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BER IMPROVEMENT USING ICI CANCELLATION USING MIMO-OFDM SYSTEMS

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Abstract—The employment of MIMO OFDM technique constitutes a cost-effective approach to high throughput wireless communications. The system performance is sensitive to frequency offset which increases with the Doppler spread and causes Intercarrier interference (ICI). ICI is a major concern in the design as it can potentially cause a severe deterioration of quality of service (QoS) which necessitates the need for high-speed data detection and decoding with ICI cancellation along with the inter symbol interference (ISI) cancellation in MIMO OFDM communication systems. Iterative parallel interference canceller (PIC) with joint detection and decoding is a promising approach which is used in this work. The receiver consists of a two-stage interference canceller. The co channel interference cancellation is performed based on Zero Forcing (ZF) Detection method used to suppress the effect of ISI in the first stage. The latter stage consists of a simplified PIC scheme. High bit error rates of the wireless communication system require employing forward error correction (FEC) methods on the data transferred in order to avoid burst errors that occur in the physical channel. To achieve high capacity with minimum error rate Low-Density Parity Check (LDPC) codes which have recently drawn much attention because of their error correction performance is used in this system. The system performance is analysed for two different values of normalized Doppler shift for varying speeds. The bit error rate (BER) is shown to improve in every iteration due to the ICI cancellation. The interference analysis with the use of ICI cancellation is examined for a range of normalized Doppler shift which corresponds to mobile speeds varying from 5Km/hr to 250Km/hr.

Index Terms—LDPC, Parallel Interference Canceller (PIC), QC LDPC, OFDM, STBC, Worldwide Interoperability for Microwave Access (WiMAX), Zero Force Detection (ZFD)

I. INTRODUCTION

Wideband transmission with high spectral efficiency and high mobility is required for future mobile radio communications. The key objectives are spectrum efficiency and robustness against multipath propagation along with the implementation complexity. It is well reported in the literature that MIMO physical layer techniques have the potential to significantly increase bandwidth efficiency in a rich scattering environment. Orthogonal Frequency Division Multiplexing (OFDM) is a well-established technique for achieving low-cost broadband wireless connectivity as it converts a frequency selective channel into narrow flat channels. As a result, the symbol duration is increased and the intersymbol interference (ISI) caused by a multipath fading channel is alleviated. Thus it is well suited for high data rate standards, including IEEE802.16d/e. The use of Space-time block coding (STBC) proposed by Alamode as a MIMO technique which improves the link reliability of the system is thus used with OFDM [1]. Moreover by employing FEC methods like RS, CC, LDPC or by concatenating them a more efficient system with improved BER can be built.

In a MIMO-OFDM system, ISI caused by multipath propagation (time dispersion)can be eliminated by adding a cyclic prefix (CP) between adjacent OFDM symbols. However, the CP offers no resilience against frequency dispersion, where carrier frequency offset is introduced due to the Doppler spread. This causes a loss of orthogonally between the subcarriers, and thus results in ICI. Due to the high demand for bandwidth, there is a trend toward using higher frequency bands. As a result, the ICI effect becomes more severe as mobile speed, carrier frequency, and OFDM symbol duration increases. If it is not compensated, the ICI will result in performance loss and an error floor that increases with Doppler frequency. In some circumstances, the ICI effect may degrade the BER performance significantly [2][4]. ISI and ICI are dual to each other occurring at different domains; one in the time domain and the other in the frequency domain. However, ICI caused by time-varying fading channels results in an error floor if it is not compensated for.

In literature, techniques have been proposed to reduce the effect of ICI in MIMO OFDM systems. A low computational complexity diagonal zed zero force detection (DZFD) method is proposed in [5] for STBC OFDM in a fast fading channel. The effect of ICI was first investigated in [6] and proposed a method wherein the ICI effect is modelled as an additive Gaussian random process. Recently, the PIC has been proposed to improve the MIMO OFDM system performance by removing the ICI effect [7][8].

In this paper, the ICI cancellation is performed in two stages using Zero force equalization parallel interference cancellation for a MIMO OFDM based WiMAX specifications system. In the first stage, the ICI term is modelled as noise and later stage the PIC with iterative cancellation is used. The iterative cancellation makes use of the previous estimate of the detected signal to cancel the interference from the current received signal. As STBC does not provide a coding gain so in order to enhance the performance of the system, LDPC codes are used for forwarding error correction. Moreover, to avoid the problem of short cycle, the Quasi Cyclic (QC) LDPC as channel coding method is incorporated in the system.

The paper is organized as follows:

Initially a brief under-standing of ICI and broad methods to mitigate its effects are presented. Then the system model for MIMO OFDM with LDPC is explained. It is followed by the ICI suppression method used in this paper. Finally, the results and observations for the system are presented.

II. TECHNIQUES TO REDUCE ICI

Irrespective of the factors leading to ICI, Both ICI and ISI can result in considerable performance degradation in many systems and must be combated. A wide range of techniques has been developed in recent years and can be classified based on the parameter being addressed to reduce the ICI component.

