Multiple Transceivers Inter-satellite Optical wireless communication System Performance

Abd El–Naser Mohamed
Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia University, Egypt.

Ahmed Rashed
Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia University, Egypt.

Eman El-gammal
Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia University, Egypt.

Ehab. S. Hashim
Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia University, Egypt.

Abstract

This Study clarifies the effect of using multi transceiver channel in the inter-satellite optical wireless communication system. The results obtained in this research have been simulated by optisystem version 7. This study clarifies the impact of applying 16 transceiver on the system performance. Also, it represents comparison between inter-satellite optical wireless communication system using single channel and the other used 16 transceiver at different wavelengths. Then, it clarifies the impact of increasing transmission data rate on the system performance at different propagation distances for 16 transceiver system. The impact of transmitted power on the system performance also has been explained. The performance parameters in our study are quality factor and received power.

1. *Introduction*

Optical wireless communication (OWC) is one of the most leading implementation depends on laser. OWC has many advantages over than radio frequency link such as its ability to send high speed data rate to thousands of kilometers with small pay load and that reduce the cost. The wavelength of RF is longer than it in laser so the beam width result from laser is narrower than beam width result from laser. Loss result from OWC is small compared to loss in case of RF link. In IsOWC communication occurs between satellite and another whether in the same orbit or in different orbit [1-4].

Satellite has been categorized into three orbits. The first orbit is low earth orbit (LEO), which ranges from 1000 to 5000 km above the earth, it takes approximately 2 hours for a full orbit. Due to the proximity to Earth, LEO satellites request less amplification for transmission. The second orbit is medium earth orbit (MEO) which is existing between LEO and GEO satellites and its altitude to the earth ranges from 5000 to 20000 km. It takes approximately 4 hours for a full orbit. This satellite is used for shipping systems and also used for voice and data communications. The third orbit is geostationary earth orbit (GEO) which its altitude to the earth is 36000 km. It takes approximately 24 hours for a full orbit. In IsOWC data signal must be encoding because signal encoding has many advantages such as saving bandwidth, and error correction. Also encoding data protect it from visibility to any one not sharing on the network [5-8]. In IsOWC systems light signal in satellite transmitter is modulated according to signal produced by pulse generator and transmitted through optical wireless channel to another satellite receiver. There are different methods and techniques can be used in IsOWC to improve the system performance [9-13]. In this paper, transmission between two satellites is in low earth orbit (LEO) and the medium is considered a vacuum. There are many parameters affect the system performance such as wavelength, bit rate and distance. By increasing wavelength, bit rate and distance the system performance decreases. By increasing number of transceiver, the system performance improves.

2. Simulation of 16 transceiver IsOWC System Model.

OWC consists of transmitter, channel which represents transmission medium and receiver. This model consists of 16 transceiver. Transmitter consists of pseudo random bit sequence generator, which generate the data signal. The generated data signal has been encoded by NRZ pulse generated. Then optical signal generated from light source is modulated by MZ modulator according to encoded signal out from NRZ pulse generated. The optical modulated signal has been splitted to 16 signal using splitter. Power combiner used to combine the splitted signals from each splitter and send them over OWC channels which represent the propagating medium for transmitted signals. The 16 received optical signals have combined to one signal by power combiner and then, the combined received signal has converted to electrical signal by avalanche photo diode. Then, electrical signal is filtered by using low pass Bessel filter. The 3R regenerator uses for retiming, regeneration, reshaping.

3. Simulation Results and Discussions

The operating parameters used in this paper are the following, operating wavelength is 1550 nm, antenna diameter 25 cm and transmitted power is 12 dBm [1], and propagation distance ranges from 1000 to 5000 km. Vacuum is assumed to be the medium between transmitter and receiver. Propagation has occurred in line of sight. Low pass Bessel filter has frequency equal 0.75x bit rate and its order is 4. This paper studies the impact of applying 16 transceiver on the system performance. The quality factor is a parameter that describes the resonance behavior of the system.

