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Inter Satellite Optical Wireless Communication System

SHERIN RAJ

Dept of Electronics and Communication Engineering, APJ Abdul Kalam Technological University, Thiruvananthapuram, Kerala, India, E-mail: Sherinrosh3126@gmail.com.

Abstract: Communication systems have been evolving since the time communication has been started. Inter-satellite communication systems is one of the important applications of free space optical communication technology, which is a unique method for the satellites orbiting around the earth to communicate with each other. This paper give complete analysis of Inter-satellite link (ISL) by varying various performance parameters such as distance, wavelength. In this paper IsOWC system was modified and simulation results showed a good enhanced value of Quality factor and Bit error rate. The system was simulated using optisystem software version 7.

Keywords: Inter Satellite Link (ISL), Line Of Sight (LOS), Low Earth Orbit, Optisystem.

I. INTRODUCTION

The use of satellites in communication systems is very much a fact of everyday life. Satellites offer a number of features not readily available with other means of communications. The very large areas of Earth are visible from satellite and the satellites can form the star point of communication net, simultaneously linking many users who may be widely separated geographically. As the number of the satellites orbiting the earth increases year by year, a network is required for the satellites to provide efficient communication between satellites. And the laser can now able to send information at data rates of several Gbps and at distances of thousands of kilometers apart. This has open up the idea to adapt optical wireless communication technology into space technology. Hence intersatellite optical wireless communication system is developed. It is used to connect one satellite to another, whether the satellite is in the same orbit or in different orbit. With light travelling at 3 x 10^8 m/s, data can be sent without much delay and with minimum attenuation since the space is considered to be vacuum. Satellites revolve around Earth at their own orbit and there are three commonly used orbits for satellites. Low Earth Orbit (LEO) is the orbit closest to Earth with altitude of 100km to 5,000km. LEO satellites take 2 to 4 hours to rotate around Earth. This orbit is commonly used for multi-satellite constellations where several satellites are launched to perform a single mission. A low Earth orbit is the simplest and most cost effective for a satellite placement and provides high bandwidth and low communication time lag.

The biggest problem of LEO is the need for many satellites if global coverage is required. The Medium Earth Orbit (MEO) is from 10,000 km to 20,000 km altitude and the orbital period is 4 to 12 hours. MEO orbit is usually occupied by remote sensing satellites. It is also known as Semi-synchronous. Communication satellites for broadcasting and telephone relay is placed in the Geosynchronous Orbit (GEO) which has 36,000 Km altitude from Earth. A GEO satellite takes 24 hours to rotate around the Earth which makes it stationary from Earth's point of view. The advantages of using optical link over radio frequency (RF) link is the ability to send high speed data to a distance of thousands of kilometers using small size payload. By reducing the size of the payload, the mass and the cost of the satellite will also be decreased. Another reason of using OWC is due to wavelength. RF wavelength is much longer compared to lasers hence the beam width that can be achieved using lasers is narrower than that of the RF system. Due to this reason, OWC link results in lower loss compared to RF but it requires a highly accurate tracking system to make sure that the connecting satellites are aligned and have line of sight. Intersatellite Optical Wireless Communication (ISOWC) system has a number of advantages. First, no licensing is required in terrestrial communication link. Another advantage is the immunity to the radio frequency interference or saturation has added the security features in this technology. The point-to-point laser signal is extremely difficult to intercept. With a narrow beam angle for several milliradians, it is very hard to jam or tap the ISOWC link. The ISOWC system is modeled using optisystem software.

II. METHODOLOGY

The optical wireless system consists of transmitter, propagation medium and receiver. Fig.1 shows the basic block diagram of an ISOWC system where the transmitter is in the first satellite and the receiver is in the second satellite. The free space between the satellites is the propagation medium is the OWC channel that is use to transmit the light signal. The IsOWC transmitter receives data from the satellite's Telemetry, Tracking and Communication (TT&C) system. The data that usually transmitted by a satellite are such as the satellite position and attitude tracking, captured image for remote sensing satellite, or even voice data for telephone network relaying satellite. The Pseudorandom bit sequence generator represents the information or data that is transmitted. The data is usually coming from satellite's TT&C system. Information is transmitted in the form of binary signals. These binary signals are directed towards Pulse generators, which convert the binary signals into electrical signals. The second subsystem is the NRZ pulse generator. This subsystem encodes the data from the pseudo-random bit sequence generator using the non-return zero encoding technique.

