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Advanced modulation coding schemes for an optical transceiver systems–based OWC communication channel model

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ABSTRACT

This paper examines advanced modulation coding schemes for an optical transceiver system–based optical wireless communication (OWC) channel model. These modulation techniquesinclude On-Off keying and return to zero (RZ)/non–return to zero (NRZ) coding. The signal power level against time and frequency spectral variations are measured. The max. Q factor and min. bit error rate (BER) are estimated and clarified for each modulation code scheme by using an optisystem simulation model. Transmission bit rates of up to 40 Gb/s can be achieved for possible distances up to 500 km with acceptable Q factor. The received power and max. Q factor are measured and clarified with OWC distance variations. The On-Off keying modulation code scheme resulted in better performance than the other modulation code schemes did.

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1. INTRODUCTION

Free space optics (FSO) communication is a growing technology to handle high data rate and it has very large information handling capacity [1-4]. FSO communication systems are presented as an available alternative to the fiber optics technology which is capable of full duplex transmission of data, voice and video. Even though light can be competently inserted into fiber cables to route the light information [5-9], there are various applications where only the free space between the transmitter and receiver is the only available means to establish a communication link. This free space technique needs only a clear line of sight path between the transmitter and the remote receiver [10-14].

The demands for solutions for traffic problem such as accidents, jams and environmental impact are increasing. Heavy economical losses are caused by traffic congestion apart from inconvenience to users [15-19]. Visible light communication systems have multiple benefits [20-25]. Indoor wireless communication used two major transmission technologies, they are RF and Optical Wireless Communication (OWC) systems. While the requirement of line of sight link, atmospheric absorption, scattering and scintillation can be thought of as drawbacks of the OWC system, it becomes advantageous in the indoor from one room to another room or cell based links without interference from each other [26-34]. Also, OWC has many advantages such as it is inexpensive, low power consumption, quickly-deployable and provides security over RF communication. Infrared (IR) to Ultraviolet (UV) including visible light are used in OWC [35], this wide range and unlicensed bandwidth make OWC system has potential to deliver several hundreds of Mbps data rate [36]. Many studies show that OWC able to transmit at data rates up to 25 Gbps in indoor systems [37-40]. The first and the foremost limiting factor for achieving high data rate in indoor OWC is the limited modulation bandwidth of light sources. There are various modulation techniques have been used in indoor OWC System [41-45]. The using of either depends on the intended application and channel configuration.For example, OOK (On-Off Keying) and PPM (Pulse Position Modulation) are favored for high power effectiveness. Pulse interval modulation (PIM) procedures are utilized presumed for its intrinsic synchronization pulse. Differential PPM (DPPM), Differential Amplitude PPM (DAPPM) Multilevel Digital PIM (MDPIM), Digital PIM (DPIM) and Dual Header PPM (DH-PIM) are the substitutes to improve power efficiency, bandwidth efficiency and speed throughput. Trellis coded PPM (TC_PPM) enhances the execution of the PPM on multipath channels. Multiple PPM (MPPM) minimizes the impact of multipath scattering.OOK is a most simplest modulation technique for intensity modulation/direct detection (IM/DD), which represents one bit for an optical pulse and a bit zero for the absence of an optical pulse.The paper presents a simulation of different OOK modulation code schemes with estimation of their parameters which can be used to easy compare among the proposed schemes.

2. RESEARCH METHOD

This study used advanced modulation schemes such as On-Off keying, NRZ, and RZ. On-Off keying represents a binary data stream in the absence of a carrier signal. Bit sequence user-defined sequence generators were used to generate a stream sequence of bits as 10-bit sequences of 0101101110. The transmitter consists of two electrical units/light sources with two data user-defined generators and Gaussian/NRZ pulse generators. The sequence stream bits were encoded through pulse code generators. The technical specifications for the light optical sources included frequency=193.1 THz and power=0 dBm. After encoding, the electrical/light signals then needed to be modulated through $LiNbO_3$ Mach Zehnder modulators using the following technical parameters: extinction ratio=20 dB, switching bias/switching RF voltages of 4 V/2 V respectively, and insertion losses=5 dB. Figure 1 shows the optical transceiver system based OWC communication system model.