Section 1 represents the comparison between system performance of 16 TX/RX IsOWC system and simple IsOWC system [1] at propagation distance ranges from 500 km to 2500 km and transmission data rate is 80 Mb/s [1]. Section 2 represents the system performance of simple and 16 TX/RX IsOWC system at wavelengths 850 nm, 950 nm, 1310 nm and 1550nm, transmission data rate is 80 Mb/s, transmitted power is 12 dBm and propagation distance is 1000 km. Section 3 represents the relation between quality factor and transmission data rate at different propagation distances. Section 4 represents the impact of transmitted power on system performance at propagation distance 5000 km.

3.1 Comparison between system performance for 16 TX/RX IsOWC system and simple IsOWCsystem[1].

Fig. 2 shows the relation between received power and propagation distance for Simple IsOWC system and 16 TX/RX IsOWCsystem. It is observed that by increasing propagation distance, the received power decreases.The system performance improved by applying 16 TX/RX on the system. For example, the received power at distance 1000 km for proposed model is -23.6 dBmbut in case of reference model [1] is -59.6. So the obtained received power in case of applying 16 TX/RX is better than it in simple model [1]. The results in fig. 1 is shown in Table 1.

3.2 The system performance of 16 TX/RX and simple IsOWC system at different values of wavelengths.

Figures (3-6) show the eye diagram of the IsOWC system for one transceiver and 16 TX/RX at different wavelengths. It is observed that by increasing wavelength the system performance decreases. The system performance at wavelength 850 nm in both systems is better than system performance at 950nm, 1310 nm and 1550 nm. It is shown that the quality factor for 16 TX/RX system at wavelength 850 nm is 6396.5 quality factor at wavelength 1550 nm is 3798.4. The system performance for 16 TX/RX system at all wavelengths is better than it for simple model system [1]. For example in fig. 3.the quality factor for 16 TX/RX at wavelength 850 nm is 6396.5 and quality factor for simple model [1] is 562.6. The difference between two cases is too large and that illustrated in table. 2.

3.3 Relation between signal quality and transmission data rate at different distances.

Fig. 7 shows the relation between quality factor and transmission data rate at different values of propagation distances ranges from 1000 km to 5000 km and wavelength is 1550 nm. It is observed that increasing transmission data rate leads to decreasing quality factor. Transmission data rate ranges from 20 Gb/s to 100 Gb/s. The best system performance is obtained at propagation distance 1000 km. The least quality factor has obtained for all used transmission data rate is at propagation distance 5000 km. Increasing propagation distance leads to decreasing. Table.3 shows the results which has simulated at fig. 7.

3.4 Relation between signal quality and transmitted power.

Fig. 8 clarifies the impact of increasing transmitted power on the system performance at propagation distance 5000 km and transmission data rate 200 Gb/s. The transmitted power is chosen in range from 10 dBm to 25 dBm. By increasing transmitted power, quality factor increases. At transmitted power 25 dBm the quality factor 68.3. If the transmission data rate in this case increases than 200 Gb/s, the quality factor at transmitted power 10 dBm will be very small and the signal will be very bad. The results plotted in fig. 8 is shown in table. 4. At transmitted power 25 dBm and propagation distance 5000 km, the used transmission data rate can be reached to 600 Gb/s and the quality factor in this case is 39.4. Also at transmitted power 25 dBm and transmission data rate 200 Gb/s the propagation distance can be extended to 20000 km at the same previous operating parameters and the quality factor in this case is 10.1.

Table 1.Comparison between received power for reference model [1] and proposed model

Distance (km)	Received Power, P_R (dBm)	
	Reference model	Proposed model
500	-47.6	-11.5
1000	-59.6	-23.6
1500	-66.7	-30.6
2000	-71.6	-35.6
2500	-75.4	-39.5

