A Novel Orthogonal Frequency Division Multiplexing (OFDM) System for Optical Communication

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ABSTRACT: **In wireless communication, orthogonal frequency division multiplexing (OFDM) plays a major role because of its high transmission rate. In space-time shift keying (STSK), information is transmitted by both spatial and temporal dimensions, which can be used to reach a compromise between diversity and multiplexing gains. Space Time Block Code (STBC) is a powerful technique used at the transmitter to obtain high data rates, a larger capacity, and a low Bit Error Rate (BER). In this research compressed sensing (CS) is studied in order to increase throughput and to decrease bit-error performance by transmitting extra information bits in each subcarrier block as well as to decrease the complexity of the equalizer. In this research, space time block coding algorithm is implemented with channel estimation using ANN technique.**

KEYWORDS: **OFDM, Space Time Block Code, Index Modulation, Compressed Sensing (CS), BER, Optical Communication**

1. Introduction

In today's wireless communication systems there is need of better quality and high data rate for an application of multimedia data over internet. In order to improve the quality of the data packets or symbols, there is need of high data transfer rate from sender to receiver. Whereas, these data bits are transmitted in wireless environment where there is full chance of interference of noisy data. So, the data rate is limited to Inter Symbol Interference (ISI) that affects individual antenna's performance [1]. The problem of interference is resolved by dividing the channels into narrow-band sub-channels.

OFDM is a multi-carrier modulation technique that modulation is performed in parallel collection of subcarriers with input data streams. The transmitter requires the minimum frequency range for arranging orthogonally the modulated signals in time domain whereas the signals of different vectors may overlap in frequency domain. This overlapped data spectral range provide a waveform that utilizes the given bandwidth range in order to enhance bandwidth efficiency. So, the channel that have available time and frequency domain may use OFDM easily.

The channels which are selected on the basis of frequency are characterized by their time delay interval or by their channel coherence bandwidth. This will help in measuring the decorrelation of the frequency channel. The time delay is considered to be inversely proportional to bandwidth coherence. For using OFDM to convert selective frequency channel in parallel frequency sub-channels it is required to correctly select the spacing between channels with respect to bandwidth coherence. Therefore, techniques adapted to channel attenuation can be applied directly.

In optical fiber communication systems, the validity and reliability of data transmission depends not only on the performance of optical transmitter and receiver, but also on the influence of chromatic dispersion and polarization mode dispersion (PMD) of optical fiber links. With the development of communication technology and the continuous improvement of communication requirements, the data rate of single channel transmission in optical communication increases greatly, reaching 100 Gb/s. However, when the data rate reaches 100 Gb/s, the traditional optical fiber compensation becomes expensive and time-consuming, and it is difficult to accurately compensate the dispersion. Owing to the good computational characteristics of OFDM, it can be achieved by complex operation in frequency domain. As the dispersion of optical fibers is compensated effectively, OFDM technology is considered to be used in optical communication, namely, optical OFDM(O-OFDM). In this way, the tolerance to optical fiber chromatic dispersion and PMD can be improved.

Machine learning approaches, but will be appended to those obtainable technique to produce innovative solution to the channel modelling. By using Artificial Neural Network (ANN) is one amongst the innovative tool to estimate performance. Such system additionally uses the conception of OFDM. Also, ANN will learn complex patterns and may act as reliable estimator and therefore will be used for modelling optical OFDM.

2. Related Work

The ultimate goal of the optical signal transmission is to achieve the predetermined bit error ratio (BER) between any two nodes in an optical network. The optical transmission system has to be properly designed to provide reliable operation during its lifetime, which includes the management of key engineering parameters. The optical transmission system design involves accounting for different effects that may degrade the signal during modulation, propagation, and detection processes. The transmission quality is assessed by the received signal-to-noise ratio (SNR), which is the ratio between signal power and noise power at the decision point.