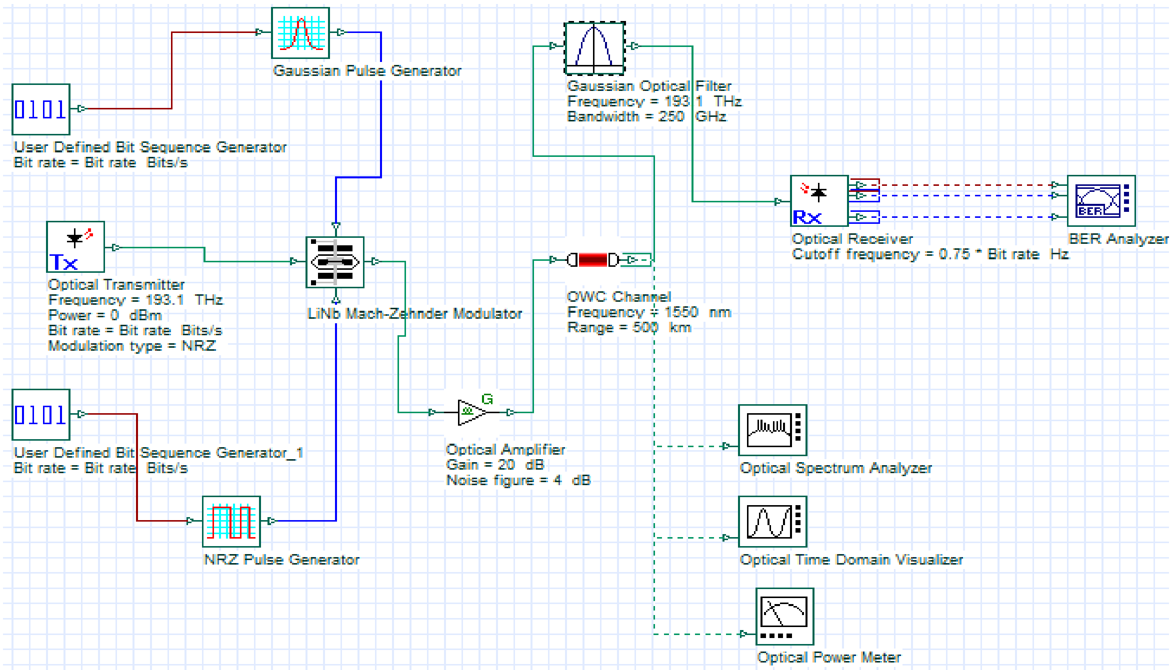

Figure 1. Optical transceiver system based OWC communication channel model

The modulated signal was then amplified with light amplifiers to compensate for losses before it was injected into the OWC channel with a distance of 500 km. The signal was filtered through Gaussian light filters to eliminate all the ripples from the modulated original signal. The Gaussian light filter used the following technical variables: bandwidth=250 GHz, frequency=193.1 THz, loss=0 dB, filter order=1, and filter modulation depth=100 dB. Then, the filtered signal was converted from light signal form to electrical signal form through the light receiver side. All the clarified measurement devices measured the max. Q factor/min. bit error rate, the max. signal power/min. noise power, and the total received power after the light detectors (optical receiver side). All simulation results are shown based on the variables in Table 1.

Table 1. Parameters used in this proposed work

Transmitter technical specifications		
Optical Tx.	Frequency	193.1 THz
	Power	0 dBm
	Extinction ratio	10 dBm
	Linewidth	10 MHz
OWC channel technical specifications		
Frequency		1550 nm
Range		500 km
Data rate		40 Gb/s
Tx. Aperture diameter		15 cm
Rx. Aperture diameter		15 cm
Tx. gain		dB0
Rx. gain		0 dB
Tx. Optics efficiency		1
Rx. Optics efficiency		1
Tx. Pointing error		0 µrad
Rx. Pointing error		0 µrad
Attenuation		0 dB/km
Receiver technical specifications		
Photodetector		PIN
Gain		3
Ionization factor		0.9
Dark current		10 nA
Responsitivity		A/W1
Insertion loss		0 dB
Internal filter order		1

3. RESULTS AND DISCUSSION

Figures 2-4 show the max. Q factor with min. BER values for the various modulation coding schemes at a 500-km transmission distance. Figure 2 clarifies the max. Q factor was 6.45 and the min. BER was 5.08 x $10^{-11}$when using the NRZ modulation coding scheme. Figure 3 outlines the max. Q factor was 5.146 and the min. BER was 1.29 x $10^{-7}$when using the RZ modulation coding scheme. Figure 4 shows that the max. Q factor was 7.42 and the min. BER was 5.76 x $10^{-14}$when using the On-Off keying modulation coding scheme.

