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# PERFORMANCE ANALYSIS OF INTER SATELLITE OPTICAL LINK AND THE EFFECT OF TRANSMITTER AND RECEIVER APERTURE ON ITS PERFORMANCE PARAMETERS

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**ABSTRACT:**

*Optical communications link have evolved from lengthy fibers to wireless system such as intersatellite transmission system, for which transmission capacity and distance of optical signal are always an important consideration factor to improve the performance of the optical wireless transmission system. In this paper we have investigated the effect of bit rates and Q-factor on link distance by varying transmitter and receiver aperture. The value of aperture diameters varies from 20 cm to 60 cm and further results are observed fot bit rate of 800 Mbps. The simulation results recommended that for lower bit rates and for large aperture diameters we can achieve a high value of Q factor.*

***Keywords:*** *Intersatellite links, OWC, Optical-satellite links, BER, Q-Factor*

## I. INTRODUCTION

Laser communication is now able to send information at data rates up to several Gbps and at distance of thousands of kilometres apart. This has open up the idea to adapt optical wireless communication technology into space technology; hence intersatellite optical wireless communication (IsOWC) is developed. IsOWC can be used to connect one satellite to another, whether the satellite is in the same orbit or in different orbits. With light travelling at 3 x 108 m/s, data can be sent without much delay and with minimum attenuation since the space is considered to be vacuum. 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 . 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 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.

Conventional communication between satellites and also to Earth is by using RF system. The problem with RF system is that there are many limitations in the systems, limitation that optical links can recover. Frequency is one of the many limitations of RF links as there are regulations and license to the frequency that can be used for satellite communications. The regulations are not applicable in optical link. Since optical link are able to transmit very high frequency which is up to 194THz for wavelength 1550nm, therefore it can support high data rate transmission . For intersatellite communications, signal need to travel thousands of kilometers from one satellite to another. If RF system is to be employed, the size of the transmitting and receiving antenna that is needed would be very big (about meters wide) and also heavy, compared to using optical link that would only need an optical antenna of several centimetres big. Reducing size and weight of the satellite's payload can reduce the cost of the satellite, which is what every satellite designer aims for.

## II. SYSTEM DESIGN

Several designs were built to obtain the optimum design for the IsOWC system. The first design consists of basic OWC communication system and is shown in Figure.1. The design was then improved by expanding the optical transmitter and receiver with specific subsystems. This is shown in Figure 2.

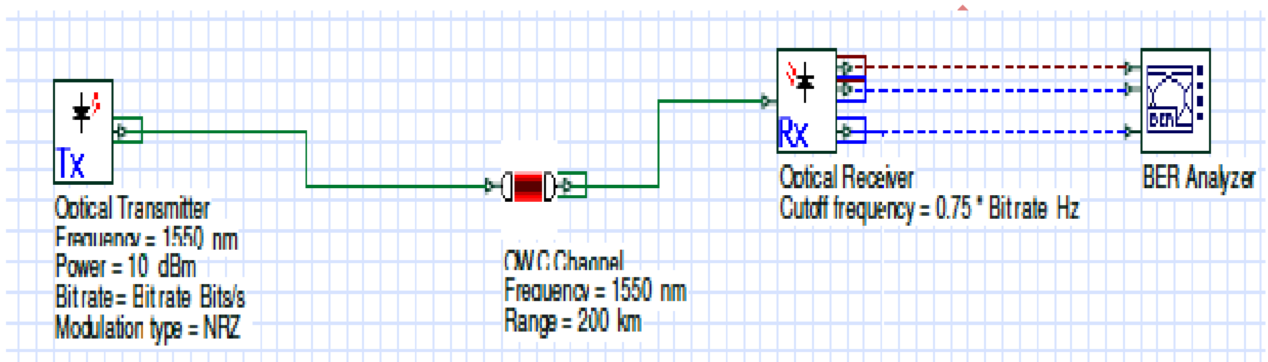


**Figure 1. IsOWC first design with basic subsystems**

In the design model shown, note that the model is for simplex system. Which means the model is for one way data transmission from one satellite to another. The full-duplex system model consists of two simplex systems. Hence it can be used for two way data transmission from one satellite to another and back. Figure 3 shows the final system model for full-duplex communication between two satellites.

