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Comparison of FSO and OWC Channel for Various Line Coding Techniques

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ABSTRACT
Free space optics is the most prominent approach in the field of communication as it offers many advantages such as small size, high bandwidth, low cost and ease of deployment. Also it has few limitations such as beam dispersion, scintillation etc. depending on weather conditions. In this paper, two free space optic links are presented, one for spatial communication, based on the OWC channel, and another one for terrestrial communication, based on the FSO channel. The performance of these models has been analyzed by measuring the values of Q-factor or bit error rates (BER) with the variation of link range, input laser power and other loss factors. It has been observed that that by using simple NRZ-OOK line coding, OWC system works better at 780 nm instead of 1550 nm channel wavelength. In contrast, FSO system performs better at 1550 nm under the practical conditions of scintillation effect, attenuation and pointing errors.

Keywords – Optical Wireless Communication (OWC), Free Space Optics (FSO)

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I. INTRODUCTION

In the era of communication, one of the most prominent approaches is the use of low-loss optical fiber cables based on optical communication technology due to its numerous advantages. It is medium of carrying information from one point to another in the form of light. Free Space Optical (FSO) communication is the transmission of high speed data over long distances using optical signals through free space [2]. Optical fiber communication system can be classified into two types-guided and un-guided. Guided media often uses fiber cable and in case of unguided media, transmission of optical bean can be space, similar to optical wireless communication (OWC) and free space (FSO).

Free Space Optical (FSO) communication can be considered as a viable technology for next generation communication due to its wide range of application. Some of its applications are links involving satellites (inter-satellite communication), High Altitude Platforms (HAPs), Unmanned Aerial Vehicles (UAVs), terrestrial communications, aircraft and ship-to-ship communication [3]. FSO can be used to provide high data rates in areas where it is difficult or impossible to lay optical fiber cables. It is assumed to be existed inside the earth's atmosphere and thus considered for terrestrial communication and attenuation is caused by many factors like fog, smoke, cloud, rain etc. because of the presence of the atmosphere [4, 5].

Optical wireless communication is a technique of transmitting message through air or free space with light as a carrier wave and information carrying signal modulates this carrier signal using optical amplifier [6]. It is assumed to be existed outside the earth's atmosphere and hence considered for spatial communication. No major attenuation factor like FSO except scintillation, pointing errors and beam divergence is present because of the absence of atmosphere [7].

In this paper, the work is mainly focused on comparing the performance of two types of free space optical communication channels viz. FSO and OWC for different line coding techniques such as NRZ, RZ, on-off keying (OOK), Gaussian and raised-cosine etc. [8]. The characteristics of the two channels in terms of the received signals Q-factor or BER for a given set of conditions (like input power level, data rate, and link range) has been investigated.

II. SYSTEM DESIGN

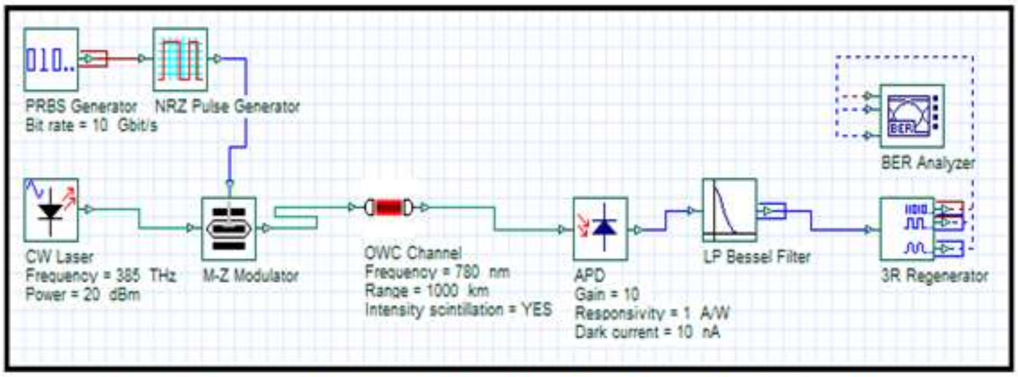

Fig. 1: OWC channel at a channel wavelength of 780 nm with scintillation effect.

