Performance Analysis of a Dual Polarization CO-OFDM System

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Abstract: *The growth in internet traffic has driven the increase in demand for bandwidth and high data rates. Optical Orthogonal Frequency Division Multiplexing (OFDM) is considered asa promising technology to satisfy the increased demand for bandwidth in broadband services. Optical OFDM has received much attention after proposing it as a modulation technique for the long-haul transmission in both direct and coherent detection. Coherent Optical OFDM (CO-OFDM) is the next generation technology for the optical communications, since it integrates the advantages of both coherent systems and OFDM systems. It has the ability to overcome many optical fiber restrictions such as chromatic dispersion (CD) and polarization mode dispersion (PMD).In this paper, a Coherent Optical OFDM System have been investigated for varying fiber length, launch power and bit rates for single and multiple users.*

Keywords: BER(Bit Error Rate), CO-OFDM, DD-OFDM, OFDM, QAM(Quadrature Amplitude Multiplexing).

1. Introduction

The need for high data rates has led the increased interest in Orthogonal Frequency Division Multiplexing (OFDM) in optical communication. OFDM is intended to be used as the modulation technique in the next generation broadband wireless networks because it supports increased robustness with respect to narrowband interference and frequency selective fading. Also, OFDM has the ability to deal with the delay spread of the multi-path. The principle of operation of OFDM is that it divides high data rate streams into lower data rate streams. Then, the entire low data rate stream is transmitted at the same time over a number of sub-carriers. Because of this the duration of symbol is increased. Therefore, the amount of dispersion generated from delay spread of the multi-path will be reduced significantly.One of the main advantages of using CO-OFDM in the optical fiber communication system is its ability to reduce the effect of the chromatic dispersion (CD) and the polarization mode dispersion (PMD). Also, it can give high spectral efficiency because the OFDM subcarriers spectra are incompletely overlapped. Moreover, the electrical bandwidth of the CO-OFDM transceiver can be considerably reduced by using direct up/down conversion. These features are greatly appealing for designing high-speed circuits. CO-OFDM is a technology that has a great potential for getting high speed data rates in today's transmission systems.

2. Literature survey

2.1 Multiplexing

Multiplexing is a method by which multiple analog message signals or digital data streams are combined into one signal and transmitted over a shared medium. Multiplexing technologies can be divided into several types, all of which have significant variations. They are Time Division Multiplexing (TDM), Frequency Division Multiplexing (FDM) and Wavelength Division Multiplexing (WDM).

- Time-Division Multiplexing (TDM) is a technique of transmitting multiple digitized data simultaneously over one communication medium, such as wires, by interleaving pulses representing bits from different time slots. Thus, combining a set of low-bitrate streams, each with a fixed and pre-defined bit rate, into a single high-speed bit stream that can be transmitted over a single channel and then separating them through demultiplexers, summarizes the process of TDM.

- FDM is a technique by which the total bandwidth available in a communication medium is divided into a series of non-overlapping frequency sub-bands, each of which is used to carry a separate signal. These sub-bands can be used independently with completely different information streams, or used dependently in the case of information sent in a parallel stream.

- WDM is the act of combining light by using different wavelengths. Like FDM signals are assigned a given frequency, WDM signals are assigned a wavelength. That way the signals can be retrieved upon reception. WDM systems provide a significant increase in the data rate that is carried over a single fiber by using multiple wavelengths, where each wavelength carries a separate channel.

2.2 Orthogonal Frequency Division Multiplexing

Orthogonal frequency division multiplexing (OFDM) is a Multi Carrier Modulation (MCM) technique which uses many subcarriers to carry the information. The main advantage of the OFDM is its ability to overcome channeldispersion. Figure 1 shows an OFDM spectrum. Also, OFDM has the ability to transmitinformation with high data rates which has made it popular. The structure of a complex multiplier (IQ modulator/demodulator), which is commonly used in MCM systems, is also shown in Figure 2.

Figure 1: OFDM Spectrum
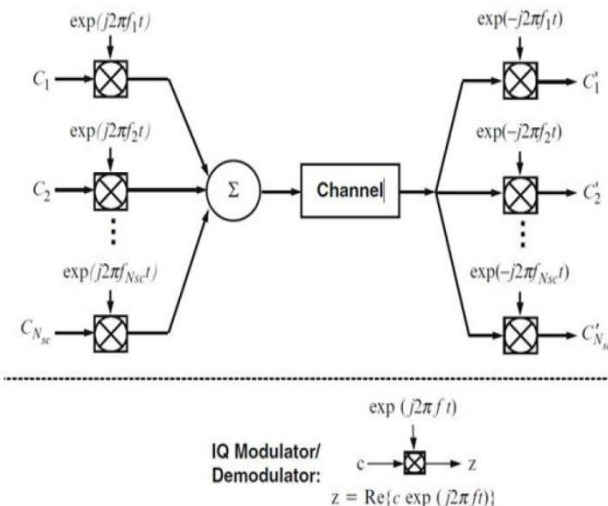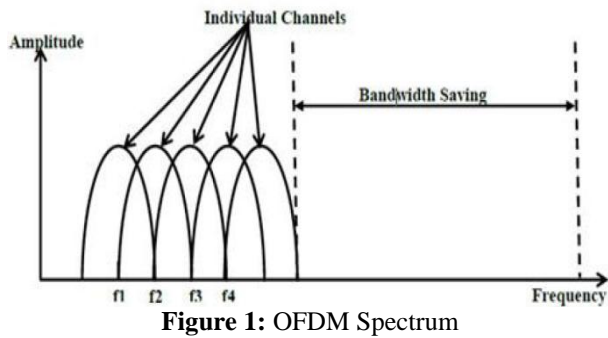
**Figure 2:** Conceptual diagram for a multi-carrier modulation (MCM) system

