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Comparison between high orders Phase Shift Keying (PSK) and Quadrature Amplitude Modulation (QAM) for Coherent Detection Optical Frequency Division Multiplexing System (CO-OFDM)

Mahmoud Alhalabi[1],Necmi Taşpınar[2]
[1]*Institute of Natural and Applied Science, Erciyes University, Kayseri, Turkey*
[2]*Department of Electrical and Electronics Engineering, Erciyes University, Kayseri, Turkey*

Abstract:
In this paper, we have simulated Coherent Detection Optical Orthogonal Frequency Division Multiplexing (CO-OFDM) system with different type of modulation techniques such as Quadrature Amplitude Modulation (QAM) and Phase Shift Keying (PSK). 64-QAM and 16-PSK modulation with same number of subcarriers were applied to CO-OFDM system to achieve the best Bit Error Rate (BER) performance. According to the best BER, the downstream data rate was chosen to be 60 Gbps and transmission distance was changed from 50 to 350 km. According to the simulation results by using Optisystem software, CO-OFDM system with 16 PSK and 128 subcarriers achieved the best BER performance for long propagation.
Key Word*:Orthogonal Frequency Division Multiplexing (OFDM), Phase Shift Keying (PSK), Quadrature Amplitude Modulation (QAM), CoherentDetection OFDM (CO-OFDM)*

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I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) technique is considered multicarrier modulation technique that used to support high spectral efficiency, high transmission bit rate and immunity to chromatic dispersion. In these days, OFDM is used widely in different type of optical communication systems because it is an effective solution to both inter-carrier interference (ICI) and inter symbol interference (ISI) by using cyclic prefix (CP). CP is used to extend the OFDM symbol period and protect it against channel dispersion that effects the BER performance. OFDM with Quadrature Amplitude Modulation (QAM) increases the efficiency of short range optical communication systems to support high data rate and low Bit Error Rate (BER) [1-3]. Optical OFDM systems can be, according to the structures of optical receivers, classified as a coherent and direct-detection system. Coherent optical OFDM (CO-OFDM) is an OFDM data that is being modulated to light frequency and being detected in coherent manner compared with Intensity Modulated/Direct Detection (IM/DD) OFDM system that consists of two Mach-Zehnder Modulators (MZM) at the transmitter and Optical Coherent Photodetector (PD) at the receiver. Compared with (IM/DD) OFDM system, CO-OFDM has better sensitivity and spectral efficiency but needs additional devices and technique such as: optical local oscillator, 90-deg optical hybrids, the high-speed analog/digital (AD) convertor, and the digital signal processing. These devices increase the cost and complexity of the system [4-6]. Coherent reception requires that the polarization of local oscillator should be matched with that of the received signal. In [7], 70-km-reach colorless OFDM wavelength-division-multiplexing (WDM) passive optical network (PON) with centralized light wave and direct detection is investigated and was demonstrated for 10 Gbps 16 quadrature amplitude modulation (16-QAM) intensity-modulated OFDM downstream signals and 2.5 Gbps On-off keying (OOK) upstream signals respectively. In [8], (IM/DD) OFDM system with different type of modulation techniques such as Quadrature Amplitude Modulation (QAM) and Phase Shift Keying (PSK) have been simulated and demonstrated. As a result, IM/DD system with 16 QAM and 128 subcarriers achieved the best BER performance by choosing the best parameters such as downstream data rate of 10 Gbps and transmission distance of 100 km, respectively.

In this paper, two different optical OFDM systems with different type of modulation schemes and same number of subcarriers are simulated, and compared to achieve the best BER performance by using Optisystem software [9].