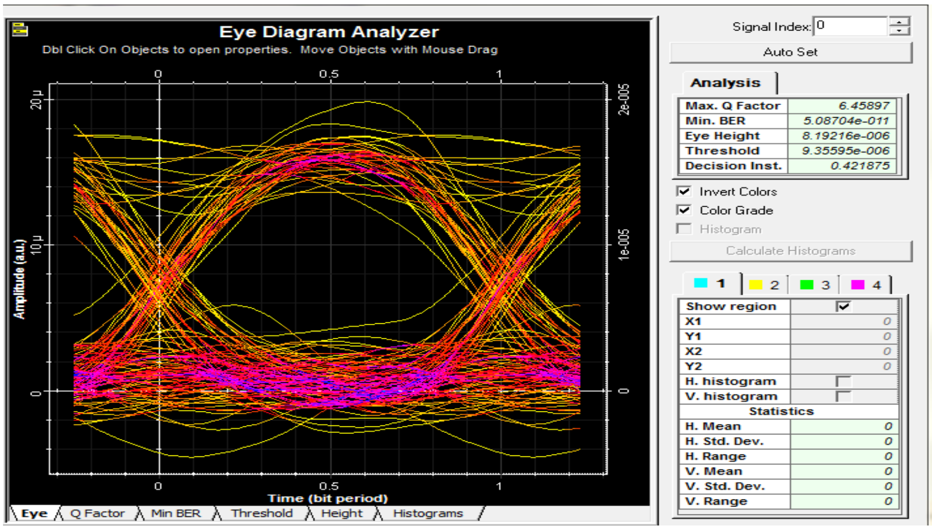

Figure 2. Max. Q factor with min. BER values by using NRZ modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

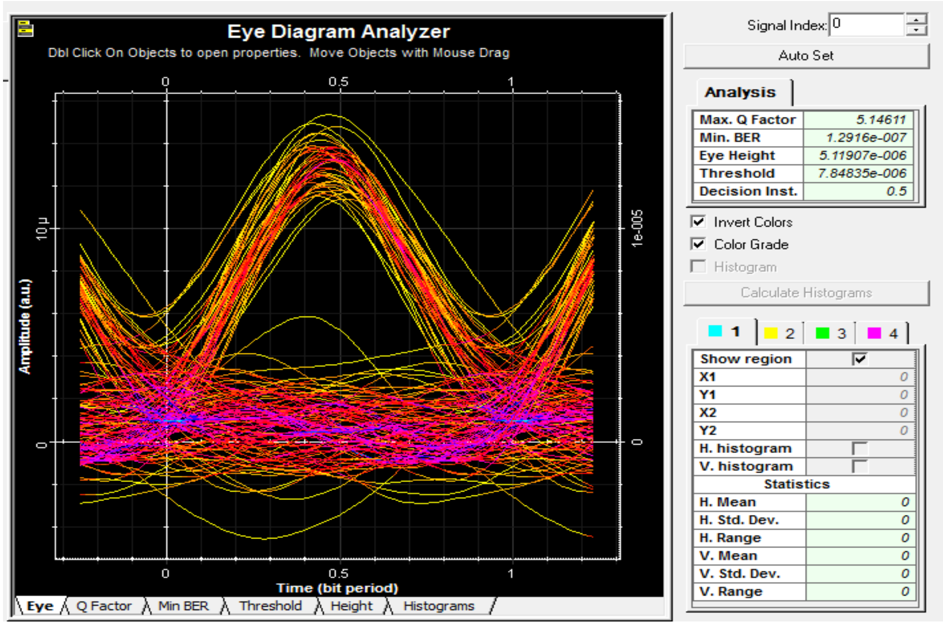

Figure 3. Max. Q factor with min. BER values by using RZ modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

