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Comparative Study of CO-OFDM System with Fiber Length and Launch Power

Sangeeta Mokhria
Assistant Professor, Electronic Science Dept.
Acharya Narendra Dev College,
University of Delhi, India

Mamta Sinha
M.Tech, ECE Dept.
(AIACT&R), GGSIPU,
Govt. of NCT of DELHI, India

Abstract:

The system performance of single channel CO-OFDM and multi-channel WDM CO-OFDM system with 100GHz channel spacing at 10-Gb/s data rate with and without equalizer is shown through simulation for different fiber length and launch power. The simulation results reveal that single channel CO-OFDM has better transmission performance up to 400km in comparison to WDM CO-OFDM system where the transmission distance reduced to 300km instead of 400km for the same launch power and then the effect of equalizer is also demonstrated and the result show that the system having equalizer has better system performance with less BER.

Index Terms – OFDM, WDM, QAM, equalizer, nonlinear distortion and nonlinear system.

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is an attractive modulation format that recently received a lot of attention in the fiber-optic community [1, 3-9]. Coherent Optical OFDM (CO-OFDM) is considered an enabling technology of the next generation optical communication system since it possesses the merits of both a coherent system and an OFDM system [1]. As a coherent system, the CO-OFDM system maintains both signal amplitude and phase [2], thus increasing bandwidth utilization. The coherent optical communication system makes full compensation of chromatic dispersion, after optical/electrical conversion, possible. The OFDM modulation scheme also leads to a high spectral efficiency because of its partially overlapping subcarriers [1]. Moreover, the cyclic prefix code of the CO-OFDM system makes the system more resistant to inter-symbol interference caused by chromatic dispersion and polarization mode dispersion (PMD) [1, 3]. The main advantage of optical OFDM is that it can cope with virtually unlimited amount of inter symbol interference (ISI) which is serious issues in long-haul systems whose bit rate is higher than 10 Gbit/s.

One major concern people have about the CO-OFDM system is its vulnerability to fiber nonlinear effects such as self-phase modulation (SPM) and cross-phase modulation (XPM). Both of SPM and XPM are caused by the optical signal intensity fluctuation [4]. Since the OFDM system has a high peak to average power ratio (PAPR) [5], a CO-OFDM system has more severe SPM and XPM compared with traditional is a multi-carrier modulation scheme, the four-wave mixing (FMW) among subcarriers within one channel also causes concerns among researchers [6]. As a result, nonlinearity compensation is a crucial component of the CO-OFDM system. In this paper, we concentrate on intra-channel nonlinearity distortion of the CO-OFDM system caused by SPM and FWM among subcarriers and present a nonlinear signal processing schemes to compensate for intra-channel nonlinearity that means estimating sequence by the help of equalizer at the receiver.

The Maximum likelihood sequence estimation (MLSE) is a widely used nonlinear signal processing tool [7]. MLSE is a mathematical algorithm to extract useful data out of a noisy data stream. For an optimized detector for digital signals the priority is not to reconstruct the transmitter signal, but it should do a best estimation of the transmitted data with the least possible number of errors. The receiver emulates the distorted channel. All possible transmitted data streams are fed into this distorted channel model. The receiver compares the time response with the actual received signal and determines the most likely signal. In cases that are most computationally straight-forward, root mean square deviation can be used as the decision criterion for the lowest error probability.

In this paper some of the basics of an optical OFDM system are discussed. Furthermore, transmission performance is investigated with and without equalizer at 10Gbps data rate for single channel CO-OFDM system and the results is presented in the form of simulations for different launch power.