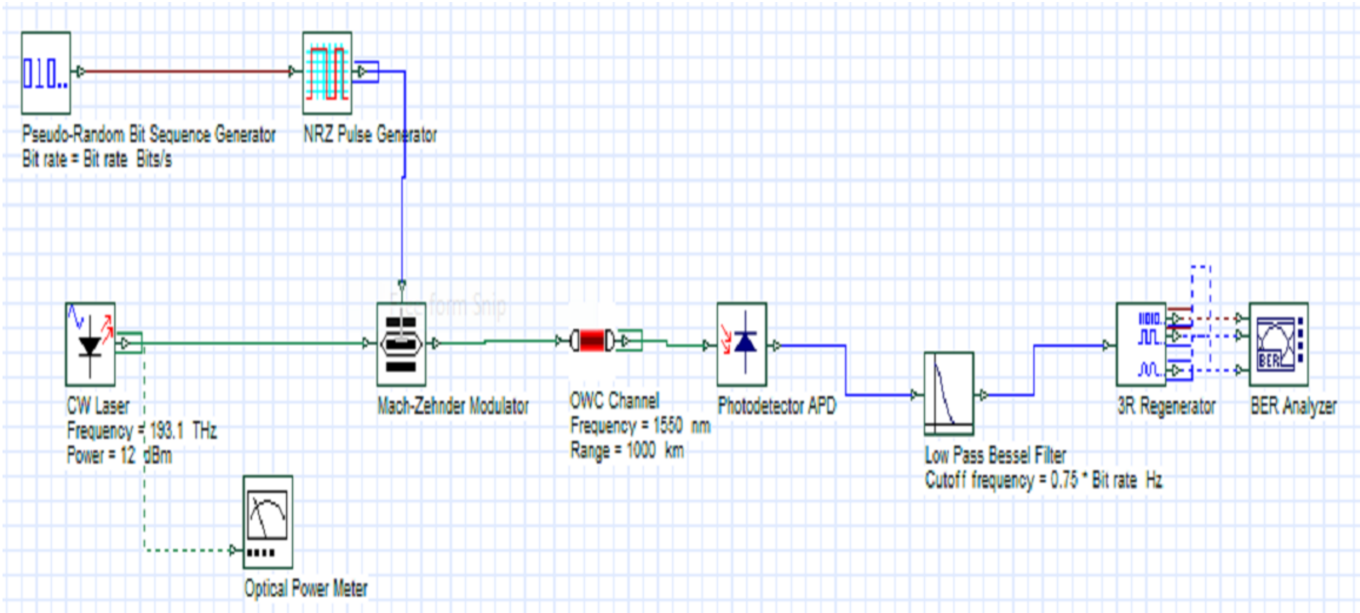


Fig. 1. A. Simple model of IsOWC system.

