Study of Inter-Satellite Optical Wireless Communication System with different Modulation Techniques

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ABSTRACT
Communication has become a utility like electricity and water. With the advancement in the technology, needs of users, services, demands have been increasing day by day. So it requires high bandwidth, higher data rates, and better reliability. So for these reasons optical fibers have been used. Optical communication has advanced from long strands to wireless technology. This has resulted to use the optical communication in space. Inter-Satellite communication is one among them. Large numbers of satellites are revolving around the Earth. So a network is required which can hand-off data from one satellite to another and afterwards to the ground station. Inter-Satellite communication is one of the remarkable technologies. In this paper, inter-satellite optical wireless communication system (Is-OWC) is analyzed using different modulation techniques and formats. Various specifications such as bit error rate, Q factor, and input power are studied.

Keywords
Optical fiber, Inter-satellite, Modulation, Bandwidth, Communication

1. INTRODUCTION
Communication plays a great role in our life. We use different services like voice, video, text, data etc. Day by day, the demand of these services is increasing. Also there is large demand of transmission capacity. So, light wave technology has been used which includes higher data rate, enormous bandwidth. [1, 2]. Fiber optic systems are used worldwide for broadband networks. It is a method of transmitting information from one place to another by using light pulses through an optical fiber. Its main benefits are low loss, higher data rates, can be used up to large distances, used in light prone areas, no crosstalk, higher reliability etc. [3,4] Its applications include short-run remote communication, which includes convenient computers, to laser in space links. [5]

Indoor applications include infrared correspondence and outside remote correspondence includes Free Space Optics (FSO) and its one of the applications is Inter-Satellite Optical Wireless Communication System (Is-OWC). Is-OWC includes Line Of Sight and laser links from transmitter to receiver [6-29]

Is-OWC can be used to connect one satellite to other. Commonly used orbits are GEO, LEO, MEO. [30] It provides higher data transmission, low Power requirement, and small size as compared with microwave satellites. [31] It provides huge communication capacity as it has unlicensed optical wavelengths. But there are homogeneities in pressure, temperature in the atmosphere which changes the refractive index which leads to change in the transmission path. This results in fading. These faded links results in increased bit error rate (BER) and delay in the transmission. [32-33]. Modulation is the process to vary the characteristics of the carrier signal with respect to the input signal which is the modulating signal that contains the original information [34-47].

Some of the modulation techniques are described as follows:

(a) ASK: Amplitude Shift Keying. It is a type of modulation in which the amplitude of the carrier signal is varied while the frequency and phase remains constant. If the value of signal is 1 then the carrier is transmitted otherwise not.

(b) PSK: Phase Shift Keying. It is a technique in which the phase of the carrier is varied in terms of the Sin and Cosine inputs while there is no change in amplitude and frequency.

(c) FSK: Frequency Shift Keying. In this method the frequency of the carrier signal is varied. It is commonly used for radio signals, caller ID etc.

(d) DPSK: Differential Phase Shift Keying. In DPSK, there is no reference signal. The phase of the next input signal is shifted and compared to the previous signal. Next bit depends on the previous bit.

(e) QPSK: Quadrature Phase Shift Keying. This is a type of Phase Modulator in which two successive bits are grouped together. These grouped bits are called as symbol. These are grouped together and then modulated.

(f) QAM: Quadrature Amplitude Modulation. It is used for both analog as well as digital signals. Two carrier waves are transmitted at a time whose amplitude is varied using the Amplitude Shift Keying (ASK). These carries waves have the same frequency but their phase differs by 90 degrees. That is why they are called as Quadrature Carriers.

A general block diagram of a simple optical communication system is shown as below. First block contains the bit sequence generator which is used to generate the sequence of bits which is then fed to the Pulse Generator. It generates the train of pulses. The output of the pulse generator is fed to the modulator. There is one CW Laser which is the light source which produces the highly directional beam which covers a large distance. These data source and light source are connected to the modulator which modulates the optical signal. This signal is transmitted through the optical channel. And at the receiving end APD is used which converts back the signal into its original form. Output is then passed through the Low Pass Filter (LPF) which does the necessary filtration. At the end Bit Error Rate (BER) Analyzer is used which gives us the required Q factor and BER measurements.