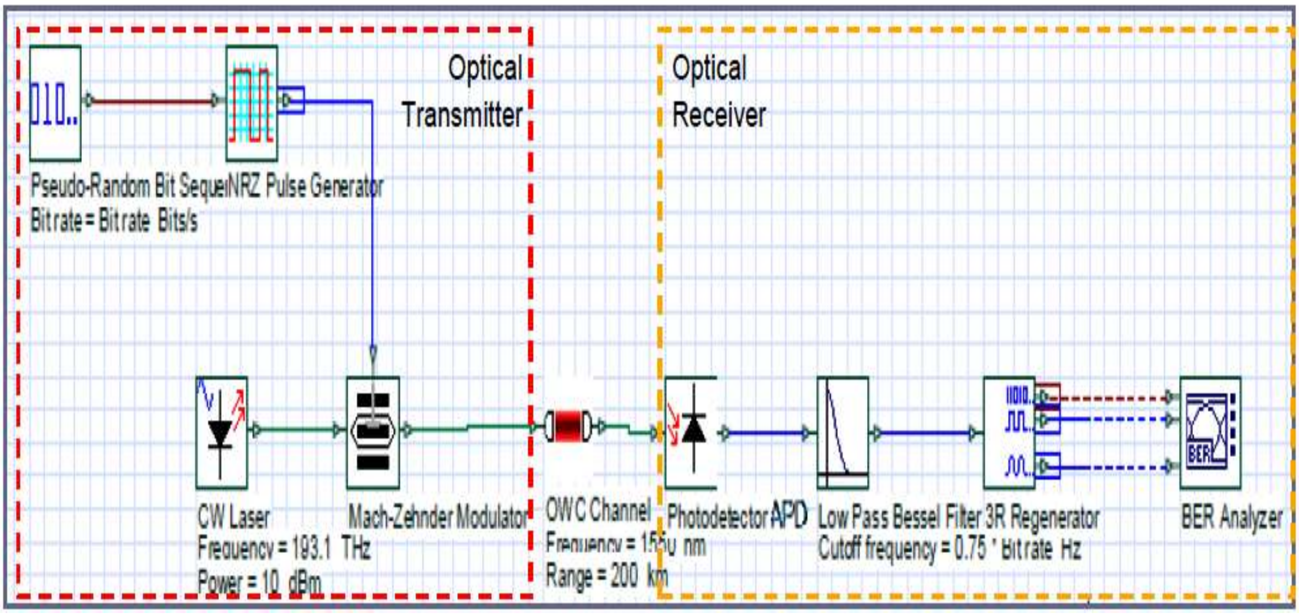


**Figure 2. IsOWC simplex design model**

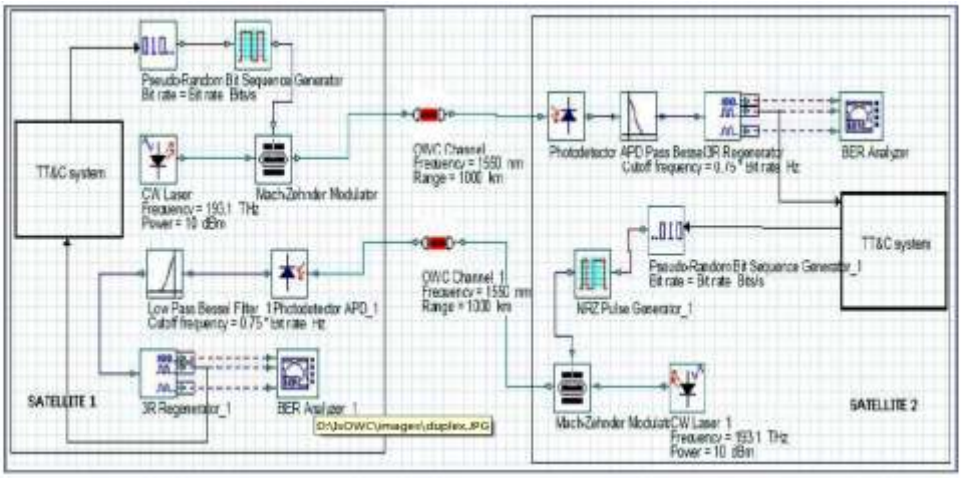


**Figure 3. Full-duplex communication between two satellites**

***i. IsOWC Transmitter Design***

The transmitter consists of four subsystems. The first subsystem is the pseudo-random bit sequence generator. This subsystem is to represent the information or data that wants to be transmitted. The data usually come from the satellite's TT&C system. In this project the bit rate is varied to observe the system performance and the relationship between bit rate and distance.

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. 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 un-modulated. 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 with input power of 10dBm.

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 input optical signal from the laser will split in to two and go through phase shifting process in the waveguides. Phase-shifting happens due to the electro-optic effect where the output electrical pulse from the NRZ pulse generator will vary the voltage hence varying the refractive indices of the waveguides. The output of the Mach-Zehnder modulator will be transmitted to the other satellite through the space of OWC channel.

**ii. 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 15cm optical antenna at each end. The transmitter and receiver gains are 0dB. The transmitter and receiver antennae are also assumed to be ideal where the optical efficiency is equal to 1 and there are no pointing errors. Additional losses from scintillation and mispointing are also assumed to be zero. Due to the altitude of the satellites that is above the Earth's atmospheric layers, there is no attenuation due to atmospheric effects.

**iii. IsOWC Receiver Design**

The receiver of the data consists of an APD 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



