Performance Evaluation of Optical Intersatellite Links with Varied Parameters

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***Abstract*— The number of satellites orbiting Earth increase year by year, a network between the satellites provides a method for them to communicate with each other. Laser communication is now able to send information at data rates up to several Gbps and at distance 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 (IsOWC) is developed. The system performance including Q factor ,bit rates, receiver sensitivity and distance of Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) links were analyzed. The intersatellite link was modeled and simulated using a commercial optical system simulator named OptiSystem 12.0 by Optiwave.**

Keywords: Intersatellite Optical Wireless Communication (IsOWC), OWC, wavelength, Q Factor , bitrates.

I. INTRODUCTION

The number of satellites orbiting Earth increases year by year. The Optical Wireless Communication (OWC) technology is very much advanced now. Intersatellite Optical Wireless Communication (IsOWC) can be used to connect one satellite to another, whether the satellite is in the same orbit or in different orbits. The advantages of using optical link over Radio Frequency (RF) links is the ability to send high speed data to a distance of thousands of kilometers using small size payload, due to this 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 beamwidth 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.

The 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 miliradians, it is very hard to jam or tap the IsOWC link. Environmental wise, FSO does not pollute the environment with electromagnetic radiations since the wavelength of IsOWC is only from 850 nm to 1500 nm. The performance analysis will be in terms of measured received power, eye diagram and simulated BER.

II. OVERVIEW OF SATELLITES

A satellite is an object that orbits or revolves around another object in space. The Moon is a satellite to Earth and the Earth is a satellite to the Sun. These are natural satellites. In 1945, Arthur Clarke wrote on the possibilities of having man-made satellites that could be able to relay telephone channels and broadcast programs. Thirteen years later, in 1958 the first communication satellite named SCORE (Signal Communication by Orbital Relay) was launched and proved that Clarke's theory was indeed possible. Following the success of SCORE, many more satellites were launched by the United States, Russia, United Kingdom and Canada. Since then, satellites are launched for many applications such as for communication, remote sensing, scientific research and global positioning.

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. Satellites said to be semi-synchronous have a period of 1/2 day. Thus, they orbit the earth two times per day. Geopositioning and navigation satellites use this type of orbit. The most common altitude is approximately 20,200 kilometres which yields an orbital period of 12 hours, as used, for example, by the Global Positioning System (GPS). It need higher transmit power and special antennas for smaller footprints. 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 seems stationary from Earth's point of view.

III. SYSTEM DESIGN

The design model for a simplex system is depicted in Figure 1.Transmitter part consists of a pseudo random generator, NRZ modulator, continuous wave laser and a Mach-Zehnder modulator. The first subsystem is the pseudo-random bit sequence generator. This subsystem represent the information or data that is transmitted. The data usually comes from the satellite's TT& C system. The second subsystem is the NRZ pulse generator, which encodes the data from the pseudo-random bit sequence generator. Each component block has its own parameters apart from the parameters of the design called as global parameters.

Wavelength, frequency and power of the signal is initialized and phase parameter of signal is set to random in CW laser block. The transmission rate of the signal and power of light wave is varied from 5 Mbps to 5 Gbps and 10-25 dBm respectively. The frequency of the CW laser is set to 193.1 THz. The last subsystem in the transmitter is the Mach-Zehnder Modulator. It is an optical modulator whose functions is to vary the intensity of the light source according to the output of the NRZ pulse generator. The output of the Mach-Zehnder modulator is transmitted to the other satellite through the OWC channel.

The free space between two connecting satellites is considered as OWC channel which is the propagating medium for the transmitted light. In the OptiSystem software, the OWC channel is between an optical transmitter and optical receiver with 15 cm optical antenna at each end. The transmitter and receiver gains are 0 dBm. The transmitter and receiver antennae are assumed to be ideal whose optical efficiency is equal to 1 and there are no pointing errors. Additional losses from scintillation and mispointing are also assumed to be zero and there is no attenuation due to atmospheric effects.