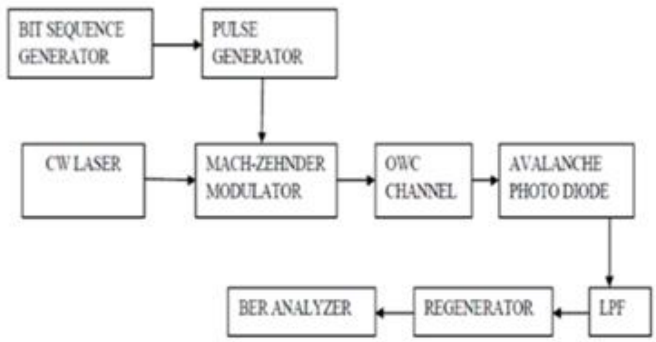

Fig.1. Basic block diagram of ISOWC system.

The third subsystem in the satellite IsOWC transmitter is the CW laser. CW stands for continuous wave where the output signal of the laser is nonstop and unmodulated. Lasers are used instead of LED for this system because of its ability to transmit at further distance. The frequency of the light is chosen to be 1550nm or 193.1THz. Generally Lasers are used for the creation of light pulses. The electrical signal from TT&C system and optical signal from the laser will be modulated by an optical modulator before it is transmitted out to space. An optical modulator varies the intensity or amplitude of the input light signal from laser according to the electrical signal. This is done by changing optical parameters such as refractive index, reflection factor and transmission factor of the optical modulator that is made from fiber waveguides. The modulation is the process of varying one or more properties of a periodic waveform called the carrier signal, with a modulating signal that typically contains the information to be transmitted. The last subsystem in the transmitter is the Mach-Zehnder Modulator. It is an optical modulator that functions is to vary intensity of the light source from the laser according to the output of the NRZ pulse generator. The output light pulses from the optical modulator are transmitted in the transmission medium to the receiving satellite. In the case of ISOWC system, the transmission is the optical wireless channel. The receiving end of the ISOWC signal consists of a photodiode and a low pass filter. A photodiode is a device that detects the received light signal and converts it into electrical signal.

Avalanche photodiode (APD) is used in long distance free space optical data transmission due to its characteristics of producing high amplification for low or weak light signals. Bessel filter is the most commonly used filter due to linear phase response characteristics. Also this filter is free from ripples in pass band and possesses monotonic delay in stop band. This type of filter is generally preferable only for signals like square and triangular wave which have wide spectrum. The main purpose is to filter out the unwanted high frequency signals. The 3R regenerator is used to regenerate the electrical signal corresponding to the original bit sequence and the electrical signal is analyzed by the BER analyzer. The visualizer tools are available in the form of optical and electrical analyzers for visualizing the results at the output. The system performance can be evaluated in many ways such as by analyzing the BER and Q-factor. BER can be said to be the ratio of the number of bit errors detected in the receiver and the number of bits transmitted. Bit errors happen as the result of incorrect decisions being made in a receiver due to the presence of noise on a digital signal Meanwhile, Q-factor is a measurement of the signal quality. It is proportional to the system's signal to noise ratio.

A. OptiSystem

OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. OptiSystem is an optical communication system simulation package for the design, testing, and optimization of virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broadcasting systems to intercontinental backbones. A system level simulator based on the realistic modeling of fiber-optic communication systems, OptiSystem possesses a powerful simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be easily expanded with the addition of user components and seamless interfaces to a range of widely used tools.

III. RESULTS AND DISCUSSION

A. Simulation Layout of Simplex and Full duplex ISOWC System

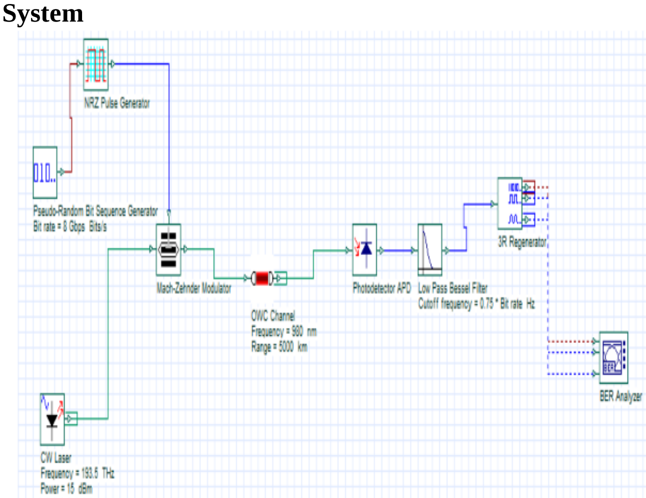

Fig.2. Simplex design.