II. System Model

Fig. 1 shows the CO-OFDM system model using downstream OFDM with 64 QAM/16 PSK and 128 subcarriers.Transmitter consists of a Pseudo Random Binary Sequence (PRBS) that generates serial 60 Gbps, QAM/PSK sequence generator that is mapping the serial bit streams to parallel symbols and OFDM modulator is used with Fast Fourier transform (IFFT/FFT) size of 128 and CP of 10 and the downstream signal is up-converted to optical frequency of 193.1 THz, by a Continues Wave (CW) laser with two MZMs. The number of training OFDM symbols and pilot symbols were chosen to be 10 and 5, respectively. Low pass filter (LPF) is used to constrain the OFDM spectrum bandwidth and its cutoff frequency equals to (0.75*Symbol rate). Inside the RF to optical up converter (RTO), two MZM's are used to modulate the electrical OFDM signal to the optical domain by using CW laser at 193.1 THz and its power equal to 10 dBm. The resulting optical signal is then transmitted over 50 – 350 km SMF with attenuation (0.2 dB/Km), a dispersion of 16 ps/nm/km, a dispersion slope of 0.08 ps/nm^2/km and a nonlinearity coefficient of 2.6×10^{-20}. The propagation length of optical fiber changed from 50 till 350 km to evaluate the BER performance on both of CO-OFDM systems. The gain of optical amplifier (EDFA) equal to 10 dBm and is used to amplify the signal against the attenuation of optical fiber. The loop was taken values from 1 to 5 that is used to compare the BER values against the propagation length.

TABLE 1. Parameter setting of the OFDM signals in Optisystem software

Sample rate	60 GHz
IFFT size	128
CP length	10
Modulation format	64-QAM, 16-PSK
Data subcarriers	80
Number of prefix symbols	10
Number of training OFDM symbols	10
Number of pilot OFDM symbols	5

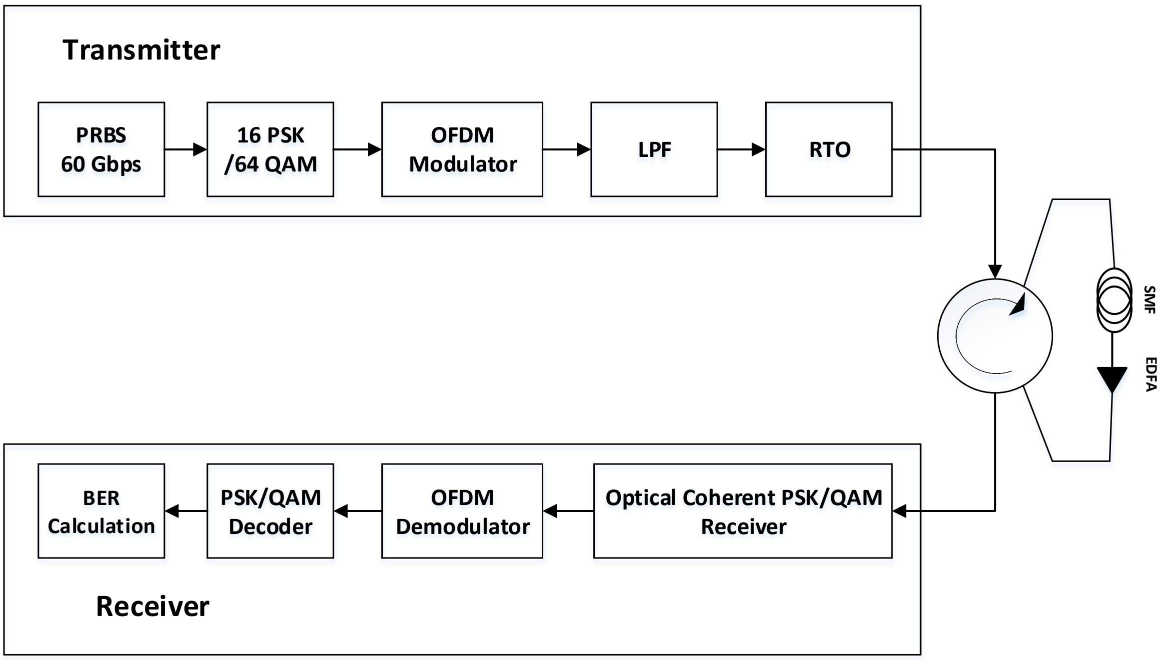


Fig. 1. CO-OFDM Block Diagram

At the receiver side, the optical signal is detected by optical Coherent PSK/QAM receiver. The PIN photodetector has a dark current of 10 nA, a responsivity of 1 A/W, a thermal power density (100×10^{-24} W/Hz), and a center frequency of 193.1 THz. The electrical signal is ready to enter the OFDM demodulator stage which has similar parameters as the OFDM modulator and the guard interval is removed. Finally, the resulting signal is fed in to 64-QAM/16-PSK decoder to build the binary signal. Details of OFDM parameters are showed in Table 1.

