PERFORMANCE ANALYSIS OF DISPERSION COMPENSATION TECHNIQUES IN A 100 Gbps COHERENT-OPTICAL SYSTEM

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***Abstract*- Long haul transmission links evolve with the advent of new multiplexing and modulation schemes. We propose a new approach of dispersion compensated coherent optical orthogonal frequency division multiplexing scheme which is combined with quadrature amplitude modulation to double the data rate and spectral efficiency as transmitted in an optical OFDM system. Quadrature amplitude modulation (QAM) technique is used for data mapping in the OFDM system. In-phase and quadrature-phase signal are modulated with two different Mach Zehnder modulators with a laser source of 1550nm wavelength and transmitted through a standard single mode fiber. Though the addition of cyclic prefix minimizes the effect of dispersion the use of various dispersion compensation techniques improved the bit error rate performance enabling long distance transmission.**

Keyword- Dispersion compensation, Mach-Zehnder modulator, orthogonal frequency division multiplexing (OFDM), quadrature amplitude modulation, single mode fiber.

I. INTRODUCTION

Optical orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation scheme gaining more interest in optical communication research community owing to high data rate and its robustness to inter symbol interference. Due to efficient implementation, high spectral and power efficiency, and simple frequency-domain equalization, OFDM has been adopted in prominent wired and wireless broadband standards, including high-definition television (HDTV) broadcasting [1], digital subscriber line (DSL), and IEEE 802.11 (WiFi) and 802.16 (WiMAX) and multimedia mobile access communications wireless LANs [2]. More recently, OFDM has received much attention as a high-speed fiber transmission technique capable of electronic compensation of optical impairments .The Up-conversion of OFDM on optical carrier is done using Mach-Zehnder modulation techniques Amplitude modulation and phase modulation (MZ-AM, MZ-PM).

One of the central features that sets orthogonal frequency-division multiplexing (OFDM) apart from single-carrier modulation is its uniqueness of signal processing. The single-carrier technique has been employed in optical communication systems for the past three decades. It is not a surprise that OFDM signal processing seems to be quite strange to an optical engineer at a glance. OFDM technology is exceptionally scalable for migration to higher data rate. In this respect, OFDM is a future-proof technology, and subsequently various aspects of OFDM signal processing deserve careful perusals.

II. COHERENT OPTICAL OFDM SYSTEM

A 100 Gbps bit stream is mapped using 16 QAM Fig 1. The QAM symbols are the input samples of IFFT of size 32. To the complex valued signal a short cyclic prefix 4 bit is added, which removes inter symbol interference (ISI) and inter carrier interference (ICI) [1].The In-phase and Quadrature-phase components of the OFDM[4-6] signal in the RF domain are separately allowed to modulate two Mach-Zehnder modulators operating at 1550nm with 10 mW peak power. One of the optically modulated lights is rotated at an angle 90º. Both the optical signals are combined into a single signal with a power combiner. The combined signal is passed through a standard single mode fiber where a combiner loss of 3dB is observed. At the other end of fiber, the light wave is split into two parts by power splitter (PS) where a 3dB split loss is observed.

DCF fibers have negative dispersion value (-90ps/nm-km) by which the dispersion phenomenon can be compensated. The core diameter of DCF is smaller than the standard single mode fiber, so power lost i.e attenuation is high in DCF. There is a need of amplification of optical wave. EDFA amplifier with a pump wavelength 980nm (for peak absorption in erbium doped matter), noise figure value of 4dB, and a flat gain of 20dB is used [3].

