MATEC Web of Conferences **57**, 01023 (2016) DOI: 10.1051/matecconf/20165701023
ICAET-2016

Investigations on 16x16 multiple Tx/Rx in IsOWC using IM/DD and CO-QPSK schemes

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Abstract. The intersatellite optical wireless communication (IsOWC) is used because higher data rates for longer distances can be achieved with minimum time delay. The analysis of 16x16 multiple Tx/Rx system using IM/DD and CO-QPSK techniques is done and from simulations, it is observed that maximum achievable distance of IsOWC link is a function of bit rates. For the transmission of data at longer distances, data rates should be low. The results of simulation for comparison between the two techniques in ISOWC system model are presented and discussed.

1 Introduction

The IsOWC is the line-of-sight technology that transmits a light beam through atmosphere for broadband communications [1]. Free-space optical communication between satellites networked together can make possible high-speed communication between different places on earth [2]. The information is transmitted with light as a carrier wave. A narrow beam of light which carries the information signal is launched at transmitter station, transmitted through the atmosphere and subsequently received at the receive station[3][4]. Hence, the clear line-of-sight between both transmitter and receiver terminals is essential to establish a seamless communication [5]. The Intersatellite links has many advantages as comparing to the microwave links, such as (i) higher bandwidth (ii) lower transmission power (iii) small antenna size (iv) less weight (v) higher immunity to interference and (vi) security of signals etc. All of these reasons are vital for a satellite communication system, because it can reduce the payloads and consequently reduces the cost [6-8]. Many alternatives are proposed by researchers to improve the IsOWC link performances. Some of the techniques are multiple transmitted beams or multiple receivers, aperture averaging, adaptive optics and MIMO. Multiple Tx/Rx are used to improve quality of IsOWC system [4] [8]. In 2010, Hashim et el. Proved that among all ON-OFF keying techniques, non-return to zero (NRZ) is the best technique for obtaining maximum coverage distance in IsOWC system [3]. In 2010, Sodnik et el. used the BPSK modulation technique for IsOWC system [13]. Patnaik et el. (2012) used CO-QPSK technique; as its spectral efficiency is double that of BPSK technique [9]. Kuldeepak et el. (2012) Investigated high capacity IsOWC link by integrating WDM technology, and achieved a distance of 2100 km with a bit rate of 8 Gbps using IM/DD technique [5]. In 2013, Patnaik et el. Designed and simulate the FSO model by employing QPSK modulation scheme with line-of-sight and diffused link setup. They have also simulate the system for 1.25 Gbps, 2.5 Gbps, 10 Gbps, 40 Gbps nd 100 Gbps with free space attenuation of 200 dB/km [10]. Hence we have designed and simulated two IsOWC systems having 16x16 multiple Tx/Rx using CO-QPSK and IM/DD modulation techniques. The observations were made using comparison analysis between the two techniques. Quality factor, bit rate and transmission distance are the parameters used to determine IsOWC link performance. The relationship between these parameters are compared and analyzed.

2 ISOWC model design

16x16 Multiple Tx/Rx System- Figure 1 shows the layout model for 16Tx and 16Rx combinations employing IM/DD Technique. The frequency of transmitter is set to 193THz or 1550 nm in wavelength and power is 12 dBm. The output of transmitter is connected to fork which is used to duplicate number of output ports. Each signal coming out from the fork's output has same value as output signal from previous component. Each fork connected to the transmitter will produce multiple laser beams from one source. Then, each output signal will be connected to another set of forks to produce another set of multiple laser beams which are combined by a power combiner. The output signals from power combiners are then sent to OWC channel which is the reproduction of free space channel. The OWC has two telescopes with apertures of 15cm. All multiple signals from OWC channel are combined using the power combiner before received by the receiver. The receiver consists of photo detector, LPF and visualizers.

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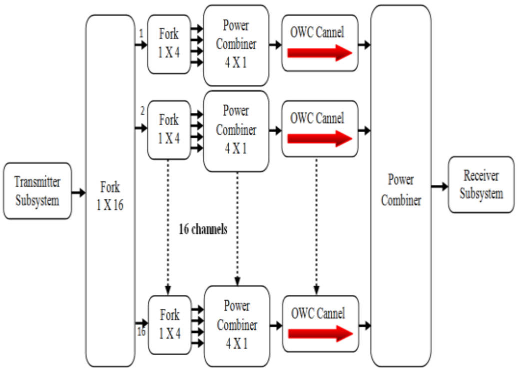

Figure 1. Block diagram of 16x16 multiple Tx/Rx system for IsOWC link.