III. Simulation Results

CO-OFDM system for both 64 QAM and 16 PSK are simulated by using Optisystem software. The global parameter of bit rate is chosen to be 60 Gbps. For 64-QAM and 16-PSK modulation, the symbol rate will be equal to 10 and 15 Gsym/s, respectively. The used number of subcarriers is chosen to be 80 so the used bit rate is limited to 37.5 Gbps. However, OFDM symbol period is inversely proportional to the symbol rate. Fig. 2 shows a clear constellation diagram of the 64-QAM and 16-PSK modulator at the transmitter side, respectively.

The constellation diagram shows the modulated signal as a two-dimensional scatter diagram which helps to study the distortion and the interference that occurs in the signal.

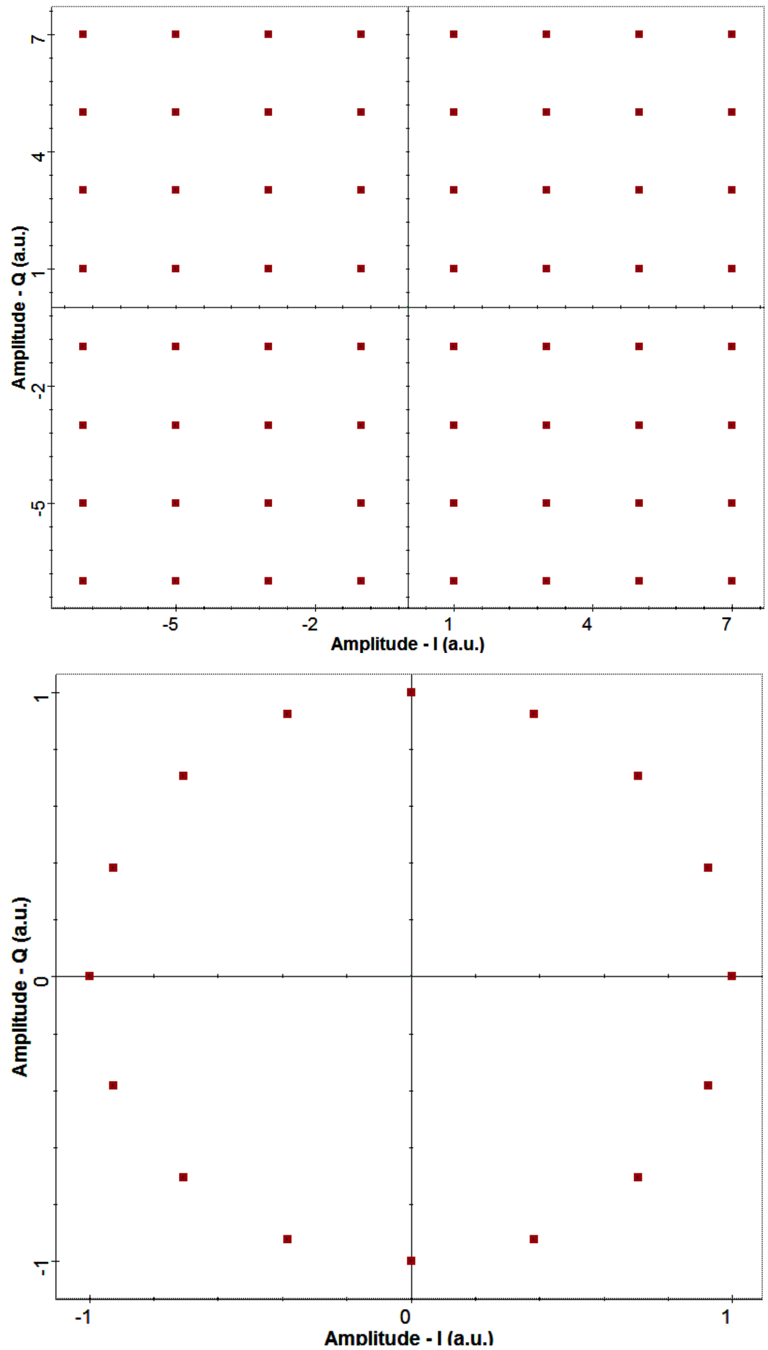


Fig. 2. Constellation Diagram of 64-QAM (up) and 16 PSK (down) at the transmitter

Fig. 3 shows the OFDM FFT/IFFT subcarrier spectrum of the system that use maximum number of subcarriers and data subcarriers equal to 128 and 80, respectively.

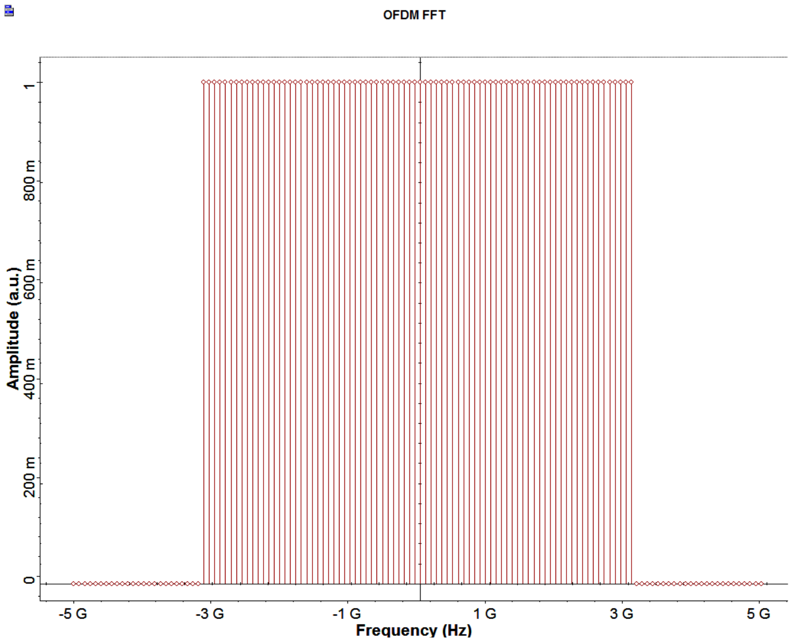
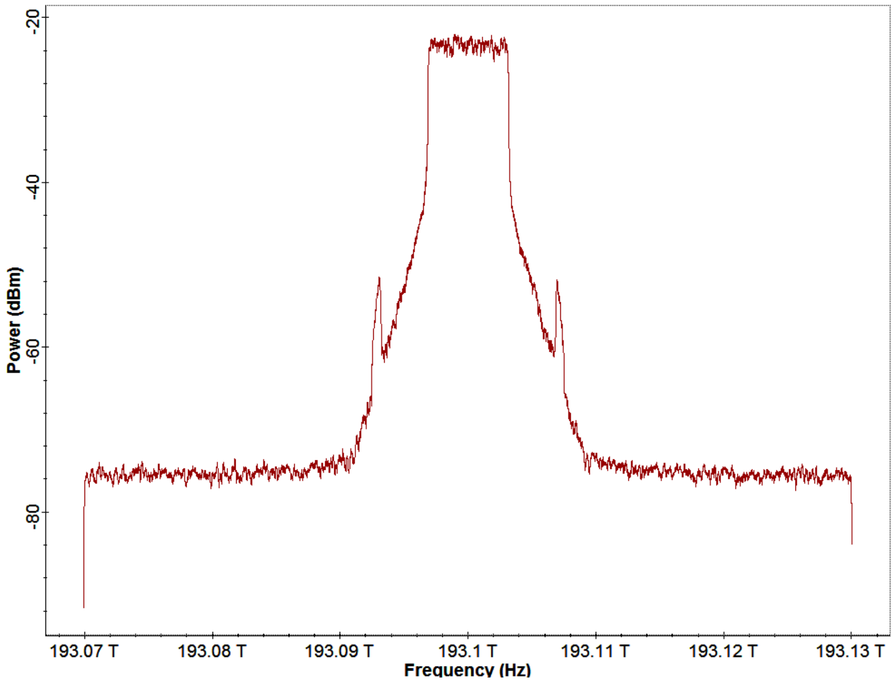