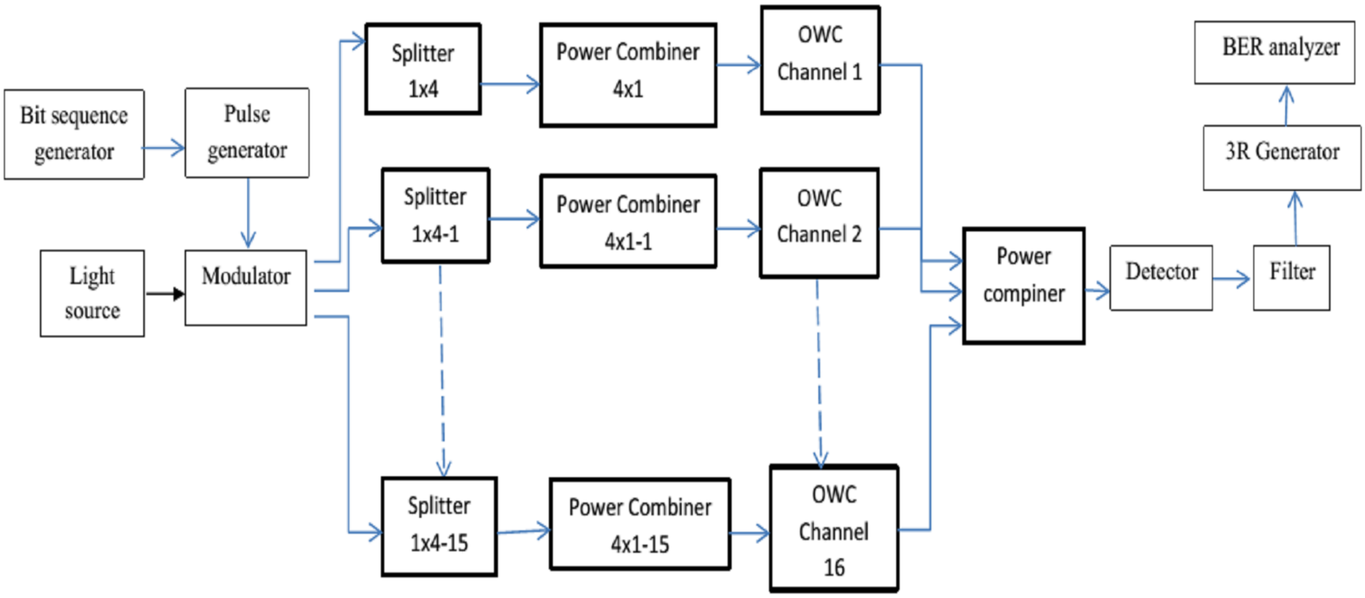


Fig. 1. B. Simulation Model 16 TX/RX IsOWC system.

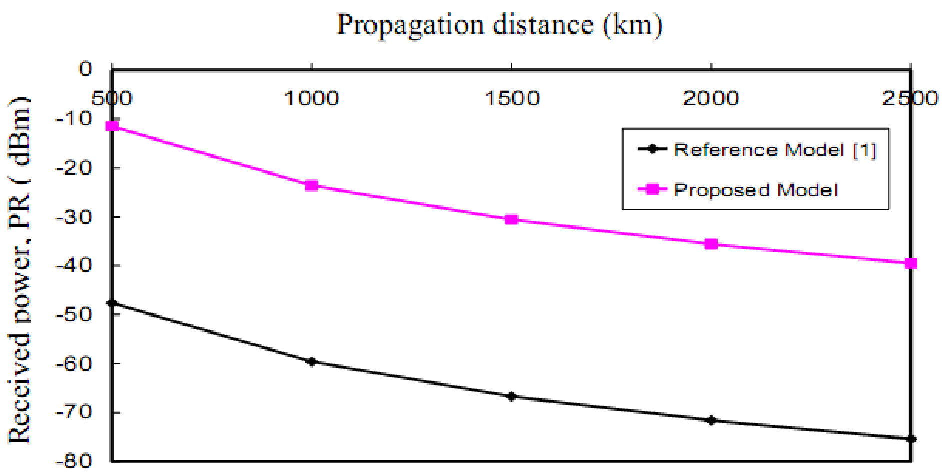
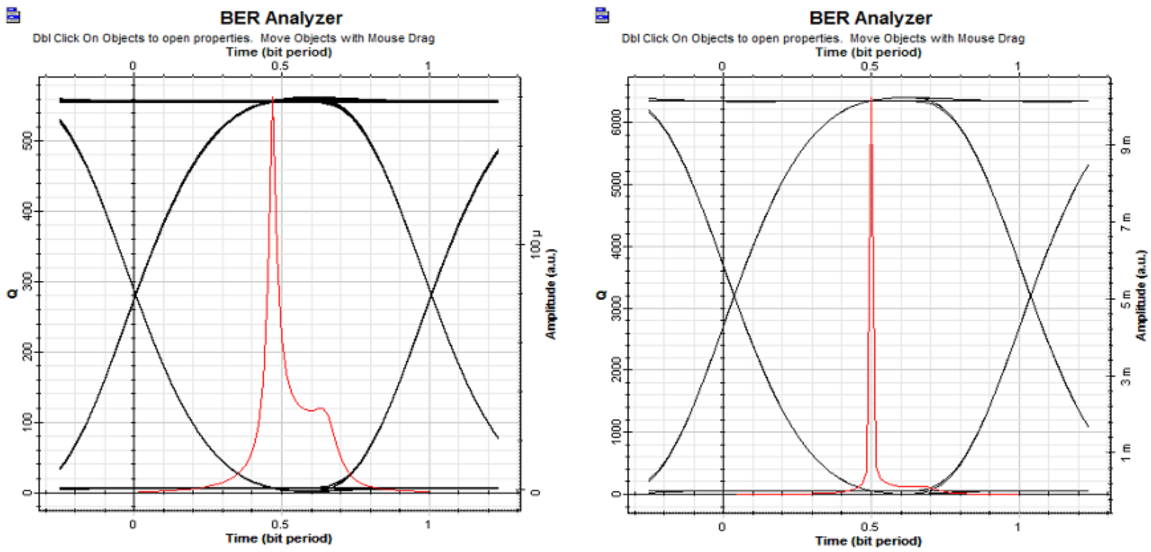