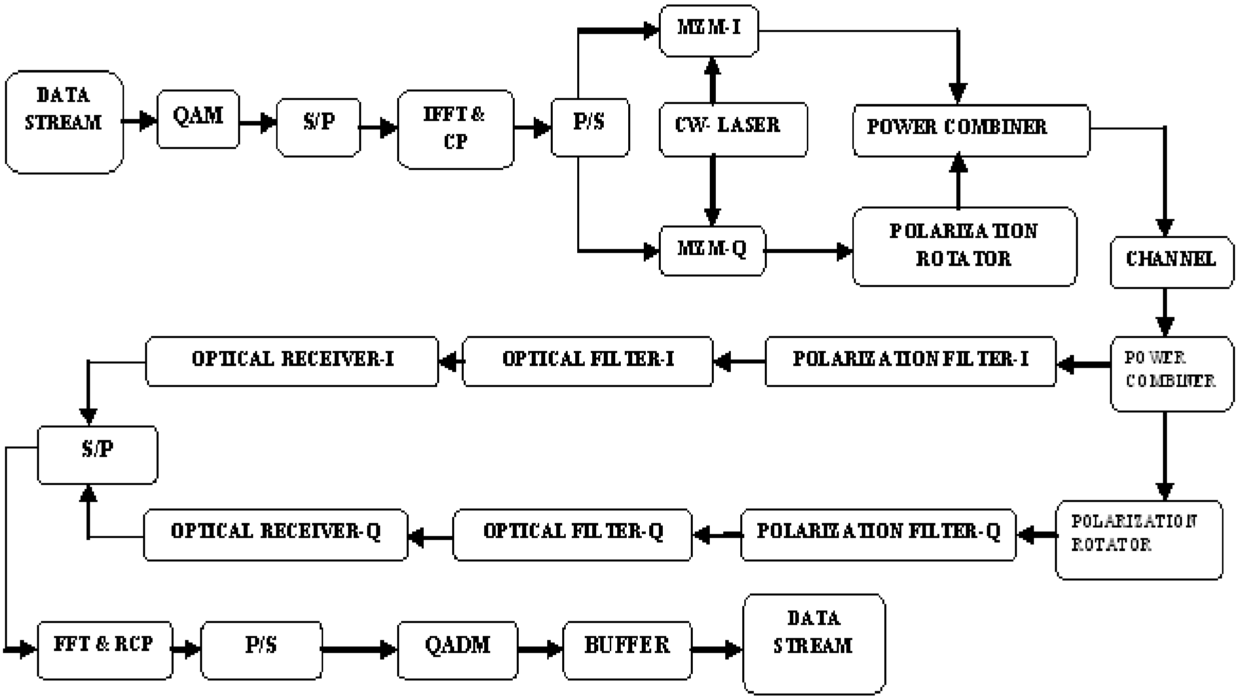

Fig. 1.ofdm transmitter and receiver

In phase and quadrature phase components are passed through the polarization filter where the signal is rotated again by -90^0.The optical receiver (O/R) is a combination of a photo detector (PIN) and a low noise electrical filter. After conversion of optical to electrical signal, both signals are sent, In-phase and Quadrature-phase, via a serial to parallel converter to a cyclic prefix remover (CPR) and then forwarded to a fast fourier transform (FFT) for the conversion from time domain to frequency domain. The serial data is 16 – Quadrature amplitude demodulation /remapping (QADM) the data is sent to a storage device.

The transmitted ofdm signal is given in terms of jones vector by

$$s(t) = \sum_{i=-\infty}^{\infty} \sum_{k=-\frac{N}{2}}^{\frac{N}{2}} \vec{D}_{ik}\, \Pi(t - iT_s) \exp\left(i2\pi f_k (t - iT_s)\right) \quad (1)$$

$$\vec{D}_{ik} = \begin{pmatrix} D_{ik}^{x} \\ D_{ik}^{y} \end{pmatrix} \quad (2)$$

$$s(t) = \begin{pmatrix} s^{x} \\ s^{y} \end{pmatrix} \quad (3)$$

$$f_k = \frac{k-1}{t_s} \quad (4)$$

$$\Pi(t) = \begin{cases} 1, (-\Delta_g < t \le t_s \\ 0, (t \le -\Delta_g, t > t_s \end{cases} \quad (5)$$

where s^x and s^y are the two polarization components for s(t) in the time domain. $\vec{D}_{ik}$ is the transmitted ofdm signal and D_{ik}^{x} and D_{ik}^{y} are the two polarization components of it. f_k is the frequency of the K^{th} subcarrier.N is the number of ofdm subcarriers, T_s , Δ_g and t_s are the ofdm symbol period, guard interval length and observation vector respectively.