Fig. 3. OFDM FFT/IFFT subcarriers

Fig. 4 shows the OFDM spectrum of the system at frequency of 193.1 THz in the optical domain for 64-QAM and 16-PSK, respectively.



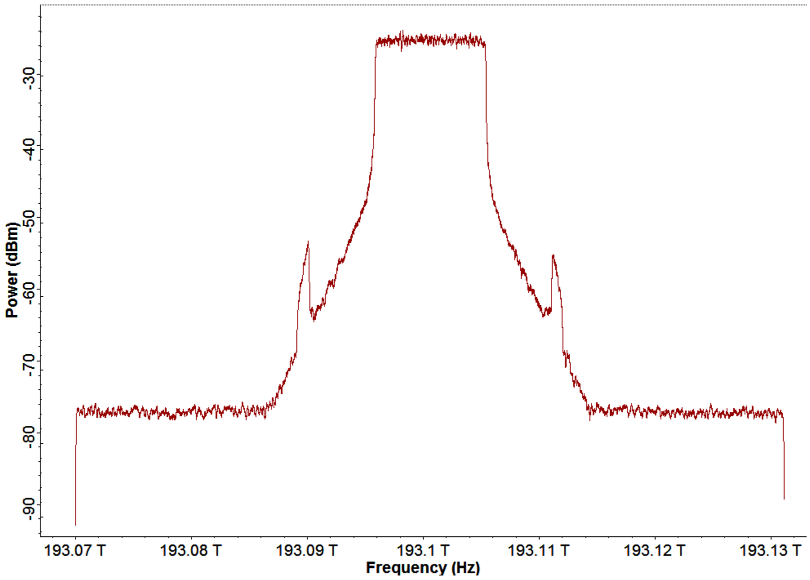


Fig. 4. OFDM spectrum of 64-QAM (up) and 16-PSK (down) in the optical domain

Fig. 5 shows the constellation diagram of 16 PSK OFDM at global bit rate of 60 Gbps and after 250 km transmission distance. 16 PSK modulation achieved good BER performance (10-3) at propagation length of 250 km. PSK modulation is considered more better than 64-QAM for long transmission distance with high data rate in this system.

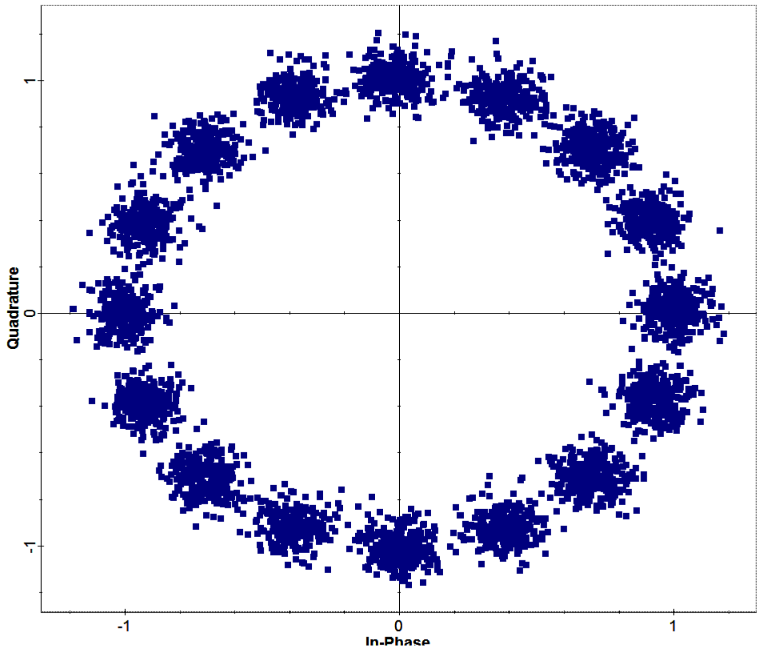


Fig. 5. Constellation diagram of 16 PSK modulation at transmission distance of 250 km

