Ultra High Capacity Wavelength Division Multiplexed Optical Wireless Communication System

[1]Meenakshi, [2]Gurinder Singh

[1]Student, [2]Assistant Professor
[1]Electronics and communication,
[1]Ludhiana College of engineering and technology, India

Abstract : In this research work, a 128 × 40 Gb/s WDM system is demonstrated at ultra dense spacing (25 GHz) among adjacent channels to realize a bandwidth efficient system. Different antenna sizes of transmitter and receiver antenna are investigated in the system. Investigation is also carried out on different pointing errors such as 1 micro rad, 2 micro rad and 3 micro rad. Further, a comparison of different atmospheric condition such as air and vacuum are analyzed in proposed system.

***IndexTerms* - WDM, FSO, OWC, Pointing errors, attenuation.**

I. INTRODUCTION

Optical wireless communication systems are based on the use of lasers as a carriers. Optical wireless communication is considered to be the key technologies for realizing an ultra-high speed and large capacity aerospace communication [1]. Laser satellite communication is extremely sensitive to the mechanical vibrational impacts and electronic noise in the control system, which leads to the misalignment between transmitter laser beam and the receiver field. This results in pointing errors and impaired link performance. That is why the system is analyzed with the optical pre-amplifier by realizing the pre-amplifier characteristics and communication parameters. Several works had represented their models and numerical calculations for random pointing errors for optical amplifiers and noise figures [2]. In order to transmit information over a longer transmission range in IsOWC, amplification is recommended. For amplification EDFA plays a vital role in space laser communication. EDFA introduces small noises to the communication system which are unresponsive to the polarization of the optical signal [3]. In DWDM system, non-linear effects degrade the system's performance. The non-linear impacts have a propensity to show themselves when channel spacing is low and data rates are high as in case of DWDM systems [4].

Today the most common type of optical communication systems are using optical medium that can reach even beyond 1 Terabit/s capacity and this is all because of dense wavelength division multiplexing (DWDM) [5]. DWDM is basically wavelength division multiplexing (WDM) with small channel spacing, where different optical frequencies are used in order to achieve simultaneous transmission of a definite number of optical channels over the transmission medium [6]. In modern inter-satellite optical wireless communication systems the role of transmitter/receiver aperture, beam divergence, attenuation and pointing errors is really significant for better system performance. In order to design a high speed and high capacity WDM-IsOWC system, aforementioned parameters are important to investigate.

II. SYSTEM SETUP

Figure 1 depicts the proposed architecture of 128 channel DWDM system over optical wireless channel with non-coherent detection and polarization diversity. In this research article, a 128 × 40 Gb/s WDM system is demonstrated at ultra dense spacing (25GHz) among adjacent channels to realize a bandwidth efficient system. A continuous wave laser array signals with starting frequency 193.1 THz is used. A system is realized at 40 Gb/s data rate for different polarizations at 25 GHz dense spacing in WDM system. Mainly, the regions that affect or influence the transmitting beams are troposphere and ionosphere. Reach of troposphere is 10 Km-15 Km with respect to ground and ionosphere spreads up to 60 Km -1000 Km. The influence of atmospheric instabilities is less till the height of 2 Km on free space communication channel. All the work is considered for clear weather and attenuation corresponding to it is fixed as 0.14 dB/Km. DWDM system over optical wireless channel is analyzed for with and without polarization diversity in terms of Q-factor and bit error rate (BER). First and foremost, a loop length that consists of EDFA-OWC-EDFA is varied and Q factor is observed at 250 Km - 1250 Km. An effect of geometrical losses such as size of transmitter and receiver antenna is an important factor to analyze. It is interesting to investigate the system for different sizes of antenna sizes. Moreover, pointing errors are also major degrading issue of performance and also need to be investigated. Different atmospheric condition affects the lower atmosphere, thus change the attenuation of system. Thus, attenuation for different values is also important to study in proposed system. An optical wireless channel with 250 Km link reach is considered for each loop and total loops are set to 5 to get 1250 Km distance. A 1:128 demultiplexer route the specific frequency to their respective output port with the help of reference frequency and filtering of Gaussian filter. Receiver section consisting of optical couplers with coupling ratio of 50:50 and divide signal for two pairs of photo detectors that receives drive from time delay and phase shift to input signal. A p-i-n photodetector with 100% responsivity and 10 nA dark current are placed in the receiver by considering shot, thermal and ASE

(Amplified spontaneous emission) distortions. Electrical bias is provided to electrically subtracted output of balanced photodetectors followed by 3-R regenerator.