ISOWC system designed was modeled and simulated for performance characterization. Several parameters of the system were varied to obtain optimum system performance. The main parameter that was considered is the light propagation distance of the specific OWC channel.

Furthermore, other OWC link performance characteristics were also considered which includes the frequency of light carrier signal of CW laser and multiple filters. Fig.2 shows the simplex design model, which means the model is for one way data transmission from one satellite to another. From the simulation, two observation was done which is the relationship of the Q-factor and the distance and also the relationship between Q-factor and the signal wavelength. The full-duplex system model shown in fig.3 consists of two simplex systems. Hence it can be used for two way data transmission from one satellite to another and back.

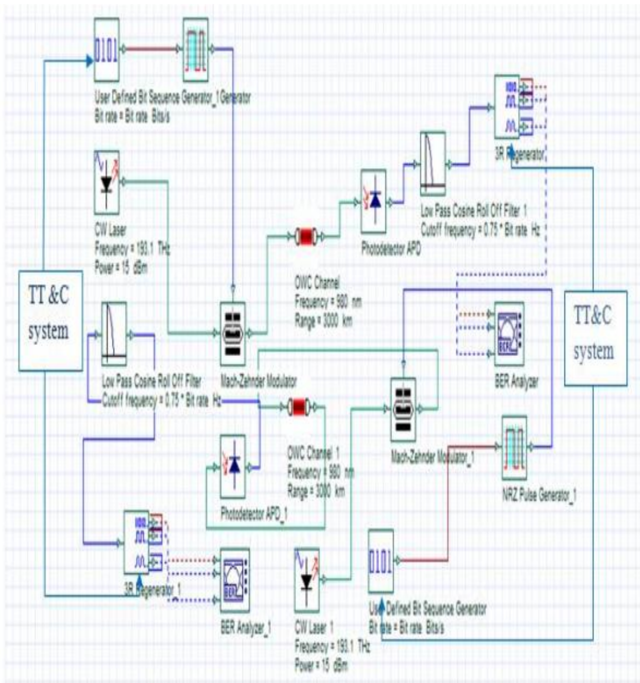

Fig.3. Full duplex design.

B. Relationship Between Wavelength, Range And Q-Factor

The wavelength is varied from 980nm to 1550nm, with a constant distance of 5000 km, Power of 15 dBm and bit rate of 8Gbps. From the graph of Fig.4, it can be observed that at longer distance the Q-factor of the system decrease. This shows that the error in the received signal increases as the distance increase. For long-haul transmission, the common wavelength used is 1550nm but shorter wavelengths can also be used. The range of the satellites is varied from 1000 to 5000km, with a constant wavelength of 1550 nm ,power of 15dBm and bit rate of 8Gbps.It can be observed that at higher wavelength, more error is produced due to lower value of Q-factor. However, by using longer wavelength, the effect of scattering can be reduced. Attenuation due to Rayleigh and Mie scattering is inversely proportional to the wavelength. Though in this project it is assume that there are no particles obstructing the light signal, but small and large particles by the means of space dusts and meteorites can happen to be within the light signal's way. Therefore, the longest possible wavelength is to be used which is 1550nm. Another reason of using 1550nm is because the compatibility with current technology and device as shown in Fig.5.

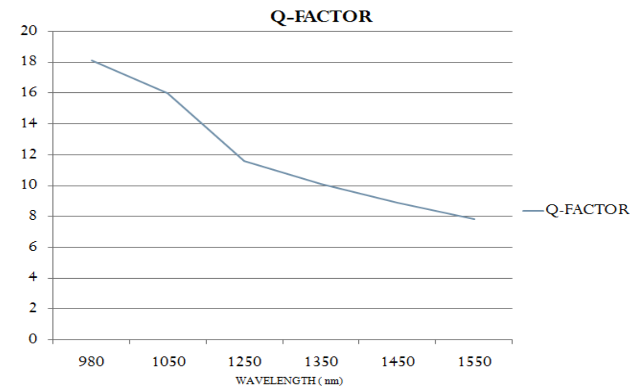

Fig.4.Wavelength versus Q-Factor.