C. Jing, et al. [1], this paper combines the benefits of qPSK OFDM system and 16qAM OFDM system in optical communication. It is demonstrated that the proposed scheme shows high CFO estimation accuracy and synchronous accuracy. Under CFO and linewidth of laser source, BER of qPSK OFDM system is below 3.8e-3 at the optical signal-to-noise ratio (OSNR) of 13dB, and BER of 16-qAM OFDM system is below 3.8e-3 at the OSNR of 20dB.

Hao Wu et al. [2], showed the impact of extended Kalman filter channel estimation technique over massive-MIMO system. It has been observed that in low SNR scenario, the non-allocating sub carriers with Zero padding gives optimal results. The work is based on fast Fourier transform/inverse fast Fourier transform for reducing the transmission complexity. In this research work, DFT based channel estimation is also discussed for uplink massive MIMO system. The simulation result shows the limitation of the proposed methodology in low SNR AWGN channel. The optimal result is shown with extended Kalman filter with FFT system that reduces the computational complexity of the system significantly.

Aqiel et al. [3] proposed the Channel state information (CSI) estimation for detection of input signal data with Kalman Filter and prior knowledge of the channel or known pilot bits. The researcher designed the system with qPSK modulation based OFDM. The received signal is processed by modified Kalman filter to produce channel state information (CSI) and to estimate the channel noise. The result analysis of modified Kalman filter is less dependent on the statistics of the channel and gives minimum MSE.

J. W. Choi et al. [4], provided an overview of CS technology, including basic configuration, piecemeal recovery algorithm and performance assurance. We therefore describe three different CS sub-problems, namely vulnerability estimation, medium identification and vulnerability detection in various wireless communication applications. We also address the key issues of designing CS-based wireless communication systems. These include the potential and limitations of CS techniques, useful tips to know, subtle points to watch out for and some preliminary knowledge for better performance.

Z. Gao et al. [5], suggested a low complexity signal detector based on structured compression detection (SCS) to improve signal detection performance. In particular, we first propose the transmission scheme grouped at the transmitter level, in which different SM signals are grouped in different continuous time intervals to carry the symbol of the common space constellation in order to introduce the desired structured economy. Consequently, a structured subspace tracking algorithm (SSP algorithm) is proposed to the receiver to collectively acquire several SM signals using structured scarcity. We also offer SM signal interlacing to exchange SM signals in the same transmission group, allowing the use of channel diversity to further improve signal detection performance.

3. Proposed Methodology

The principle of O-OFDM is similar to that of OFDM. The only difference is that the signal is transferred from wireless signal in electrical domain to optical signal in optical domain. Figure 1 shows the structure block diagram of O-OFDM system. The transmitter includes OFDM baseband transmission, RF up-conversion and optical modulation. The receiver includes optical detection, RF down-conversion and OFDM baseband reception. The binary serial digital signal is input at the transmitter and divided into N-channel parallel data by S/P transformation. Each data is modulated by M-ary PSK or qAM method. The signal is mapped to the corresponding complex domain by constellation diagram. Then N parallel carriers are converted into serial ones by IFFT and are added as an OFDM symbol before each symbol. The cyclic prefix(CP) is added and then converted into OFDM baseband analog signal by digital-to-analog conversion. The baseband signal is modulated to RF carrier frequency and optical carrier in turn and then transmitted into single mode fiber (SMF). The DSP in receiver is essentially the inverse process of transmitter. The optical signal is converted into electrical domain by a detector (PD) and then the signal is converted into digital domain by analog to digital converter (ADC). Next, CP is removed and P/S conversion is performed. Then the signal is converted into frequency domain by FFT. Finally, the signal is de-mapped and converted into serial data.