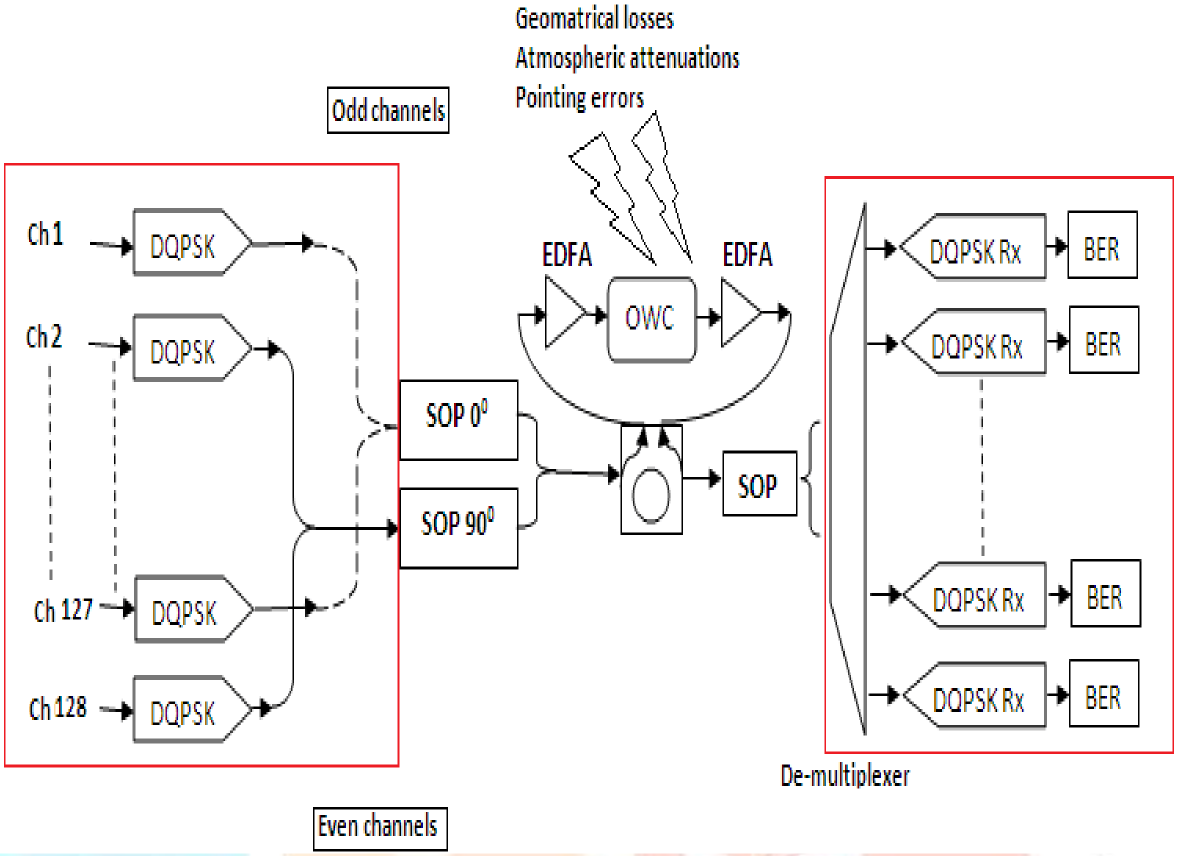

Figure 1 A 128 × 40 Gbps UDWDM- IsOWC proposed system

A 3-R regenerator employed for re-sampling, re-shaping and re-amplification of the received data. Bit error rate analyzer is decision making component which calculate the final received quality factor, bit error rate (BER) and signal to noise ratio (SNR) of the received signals.

III. RESULTS AND DISCUSSIONS

Proposed system is investigated with different parameters of antenna, pointing errors and attenuations. Figure 2 depicts the performance of 128 WDM channels system at 25 GHz frequency spacing for different diameters of transmitter and receiver antenna of IsOWC channel. Analysis has been carried out at different link lengths such as 250 km, 500 km, 750 km, 1000 km and 1250 km. Losses due to diameters of IsOWC transmitter and receiver aperture are considered as geometrical losses. It plays a noteworthy role in the satellite design and transmission to longer distances. It is evident that enhancement of link length cause Q factor degradation. However, our major emphasis is to evaluate different geometrical antenna diameters.

