goes through Mach-Zehnder Modulator and then passes to phasemodulator. The main difference between CSRZ and NRZ modulation format is 180^0 degree phase shift caused by the adjacent bits.

The second technique is modified duo-binary return to zero technique. This type of modulation contains NRZ signal which is duo-binary having electric subtractor and time delay circuit which runs the Mach-Zehnder Modulator and it is having connection with another Mach-Zehnder Modulator which is followed by generator that is sine-wave having a phase shift of 90^0.

The third technique used is duo-binary return to zero technique. This type of modulation which contains frequency to be 0.5RHz and bandwidth which contains transmission at R bits/sec. This DNRZ modulation technique has better resistance towards the consequences of dispersion and it has developed optical filtering [4].This technology is emerging and advancement in OWC. In paper [4], authors have described Inter-satellite OWC with 64 channels as shown in block diagram shown in Fig. 3.

The results of various modulation methods has been taken at 10, 20 and 40Gbps using a distance of 1250 km[4]. But now 64-WDM transmitter, receiver, WDM multiplexers and optimized modulation methods have been used.The optical receiver usually includes APD photodiode and 3R Regenerator that is being preferred to determine the presence of signal. BER analyzer has been preferred for the measurement of Q-factor and it has been placed after 3R regenerator. The optical amplifiers have also been used.It has been observed that at 10 and 20Gbps, high quality factor and less bit errors have been achieved and the performance of CSRZ was best. But at 40Gbps, quality factor decreases but performance of MDRZ and DRZ was better as compared to CSRZ [4].Now, the results at 50 and 60Gbps have been demonstrated.

Inter-satellite communication has been useful to determine the effect of gamma radiations on the performance of BPSK, DPSK, QAM and OOK. Performance has been deteriorated due to effects of radiation caused in transmitter laser. One unique method discovered to reduce the radiation effects is to prefer local laser [11]. QAM is adversely affected by radiation effects of gamma rays having dose of 20Krad.To reduce the effects of gamma radiations, some adaption techniques like the use of EDFA amplifier and its reinforcement can be done[12].

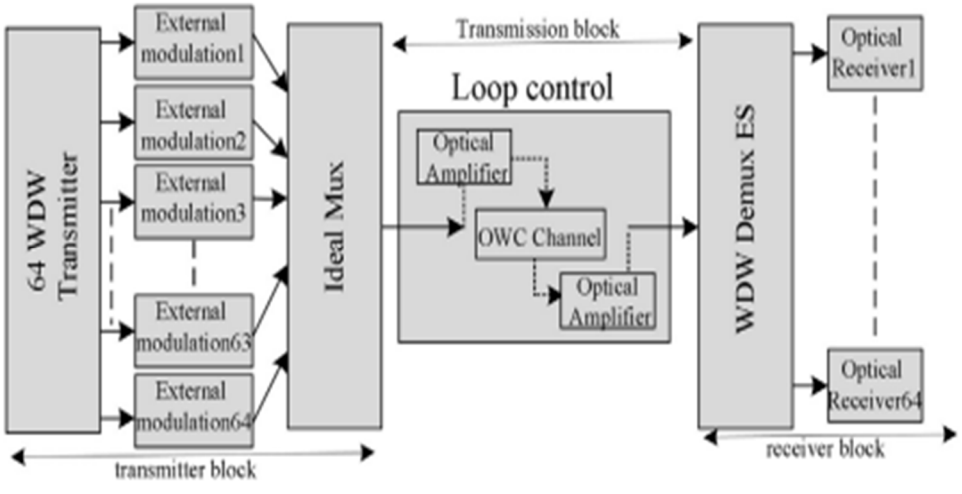

Fig. 3 Proposed Diagram of IS-OWC system having 64 channels[4]