OFDM was introduced to optical domain in 2005, and has since been studied and investigated in two main techniques classified according to the detection scheme. The first technique is the direct detection optical OFDM (DD-OOFDM) and the second technique is the coherent optical OFDM (CO-OFDM).

2.3 Direct Detection Optical OFDM

A direct detection optical OFDM aims for simpler transmitter or receiver than CO-OFDMfor lower costs. It has many variants which reflect the different requirements interms of data rates and costs from a broad range of applications. DD-OFDM has anadvantage that it is more immune to impulse clipping noise.Figure 3 shows the block diagram of the DD-OFDM system which consists of a DD-OFDM transmitter, optical fiber link, and DD-OFDM receiver.

2.4 Coherent Detection Optical OFDM

Figure 4 shows the block diagram of CO-OFDM system. As can be seen fromthe figure, the CO-OFDM system is similar to the DD-OFDM system except for thereal/imaginary (I/Q) modulator and the local oscillator. An optical local oscillator is usedin optical coherent systems to generate optical signals at specific wavelengths. Accordingto the frequency of the local oscillator, the optical coherent detection can be classified intotwo categories, heterodyne detection and homodyne detection.
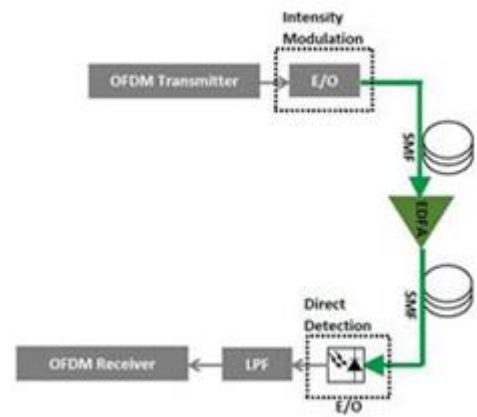
Figure 3: DD-OFDM Block Diagram
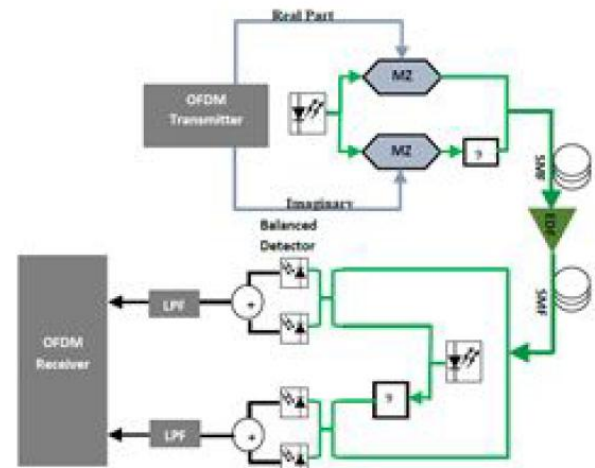
Figure 4: CO-OFDM Block Diagram