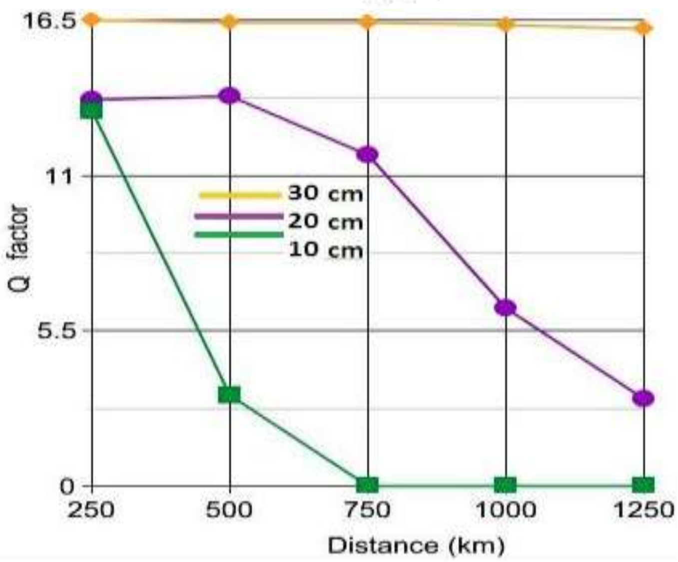

Figure 2 Q factor versus distance for different transmitter/receiver antenna aperture diameters

Transmitter and receiver antenna diameters are considered such as 10 cm, 20 cm and 30 cm to evaluate the effect on the transmission. It is observed that as the diameter of the antenna increases, Q factor of the system also increases. So it is seen that to cover larger distances, we need larger diameter of IsOWC channel. However, larger size of the antenna makes satellite bulky and heavy with also adding extra cost. So, cost of antenna size is also main concentration in inter-satellite system design.

Figure 3 illustrates the bit error rate (BER) for the different diameters of transmitter and receiver antennas.

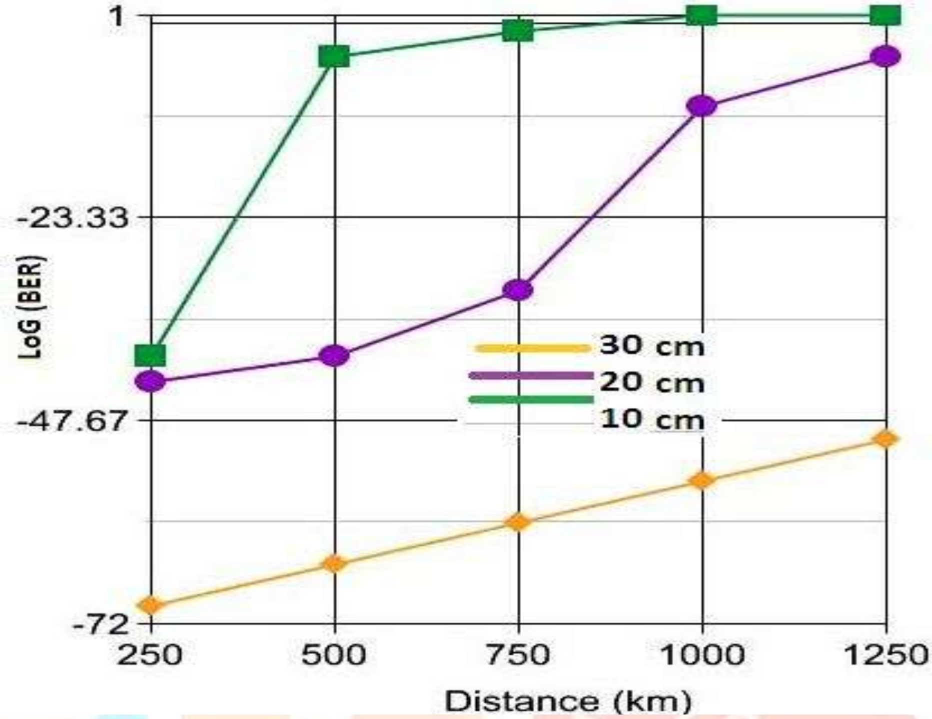

Figure 3 LoG (BER) versus distance for different antenna diameters

Diameters are same as 10 cm, 20 cm and 30 cm and performance is checked on these parameters in terms of BER. There is significant increase in BER with distance and maximum BER observed in case of 10 cm antenna diameter.
In further investigation, the analysis has been done on the pointing errors in the system. Pointing errors are the major performance degrading issue in inter satellite optical wireless systems. Investigation of this issue is important to study in proposed work and we hence considered different values of pointing errors such as 1 micro rad, 2 micro rad and 3 micro rad for transmitter and receiver as shown in Figure 4.