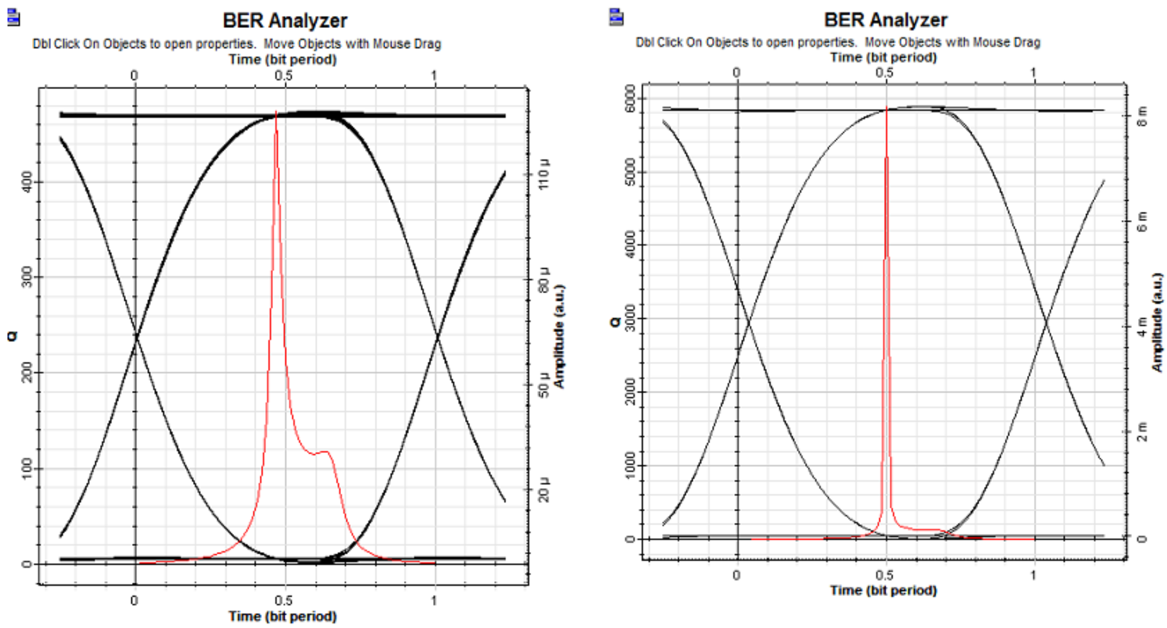
Fig. 2. Received power in relation to propagation distance using reference model [1] and proposed model.

Fig. 2 Received power in relation to propagation distance using reference model [1] and proposed model.



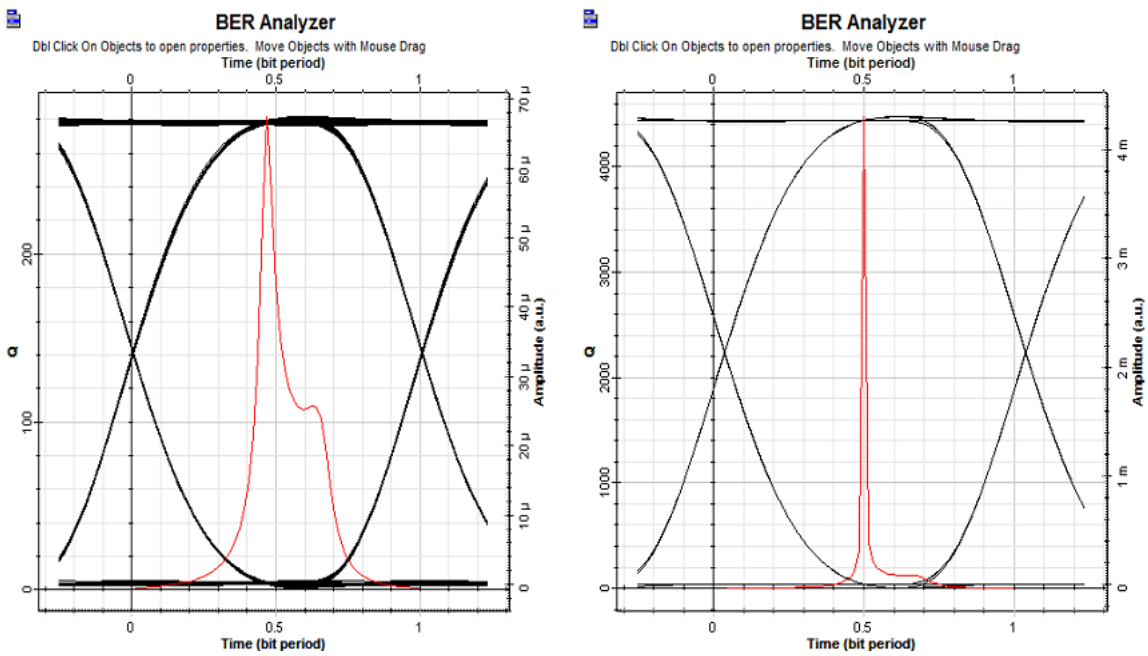
(a) simple IsOWC system [1] (b) 16 TX/RX IsOWC system

