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Performance Analysis of Coherent Optical OFDM System using Different Mach-Zehnder Modulators

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Abstract
The OFDM technique has been proposed in coherent optical system to combat the fiber dispersion. The choice of a particular modulation technique has a greater impact on the system performance. In this paper, the different performance parameters of CO-OFDM system such as BER, Q factor (dB) etc. are analysed for both single-drive and dual-drive MZMs over 20Km SMF without using any dispersion compensation technique.

Keywords
Coherent Optical-Orthogonal Frequency Division Multiplexing (CO-OFDM), Mach-Zehnder Modulator (MZM), Quadrature Amplitude Modulation (QAM).

I. Introduction

To support the demand for high speed data rate and high capacity of bandwidth, the advance research work focus on the integration of wireless communication networks and fiber optic networks. The Passive Optical Networks (PONs) can provide high data rate and OFDM is a promising technique to improve the efficiency of PONs [1]. OFDM is an efficient technique for use in both wired and wireless communication systems as it offers several advantages such as it provides solution to intersymbol interference (ISI) resulting from a dispersive channel, transfers the complexity of transmitters and receivers design from analog to digital domain [2], provides good protection against impulsive parasitic noise and co-channel interference etc. The use of quadrature amplitude modulation (QAM) for subcarriers of OFDM symbols can reduce the bandwidth requirements of electrical and optical components or can increase the bit rate [3].

For optical communication, OFDM has been realised for both direct detection [4] and coherent detection systems [5]. The direct detection system is preferred for short and medium distance transmission due to its receiver simplicity and the coherent detection system becomes preferable for long-haul transmission because of its better receiver sensitivity and high bandwidth efficiency than a direct detection system. The coherent detection optical OFDM (CO-OFDM) system provides solution to the fiber impairments resulting from polarization-mode dispersion [6]. But it requires high complexity in transceiver design than a direct detection system.

In this paper, we design a CO-OFDM system using a single-drive Mach-Zehnder Modulator (MZM) and a dual-drive MZM and a simulative analysis is carried out to evaluate the performance of system for both modulators. At last, conclusion is presented.

II. CO-OFDM System Design

The CO-OFDM system combines both coherent detection and OFDM technique to improve spectral efficiency and power. The OFDM technique divides the available frequency spectrum among several subcarriers and data is transmitted in parallel over several subcarriers resulting in longer symbol period as compared to a serial data transmission for the same total bit rate. The equalization is simplified due to lesser effect of ISI on longer symbol period [2]. The principle of coherent detection relies on the idea of mixing the received signal with local oscillator signal. The figure 1 shows the simulative set-up of CO-OFDM system using a single-drive MZM.

In CO-OFDM system, the OFDM signal is generated using a data source, a parallel to serial converter, M-QAM modulator, Inverse Fast Fourier Transform (IFFT) and a quadrature-mix inphase-inquadrature block. For coherent detection, a balanced receiver is generally preferred to suppress the common mode component i.e. direct current component and to minimize the laser RIN [7]. The OFDM receiver performs a reverse operation than an OFDM transmitter by using a quadrature-mix inphase-inquadrature block, two bessel filters, Fast Fourier Transform (FFT), M-QAM demodulator and a parallel to serial converter.

The figure 2 shows the simulative set-up of CO-OFDM system using a dual-drive MZM. The dual-drive MZM requires two electrical signals as compared to a single drive MZM which requires only one electrical signal.