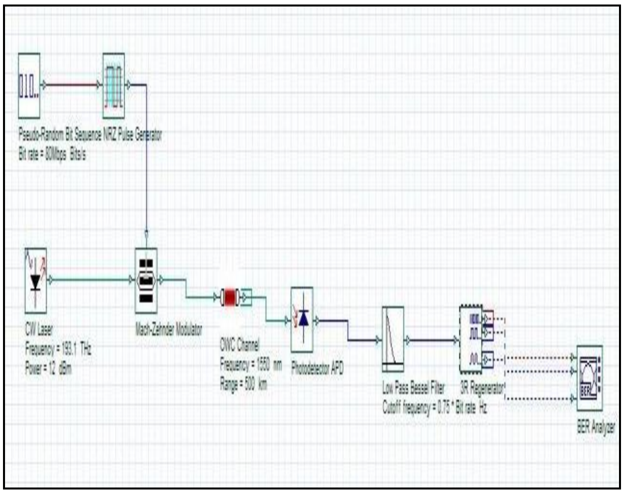


Fig. 1. IsOWC simplex design model

The receiver consists of an Avalanche photodiode, low pass filter and 3R regenerator. The photodiode acts as a front-end receiver that receives the optical signal and converts it into electrical signal. The APD photodiode has an internal gain which allows the reduction of noisy external amplifiers in optical detection systems. Apart from that, the APD photodiode is useful in low, weak or reduced light applications because the avalanche phenomenon utilized by the device provides high amplification. Hence it is ideal for thr systems where the long distance transmission reduces the intensity of the light. APD photodiode used in the OptiSystem model has a multiplication factor of 3 and default dark current used is 10nA. The frequency of the photodiode is set to 193.1 THz. The Low Pass Filter (LPF) after the photodiode is used to filter out the unwanted high frequency signals. Bessel LPF is used with cut-off frequency of 0.75 x bit rate of the signal. The order of the Bessel funtion is 4 and the maximum attenuation of the filter is 100 dB. The 3R regenerator is the subsystem used to regenerate the electrical signal corresponding to the original bit sequence and the electrical signal is analyzed by the BER analyzer.

IV. RESULTS AND DISCUSSION

A. Relationship between received power with link distance.

The received power of the intersatellite system is observed by varying the link distances from 0 to 2500 km keeping the transmitter power at 12 dBm, input bit rate 80 Mbps and transmitter antenna diameter 25 cm. Figure 2 shows the graphical representation of received power as a function of link distance. From the graph it is observed that the received power decreases as the intersatellite link distance increases.

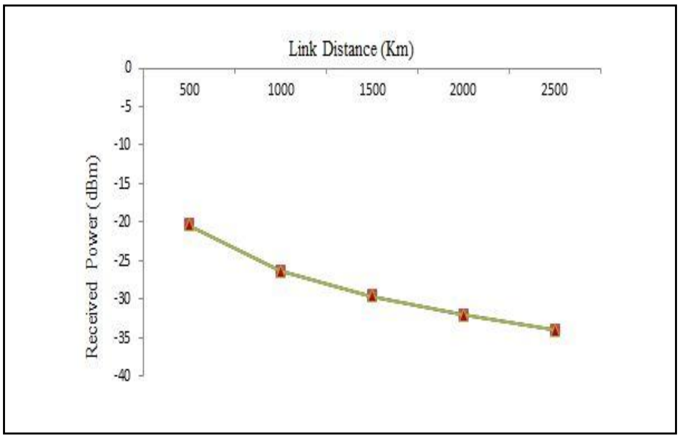
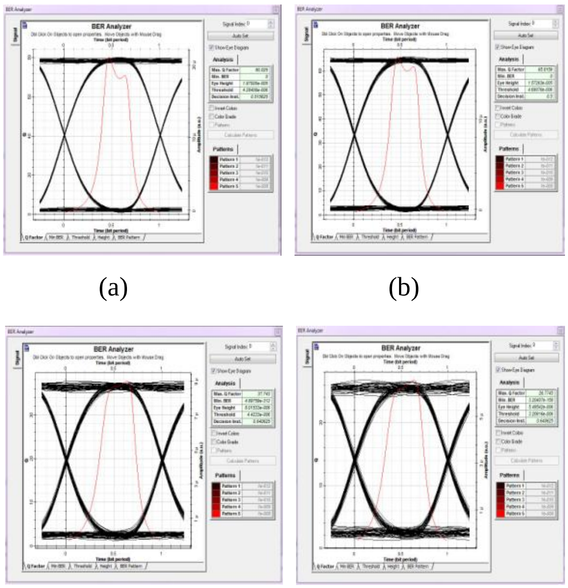