The optical OFDM systems can be divided into five functional blocks:

- Baseband OFDM transmitter
- Electrical-to-optical (E/ O) up-converter
- Optical fiber link
- Optical-to-electrical (O/E) down-converter
- Baseband OFDM receiver

Each OFDM signal frame consists of frame header (FH) and frame body (FB). A signal frame is an OFDM symbol. The baseband symbol rate for both FH and FB are the same. FH is the inserted guard interval in order to maintain the good orthogonal state between the subcarriers. There are several major differences that TDS-OFDM reflects technical breakthrough in optical communication areas. Firstly, TDS-OFDM using PN as the guard in - terval to achieve much faster synchronization than CP-OFDM. Secondly, PN provides the unique signal frame address within each super frame. Thirdly, by choosing the known PN sequence as FH to mitigate ISI, TDS-OFDM brings the benefits of fast channel acquisition since this can be done directly in time domain. Lastly, PN can also be used for the channel estimation and equalization to achieve higher spectrum efficiency, avoiding both continuous and scattered pilot insertion into FB by CPOFDM approach.

In this research work optical communication is used instead of wireless communication with an integration of OFDM. The block diagram of the proposed scheme is shown in Fig. 3, where bN number of information bits are divided into N parallel groups with b number of information bits processed in each group, as shown in Fig. 3.

For each group of b bits, b1 bits are mapped to the IM selector, which chooses K active indices out of Na available indices. The remaining b2 bits are used for generating K STTC codewords, and then these K codewords are coordinate-interleaved for providing an additional diversity gain to improve the BER and MSE performance.

The K coordinate interleaved codewords are then mapped to the active indices according to the IM selector, while the inactive indices are set to zero. Then the block creator collects all codewords from G groups in parallel and forms a frame, which is mapped to the space-time trellis codewords followed by DWT-OFDM modulation and then transmission. In the system proposed in Fig. 3, we consider OFDM modulation with Nc subcarriers, which are equally divided into N subcarrier groups and each group contains Mg = Nc/N subcarriers in the frequency domain. In each subcarrier group, K number of indices are active out of Na available subcarrier indices in the virtual domain.

In OFDM, Nc may assume very large values, and if the index selector is applied directly to Nc, there could be a huge number of possible combinations for active indices, which makes the selection of active indices an almost impossible task. As a result, the subcarriers are partitioned into N smaller groups to perform index selection. As shown in Fig. 3, the information bits are divided into G groups at the input of the transmitter.