It is clear from the results that as the errors in the pointing or problem in line of sight connections increases, Q decreases significantly. From the investigation, it is evident that maximum Q factor is obtained at 1 micro rad pointing errors. So, in order to design a long reach IsOWC system, pointing errors should be as low as possible.

Figure 4 Representation of Q factor with distance at different pointing errors of Tx/Rx

Figure 5 represents the BER of the proposed system setup at different link lengths for 1 micro rad, 2 micro rad and 3 micro rad pointing errors of transmitter and receiver. It follows the inverse performance as seen in the Figure 4. It is due to the fact that BER is inversely proportional to Q factor. At maximum value of Q, BER is minimum. BER increases as the distance increases due to the attenuation and dispersion effects. Moreover, the pointing errors are here, major performance deciding factor. Minimum BER is obtained for 1 micro rad.

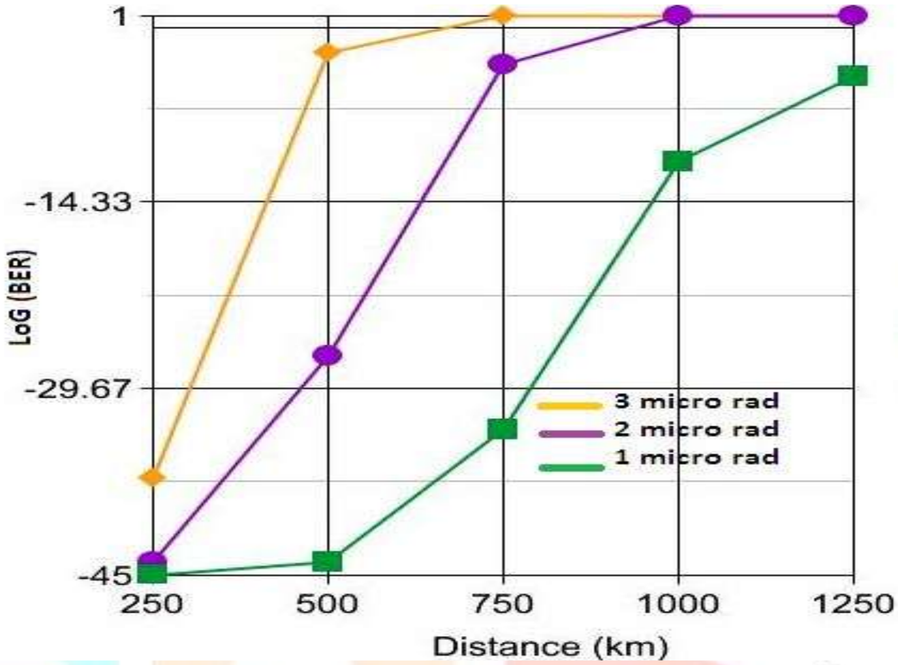

Figure 5 Graphical representation of LoG (BER) versus distance for different pointing errors of Tx/Rx

Also, a comparison is made for different attenuations in IsOWC systems for the evaluation of proposed system. There are two attenuations are considered such as 0 dB/km and 0.14 dB/km. 0 dB/km or lose less system is considered for the vacuum, where signal has no obstruction in the transmission medium. Second case is for lower layers of atmosphere which contributes in attenuation of the signal. Figure 6 depicts the LoG (BER) versus distance for vacuum and air attenuations in IsOWC system and attenuation value of vacuum is taken as 0 dB/km and for air is 0.14 dB/km. Results reveals that, in lose less medium, signal travels to longer distances. Less BER is reported for this case and as the air comes in the way of signal in lower earth layers, attenuation takes place. This results into the signal degradation and provide less Q factor and more BER. As shown in the Figure 6, the LoG (BER) curve for air is followed by vacuum and depicts that in case of air, results are better.