III. RESULTS AND DISCUSSIONS

With a standards single mode fiber SSMF), G.652b with attenuation 0.35dB/km, dispersion 16.75 ps/nm/km, dispersion slope 0.75 ps/nm^2/km , Polarization mode dispersion 0.2 ps/sqrt(km), and effective area 80 μm^2 the following results are obtained.

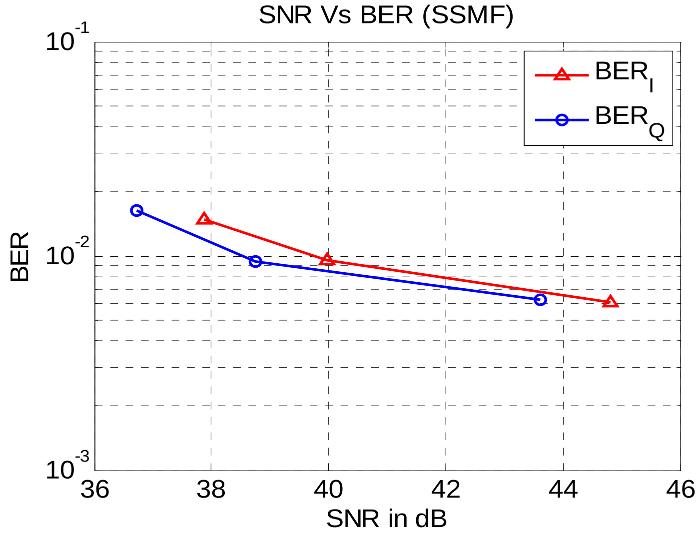

Fig. 2.Standard single mode fiber without dispersion compensation

At 100 Gbps data rate the maximum link length supported by the standard single mode fiber (SSMF) is18 km, because of dispersion. The maximum BER is 10^{-1} but up to 10km link length, the bit error rate is of the order of 10^{-2} at 100 Gbps data rate, which is acceptable. When the link length of communication increases the corresponding OSNR and SNR both decrease because of the increasing noise Fig 2.

With a Dispersion compensative fiber (DCF) and erbium doped fiber amplifier (EDFA) are used in this case for dispersion control. The parametric specification of DCF and EDFA used in the link with predispersion compensation are dispersion of DCF -90 ps/Km-nm, gain of EDFA 20dB, attenuation 0.5dB/km and noise figure 4dB and a pump wavelength 980nm.

Pre dispersion compensation can support maximum link length up to 61km comprising of 24 km of DCF and the rest link length of SSMF. Beyond this, the BER approaches very high values. The SNR decreases as the link length increases Fig 3.

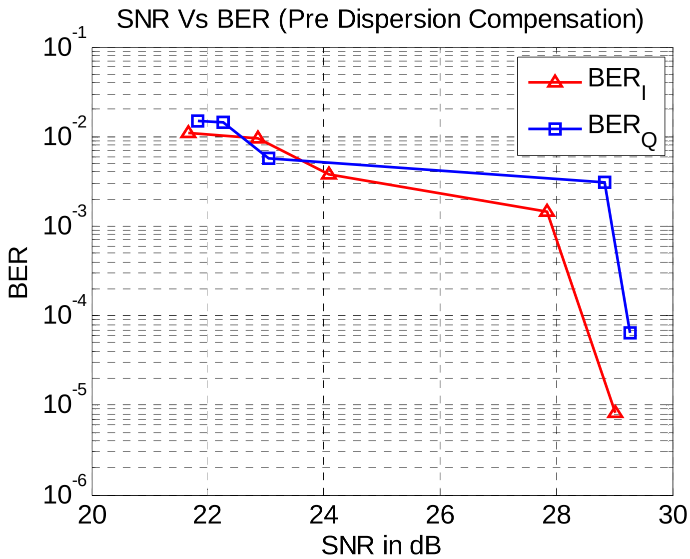

Fig. 3. Pre dispersion compensation.