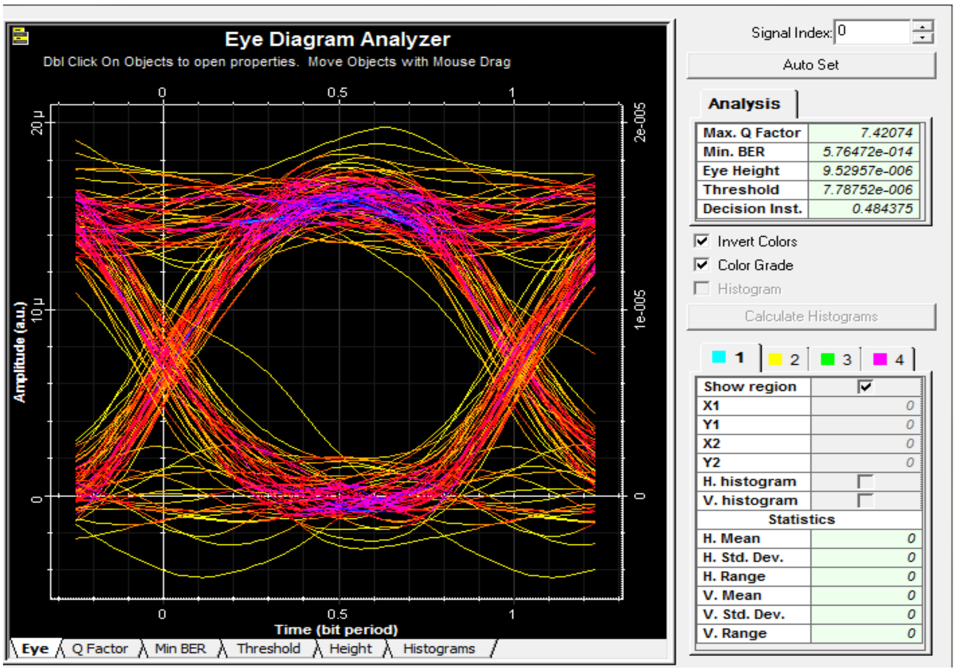

Figure. 4 Max. Q factor with min. BER values by using On Off keying modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

Figures 5-7 show the max. signal power/min. noise power when using the various modulation coding schemes at a 500-km distance. Figure 5 clarifies he max. signal power/min. noise power values were -22.67 dBm and -103.682 dBm when using the NRZ modulation coding scheme. Figure 6 shows the max. signal power/min. noise power values using the RZ modulation coding scheme were -25.43 dBm and -103.551 dBm. As Figure 7 shows, the max. signal power/min. noise power values were -19.09 dBm and -103.853 dBm for the On-Off keying modulation coding scheme.

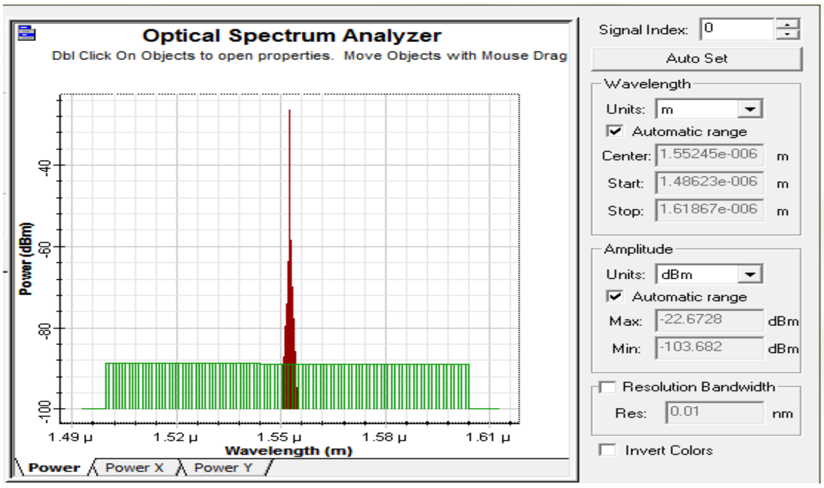

Figure 5. Max. signal power and min. noise power versus wavelength by using NRZ modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