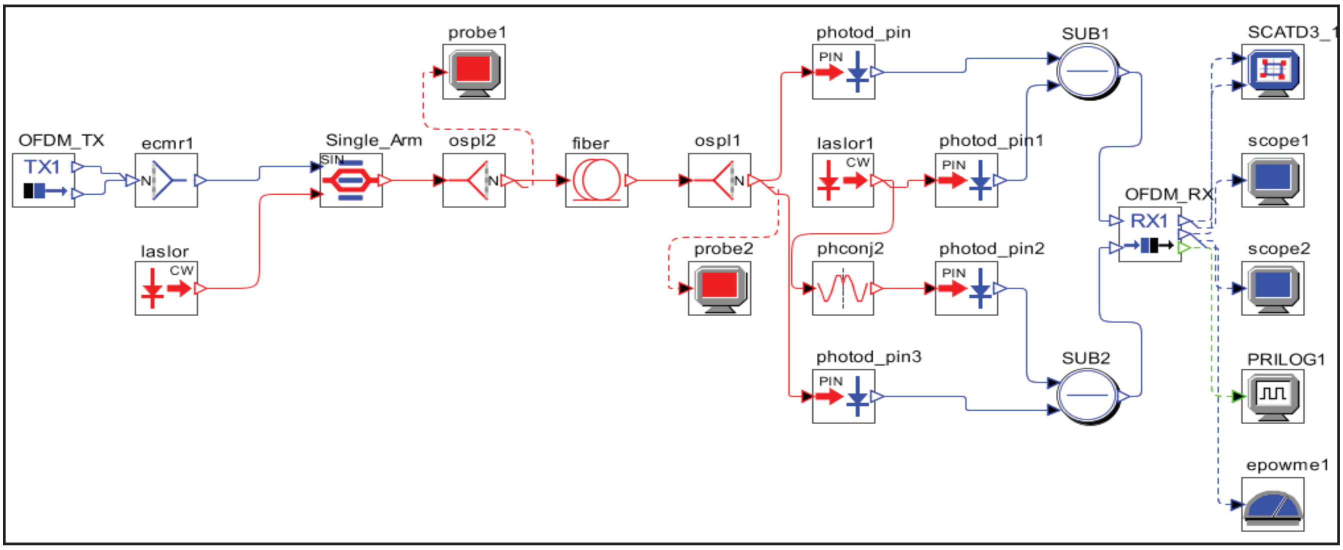

Fig. 1: Simulative Set-Up of CO-OFDM System using a Single-drive MZM

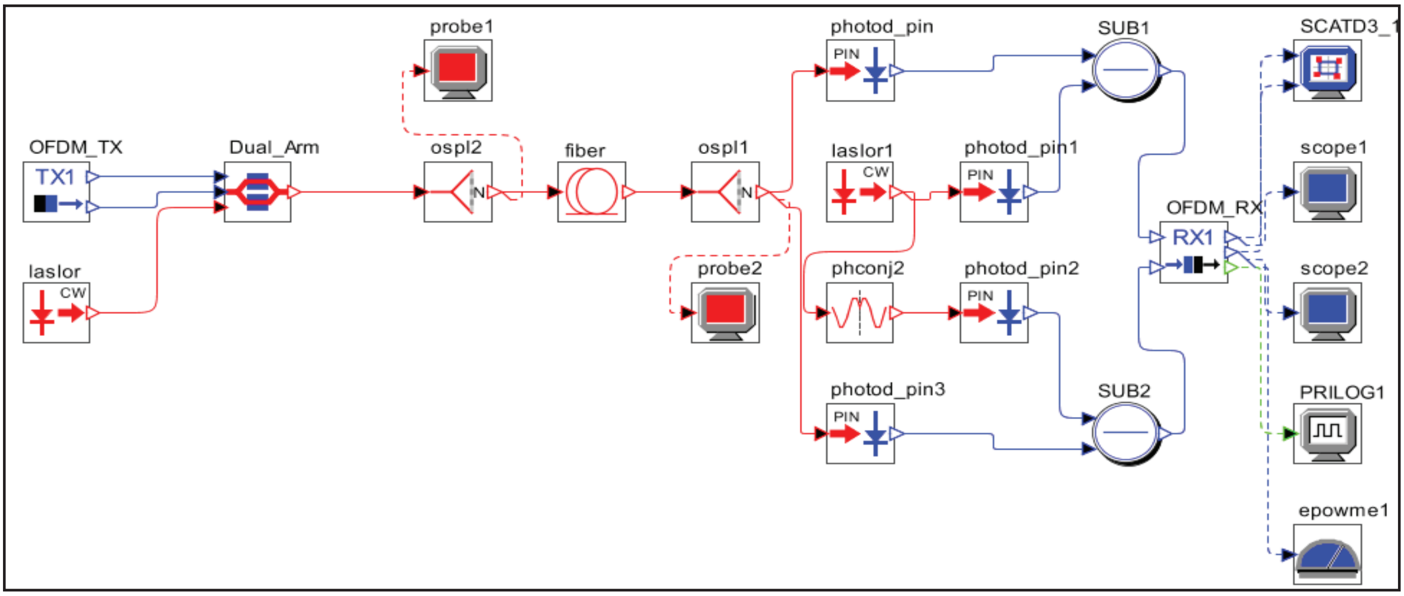

Fig. 2: Simulative Set-Up of CO-OFDM System using a Dual-Drive MZM

For normal operation, both electrical signals are applied to a dual drive MZM with a π phase shift between them, but in the model shown in fig. 2, an appropriate phase delay of ± π/2 between the input signals of dual drive MZM is used to suppress the harmonics in the modulated optical spectrum [8].