Simulation and Comparison of Results

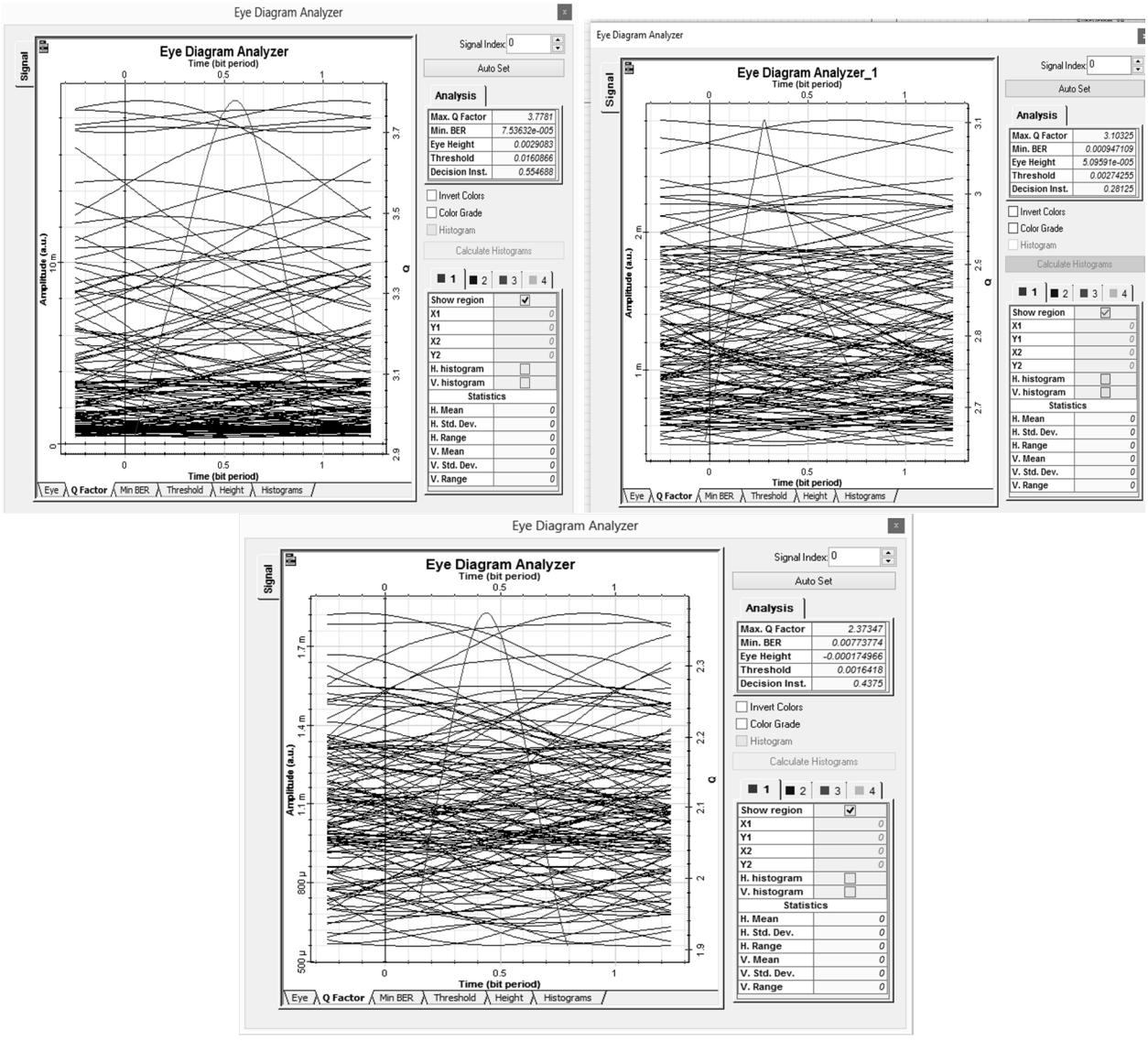

Fig. 4 Comparison of CSRZ, DRZ and MDRZ at 50 Gbps

The simulation has been done at 50 and 60Gbps. CSRZ, MDRZ and DRZ modulation methods can be used to design 64 channel IS-OWC systems. Input power has to be taken around 40 dB. Sequence length is taken to be 128 and the range is 2500 km. It has been observed that on increasing bit rate, quality factor degrades and bit errors are increased. The quality factors achieved are 3.77, 3.10 and 2.37 at 50Gbps.The bit-error rate of these modulation formats is found to be 7.53e-007, 0.0009 and 0.0077 at 50Gbps for these modulation techniques. Analysis shows that the performance of CSRZ is better than DRZ and MDRZ at 50 Gbps. The results are shown in Fig. 4 and Fig. 5.At 60 Gbps, quality factors are achieved to be 4.58, 3.35 and 2.40 at 60 Gbps. The minimum bit error-rate of these modulation formats is found to be 1.699e-006, 0.00035 and 0.004. This shows that at 60 Gbps, CSRZ proves to be the best as compared to other modulation techniques. Table 1. shows the simulation parameters of the system proposed.