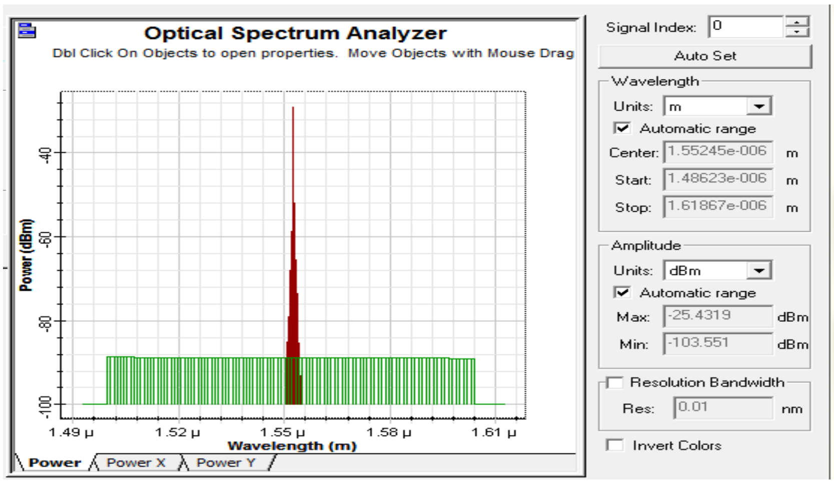

Figure 6. Max. signal power and min. noise power versus wavelength by using RZ modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

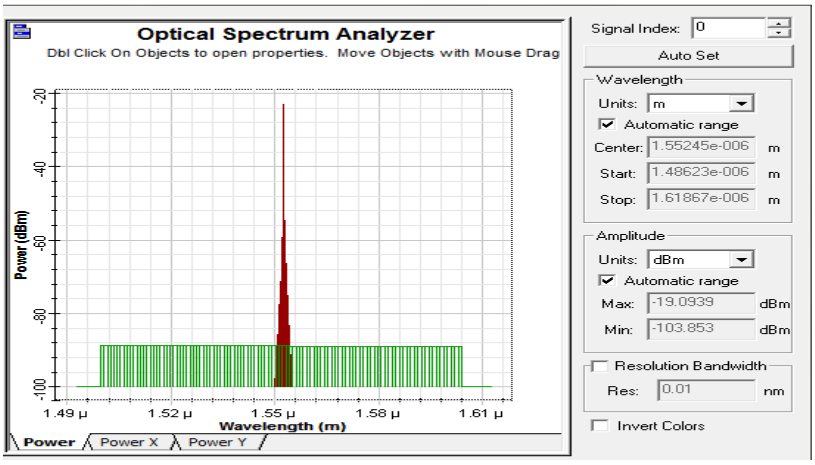

Figure 7. Max. signal power and min. noise power versus wavelength by using On Off keying modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

Figures 8-10 show the total power values in Watts and dBm when using the various modulation coding schemes at a 500-km distance. Figure 8 outlines the total power value was 5.19 µW and -22.849 dBm when using the NRZ modulation coding scheme. For the RZ modulation coding scheme, the total power value was 3.168 µW and -24.992 dBm is shown in Figure 9. The total power value was 8.96 µW and -20.477 dBm when using the On-Off keying modulation coding scheme is clarified in Figure 10.

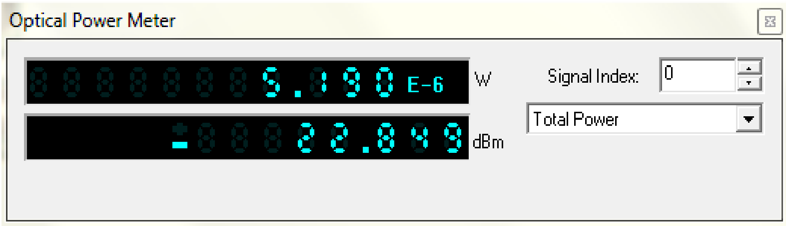

Figure 8. Total power values in Watt and dBm by using NRZ modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

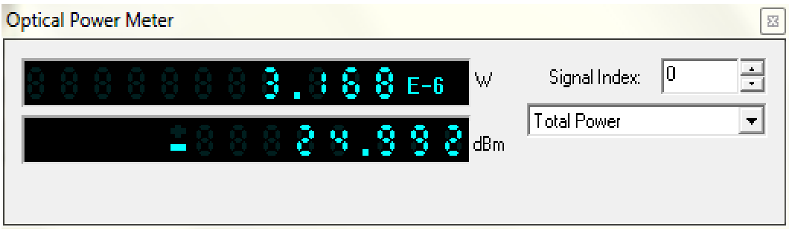

Figure 9. Total power values in Watt and dBm by using RZ modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

