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Performance Analysis of Direct-Detection Optical-OFDM System Using Different Modulation Techniques

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Abstract
Orthogonal Frequency Division Multiplexing (OFDM) is used widely in wired and wireless communication systems because it offers a better solution to intersymbol interference (ISI) caused by a dispersive channel. Recently OFDM is introduced in optical communication to achieve high bit rate data transmission. In this paper, the performance analysis of direct-detection optical OFDM system is done using different modulation techniques such as QPSK, 8-QAM, 16-QAM and 32-QAM. The different performance parameters as BER, Q factor (dB) of the system are analyzed for all these modulation techniques.

Keywords
Optical OFDM (O-OFDM), Quadrature Amplitude Modulation (QAM), Quadrature Phase Shift Keying (QPSK), Mach-Zehnder Modulator (MZM), Bit Error Rate (BER).

I. Introduction

OFDM is emerging in optical communication as leading technology for high data rates due to its robustness and flexibility in resource allocation [1]. OFDM has advantage of its robustness against channel dispersion and ease of phase and channel estimation in a time-varying environment [3]. Optical OFDM is mainly classified into direct detection system and coherent detection system. In direct detection system, there is no need of carrier generator at the receiver avoiding the circuit complexity. Whereas in coherent detection, the principle of optical mixing is utilized with local oscillator and optical hybrid at the receiver [2]. OFDM divides the available spectrum into several sub-carriers and each sub-carrier is then modulated by a lower data rate which causes reduction of symbol rate and making optical OFDM robust against polarization mode dispersion and chromatic dispersion.

In this paper, section II describes a simulation setup of direct-detection Optical-OFDM system. In section III, a simulative analysis is carried out to evaluate the various performance parameters as BER and Q factor (dB) etc. of OFDM-based system using different Modulation Techniques. At last, conclusion is presented in section IV.

II. Simulation Model

Figure 1 show the simulation model for direct-detection Optical-OFDM system designed to study the performance of different modulation techniques in terms of BER, Q factor (dB).

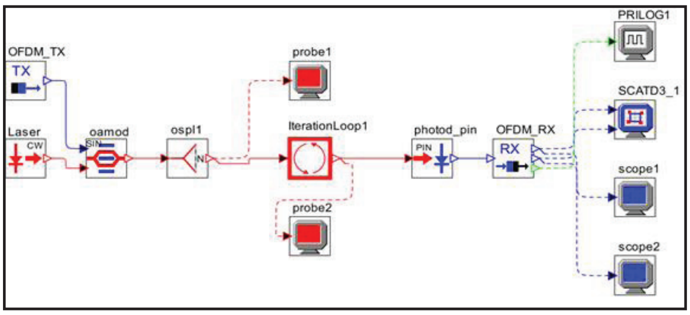

Fig. 1: Simulation Set Up for Direct-Detection Optical-OFDM System

The OFDM transmitter section consists of a data source, serial to parallel converter, M-QAM modulator, IFFT (Inverse Fast Fourier Transform) block, Quadrature-Mix Inphase-Inquadrature block and an electrical combiner.

In the simulation model of an optical OFDM system, the Mach–Zehnder modulator (MZM) is used to convert electrical signals to optical signals [10]. At the receiver, optical signal is converted to electrical signal with the help of a PIN photodiode.

OFDM receiver section consists of an electrical splitter, Quadrature-Mix Inphase-Inquadrature block, electrical filters, FFT (Fast Fourier Transform) block, QAM demodulator and a parallel to serial converter [5]. The iteration loop represents an optical fiber which is followed by an Erbium-doped Fiber Amplifier (EDFA).

III. Performance Analysis of Optical-OFDM System using Different Modulation Techniques

The simulation of optical OFDM system was obtained as in figure 1 and the detailed performance analysis of optical-OFDM system using different modulation techniques is presented in the subsequent figures.

The simulation is carried out for a common data rate of 10Gb/s for QPSK, 8-QAM, 16-QAM, 32-QAM modulation techniques, respectively. The other system parameters are: 8 number of subcarriers, FFT size of 256. The parameters of single mode fiber are listed in Table 1.

Table 1: Single Mode Fiber Parameters

Length	100 Km to 250 Km
Attenuation	<0.35/0.22 dB/Km
Zero dispersion Wavelength	1550 nm
Dispersion at Reference Frequency	-20 ps^2/Km
Reference Frequency for Losses	193.41449 THz

Figs. 2, 3, 4 and 5 shows Eye diagram of received OFDM signal for all above stated modulation techniques separately.