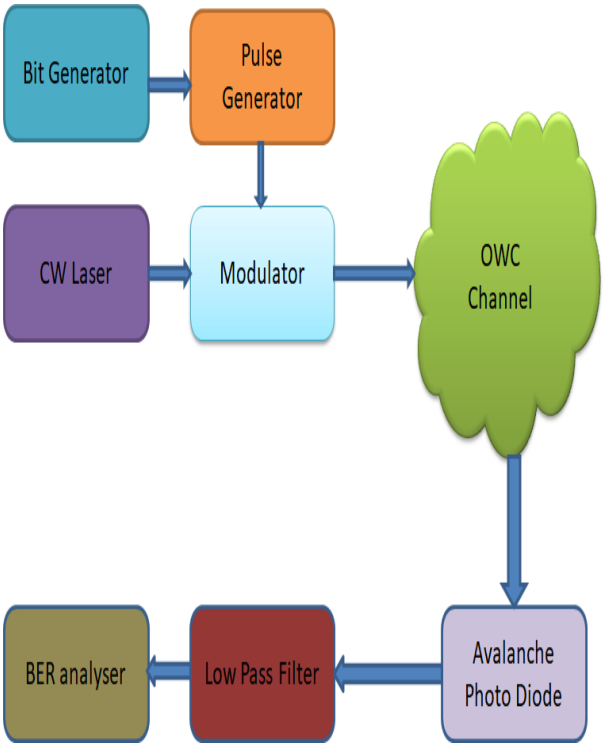

Fig. 1: Basic Structure of Is-OWC Scheme

In this paper a review is done on previous works of Is-OWC. Performance analysis is done with various modulation techniques such as QPSK, DPSK, QAM etc. and some formats like NRZ, RZ. Section II contains the previous work which is done based on the modulation techniques and section III contains the conclusion.

2. STUDY RELATED WORK

In 2012 investigated the simulation and design of Is-OWC system by using Quadrature Phase Shift Keying (QPSK). Q factor, bit error rate and eye diagrams were analyzed. The objective was to achieve the highest coverage distance and highest data rates. For a power level of 30dbm with bit rates of 400, 160 and 100 Gbps respectively, the coverage distance were 4767, 7542 and 9352 Km respectively. Also this system was compared with the system designed by Sodnaiket.al and Hashim et.al. bit rate of 5.6Gbps at a distance of 40.06 Km and 438 Gbps at distance of 5000 Km were obtained. [48]

In 2014, a study regarding the performance of Inter-Satellite optical wireless communication was carried out at wavelengths of 980nm and 1550nm. A link between two satellites was established at a distance of 1300 Km at the data rate of 3Gbps. This study found that for wavelength 980nm, Q factor was calculated as 7.30323 and BER was 1.25525e-0.13 and for the wavelength 1550nm, Q factor was 14.4179 and BER was 1.58648e-0.47. This study shows that 1550nm wavelength has better results as compared to 980nm [49].

In 2014, a study regarding the inter - satellite links under the effect of atmospheric turbulences was made using different modulation techniques such as binary phase shift keying-subcarrier intensity module (BPSK-SIM), differential phase shift keying (DPSK), differential phase shift keying-subcarrier intensity module (DPSK-SIM), M Mary pulse position modulation (M-PPM) and Polarization shift keying (POISK). Bit Error Rate (BER) and channel capacity for these modulation techniques has been compared. Out of these, DPSK has the best BER performance and POISK has the best probability performance and again DPSK has the highest channel capacity [50].