Fig. 3. Eye diagram of the simple and 16 Tx/RX IsOWC at wavelength 850 nm.



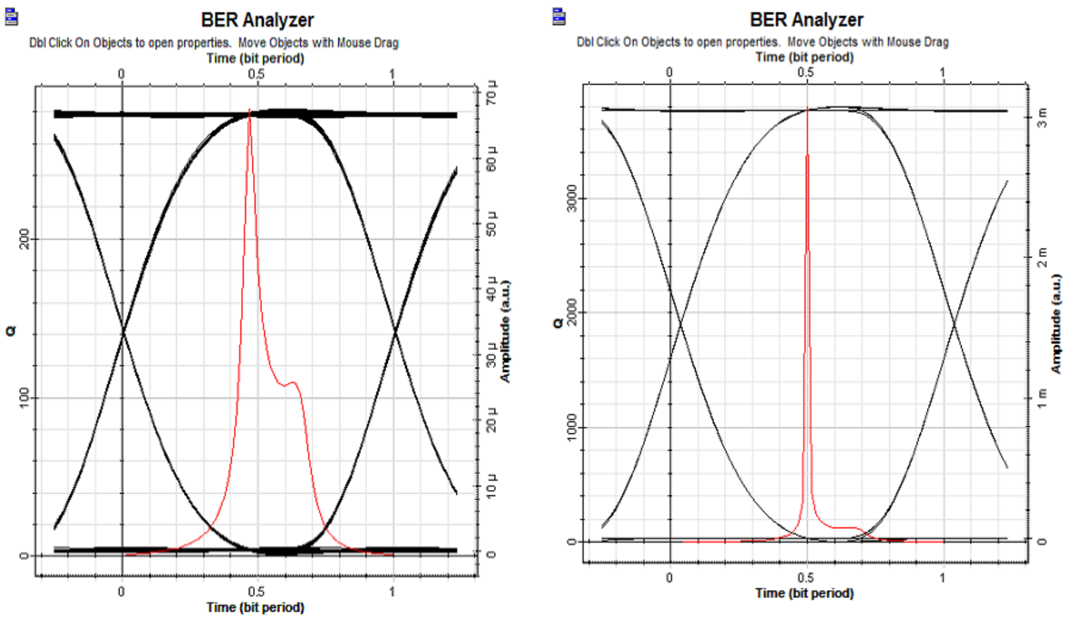
(c) simple IsOWC system [1] (d) 16 TX/RX IsOWC system

Fig. 4. Eye diagram of the simple and 16 Tx/RX IsOWC at wavelength 950 nm.



(e) simple IsOWC system [1] (f) 16 TX/RX IsOWC system

Fig. 5. Eye diagram of the simple and 16 Tx/RX IsOWC at wavelength 1310 nm.



(g) simple IsOWC system [1]   (h) 16 TX/RX IsOWC system

Fig. 6. Eye diagram of the simple and 16 Tx/RX IsOWC at wavelength 1550 nm.