Fig. 2. Received power vs. Link distance

B. Relationship between Q-factor and Signal Wavelength.

For long-haul transmission, the wavelength used is 1550 nm but shorter wavelengths can also be used. Figure 3 shows the effect of the variable wavelengths on the system performance.



(a) (b)

(c) (d)

Fig. 3. System eye diagram obtained at wavelength (a) 850 nm (b) 950 nm (c) 1310 nm (d) 1550 nm.

For the simulation, the distance between the satellites is set constant at 1000 km, bit rate 80 Mbps and input laser power at 12 dBm . It is observed from the eye diagrams that as the wavelength increases, the Q factor decreases. However, longer wavelength, are less prone to scattering and attenuation due to Rayleigh and Mie scattering is inversely proportional to the wavelength. Therefore, the longest possible wavelength that can be used is 1550 nm. In this work it is assumed that there are no particles obstruct the light signal. But small and large particles such as space dusts and meteorites can obstruct the light signal.

C. Relationship between Q Factor with Transmitted Power by varying bit rates.

The two parameters mainly bit rates and transmitted optical power of IsOWC link are adjusted. The transmitted laser power plays an important role in determining the system performance because as the transmitted power increases the link distance increases. The bit rates used are 0.005, 0.05, 0.5 and 5 Gbps. Lower bit rates (5 Mbps) require less power while higher bit rates (5 Gbps) require high transmission power to achieve a successful communication upto a link distance of 1000 Km. A graph is plotted between Q Factor and Transmitted optical powers for different bit rates. The transmitted power values are taken from 5-30 dBm. It is observed that for a bit rate of 5 Mbps at 30 dBm transmitted power, a large value of Q factor above 4000 is obtained. Similarly small value of Q factor is obtained for a bit rate of 5 Gbps at 30 dBm transmitted power.

The graphical representation in Figure 4 shows the variation of Q Factor as a function of transmitter power for different bit rates. In IsOWC simplex model, results show that large distance communication at high data rates can be achieved by increasing the transmitted power and aperture diameters.

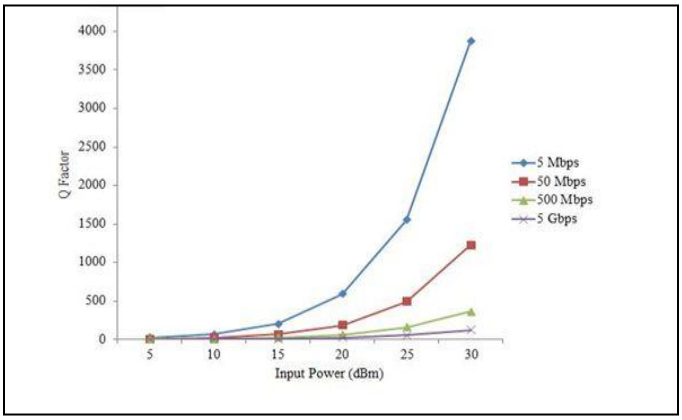


Fig. 4. Q Factor Vs Input power by varying bit rates

V. CONCLUSION

More and more satellites are deployed in space to perform many applications for the benefit of mankind. Intersatellite Optical Wireless Communications (IsOWC) can provide intersatellite communication at high speed and achieve farther distance compared to RF links. The Q factor decreases as the distance between satellites increases. The optical signal with lower bit rate can be used for large distance transmission. Longer signal wavelength produces more errors but transmission at 1550 nm is used to reduce the effect of scattering in IsOWC systems. In simplex model results show that long haul communication using high data rates can be achieved by large transmitted power.

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