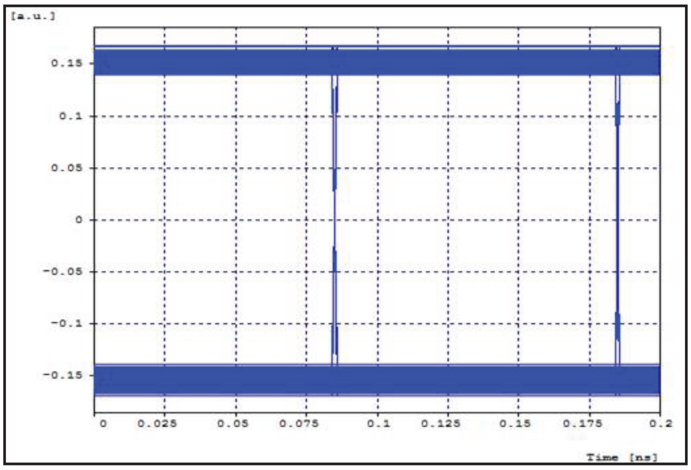

Fig. 2: Eye Diagram of QPSK Modulation Technique.

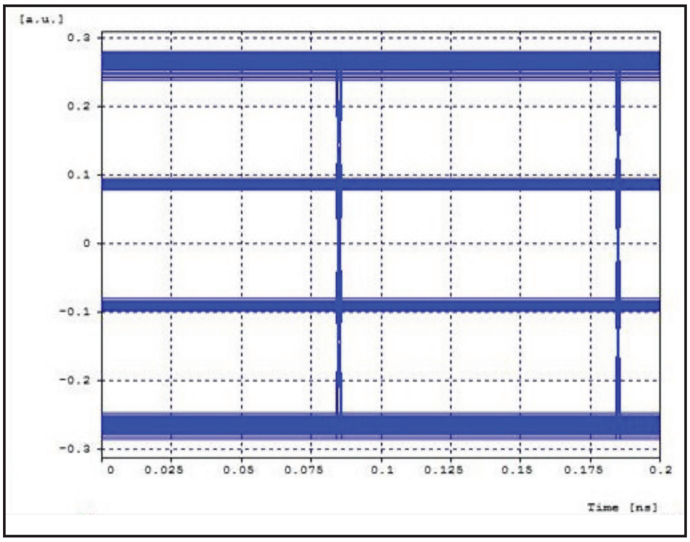

Fig. 3: Eye Diagram of 8-QAM Modulation Technique

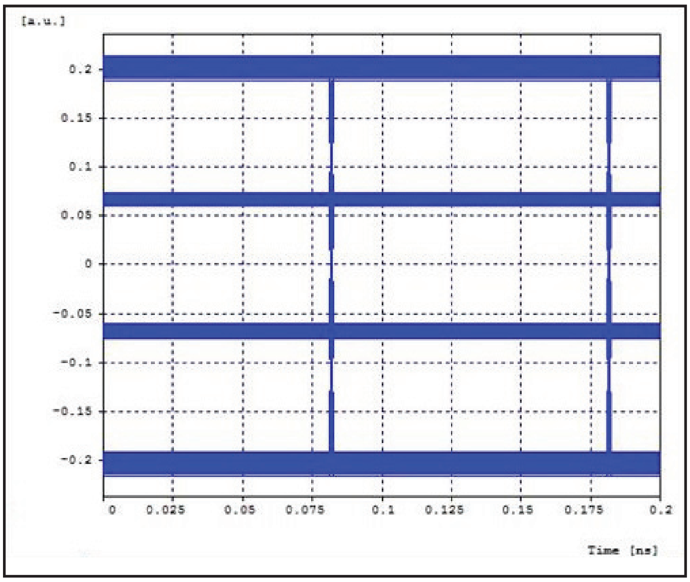

Fig. 4: Eye Diagram of 16-QAM Modulation Technique

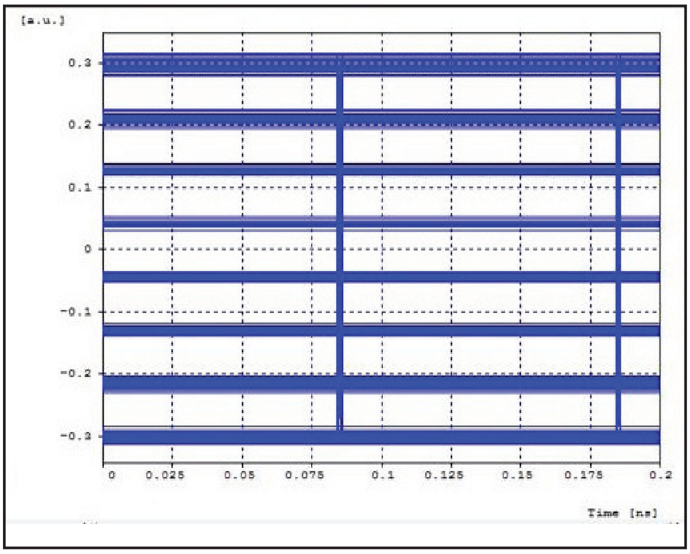

Fig. 5: Eye Diagram of 32-QAM Modulation Technique

The detailed comparison of various performance parameters of QPSK, 8-QAM, 16-QAM and 32-QAM modulation techniques in optical-OFDM system are listed in Table 2.