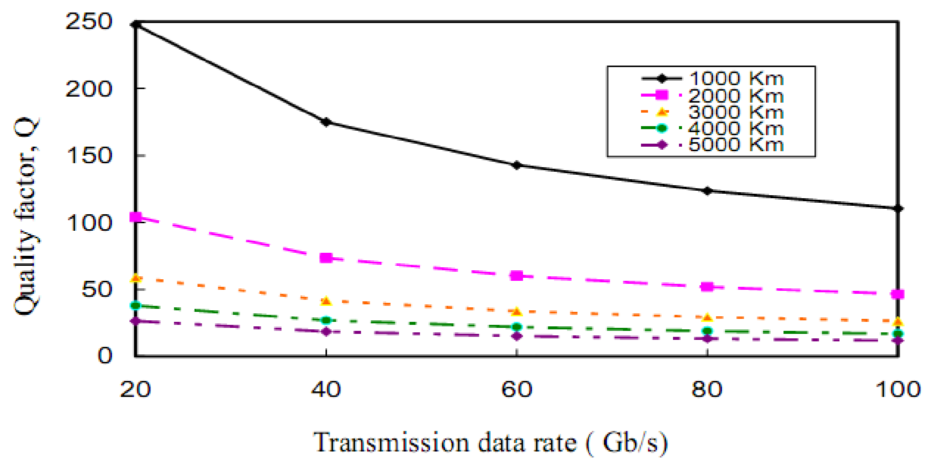


Fig. 7. Signal quality factor in relation to transmission data rate at different values of propagation distance.

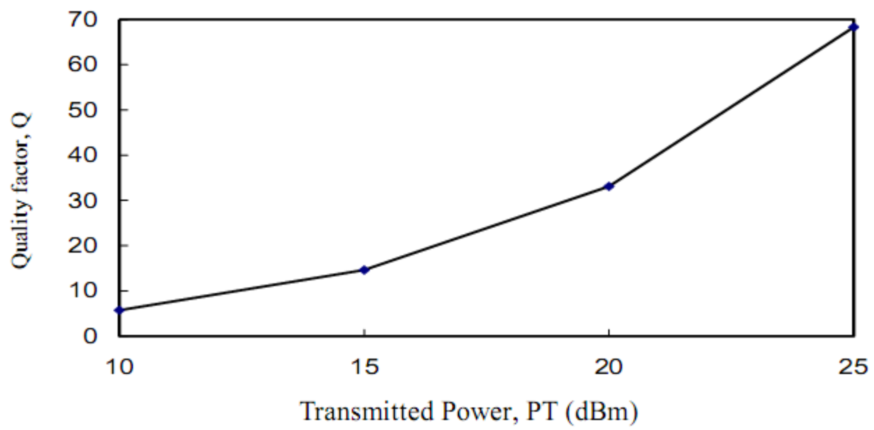


Fig. 8. Signal quality factor in relation transmitted power.

Table 3.Relation between quality factor and transmission data rate at different values of distances.

Distance (km)	Quality factor, Q				
	20 Gb/s	40 Gb/s	60 Gb/s	80 Gb/s	100 Gb/s
1000	247.8	175	142.8	123.6	110.6
2000	104	73.6	60.1	52	46.5
3000	58.9	41.6	33.9	29.4	26.3
4000	37.9	26.8	21.9	18.9	16.9
5000	26.3	18.6	15.3	13.3	11.9

Table 2.Quality factor for simple model [1] and proposed model at different values of wavelengths.

Wavelength (nm)	Quality factor, Q	
	Reference model	Proposed model
850	562.6	6396.5
950	474.3	5882.9
1310	281.8	4475.1
1550	211.2	3798.4

Table 4. Relation between quality factor and transmitted power at transmission data rate 200 Gb/s.