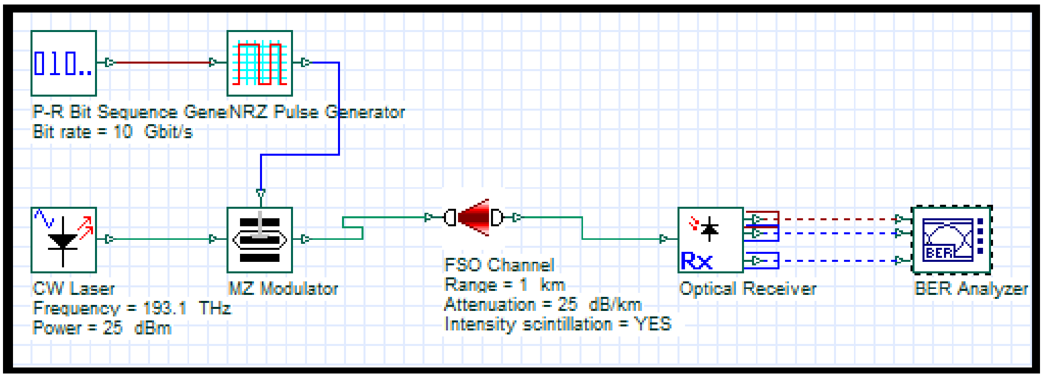

Fig. 2: FSO channel at a channel wavelength of 780 nm with scintillation effect.

The presented OWC-system consists of a single channel simulated at two different channel wavelengths 780 nm and 1550 nm. In OptiSystem software, the OWC link is modeled between an optical transmitting antenna with 5 cm aperture diameter and an optical receiving antenna with 20 cm aperture diameter. The simulation model also includes the scintillation effect and pointing errors. At the transmitting end, a 10 Gbps data stream is generated by using a pseudo random sequence generator [9]. This data is fed to different encoder and further modulated by using MZM modulator [10]. A CW laser diode of line-width of 10 MHz with power of 20 dBm is used in this proposed system [11]. The optical signal is received by an APD having a gain of 10, responsivity of 1 A/W and dark current of 10 nA [12] as shown in fig. 1.

Table 1 shows the various parameters and their specifications taken into consideration during the simulation.

Fig. 2 shows the simulation model of FSO system using NRZ line coding at a channel wavelength of 780 nm. The scintillation effect, attenuation of the signal at 25 dB/km and other losses are considered also. Similar models at a channel wavelength of 1550 nm can be modeled.

Table 1: Parameters used for10 Gbps OWC-system with scintillation effect and pointing errors

Parameter	**Value(s)**
Bit rate	10 Gbps
Laser frequency	193.1 THz; 385 THz
Transmitted power	20 dBm
Modulator type	Mach-Zehnder
Extinction ratio	30
Channel wavelength	1550 nm; 780 nm
Transmitter and receiver aperture diameters	5 cm; 20cm
Transmitter and receiver optics efficiencies	0.9
Transmitter and receiver pointing errors	1 µrad
Photo-detector	APD
Gain of APD	10
Responsivity	1 A/W
Dark current	10 nA

III. RESULTS AND DISCUSSIONS

3.1 OWC Channel

From the simulation results, the observations are made which is a relationship of the Q factor with the link range and the input laser power for various line codes at two different channel wavelengths. By varying the link range for different line codes, the value of Q-factor is obtained as shown in Table 2 and correspondingly, a graph has been plotted shown in Figure 3, where the link range varies from 200 km to 2000 km at a channel wavelength of 780 nm. The input laser power is maintained at 20 dBm for a bit rate of 10 Gbps. As the link-range increases, the value of the Q factor decreases in an exponential manner. Maximum possible range for different line codes is taken to be 1600 km without any error in the received information-conveying signal.

Similar models at 1550 nm channel wavelength are also simulated with same parameter values. But, results show that the value of the Q-factor decreases at a rate higher than that for the case of 780 nm. The main reason behind the decrement of Q-factor at 1550 nm may be the absence of atmosphere over the OWC channel, which causes scattering and absorption of light passing through it, in space.

A comparison among various line codes at two channel wavelengths i.e. 780 nm and 1550 nm, in terms of Q-factor for OWC channel, is shown in Table 3 for a link range of 1000 km and 20 dBm of input laser power at a bit rate of 10 Gbps. It can be observed that transmission at 780 nm is better with a Q-factor of 32.70 to that of 1550 nm.