Table 2: Performance Analysis of Direct-Detection optical-OFDM system for Different Modulation Techniques

Modulation Techniques	Fiber Length(Km)	BER	Q-factor (dB)
QPSK	100	3.4720×10^{-11}	16.3797
	150	1.63529×10^{-5}	12.7425
	200	4.30641×10^{-4}	11.0525
	250	6.78255×10^{-3}	7.03517
8-QAM	100	2.86603×10^{-6}	14.9226
	150	4.13036×10^{-5}	13.8318
	200	2.71403×10^{-4}	10.4566
	250	2.22701×10^{-1}	6.02606
16-QAM	100	1.35471×10^{-5}	11.0680
	150	8.29056×10^{-4}	10.3881
	200	1.66587×10^{-3}	9.10544
	250	2.22701×10^{-1}	6.02606
32-QAM	100	4.5705×10^{-12}	16.7913
	150	6.87884×10^{-9}	15.1174
	200	1.07608×10^{-5}	12.4717
	250	1.58201×10^{-3}	12.1868

The BER curves with respect to varying fiber length for different modulation techniques in optical-OFDM system are shown in fig. 6.

The BER curves with respect to varying fiber length for different modulation techniques in optical-OFDM system are shown in figure 6. It is clear that with QPSK modulation technique, BER is increased from 3.47×10^{-11} to 6.78×10^{-3} at varying fiber lengths from 100 km to 250 km, respectively. With 8-QAM modulation technique, BER of optical-OFDM system is increased from 2.86×10^{-6} to 2.22×10^{-1}, respectively. With 16-QAM modulation technique, BER of optical-OFDM system is increased from 1.35×10^{-5} to 2.22×10^{-1} respectively. With 32-QAM modulation technique, BER of optical-OFDM system is increased from 4.57×10^{-12} to 1.58×10^{-3} respectively.

The BER increases with the increase in fiber length. Thus 32-QAM technique offers low Bit error rate as compared to other modulation techniques. From fig. 6, it is clear that BER of 32-QAM is better as compared to other modulation techniques.

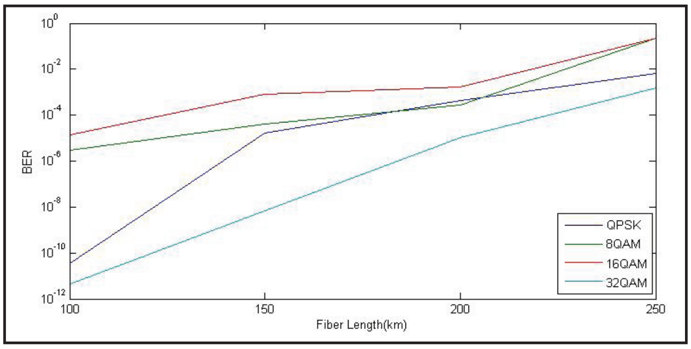

Figure 6: Comparison of BER vs. Fiber Length for different Modulation Techniques

Further, the Q factor curves with respect to varying fiber length for different modulation techniques in optical-OFDM system are shown in fig. 7. The Q factor decreases with the increase in fiber length. The Q-Factor of QPSK modulation technique is decreased from 16.379 to 7.0351 at fiber length of 100km to 250km, respectively. The Q factor of 8-QAM modulation technique is decreased from 14.922 to 6.0260, respectively. The Q factor of 16-QAM modulation technique is decreased from 11.068 to 6.0260, respectively. The Q factor of 32-QAM modulation technique is decreased from 16.791 to 12.186, respectively.

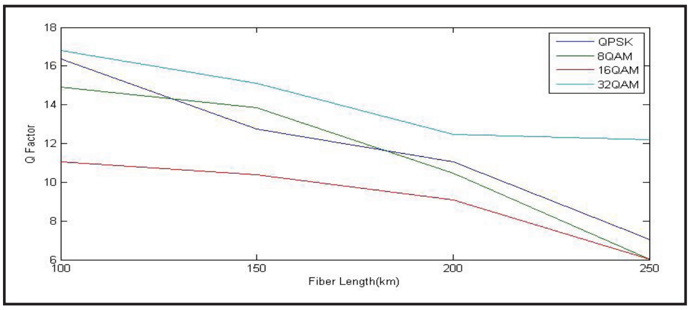

Fig. 7: Comparison of Q-Factor vs. Fiber Length for different Modulation Techniques

After analyzing the fig. 7, it is clear that 32-QAM technique offers high Q factor as compared to other modulation techniques.

VI. Conclusion

Performance analysis of direct-detection optical OFDM system for different modulation techniques such as QPSK, 8-QAM, 16-QAM and 32-QAM has been carried out in this paper. The various performance parameters as BER, Q factor of OFDM signal are analyzed. From the comparison of different modulation techniques, it is clear that the BER and Q factor of the 32-QAM modulator are better than QPSK, 8-QAM, 16-QAM. Therefore, it can be concluded that performance of direct-detection optical-OFDM system can be improved by using higher modulation techniques as 32-QAM.

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