Transmitted power (dBm)	Quality factor, Q
10	5.7
15	14.6
20	33.1
25	68.3

4. Conclusion

In a summary, applying multiple transceivers in IsOWC system improves the system performance. By increasing Wavelength, the quality signal decreases. The system performance for 16 TX/RX system at all wavelengths is better than it for simple model system [1]**.**Increasing transmission data rate leads to decreasing quality factor**.**
By increasing transmitted power, quality factor increases. If the transmission data rate in case of using 5000 km and wavelength 1550 nm increases than 200 Gb/s, the quality factor at transmitted power 10 dBm will be very small and the signal will be very bad**.** At transmitted power 25 dBm and propagation distance 5000 km, the used transmission data rate can be reached to 600 Gb/s and the quality factor in this case is 39.4. Also at transmitted power 25 dBm and transmission data rate 200 Gb/s the propagation distance can be extended to 20000 km at the same previous operating parameters and the quality factor in this case is 10.1.

References

[1] R.R.S, R.M.J, " Performance Evaluation of Optical Intersatellite Links with Varied Parameters," International Journal of Engineering Research & technology science, vol. 4, no. 1, pp. 271-273, 2015.

[2] N. Kaur, G. Soni, "Performance analysis of inter-satellite optical wireless communication (IsOWC) system by using NRZ and RZ modulation," International Journal of Scientific and Research Puplication , vol. 5, no. 1, pp. 1-5, 2015.

[3] A. Z. M, H.A.Fayed, A.A.El Aziz and M.H.Aly, 'The Influence of Varying the Optical Wavelength on ISL Performance Recognizing High Transmission data rates," IOSR Journal of Electronics and Communication Engineering, vol. 9, no. 1, pp. 64-70, 2014.

[4] N. Noor, A. W. Naji, W. Al-Khateeb, "Theoretical Analysis of Multiple Transmitters and Receivers on The Performance of Free Space Optics link," IEEE International Conference on Space Science and Communication, pp. 291-295, 2011.

[5] F. A. Wahab, T. K. Leong, H. Zulkifili, M. I. B. Ibrahim, M. A. B. Talib, N. A. Zamri, O. K. Ibrahim, "Multiple Transmitters & Receivers For Free Space Optical Communication Link Performance Analysis," Journal of Telecommunication, Electronic and Computer Engineering, vol. 8, no. 5, pp. 29-32, 2016.

[6] B. Patnaik, P. k. Sahu, "Inter-satellite Optical Wireless Communication System Design and Simulation," Institute of Engineering and Technology (IET) Communications, vol. 6, no. 16, pp. 2561-2567, doi:10.1049/iet-com.2012.0044, 2012.

[7] T. Mehmood, N. Hameed, "Modeling and Performance Analysis of 10 Gbps Inter-Satellite-Link (ISL) Inter-Satelitte Optical Wireless Communication (IsOWC) System between LEO and GEO Satelitte," IEEE 17Th International Multi-Topic Conference, 2014.

[8] V. K. K. Sarath, V. Kumar, A. k. Turuk, S. K. Das, "Performance Analysis of Inter-Satellite Optical Wireless Communication" I.J. Computer Network and Information Security, vol. 4, pp. 22-28, 2017,doi: 10.5815/ijcnis.

[9] Y. Singh, "Performance Analysis of Optical Wireless Communication Channel Link at Various Transmission data rates," International Journal of Computer Science & Engineering Technology (IJCSET), vol. 5, no. 1, pp. 26-30, 2014.

[10]H. Kaur, "Review on Inter-satellite Optical Wireless Communication System," International Journal of Advanced Research in Computer Science, vol. 8, no. 4, pp. 48-51, May 2017.

[11] K. Singh and M. S. Bhamrah, "Investigations of Transmitted Power in Inter-satellite Optical Wireless Communication," International Journal of Computer Sience and Information Technology & Security, vol. 2, no. 3, pp. 568-573, 2012.

[12] H. A. Sharsher and E. M. Elgammal, "Operation Performance Evaluation of Inter-satellite Optical Wireless Communication Systems in Low Earth Orbits", International Journal of Advanced Research in Electronics and Communication Engineering, vol. 4, no. 5, pp. 1691-1698, 2015.

[13] S. Singh, G. Singh, R. Kaur and M. Singh, "Inter-satellite Optical Wireless Communication System Design a Study," Trends in Opto-Electro & Optical Communicatio, vol. 8, no. 1, pp. 20-24, 2018.