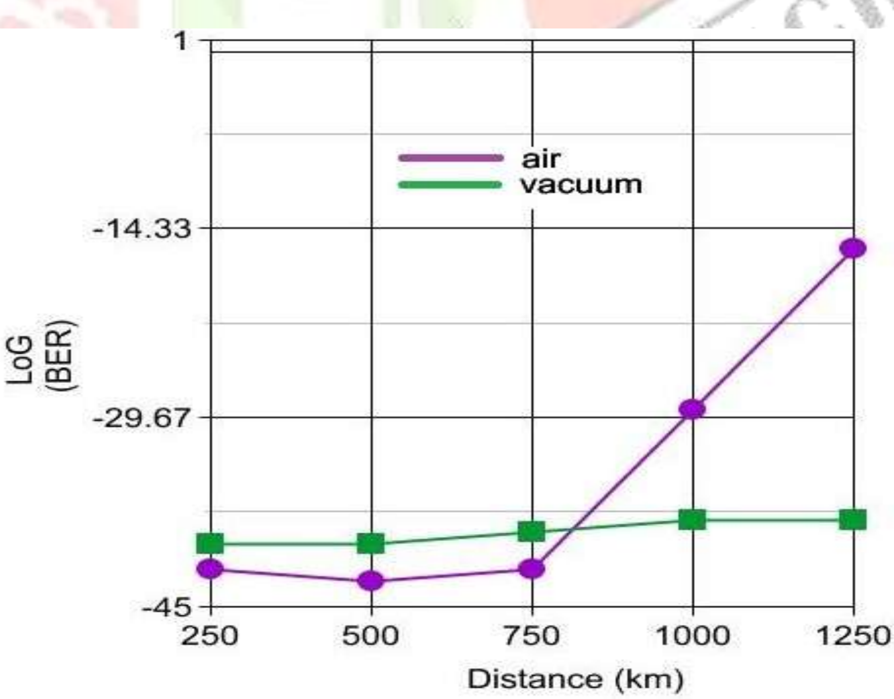

Figure 6 LoG (BER) versus distance for vacuum and air attenuations in IsOWC system

Figure 7 depicts Q factor versus distance for air and vacuum in IsOWC system. Results reveal that maximum Q factor is obtained for air. Thus results are better in case of air.

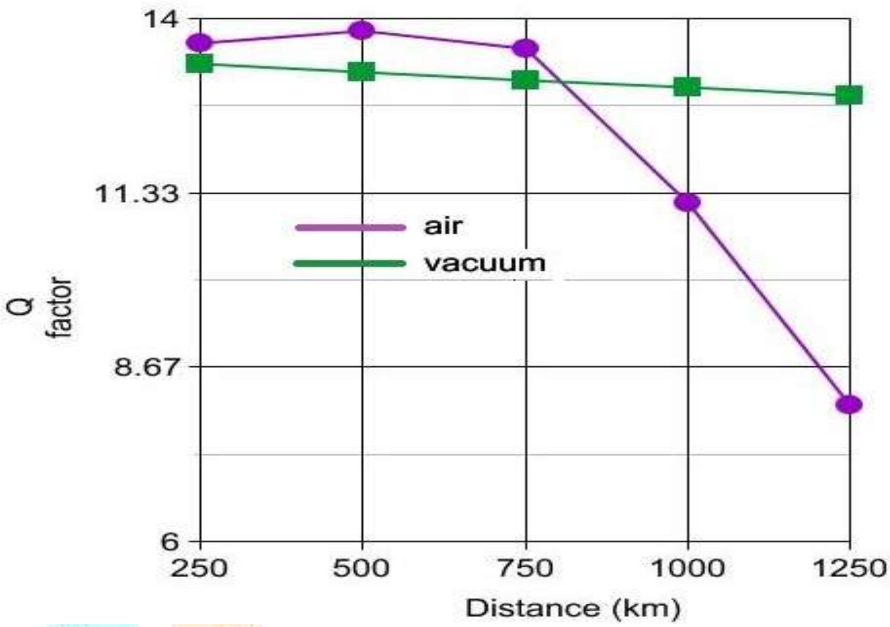

Figure 7 Q factor versus distance for vacuum and air attenuations in IsOWC system

IV. CONCLUSION

In this work, a proposed architecture of 128 channel DWDM system over optical wireless channel with non-coherent detection and polarization diversity is presented. In this research article, a 128 × 40 Gb/s WDM system is demonstrated at ultra dense spacing (25 GHz) among adjacent channels to realize a bandwidth efficient system. Different antenna sizes of transmitter and receiver antenna are investigated in the system and it is observed that at larger diameters of antenna, better Q factor and improved BER is obtained. Line of sight is an important directional connection and vibration and pointing variation in LOS cause pointing errors. Investigation is also carried out on 1 micro rad, 2 micro rad and 3 micro rad, it is seen that high Q factor is emerged for low pointing error and also improved at less errors. Further, comparison of air and vacuum is done and results are best at vacuum conditions.

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