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which allows for the reduction of noisy external amplifiers in optical detection systems. Therefore, in this system model, no optical amplifier is needed. Apart from that, the APD photodiode is useful in low, weak or reduced light applications because of the avalanche phenomenon utilized by the device provides high amplification. Hence it is ideal to be used in this system 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 193.1THz.

## III. RESULTS:

Here we have taken transmitter and receiver aperture diameters of same values. The effect of both is studied by plotting two graphs, one for transmitter aperture and second for receiver's aperture. Fig.4. graph is plotted between Q factor and intersatellite distance with transmitter aperture diameter as a variable. Transmitter aperture diameters were set at four values which are 20 cm, 35 cm, 50 cm, 60 cm and the link distance was set from 500 km to 3000 km. We analyzed from graph that as we increase the aperture diameter, Q factor also increases for a fixed value of distance. But when we increase the distance our Q factor starts decreasing. Graph below shows the relationship between Q factor and link distance for multiple aperture diameters. It can be observed that aperture diameters are directly proportional to Q factor. Further investigation reports that for a fixed date rate and input power of 12 dbm, when we adjust our transmitter and receiver aperture diameters at 20 cm value for data rate of 800 Mbps we can obtain error free communication (BER < 10-9) up to a distance of 2000 km only. Then we set the value of aperture diameters at 35 cm and now distance comes out to be 6000 km, for 50 cm it comes 13000 km and for 60 cm the distance becomes 22,500 km. It is observed that as we increase the aperture diameters, Q factor increases and so our link distance. It is further investigated that for a fixed data rate, if we want to increase link distance we have to either increase the aperture diameters or transmitted power. For LEO to LEO intersatellite links we can achieve successful communication for aperture diameters having value of 35 cm for bit rate of 800 Mbps. For higher data rates we have to either increase aperture diameters or transmitted power.