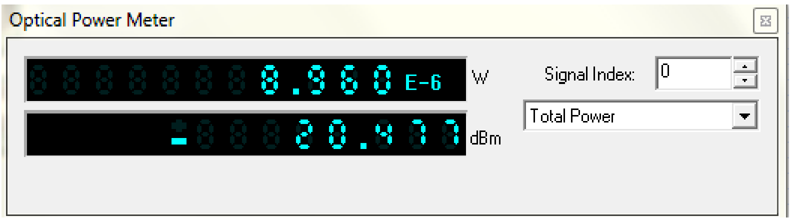

Figure 10. Total power values in Watt and dBm by using On Off keying modulation coding scheme based OWC channel (500 km distance) for optical transceiver systems

Figure 11 shows the max. Q factor variations with OWC distance for the various modulation coding schemes. The max. Q factorswere 18.18 for the NRZ modulation coding scheme, 13.8 for the RZ modulation coding scheme, and 124.75 for the On-Off keying modulation coding scheme at an OWC distance of 100 km,while the max. Q factorswere 12.26 for the NRZ modulation code scheme, 10.09 for the RZ modulation code scheme, and 20.53 for the On-Off keying modulation code scheme at an OWC distance of 300 km. At an OWC distance of 500 km, themax. Q factorswere 6.45 for the NRZ modulation coding scheme, 5.14 for the RZ modulation coding scheme, and 7.42 for the On-Off keying modulation coding scheme.

Figure 12 shows the received power variations with OWC distance for the various modulation coding schemes. The power received was 129.7 µW for the NRZ modulation code scheme, 79.2 µW for the RZ modulation code scheme, and 224 µW for the On-Off keying modulation code scheme at an OWC distance of 100 km. At an OWC distance of 300 km, the power received was 14.41 µW for the NRZ modulation coding scheme, 8.8 µW for the RZ modulation coding scheme, and 24.89 µW for On-Off keying modulation coding scheme. The power received was 5.19 µW for the NRZ modulation coding scheme, 3.169 µW for the RZ modulation coding scheme, and 8.96 µW for the On-Off keying modulation coding scheme at an OWC distance of 500 km.

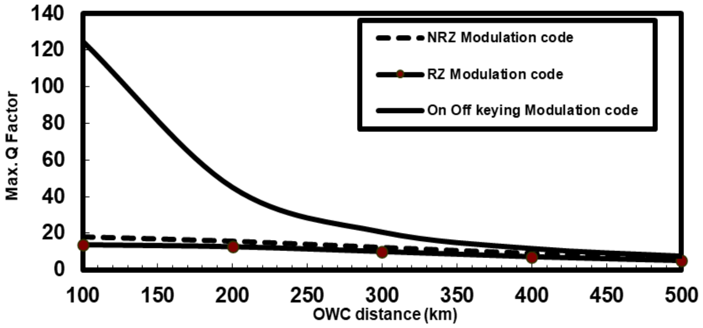

Figure 11. Max. Q factor variations with OWC distance for various modulation coding schemes based OWC channel for optical transceiver systems

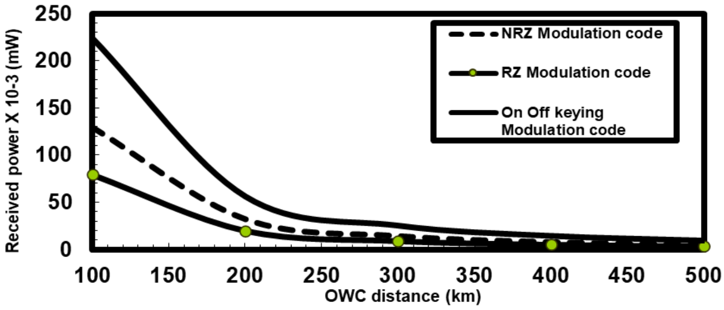

Figure 12. Received power variations with OWC distance for various modulation coding schemes based OWC channel for optical transceiver systems

4. CONCLUSION

We simulated the different modulation coding schemes for an optical transceiver system–based OWC channel. The max. Q factors/min BERs for the different modulation schemes were estimated. The max. signal power/min. noise power and the total received power were clarified for the various modulation coding schemes. The study found that On-Off keying resulted ina better max. Q factor/min. BER and max. received power than the other modulation schemes. On-Off keying led to an improvement percentage ratio of 13% in signal quality and an enhancement percentage ratio of 28% in max. received power compared with the other modulation schemes at an OWC distance of 500 km.

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