At transmission distance of 50 km, CO-OFDM system with 16 PSK achieved the best BER performance (approx. 10^{-4}) compared with others and this value is accepted in optical communication systems. The constellation diagram of this system is shown in Fig. 6.

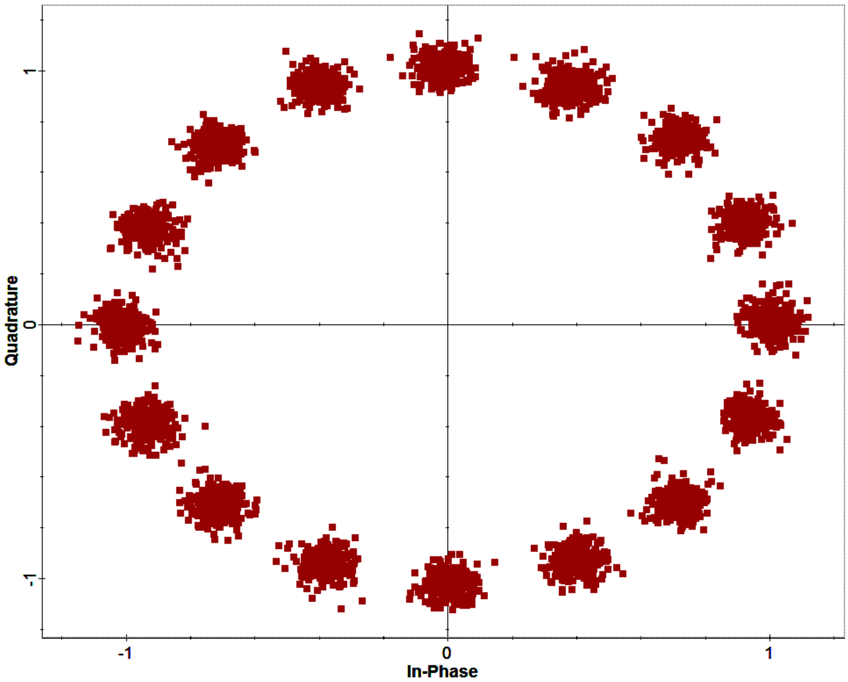


Fig. 6. Constellation diagram of 16 PSK modulation at transmission distance of 50 km

Fig. 7 shows the constellation diagram of 64 QAM OFDM with 128 subcarriers at global bit rate of 60 Gbps and after 250 km transmission distance. The obtained constellation diagram here is the worst compared with other modulation techniques. Due to increasing of data rate and symbol rate, the OFDM symbol period become very narrow. Because of the dispersion and noise in the channel, the OFDM signal was effected and the BER performance was degraded till (approx. 10^{-2}).