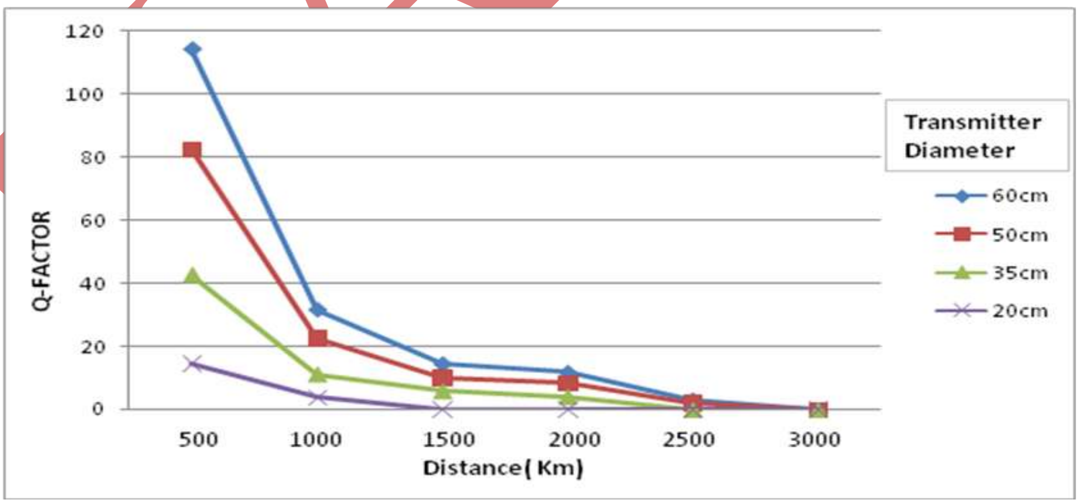


**Figure 4. Q-Factor vs distance for transmitter**

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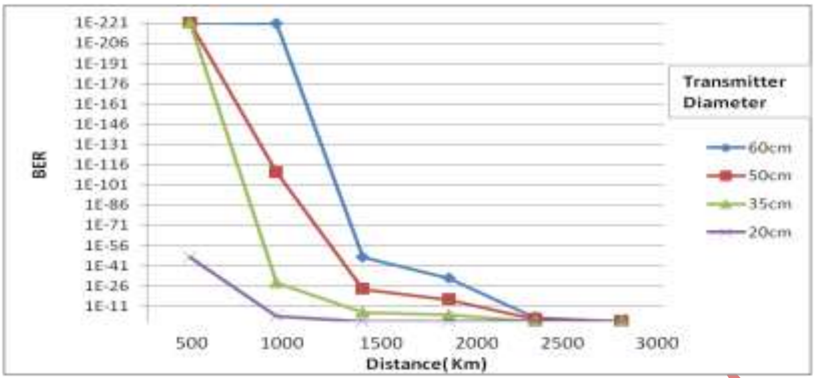


**Figure 5. BER vs distance for transmitter**

Second graph is plotted for receiver's aperture. In same way we set receiver aperture diameters at same four values which are 20 cm, 35 cm, 50 cm, 60 cm and link distance was set from 500 km to 5000 km. We get the graph as shown below.