2. SIMULATION DESCRIPTION OF CO-OFDM SYSTEM

In our study, the CO-OFDM system is simulated by a commercial fiber optics system simulation tool, OptiSystem™. A generic CO-OFDM system includes five basic functional blocks: OFDM transmitter, RF to optical (RTO) up-converter, optical link, optical to RF (OTR) down-converter, and OFDM receiver. The above schematic demonstrates a 10 Gbps coherent 512-subcarrier 16-QAM OFDM system; however the input data for the OFDM modulator can have different modulation formats such as BPSK, QPSK, QAM, etc. At the transmission block, both modulation and multiplexing are achieved digitally using an inverse fast Fourier transform (IFFT). The subcarrier frequencies are mathematically orthogonal over one OFDM symbol period. A CW laser and two Mach-Zehnder modulators are used to up-convert

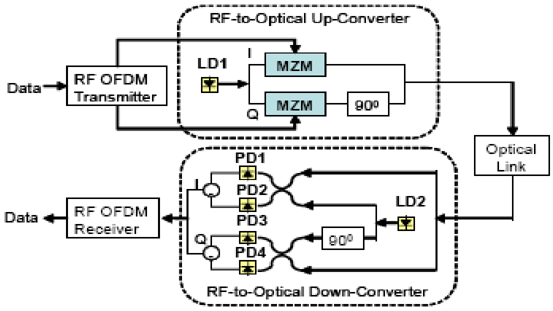

Figure 1: simulation setup of CO-OFDM system

the RF data to the optical domain. The signal is then propagated through the optical link and becomes degraded due to fiber impairments. A coherent receiver with a local oscillator is used to down-convert the data to the RF domain, and finally data is demodulated and sent to the detector and decoder for BER measurements. In our study, the CO-OFDM system is simulated by a commercial fiber optics system simulation tool, OptiSystem™. It has been used by many researchers to simulate the fiber nonlinearity and dispersion effects in optical communication systems [3], [4]. Our simulation setting takes most key optical communication system/component parameters into account including fiber nonlinearity, noise, dispersion, and PMD, etc. For the sake of simplicity, some effects such as the laser frequency drifting, and filter bandwidth drifting are ignored. The CO-OFDM simulation configuration is illustrated in figure 1.
The data transmission bit rate is 10 Gbps. On the transmitter side, a bit stream is generated using a pseudo random binary sequence generator, and the data is mapped by a 16-QAM encoder. The information stream is further parsed into 512 low speed parallel data subcarriers and processed by the IFFT processor. Cyclic prefix is added to ensure a correct data recovery. The 25 Gbaud rate OFDM in-phase and quadrature parts then pass the low pass filter. The Mach–Zehnder modulator is used to convert electrical signals to optical signals. The laser line width is set at 0.15MHz, with adjustable launch power. The frequency of the carrier wave is set at 193.1THz. The optical channel consists of 10 spans of 50km standard single mode fiber (SSMF), with attenuation = 0.2dB/km, dispersion = 16 ps/nm/km and nonlinearity coefficient=2.09 /w/km. Fiber dispersion is fully compensated by the dispersion compensation fiber (DCF) in each span which has 0.6dB/km attenuation, -160ps/nm/km dispersion and 6.4/w/km nonlinearity coefficient. Both the SMF and DCF span loss is balanced by a 4 dB noise figure optical amplifier in each loop. Amplified spontaneous emission (ASE) noise is reduced by an optical filter at the receiver. The local oscillator (LO) laser is assumed to be perfectly aligned with power set at -2dBm and line width equals to 0.15 MHz. The I/Q components of the OFDM signal is recovered by a 2 × 4 90 degree optical hybrid and two pairs of photo-detectors. Photo-detector noise, such as thermal, shot noise, dark current and ASE noise are included in the simulation. The converted OFDM RF signal is demodulated using FFT processor and the guarding interval is removed. The obtained signals are fed into a 16-QAM decoder. Transmission bits are collected and bit error ratio (BER) is calculated for both the system having equalizer and compared at the end of the receiver

In a WDM system, signals at different wavelengths travel in the same fiber, as illustrated in Figure2. In each channel, different electrical signals modulate carriers with different wavelengths. Different wavelengths are coupled by a multiplexer and transmit through the fiber. At the receiver, those wavelengths are separated by the de-multiplexer and are demodulated separately. In this paper 4 channel WDM system is discussed.
In a WDM setting, 4 channels of 25 Gbaud 16-QAM OFDM signals are transmitted. At the receiver, each channel is extracted by bandpass optical filters with different center frequencies. Then, the obtained optical signal in each channel is converted back to an electrical signal by photo-detectors separately. The carrier wave frequencies are set from 192.9 THz to 193.3 THz, with 100 GHz channel spacing. The transmission performance is investigated for different paunch power.