Another study in 2014 includes the simulation and design of inter-satellite using the Quadrature Phase Shift Keying (QPSK) modulator. A Laser source of wavelength1550nm and data rate of 2.5 Gbps is used. Mach-Zehnder modulator has been used and for demodulation LiNB03 is used. Moreover, different parameters such as Q factor, BER, Eye diagrams have been taken into consideration for comparing Quadrature Phase Shift Keying (QPSK) and Differential Phase Shift keying (DPSK).Various graphical results shows that QPSK has low BER as compared to DPSK and Quality factor is high for QPSK. Max Q factor for QPSK is 9.25 and for DPSK, it is 7.94. And Bit Error Rate (BER) for QPSK s 1.05*10^-20 and for DPSK it is 9.45*10^-16. This shows that QPSK modulation which is used for free space is better than DPSK [51].

A study in 2016 includes analyzing high-speed WDM-PI based Inter-Satellite system which is studied under the influence of Transmitting and Pointing errors. It includes transmission of 120Gbps data over a distance of 1000 Km. It studied the influence of transmitting pointing errors from 1 to 5microrad for all channels. Acceptable SNR of 20db and total received power of -80dbm is obtained at 5microrad of transmitting pointing error [29].

In order to compare the modulation formats and evaluate which one is better, a study was made in 2017. This study compared two modulation formats .They are Return To Zero (RZ) and Non Return to Zero (NRZ) at a distance of 100 Km and 400Km single-channel and wavelength Division Multiplexing (WDM) optical networks with bit rate of 10gb/s and 160gb/s. By studying the eye diagram parameters for the distance of 100 Km using the RZ format, the maximum Q factor is 34.19242 and minimum BER is 1.42307e-256 and for that of NRZ format, Q factor is 28.8535 and BER is 2.12699e-183. Now for the distance of 400 Km, Q factor and BER for RZ format is 8.92451 and 1.88235e-019 and for that of NRZ format Q factor and BER is 11.064 and 7.49404e-029 respectively. The results show that RZ technique is better and it is efficient for shorter distance communication [52].

In 2017, a study was made using Dense Wavelength Division Multiplexing (DWDM) Multiplexing technique for inter-satellite communication. The main aim was to compare the modulation formats Non Return to Zero (NRZ) and Return to Zero (RZ) at different input power levels. It is used for transmission up to the longer distances. Data rate of 10 Gbps for a range of 5000 kilometers is used. Moreover Quality factor and Bit Error Rate (BER) have also been analyzed. Different input powers of 10, 20, 30db are used. Transmission wavelength of 900nm and channel wavelength of 1550nm is used. A 31-channel DWDM transmitter is used. Q factor and BER are analyzed for 10, 20, 30dB power levels. They are given below:

a. For 10db power input, Q factor and BER for NRZ format is 12.99 and 6.74*10-39 and for RZ format it is 12.26 and 1.28*10-28

b. For 20db , Q factor and BER for NRZ is 13.36 and 4.92*10-41 and for RZ format , it is 12.98 and 7.9*10-39

c. For 30db power input, Q factor and BER for NRZ is 13.37 and 4.5*10-41 and for RZ it is 13.09 and 1.72*10-39

These results show that NRZ performs better and it is best suited to obtain the high Quality Factor and low BER. Here

the system is obtaining best results in case of 30db by using the RZ format but at the same time power input is very high. So NRZ format with power input of 20db is best out of these 3 input levels [53].

3. CONCLUSION

Inter-Satellite is one of the best ways for communication between the satellites. Research is a thing which is endless. A lot of systems are being designed to prove better than the older by doing some improvements. In this review paper, we have analyzed the inter-satellite communication system by taking into consideration various modulation techniques. These techniques are used in order to enhance the performance of the system. Various factors such as Quality factor, Bit Error Rate, data rate, range, and power input levels, capacity are studied. Researchers have used different modulation schemes such as QPSK, DPSK, WDM-PI, DPSK-SIM, M-PPM, POISK, QAM, NRZ, and RZ to perform better results. Out of these NRZ format is performing the best with highest Q factor and low BER. Moreover in future more advanced modulation schemes can be used in future in order to enhance the system.

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