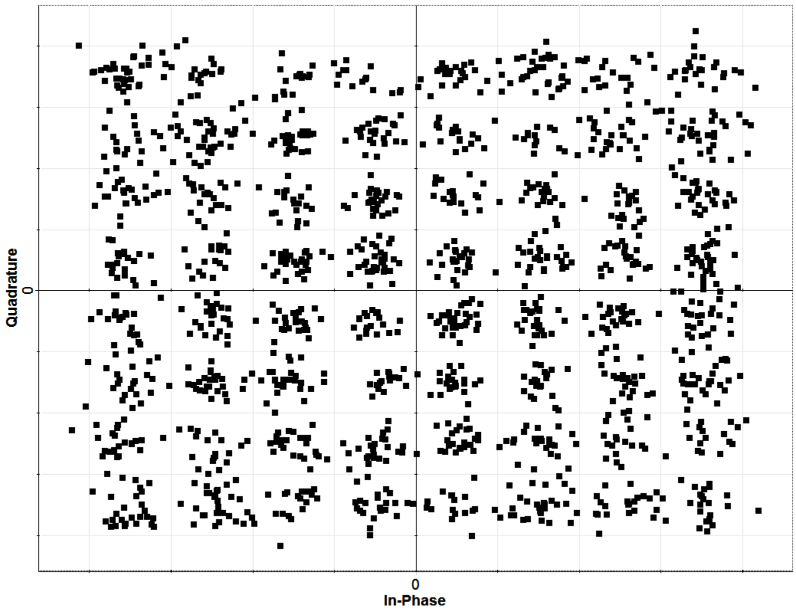


Fig. 7. Constellation diagram of 64 QAM modulation with 60 Gbps and 128 subcarriers at 250 km

At transmission distance of 50 km, BER performance of CO-OFDM system with 64 QAM had a good value (approx. $10^{-3.6}$) and the constellation diagram is very clear as shown in fig. 8.

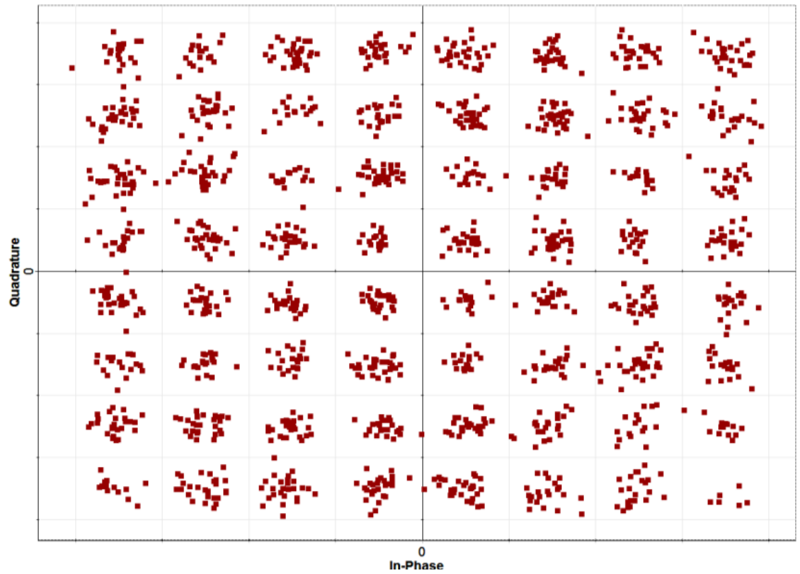


Fig. 8. Constellation diagram of 64 QAM modulation with 60 Gbps and 128 subcarriers at 50 km

64-QAM modulation is preferred to transmit data information at short propagation length in this system due to high data rate so the symbol data is detected and decoded to binary data without more distortion.

Fig. 9 compares the BER measurements for all simulated systems with the propagation length (ranging from 50 to 350 km). It can be clearly seen that a 60 Gbit/s CO-OFDM system with 64-QAM provides a good BER performance at short transmission distance but 16-PSK modulation is preferred to achieve more better BER performance at long transmission distance until 250 km as shown in fig. 9.