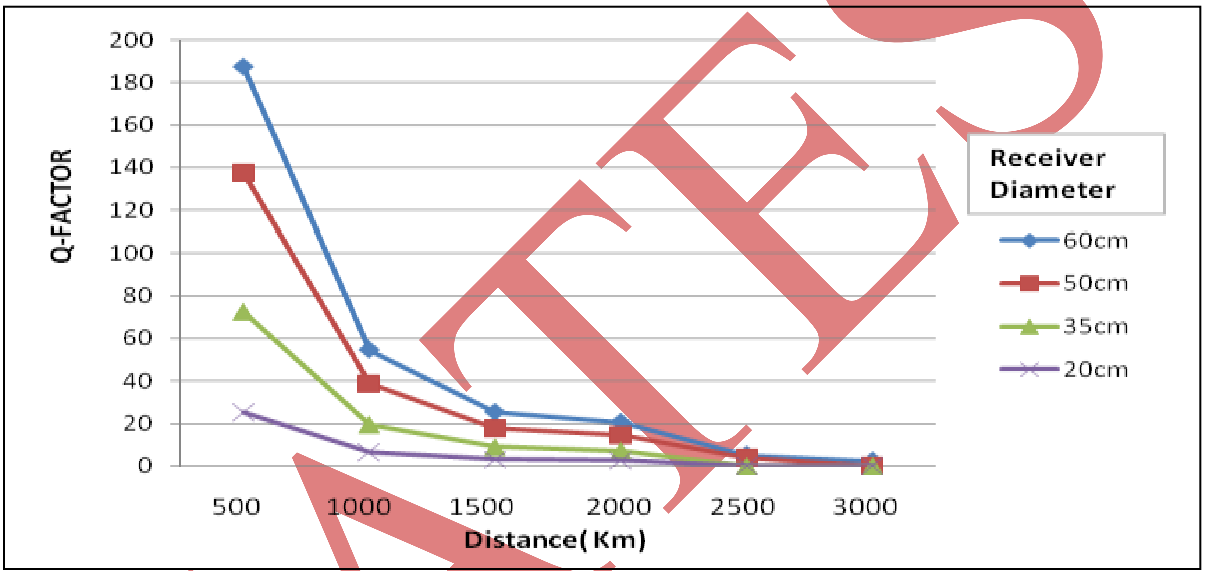


**Figure 6. Q-Factor vs distance for Reciever**

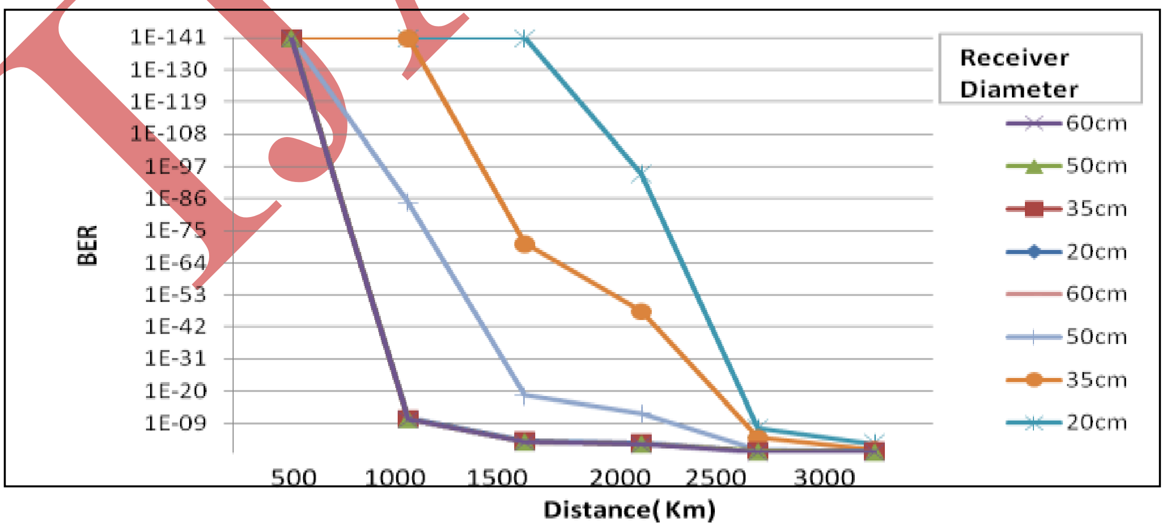


**Figure 7. BER vs distance for Reciever**

## IV. CONCLUSION

The results of the simulation for 8 channel IsOWC system model are presented and discussed. The system performance was analyzed when several parameters of the system characteristics are varied. The effect of bit rates on system performance is discussed. In this mode we investigates that to we achieve error-free communication (BER < 10-9) in our system for a bit rate of 8 Mbps we have link distance of intersatellite of 11,500 km and for 8 Gbps distance remains 2100 km only. From the IsOWC model and simulation results, it can be concluded that signals with smaller bit rate travel further than the one with higher bit rate. Next we analyzed the impact of transmitter and receiver apertures on link distance and on Q factor of our system. It is further investigated that for a bit rate of 800 Mbps as we increase the aperture diameters from 20 cm to 60 cm, the link distance varies from 2000 km to 22,500 km. For aperture diameter of 50 cm we can achieve error-free communication up to 22,500 km. As we increase our aperture diameters Q factor increases, but for a particular aperture diameter Q factor starts decreasing as we increase the link distance and bit rates.

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