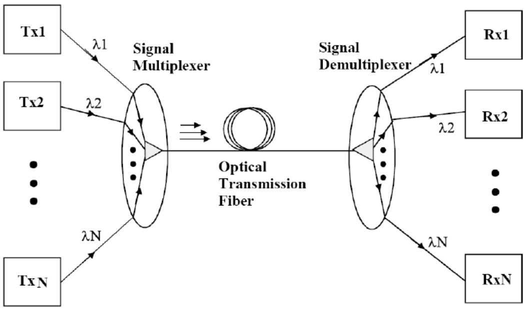

Figure 2: Point to point WDM communication system

For single frequency point-point links the bit rate is limited ~100 Gb/s due to dispersion. WDM can increase the total bit rate of point-to-point systems.

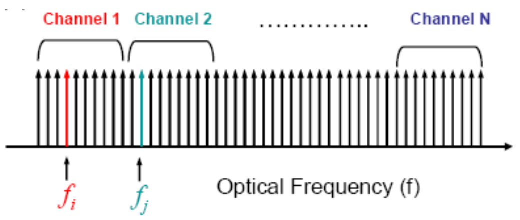

Figure 3: The optical spectrum for *N* wavelength-division-multiplexed CO-OFDM channels

For N channels with bit rates B1, B2, …, BN transmitted simultaneously over a fiber of length L, the bit rate-length product becomes B . L = (B1 + B2 +…+ BN). L for WDM system.

Transmission bits are collected at the receiver and bit error ratio (BER) is calculated for the WDM system at the end of the receiver for different transmission length and compared with the single channel CO-OFDM system.

3. RESULTS AND DISCUSSIONS

Optical Spectrum of single channel CO-OFDM and four channel WDM CO-OFDM signal at the transmitter is visualized by using Optical Spectrum Analyzer.

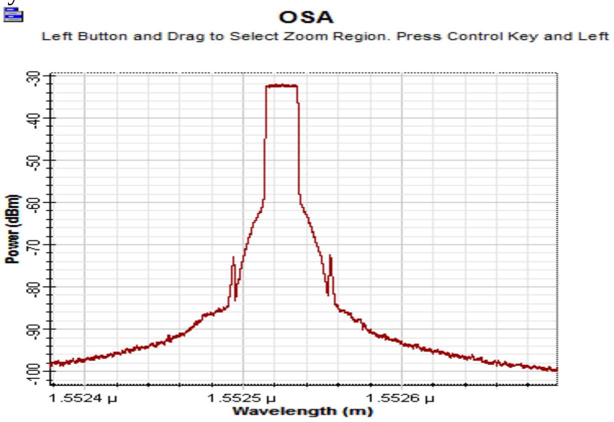

Figure 4: Optical spectrum before optical fiber transmission for single channel CO-OFDM

Performance evaluation of the system for Max Transmission Length of the CO-OFDM system with and without equalizer at different launch power is presented in figure 5.

The graph demonstrate that at low launch power (-4dbm) the transmission length is about 350Km for the system without equalizer and 360km for the system with equalizer for the same BER. Now when we increase the launch power transmission distance increases to 450Km at -1dbm launch power for the system with equalizer .Further increasing the launch power transmission distance now decreasing because as transmission length increases dispersion increases and dispersion effect is more at high launch power and it will limit the performance.

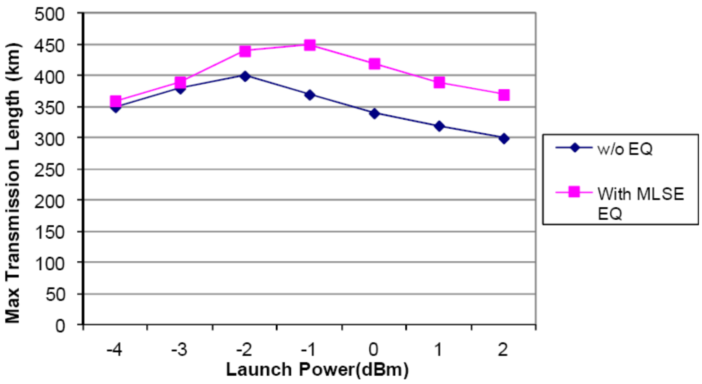

Figure 5: Max Transmission Length vs. launch power for the CO-OFDM system with and without equalizer

Transmission performance of the system is investigated for different transmission length for the CO-OFDM system with and without equalizer for acceptable BER.