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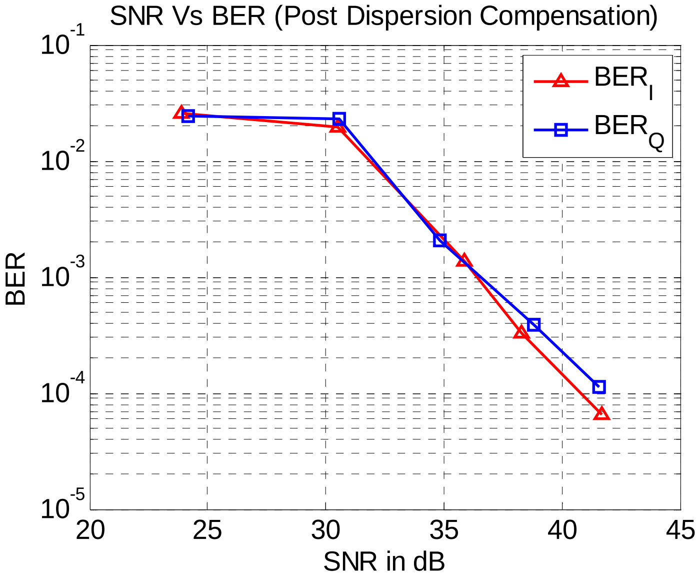

Fig . 4. Post dispersion compensation.

The post dispersion technique supported a maximum link length of 59km which is very close to previous case. The bit error rates for I-phase and Q-phase are very similar. This is an advantage of this technique for the case of post dispersion compensation Fig 4.

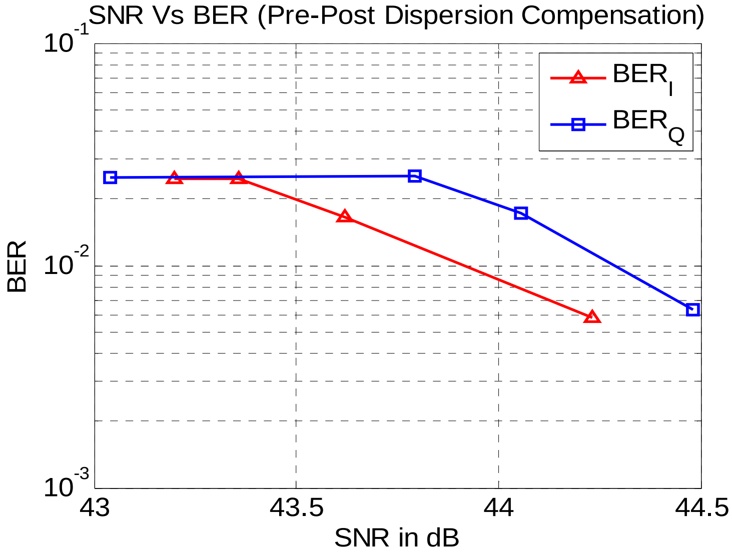

Fig. 5. Pre –post dispersion compensation

Due to the use of a combination of multiple DCF and EDFA data can be sent for a maximum link length of 100 km with a bit error rate of the order of 10^{-2}. The SNR for both I and Q phase components is observed to decrease with the increase of link length Fig 5.

IV. CONCLUSION

Coherent optical OFDM system is analyzed to transmit 100 Gbps in the physical layer. The BER for pre-dispersion compensation case is observed to be of the order of 10^{-4} and 10^{-5}. This is a novelty of this work as all the previous works in optical-OFDM with QAM have reported a BER of order 10^{-2} and 10^{-3}. Although the pre dispersion compensation technique achieved a minimum bit error rate value of 10^{-5} for 49 km link distance, but the bit error for I-phase separately is observed to be of the order of 10^{-4}. In the post dispersion compensation technique the bit error rate for I and Q phase is very close to each other. With pre-post dispersion a BER of the order of 10^{-2} is observed. Therefore it is concluded that the main advantage of this technique is that a higher link length of communication is achievable at the cost of slightly greater BER.

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