3. Simulation using Opti System

3.1 Transmitter

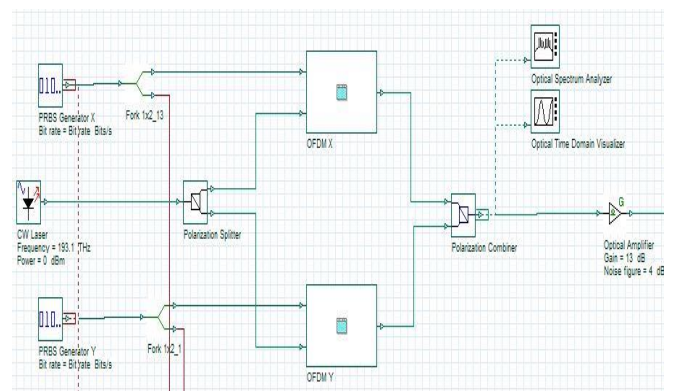
Figure 5: CO-OFDM Transmitter

Figure 5 shows the CO-OFDM transmitter design. The bit stream is generated by a PRBS generator and mapped by a 4-QAM encoder. The resulting signal is modulated by an OFDM modulator. After that, the resulting electrical signal is modulated to the optical signal using a pair of Mach-Zehnder modulators (MZM) which will be fed to the optical link.
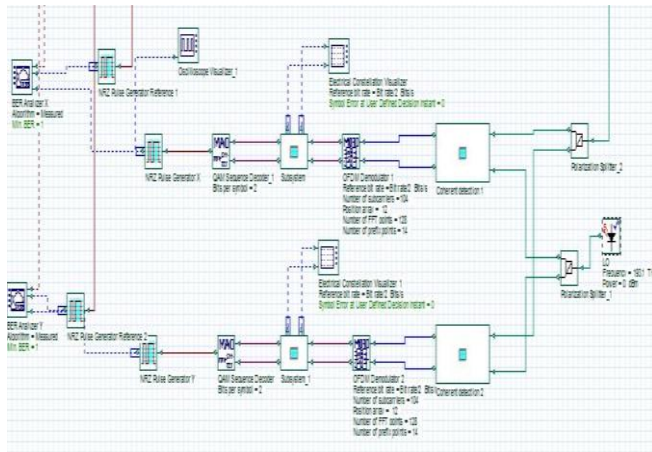
3.2 Receiver

Figure 6: CO-OFDM Receiver

Figure 6 shows the CO-OFDM receiver design. To recover the I/Q component of the OFDM signal, two pairs of balanced PIN photodetectors and LO (Local Oscillator) lasers are used. The balanced detectors perform the I/Q optical to electrical detection and help perform the noise cancellation. Electrical amplifiers are used to adjust the signal intensity. After the balanced detectors the resulting signal is demodulated using the OFDM demodulator with similar parameters as the OFDM modulator, the guard interval is removed. After that the signal is fed into a 4-QAM decoder, and the BER is calculated at the end.

4. Simulation using OptiSystem

Figure 7 shows the variation of received optical power as the fiber length varies from 10 Km to 50 Km. The variation in power is due to the fact that the signal power decreases as it propagates over the fiber due to dispersion and other non-linear effects.
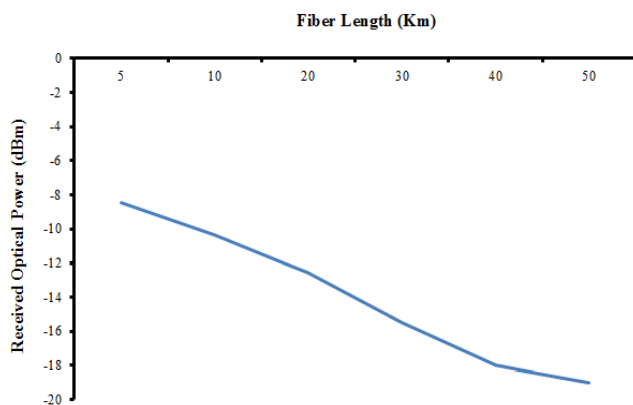

Figure 7: Received Optical Power versus Q-factor

Figure8 demonstrates that when transmission length increases, dispersion increases and the output BER increases. The output BER can be decreased by using an equalizer at the output.
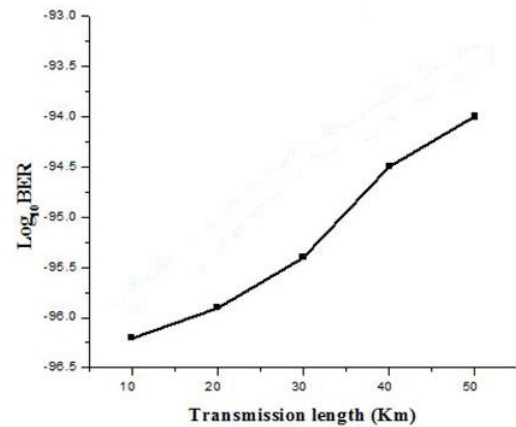

Figure 8: Log BER versus Transmission length

Figure 9 shows the variation of bit rate with Q-factor. As the bit rate increases the bits come close to each other, so the probability of dispersion to occur increases. Thus the value of Q-factor decreases
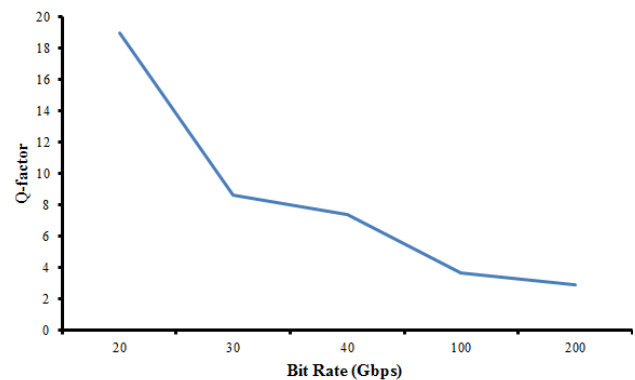

Figure 9: Bit Rate versus Q-factor

The performance of the whole system can be improved by using an equalizer, which can be a phase modulator, before the receiver section. The phase of the phase modulator can be adjusted to achieve better response.

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