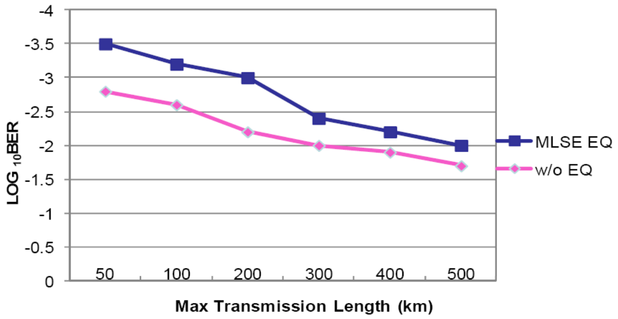

Figure 6: Log10(BER) vs. Transmission Length for the CO-OFDM system with and without equalizer

The graph shown in figure 6 demonstrates that when transmission length increases dispersion increase and the output BER increases. The output BER can be decreases by using equalizer at the output. It is clear from the graph that at low transmission length BER is low for the system having equalizer with respect to the system without equalizer. Now come to WDM system.

Optical Spectrum of four channel WDM CO-OFDM signal at the transmitter is visualized by using Optical Spectrum Analyzer.

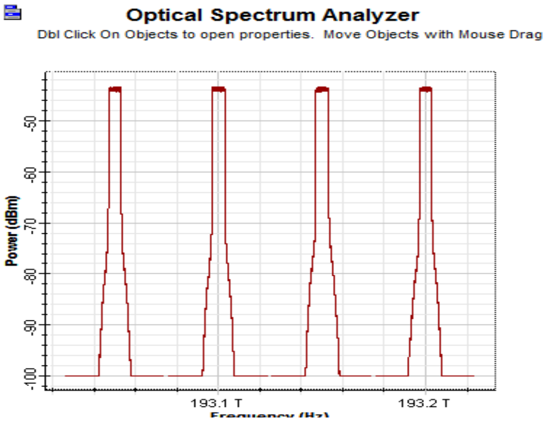

Figure 7: Optical spectrum before optical fiber transmission for WDM CO-OFDM system

The comparison of transmission performance for the single channel CO-OFDM system and WDM CO-OFDM system is illustrated in figure 6.

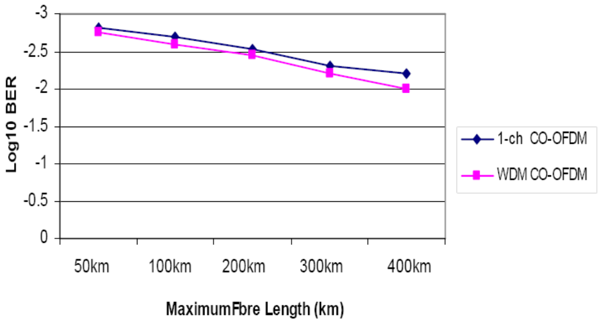

Figure 8: Log10(BER) vs. Transmission Length for the single channel CO-OFDM and WDM CO-OFDM system

The graph shown in figure 6.3 demonstrate that when transmission length increases dispersion increase and the output BER increases because as transmission length increases dispersion increases and it will limit the performance. In WDM system BER is greater than signal channel system because it has extra nonlinearity due to four wave mixing.

4. CONCLUSION

This paper presents the investigation on transmission performance of single channel and WDM 10 Gbit/s 16-QAM CO-OFDM systems for different launch power. Investigation revels that by the help of MLSE equalizer, the CO-OFDM system con approach 450km transmission distance at -1dbm launch power. The BER versus fiber length simulation is conducted for 4-channel WDM CO-OFDM systems and single channel CO-OFDM system. It is investigated that the transmission distance is reduced to 350km instead of 450km for WDM system**.**

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