The MZM nonlinearity greatly affects the system performance and for better performance, the bias point should be chosen carefully. The bias point or static phase shift (φ) of MZM is defined as

$$\varphi = V_{DC*\pi}/V_{\pi} \quad (1)$$

Where VDC is the DC bias voltage of MZM, V_{π} is the half wave switching voltage of MZM. To reduce the effect of MZM nonlinearity, the bias point of MZM should be at Quadrature for the direct-detected system and for the coherent system, it should be π [7].

III. Simulation Results

The simulation of CO-OFDM system as in fig. 1 and 2 was carried out with including OFDM transceiver parameters as- number of subcarriers of 64, FFT size of 256 and 16-QAM modulation technique is used supporting a data rate of 10 Gb/s. The other parameters of CO-OFDM System are listed in Table 1.

Both single-drive MZM and dual-drive MZM are biased at π bias point to overcome the nonlinearity of MZM in CO-OFDM system. The performance of both CO-OFDM system designs using single-drive MZM and dual-drive MZM respectively is shown in fig. 4 and 5.

Table 1: Simulation Parameters of CO-OFDM System

Parameter	Value
Data Rate	10 Gb/s
Laser Linewidth	10 MHz
Wavelength	1550 nm
CW Laser Frequency	193.4149 THz
CW Laser Power	-2.5 dBm
Attenuation	<0.35/0.22 dB/Km
Dispersion at Reference Frequency	-20 ps^2/Km
Bandwidth of fiber	512 GHz

The fig. 4 shows Bit Error Rate (BER) performance of CO-OFDM system wrt power (dBm) received after transmission over a 20 Km single mode fiber (SMF) without any dispersion compensation. As it is clear from fig. 4 that a dual-drive MZM provides better performance in CO-OFDM system with lower BER than a single-drive MZM.

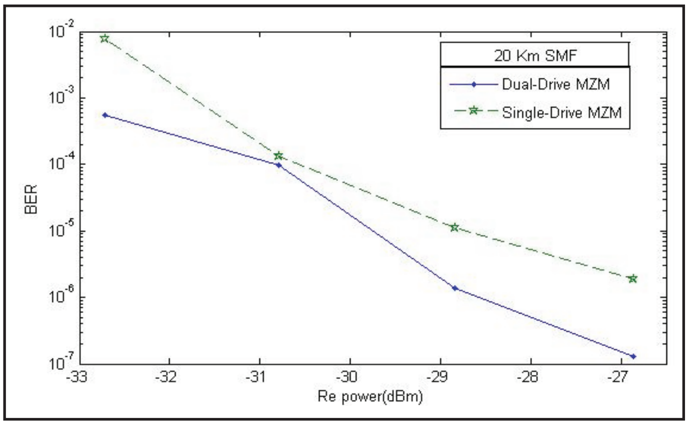

Fig. 4: BER wrt Received power (dBm).

The fig. 5 shows Q factor (dB) performance of CO-OFDM system wrt received optical power (dBm) and it is clear that a dual-drive MZM provides better performance in CO-OFDM system with higher Q factor (dB) than a single-drive MZM.

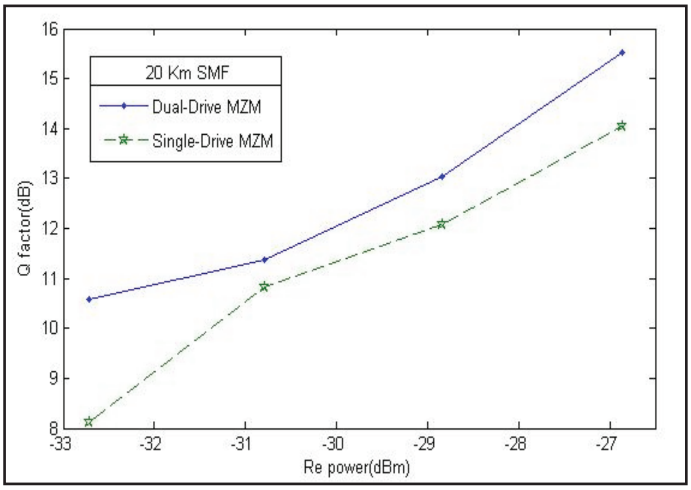

Fig. 5: Q Factor (dB) wrt Received Power (dBm).