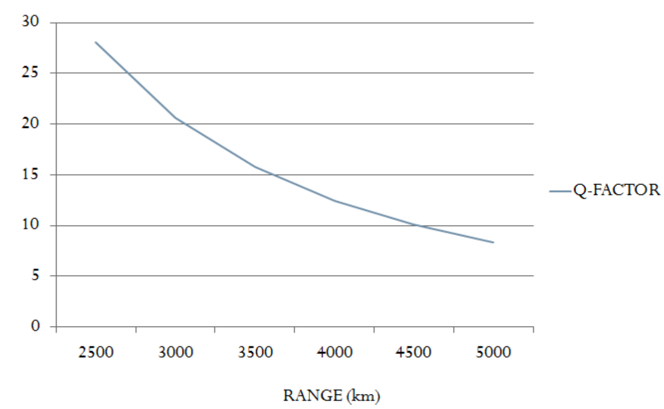

Fig.5. Range versus Q-Factor.

C. Comparative Analysis Of Different Receiver Filters

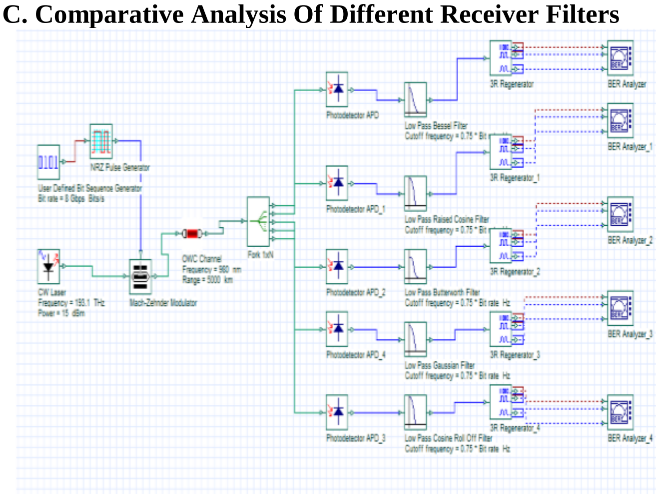

Fig.6. Simulation layout.

For the comparative analysis purpose different receiver filters such as low pass Gaussian filter, low pass Butterworth filter, low pass Raised cosine filter, low pass Bessel filter and low pass Cosine roll off filters are used in the simplex design. Gaussian filter produces no over shoot to a step function while minimizing the rise and fall time as shown in Fig.6. Butter worth filter has flat frequency response. Raised cosine filter is used for pulse shaping in digital modulation due to its ability to minimize inter symbol interference (ISI). Bessel filter produces small amount of over shoot, linear phase response and is almost same as that of the Gaussian filter. Compared to other filters low pass Bessel filter gives better performance.

IV. ISOWC SYSTEM USING MULTIPLE TRANSCEIVERS

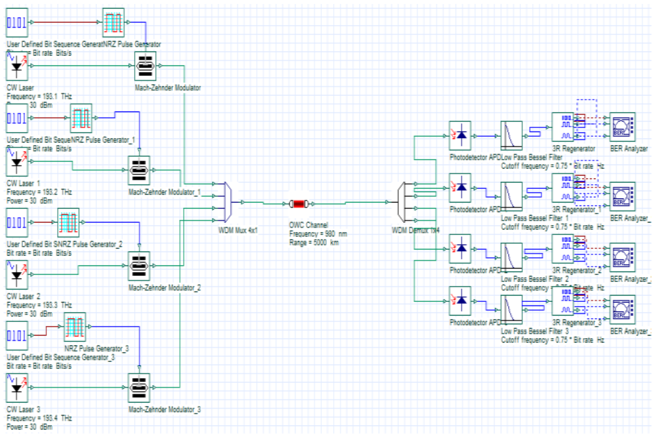

Fig.7. Multiple transceivers ISOWC system.

V. CONCLUSION

More and more satellites are deployed to space to perform many applications for the benefit of mankind. The future of space technology aims for satellites that can send its research data and images from any parts of the world, and also satellites that can give high speed internet connection and provide mobile cellular services to people at any places and anytime. This project is done to analyze a method to connect and network these satellites by using optical link. It has been discussed that ISOWC can provide Intersatellite communication at higher speed and much further distance compared to RF links.

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