Analysis and Mitigation of Receiver Pointing Error Angle on Inter-Satellite Communication

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Abstract— Inter-satellite communication is looked as one of the evolving technology in the field of data communication as it offers high speed and reliable data communication. This work concludes data transmission of 120Gbps on Inter-satellite optical wireless channel (Is-OWC) link over a 1000km by including WDM technique with polarization interleaving scheme under the effects of turbulence. The results obtained are shown in terms of total received power, signal to noise ratio (S/N) and eye diagrams which shows the successful data transmission of 20*6 Gbps data over 1000 Km.

Keywords- Inter-satellite optical wireless channel, WDM, polarization interleaving, SNR

I. INTRODUCTION

From lengthy strands of fiber to wireless transmission, optical communication had been evolved into amalgam of optical wireless communication to be used in satellite communication in space. As use of laser technology has extended reach of OWC to thousands of kilometers at high data rates thus Inter satellite communication came into being [1]. Is-OWC has offered many advantages over previous microwave system such as more bandwidth, small size, lesser power requirements as well as low cost [2]. Also laser has coherent beam width which means there are lower losses than RF. An Is-OWC system basically consist of two satellites which acts as transmitter and receiver and free space acts as channel for the light signal to travel through. Is-OWC technology is used to connect satellites orbiting in the same orbit as well as in different orbit with the prime requirement of highly accurate tracking system to ensure the satellites have maintained proper line of sight [3, 4]. First ever Is-OWC was achieved between Artemis and SPOT-4 on March 2003. Artemis was place as GEO satellite while SPOT 4 was LEO [5]. As demand for band width is never ending hence to meet the requirements, WDM had been incorporated with the Is-OWC system. WDM system revolutionized the whole communication system by enhancing the capacity of a system simply by narrowing channel spacing and increasing no. of channels without using more then on Is-OWC link. Hence making way for the use of WDM system in Is-OWC to enhance band width but in economical approach [6-8]. In examining Is-OWC performance, it is vital to include constraints like optical power, bandwidth, beam divergence angle and optical losses, BER, receiver sensitivity as well as turbulence effects. Turbulence in case of Is-OWC mainly consist of pointing error and scintillation. In this paper, we have transmitted 120 Gbps data grouped in 6 different channels with a capacity of 20Gbps each over Is-OWC link by using WDM-Polarization Interleaving Scheme. The performance of the designed systems is measured under the influence of pointing error over a transmission distance of 1000 Km. The rest of the paper is organized as follows: section 2 discusses channel model, System description is mentioned in section 3, and Results are discussed in section 4 followed by section 5 which gives the conclusion of this work.

II. IS-OWC CHANNEL MODE

To find the factors affecting quality of the link, it needs to calculate power at receiver and link margin. Link margin is ration between received power $P_R$ and receiver threshold or sensitivity (S) given in db as [9-11]

\[ \text{Link Margin} = 10 \log \frac{P_R}{S} \]  

(1)

For successful recovery of signal at receiver side, received power must be higher than receiver sensitivity. Received power at receiver can be expressed as:

\[ P_R = P_e * e^{\alpha L} * \frac{ARX}{(\theta L)^2} \]  

(2)

Where $P_e$ and $P_T$ are power at the receiver and transmitter respectively, ARX is receiver aperture area, $\theta$ divergence angle, $\alpha$ is atmospheric attenuation and L is distance between transmitter and receiver. It is clear from equation (2), received power is directly proportional to the transmitted power and receiver aperture area and inversely proportional to the divergence angle and link range. Effect of attenuation due to turbulence is maintained by exponential part and it has strongest impact upon quality of the link.

III. SYSTEM DESCRIPTION

The proposed Is-OWC system as shown in Fig. 1 is simulated in OptiSystem™ software. As given 120 Gbps non return to zero data divided into three even and three odd channels carrying 20 Gbps each
modulated over light source with the help of multiplexers.

![Diagram](image)

**Fig. 1 Proposed 120 Gbps Is-OWC system**

The output of these multiplexer is then fed to polarization controller which changes their azimuthal factor such that each adjacent channel is orthogonal to another. These polarized signal are then again multiplexed together in a single channel and then sent to the receiver through optical wireless channel (OWC). Optical wireless channel consists of transmitter and receiver antenna with aperture of 20 cm and 30 cm each. Losses due to pointing error of transmitter and receiver are examined for a range of 1000km. The polarization splitter is used at receiver side for splitting the received signal according to their state of polarization. Output of polarization splitter is then fed to de-multiplexer and then original message is received by photodiode. Bessel filter having cut off frequency of 15 GHz is used at receiver to reduce losses.

![Graph](image)

**Fig. 2 (a) Optical spectrum at Channel, (b) After 1000 Km of SMF**

### IV. RESULTS AND DISCUSSIONS

In this section, results of proposed simulated setup of WDM-PI based Is-OWC system are presented and discussed. The impact of receiver pointing error angle on the SNR and the total power received at the photo detector for channels 1 to 6 at different operating wavelength of OWC channel is illustrated in Figure 3. It has been noticed that as the receiver pointing error angle reaches 3 μrad both the SNR and the total received power has degraded for each of the channels operated at different wavelengths i.e. at 1550nm and 850nm. However, the OWC channel operated at 1550 nm has acceptable SNR and total received power when the receiver pointing error is fixed to 3 μrad.
Similarly the eye diagrams for channels 1 to 6 after the reception of 1000 km is reported in the Figure 4. It has depicted from the figure that for the receiving pointing error of 3 µrad, the eye diagrams are distorted with high bit error rate when the OWC channel is operated at 1550 nm.

Figure 3: Total Received Power and SNR Vs Receiver Pointing Error for (a & b) Channel 1 & 2, (c & d) Channel 3 & 4, (e & f) Channel 5 & 6

Fig. 4 (a & b): For Channel 1 at 1 µrad and at 3 µrad

Fig. 4 (c & d): For channel 2 at 1 µrad and at 3 µrad
Figure 4 illustrates the eye diagram for the channels 1 to 6 operating at different wavelengths for the receiver pointing error at 3 µrad.

V. CONCLUSION

In this paper, we examined and calculated a high speed hybrid WDM-PI-Is-OWC system which is proficient of transmitting the 120 Gbps over inter-satellite optical link of 1000 Km between two satellites under turbulences of receiver pointing error angle. The impact of turbulence increases with the increase in the value of the receiver pointing error angle parameters. From our results, it is concluded that the proposed WDM-PI scheme is beneficial for designing the Inter-Satellite communication system by considering the transmitting and receiving pointing errors. It is presumed that under receiving pointing errors, the OWC link performs better operating at 1550 nm.
with acceptable SNR, BER and total received power.

VI. REFERENCES