Table 2: Variation of Q-factor with link range for different line codes at a channel wavelength of 780 nm for OWC channel

Range (km)	Q-factor			
	NRZ	RZ	Raised-cosine	Gaussian
200	323.00	207.00	192.30	61.23
400	121.00	79.00	62.20	49.21
600	73.00	38.14	34.44	29.11
800	49.00	30.22	28.13	21.73
1000	32.70	27.00	24.10	19.54
1200	23.49	20.85	17.78	15.23
1400	18.10	11.13	9.30	8.51
1600	8.12	7.02	6.21	5.77
1800	5.01	4.87	4.03	3.99

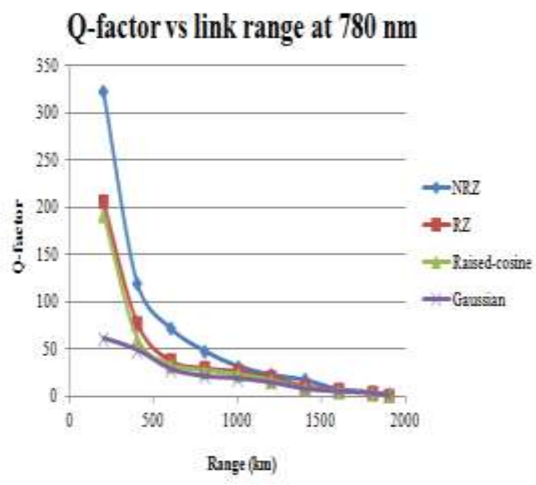

Fig. 3: Q-factor versus link range relationship for different line codes at a channel wavelength of 780 nm for OWC channel

Table 3: Comparison of various line codes for OWC-system over a range of 1000 km

Line coding	Q-factor at 1550 nm	Q-factor at 780 nm
NRZ	15.23	32.70
RZ	11.89	27.00
Raised-cosine	10.69	24.10
Gaussian	10.30	19.54

3.2 FSO channel

From the simulation results of FSO channel, the observations are made which is a relationship of the Q factor with the link range and the input laser power for various line codes at two different channel wavelengths. By varying the link range for different line codes, the value of Q factor is obtained as listed in table 4 and a graph has been plotted as shown in Figure 4, where the link distance varies from 100 m to 1200 m at a channel wavelength of 1550 nm. The input power is maintained at 20 dBm for a bit rate of 10 Gbps. As the link-range increases, the value of the Q factor decreases. NRZ is the best among all line codes with a maximum possible range of 1100 m without any error.

Table 4: Variation of Q-factor with link range for different line codes at a channel wavelength of 1550 nm for FSO channel

Range (m)	Q-factor			
	NRZ	RZ	Gaussian	Raised-cosine
100	183.3	149.10	91.13	37.32
200	91.34	80.14	64.21	32.86
300	67.25	58.70	45.66	30.21
400	45.32	33.48	39.09	23.90
500	43.71	25.97	31.71	21.41
600	30.54	20.69	21.60	19.48
700	22.90	13.96	15.53	15.34
800	22.26	11.06	13.00	12.21
900	15.46	9.20	10.87	9.93
1000	12.41	8.36	9.96	6.38
1100	7.21	4.63	4.46	5.37

It can be observed that the transmission over FSO channel at 1550 nm is better with a Q-factor of 12.41 to that of 780 nm.

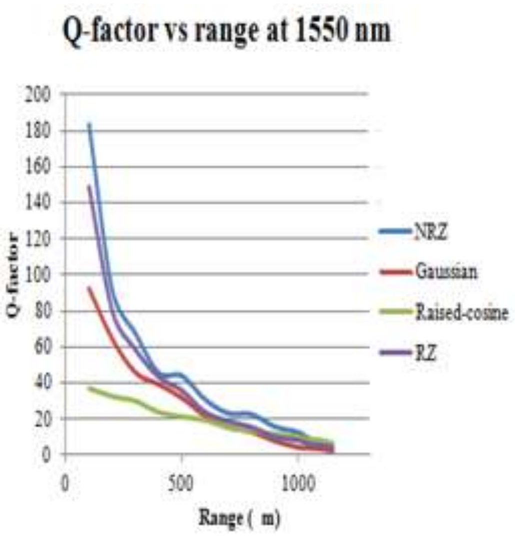

Fig. 4: Q-factor versus link range relationship for different line codes at a channel wavelength of 1550 nm for FSO channel

IV. CONCLUSION

The simulated results in terms of Q-factor or BER for different line codes NRZ, RZ, raised-cosine and Gaussian at two channel wavelengths of 780 nm and 1550 nm, with the variation of distance and input laser power for a 10 Gbps OWC and FSO systems are presented and discussed. It has been noticed that the quality factor (BER) is inversely (directly) proportional to the link range. From the results of simulation models, it can be concluded that signals with NRZ line coding get degraded lesser than the signals with other line codes. In case of OWC channel, the signal transmission at 780 nm of channel wavelength suffers less attenuation to that of 1550 nm but the case is opposite over FSO channel where the transmission at 1550 nm is better.

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