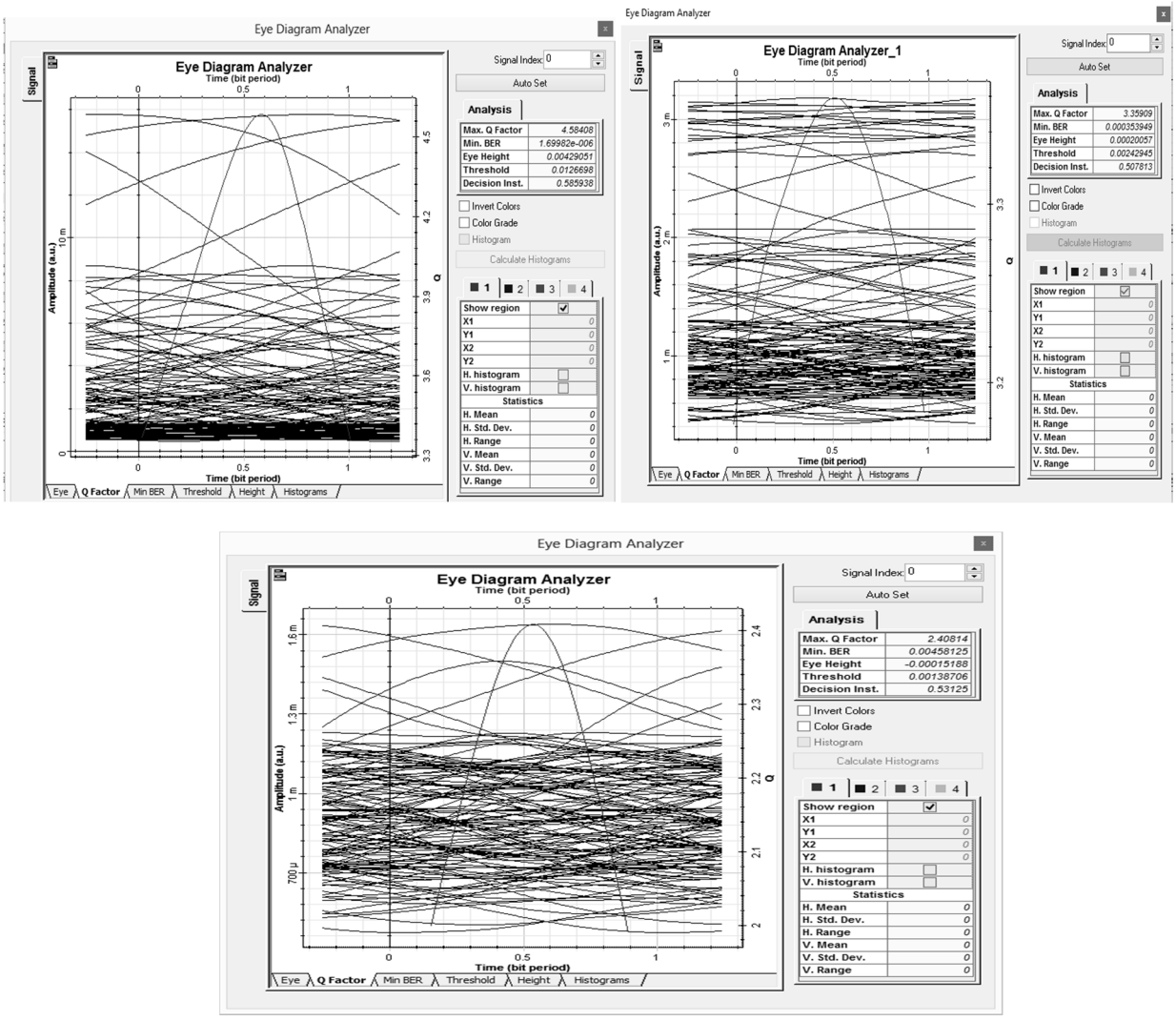

Fig. 5 Comparison of CSRZ, DRZ and MDRZ at 60Gbps

Justification of Results

Table 1. Simulation parameters of the system

Parameters	Values
Samples	64
Sequence length	128
Range	2500 km
Input Power	40db
Bit Rate	50 and 60Gbps
DWDM Channel Spacing	50Ghz

It has been justified that CSRZ technique has better quality factor and minimum errors at 50 and 60 Gbps. It contains better performance as compared to MDRZ and DRZ modulation technique. But at10, 20 and 40 Gbps, quality factor was far better. This means quality factor degrades on increasing bit rates. Quality factor at less bit rates is high because of greater eye height and higher received power. Table 2.shows the comparison of the results at different bit rates of 50 and 60 Gbps.

Table 2. Comparison of the results at different bit rates

Bit Rate (Gbps)	Parameters	CSRZ	DRZ	MDRZ
50	Q-Factor BER	3.77 7.53e-007	3.10 0.0009	2.37 0.0077
60	Q-Factor BER	4.58 1.69e-006	3.35 0.00035	2.40 0.004

Conclusion

In this paper, various technologies of OWC have been discussed and it contains huge applications in networks of communication. VLC, free-space optics, Inter-satellite OWC has been examined. As we know that, Inter-Satellite Optical Wireless Communication System with high capacity has high efficiency and huge bandwidth allocation facilities, it can be easily deployed in space in future. VLC is greatly useful in illuminating as well as communication of data. FSO has been of great use in inappropriate areas and in outdoor applications too. These technologies are preferred as compared to RF because RF usually contains congestion and security issues. It has also been observed in Inter-Satellite systems that at 50 and 60 Gbps, quality factor decreases as compared to 10, 20 and 40 Gbps.

Gamma radiation effects have also been studied on the achievement of QAM, BPSK, OOK and DPSK techniques. Radiation effects degrade the performance of these techniques dependent upon Inter-satellite system. Use of LO laser and EDFA amplifier is a key method to improve the performance of these techniques.

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