16x16 Multiple Tx/Rx System- It consists of PSK sequence generator, which generates the in-phase (I) and quadrature signals (Q) as given in equations respectively. The output of the PSK sequence generator is given to the M-array pulse generator, where M = 4. The number of bits per symbol considered here is two. Optical signal is fed to the MZ modulator by using a coupler. Both I and Q signals is combined using an optical power combiner.

$$Ii = \cos(\Phi)$$
$$Qi = \cos(\Phi)$$

Where,

$\Phi i = 2\pi(i-1)/M$ i= 1,2,3,4 and M=4 [7]

The output signals from power combiners are then sent to the OWC channel which is the reproduction of the free space channel. The OWC channel has two telescopes with aperture diameter of 15cm. All the multiple signals from OWC channel are combined using the power combiner before received by the receiver. Then receiver detects optical QPSK Modulated signal and demodulates it into original signal using photo detector and a local oscillator (laser). It uses a balanced-detection technique and produces the information signal in electrical domain. Then electrical signal is amplified, filtered using a LPF filter and given to M-array threshold detector. Then signal is fed to PSK decoder that is used to convert the values of I and Q to the equivalent binary sequence. Hence, fresh 0's and 1's are reproduced.

3 Simulations results for 16X16 multiple Tx/Rx system

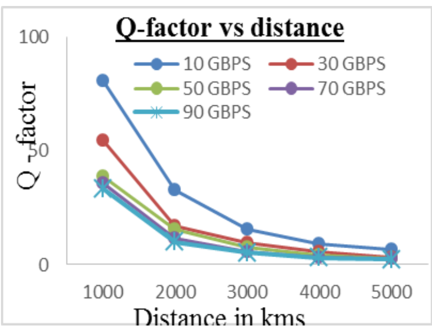

Figure 2. Relationship between Q-factor and link distance at different bit rate

The Q-factor of IsOWC system is obtained by varying the link distance for different bit rates. The link distance of the system is varies from 1000 km to 5000 km and the bit rate of each channel is varied from 10 Gbps to 90 Gbps respectively as variation in the link distance. The input power is maintained at 12 dBm and the aperture diameter of transmitter and receiver antennae are set at 15cm. The figure 2 shows relationship between Q factor and link distance at different bit rates.

The maximum possible link distance between two satellites is analyzed to achieve error-free communication (BER<10^{-9}) in our system. For bit rate of 30 Mbps maximum communication distance calculated is 22,500 km. Increase in link distance beyond this value increases BER of the system. It was also observed that as we increase the bit rates the link distance decreases. The bit rate is inversely proportional to link distance. The values for different bit rates at link distance between satellites and the value of Q-factor with minimum BER are obtained and shown in table 1.

The analysis of system performance can be shown by eye diagrams. The significance of a wider eye opening is that it will reduce the potential occurrence for data errors, the wider the eye opening, the better the system performance. Figure 3 & figure 4 shows the eye diagrams at 30 Mbps and 90 Gbps respectively.

The IsOWC link distance is varies for different bit rates and the value of Q-Factor is obtained. The link distance varies from 5000 km to 40000 km and the bit rate is varied from 10 Gbps to 90 Gbps respectively as variation in the link distance. The input power is maintained at 12 dBm and the aperture diameter of transmitter and receiver antennae are set at 15 cm.

Table 1. Table for maximum distance achievable at different bit rates with q-factor and minimum ber of 16x16 multiple tx/rx im/dd technique.

Sr. No.	Bit Rate	Link Distance	Q-factor	Min BER
1	90 Gbps	2810 km	5.70	5.67×10^{-9}
2	30 Gbps	4000 km	5.62	9.30×10^{-9}
3	1 Gbps	9250 km	5.95	1.33×10^{-9}
4	500 Mbps	11,250 km	5.64	8.10×10^{-9}
5	30 Mbps	22,500 km	5.67	7.10×10^{-9}

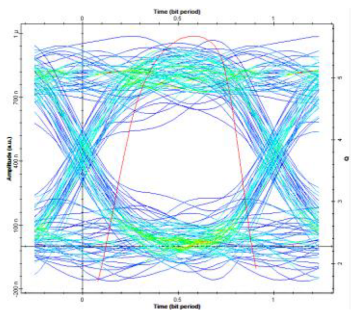

Figure 3. Eye diagram obtained at link distance 22500 km with bit rate of 30 Mbps