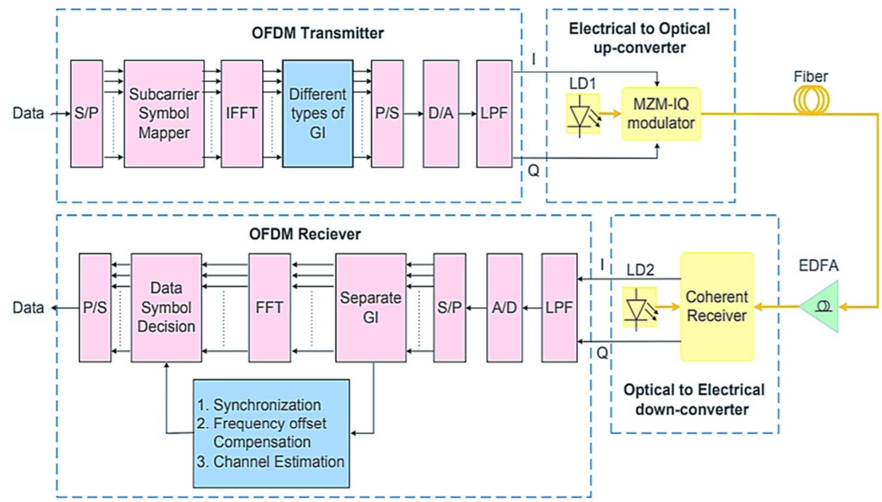

Figure 1: Optical OFDM

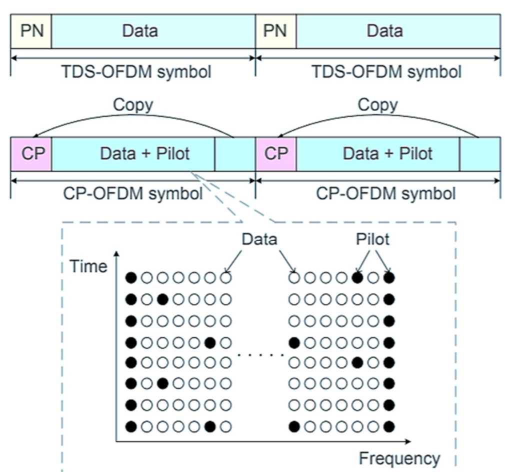

Figure 2: Optical OFDM Frame Structure

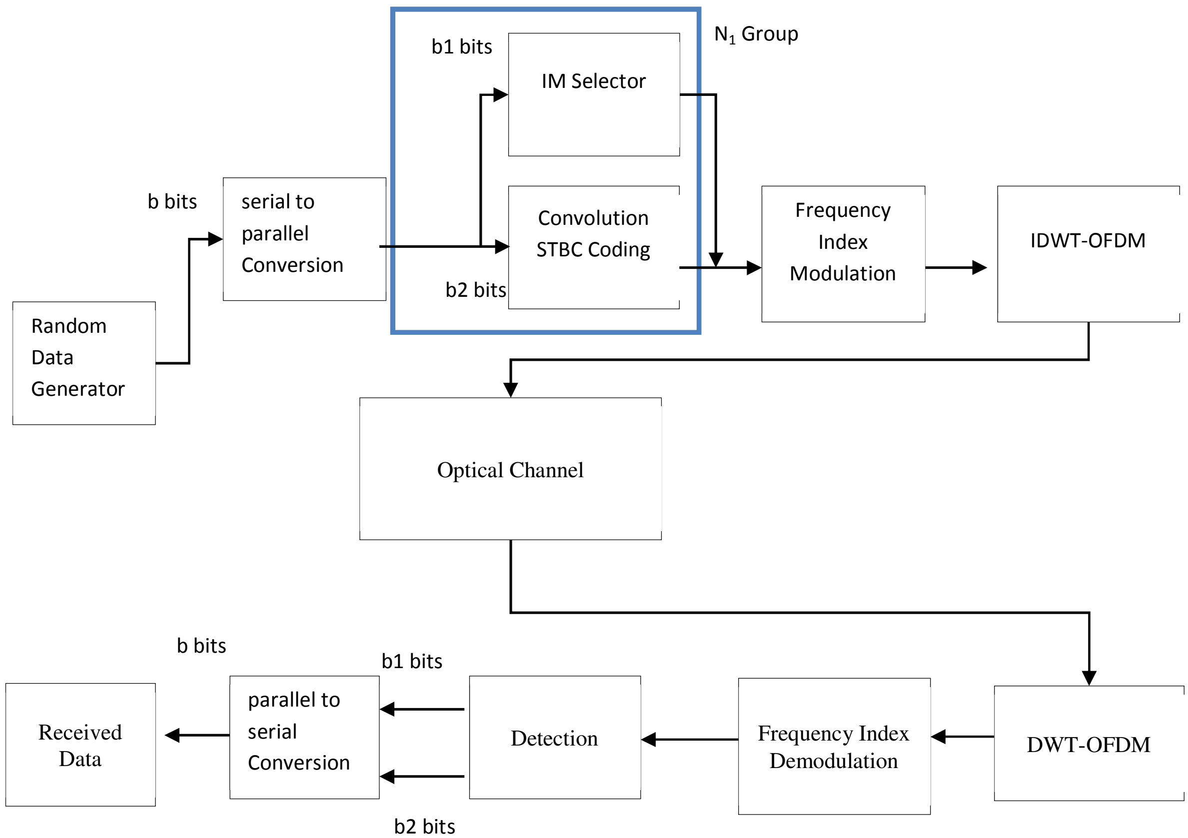

Figure 3: The Proposed Transceiver Architecture

4. Conclusion

In this research, a space time block code frequency index modulation scheme relying on CS-aided reduced complexity detections for transmission over frequency selective channels. The information bits are transmitted using space, time and frequency dimensions to improve the spectral efficiency as well as the BER performance.

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