

Investigations of Bit rates in Optical Intersatellite Wireless Links

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Abstract: *Optical communications are evolved from lengthy optical fibers to powerful wireless communications. 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 number of satellites orbiting Earth increase year by year, a network between the satellites provides a method for them to communicate with each other. 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, Q Factor, bitrates.

1. 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.

2. Satellites and IsOWC

A satellite is an object that orbits or revolves around another object in space., they 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. 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. 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.

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.

3. System Modelling

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. The last subsystem in the transmitter is the Mach-Zehnder Modulator. It is an optical modulator whose functions are 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.

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. 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 $0.75 \times$ bit rate of the signal. 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.

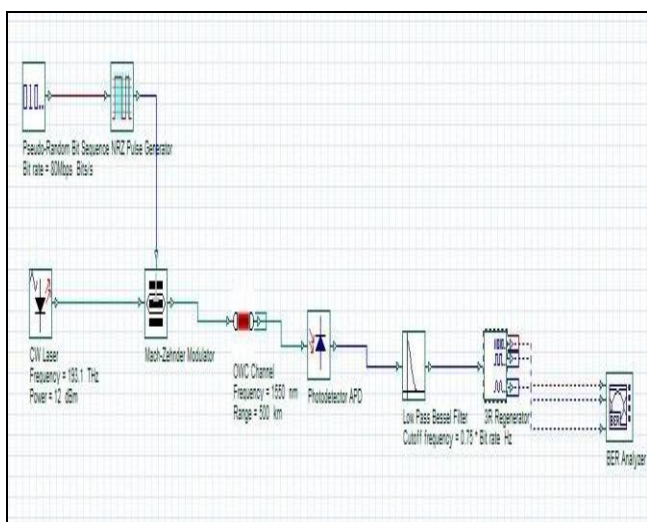


Figure 1: IsOWC simplex design model

4. Results and Discussions

4.1 Relationship between Q Factor and Link distance by varying transmitted power.

It is often necessary to determine whether a wireless optical communication can achieve a certain transmission distance. Transmission distance depends on the transmitted power. For an IsOWC link, as the transmitted power increases, the link distance increases. The system performance is evaluated by analyzing the BER and Q-factor. From the results it is clear that larger transmission distance is achieved by increasing the transmitted power. The impact of variable transmission power on link range of IsOWC is examined by considering a single channel. Here the transmitted power and link distances are varied from 10-25 dBm and 1000-11000 km respectively. Figure 2 shows the graphical representation of Q factor as a function of link distance for varying transmitted power.

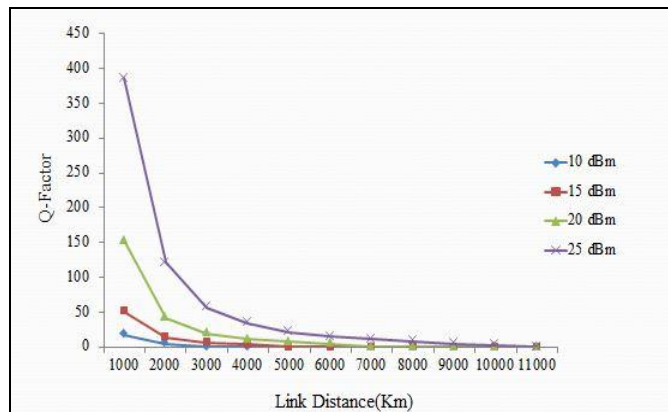


Figure 2: Q factor Vs link distance by varying transmitted power

It is observed that the link range increases as the transmitted power increases. A link range of 2000 Km is achieved for an input power of 10 dBm. If the input power is increased to 25 dBm then the link range becomes 10,000 Km. The simulation setup for input powers 10 and 20 dBm are carried out at a constant bit rate of 80 Mbps. It is analyzed that higher input powers are necessary for long distance communication.

4.2 Relationship between Q factor and Link Distance by varying bitrates.

Figure 4 shows the graphical representation of Q factor as a function of link distances for varying bit rates. By keeping the fixed power at 15 dBm, the Q factor observed for various distances from 0 to 8000 km. The bit rates used are 0.005, 0.05, 0.5, 5 Gbps. From Figure 3, it is clear that as the distance increases, the quality of the system decreases. The maximum achievable distance decreases as the bit rate increases. So lower bit rates are used for long distance communication. However, long distance can be achieved by increasing the transmitted power.

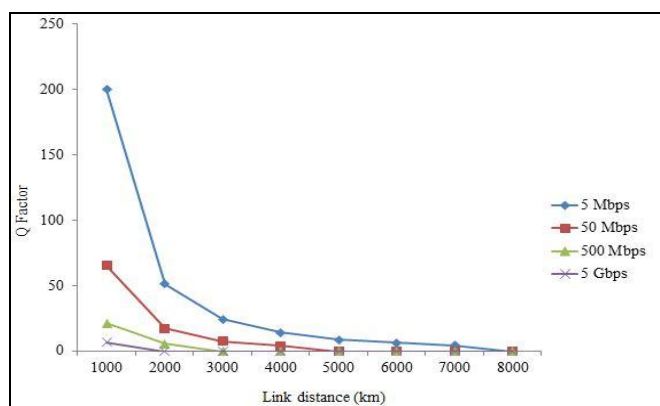


Figure 3: Q Factor Vs Link distance by varying bit rates

4.3 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.

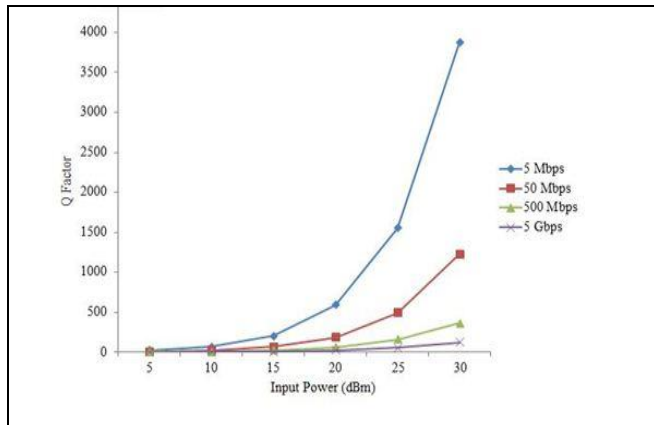


Figure 5: Q Factor Vs Input power by varying bit rates

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.

5. 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. In simplex model results show that long haul communication using high data rates can be achieved by large transmitted power, which increases the cost of the satellite. The optical signal with lower bit rate can be used for large distance transmission.

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