 DOI: 10.1051/matecconf/20165701023

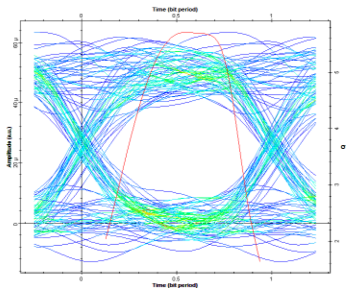

Figure 4. Eye diagram obtained at link distance 2810 km with bit rate of 90 Gbps

The figure 5 shows relationship between Q factor and link distance at different bit rates.At bit rate of 40 Gbps maximum communication distance calculated is 42,500 km. Any increase in link distance beyond this value causes BER to increase. The values for different bit rates at link distance between satellites and the value of Q factor with minimum BER are obtained and shown in table 2.

The electrical constellation diagram shows the performance of the system. The quadrature-phase and in-phase signals are shown through the constellation diagram. The distortion and interference of the signals can be evaluated and measured. Figure 6 &figure 7 shows the constellation diagram at bit rate 10 Gbps and 90 Gbps respectively.

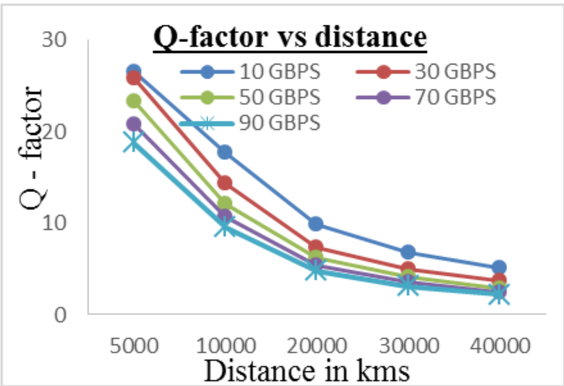

Figure 5. Relationship between Q-factor and link distance at different bit rate

Table 2. table for maximum distance achievable at different bit rates with q-factor and minimum ber of 16x16 multiple tx/rx co-qpsk technique.

Sr. No.	Bit Rate	Link Distance	Q-factor	Min BER
1	90 Gbps	15,000 km	6.42	0.13×10^{-9}
2	70 Gbps	18,000 km	5.98	2.18×10^{-9}
3	50 Gbps	20,000 km	6.03	1.57×10^{-9}
4	30 Gbps	28,000 km	5.34	8.81×10^{-9}
5	10 Gbps	35,000 km	5.57	5.63×10^{-9}

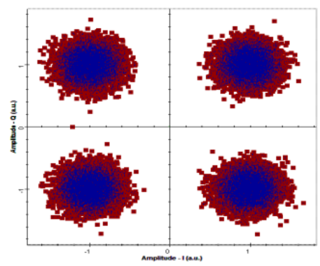

Figure 6. Constellation diagram obtained at link distance 35000 km with bit rate of 10 Gbps

The above analysis shows the comparison between the two techniques used in IsOWC link employing 16x16 multiple Tx/Rx technique.

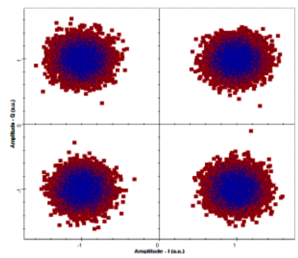

Figure 7. Constellation diagram obtained at link distance 15000 km with bit rate of 90 Gbps

It is observed from the simulation results that, link distance and bit rate of the system can be improved by using CO-QPSK scheme in comparison with IM/DD scheme. The maximum achievable distance by using IM/DD scheme is 22,500 km with the bit rate of 30 Mbps whereas a link distance of 35000 km with the bit rate of 10 Gbps is achieved using Coherent Optical QPSK scheme with a bit error rate of 7.10×10^{-9} and 5.63×10^{-9} respectively.

4 Conclusion

The analysis is done for 16x16 Multiple Tx/Rx and using IM/DD technique and CO-QPSK technique for IsOWC system. From simulations, it is observed that maximum achievable distance of IsOWC link is a function of bit rates. The optical signal with lower bit rate can be used for further distance between satellites since the system performance is better at lower bit rates. It is also observed that by using CO-QPSK technique the achieved bit rates and link distance are more than as compared with IM/DD technique. It is analyzed that the system has better performance by using CO-QPSK technique as compared with IM/DD technique. The system provides longer distance and high data rates for intersatellite communication.

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