Further, a comparative performance evaluation of CO-OFDM system for both modulators either single drive or dual-drive is shown in Table 2. The BER in CO-OFDM system using dual-drive MZM is increased from 6.24×10^{-10} to 3.34×10^{-5} at a fiber length of 20 Km to 60 Km respectively. But single-drive MZM, BER is increased from 9.86×10^{-7} to 1.37×10^{-4} at a fiber length of 20 Km to 60 Km respectively. The Q factor (dB) is 17.496 dB at a fiber length of 20 Km in case of dual-drive MZM which is better than 13.162 dB, Q factor (dB) in case of single-drive MZM at same fiber length. The dual-drive MZM also offers better eye opening as 3.852 [a.u.] than 2.143 [a.u.], eye opening in case of single-drive MZM.

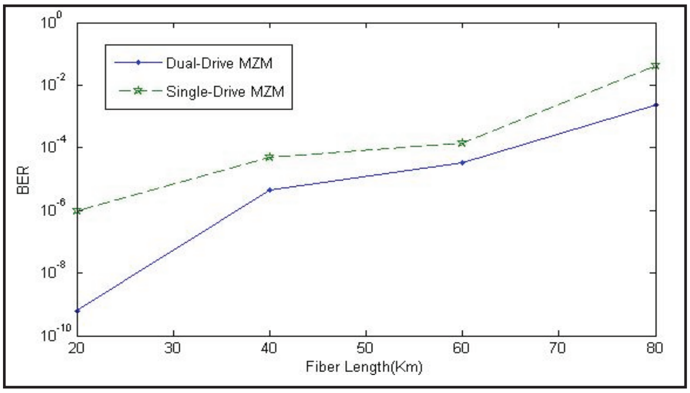

Fig. 6: BER Performance wrt Fiber Length (Km).

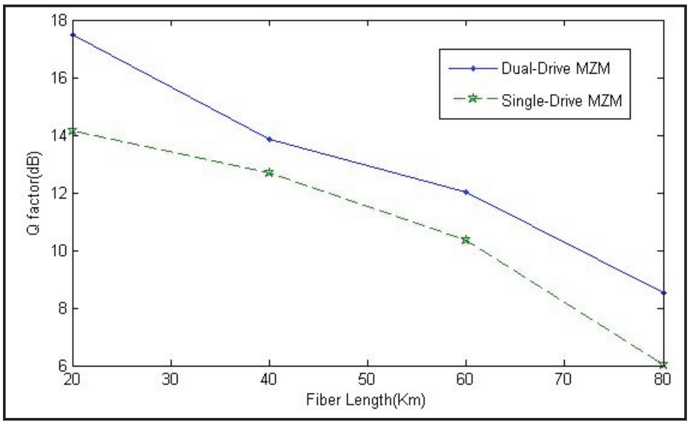

Fig. 7: Q factor (dB) wrt Fiber Length (Km).

Thus, it is clear that performance of CO-OFDM system using dual-drive MZM is better than the CO-OFDM system using single-drive MZM. The dual-drive MZM has several advantages over the single-drive MZM as it provides enhanced linearity, better peak-to-average power ratio (PAPR) control and chirp management etc.

Table 2: Comparative Performance Analysis of Single Drive MZM and Dual-Drive MZM in CO-OFDM System wrt Fiber Length

Optical Modulator	Fiber Length	20 Km	40 Km	60 Km
Single-Drive MZM	BER	9.86×10^{-7}	5.14×10^{-5}	1.37×10^{-4}
	Q factor (dB)	13.162	12.699	10.360
	Eye Opening [a.u.]	2.143	0.627	0.205
Dual-Drive MZM	BER	6.24×10^{-10}	4.44×10^{-6}	3.34×10^{-5}
	Q factor (dB)	17.496	14.560	12.039
	Eye Opening [a.u.]	3.852	2.983	0.590

IV. Conclusion

In this paper, we presented a 10 Gb/s CO-OFDM system design using single drive and dual-drive MZMs. The performance of CO-OFDM system in terms of BER and Q factor (dB) is analysed for both modulators. The effect of MZM nonlinearity on the system performance is also considered. For better performance, the used bias point for MZM in coherent system is π. The better performance of dual-drive MZM in CO-OFDM system is supported by simulation results.

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