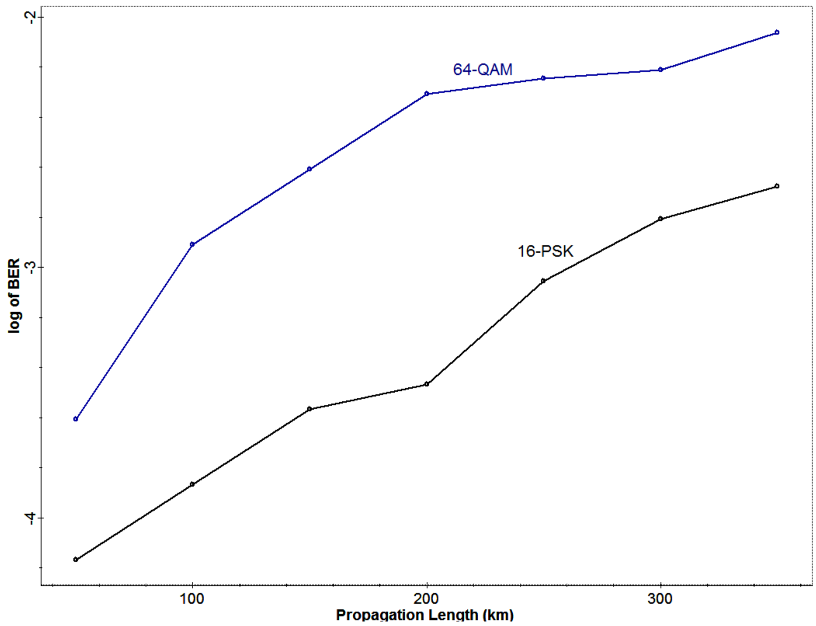


Fig. 9. BER measurements for both 64-QAM and 16-PSK modulation

IV. Conclusion

We have investigated coherent detection OFDM (CO-OFDM) system based on both high orders 64-QAM and 16-PSK modulation formats. The error performance of the 64QAM receiver has been evaluated and compared with other modulation formats such as 16-PSK. The simulation results were obtained by using Optisystem software that can show the constellation diagram and the spectrum of signals. All results are applicable and acceptable in optical communication systems. Finally, CO-OFDM system with QAM/PSK is considered a very effective system to support high data rate with good BER performance.

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References

[1]. J. Armstrong, "OFDM for Optical Communications," IEEE J. Of Lightwave Technology," J. Lightwave Technol., 27, 189-204 (2009)

[2]. T. Nguyen, S. Mhatli, E. Giacoumidis, L. Van Compernolle, M. Wuilpart and P. Mégret, "Fiber Nonlinearity Equalizer Based on Support Vector Classification for Coherent Optical OFDM, " IEEE Photonics J., 8, 7802009 (2016)

[3]. F. El-Nahal, "Coherent 16 Quadrature Amplitude Modulation (16QAM) Optical Communication Systems," Photonics Lett. Pol., 9, 57- 59 (2018)

[4]. S. Jansen I. Morita, T. Schenk, N. Takeda, and H. Tanaka, "Coherent Optical 25.8-Gb/s OFDM Transmission Over 4160-km SSMF, " J. Lightwave Technol., 1 - 10 (2007)

[5]. N. Sheffi and D. Sadot, "Direct Modulation and Coherent Detection Optical OFDM, " in 2010 IEEE 26-th Convention of Electrical and Electronics Engineers in Israel, Eilat, November 17-20, 000808 - 000810 (2010)

[6]. F. Mangone, J. Tang, M. Chen, J. Xiao, L. Fan and L. Chen, "Iterative clipping and filtering based on discrete cosine transform/inverse discrete cosine transform for intensity modulator direct detection optical orthogonal frequency division multiplexing system, " in SPIE Optical Engineering, 52, (065001) 1 - 7 (June 2013)

[7]. F. El-Nahal, "Bidirectional OFDM-WDM-PON System Employing 16-QAM Intensity Modulated OFDM Downstream and OOK Modulated Upstream," Photonics Lett. Pol., 8, 60-62 (2016)

[8]. M. Alhalabi, F. El-Nahal and N. Taşpınar, "Comparison of different modulation techniques for optical OFDM Intensity Modulation and Direct Detection IM/DD system," in 2019 IEEE 7th Palestinian International Conference on Electrical and Computer Engineering (PICECE) , Palestine, Gaza, 26-27 March 2019

[9]. Optisystem Package from Optiwave

Mahmoud Alhalabi, et. al. "Comparison between high orders Phase Shift Keying (PSK) and Quadrature Amplitude Modulation (QAM) for Coherent Detection Optical Frequency Division Multiplexing System (CO-OFDM)." *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 15(5), (2020): pp. 01-08.