• Optimum selection of carrier spacing and OFDM symbol length: This technique does not require any structural changes in either the transmitter or receiver. A similar approach is to modify the basic pulse shape for the signalling of the subcarriers.

• Self-interference cancellation techniques: The method modulates the information not just onto a single subcarrier but onto a group of them, which leads to a significant reduction in interference. This comes with a compromise on the spectral efficiency of the system.

• Temporal equalizers: The equalization in the time domain, before the FFT at the receiver was proposed [10][11].

• Techniques that depend on the presence of unused subcarriers: The concept is to introduce redundancy in the approach frequency domain by having more carriers than is strictly necessary [12].

• Forward-error correction (FEC) [13]: The use of any FEC code can be used to eliminate the errors caused by the ICI.

In [14]-[16] research was focused on self-cancellation techniques

Most of ICI Self cancellation techniques can effectively mitigate the ICI when OFDM suffers a moderate level of carrier frequency offset (CFO).To enhance the tolerance of the CFO for the ICI self-cancellation scheme, in [17] a CFO estimation algorithm for time dispersive OFDM systems was proposed. In spite of all factors, the ICI self-cancellation schemes have a major drawback of bandwidth efficiency. To overcome the above scarcity, Andreas in [9], demonstrated that the use of serial interference cancellation (SIC) or parallel interference cancellation (PIC) reduces the error floor caused due to ICI without compromising on bandwidth efficiency. The basic idea behind PIC-based ICI cancellation is that the decisions of the symbols on the subcarriers are improved iteratively. These improvements are due to the determination and subtraction of the interference of all the other subcarriers, based on the decisions of the previous iteration. A proper initialization has to be done before entering the iteration loop.

In this paper the ICI cancellation using Zero force equalization parallel interference cancellation for a MIMO OFDM based WiMAX specifications system.

is a process which applies the FIR filter that provides an approximate inverse of channel frequency response on the received signal. The process thus enhances the performance of communication against the ISI and ICI. The equalizer applies the inverse of the channel to the received signal, this restores the received signal. It thus brings down the ISI to zero. This can be justified mathematically, for a channel with frequency response F(f) the zero forcing equalizer C(f) is constructed such that C(f) = 1 F(f). . Effectively the combination of channel and equalizer aims to give a flat frequency response and linear phase For simplicity let us consider a 2x2 MIMO system, the received signal on the first receive antenna is,

$$y1 = h1,1x1 + h1,_{2x2} + n1 \quad (1)$$

The received signal on the second receive antenna is,

$$y_2 = h_2,1x1 + h2,_{2x2} + n2 \quad (2)$$

where y1, y2 are the received symbol on the first and second antenna respectively, hi,j is the channel from transmit antenna i to receive antenna j
x1, x2 are the transmitted symbols
n1, n2 is the noise on the receive antennas

In simplified form it can be written as

$$y = Hx + n \quad (3)$$

To solve for x, The Zero Forcing (ZF) linear detector for meeting the constraint $WH = I$, is given by,

$$W = (H^H H)^{-1} H^H \quad (4)$$

Thus the estimate of the two transmitted symbols x_1, x_2, can be obtained as,

$$\begin{bmatrix} \bar{x_1} \\ \bar{x_2} \end{bmatrix} = W \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} \quad (5)$$

III. SYSTEM MODEL

A Representation of the block scheme of a typical structure of the MIMO system is shown in fig 1 and 2. The system combines Space Time Block Coding (STBC) with MIMO OFDM enabled WiMAX system.The channel coding method used is LDPC as it is more performance efficient. The Block diagram represents the whole system model or the signal chain at base band. The system flow is explained concisely.

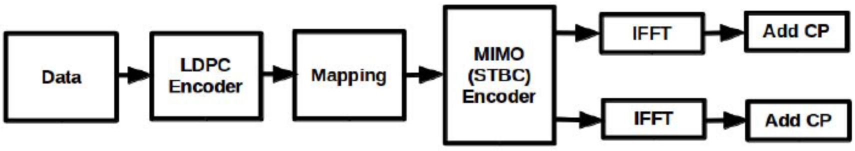

Fig. 1: MIMO OFDM Transmitter Model

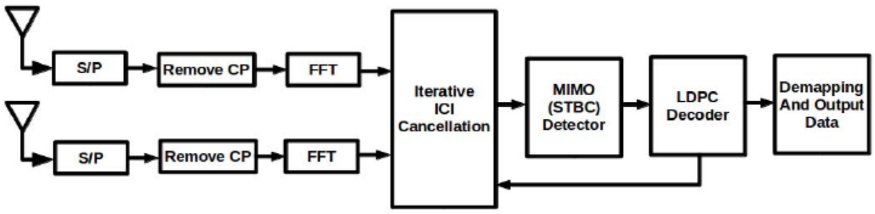

Fig. 2: MIMO OFDM Receiver Model

IV. SIMULATION RESULTS

The simulation proceeds in the flow as represented by the system model. The PHY parameters considered for simulation are depicted in the table. The Simulation model was implemented in MATLAB. Since the speed of the moving vehicle is the main cause of doppler shift which causes ICI, the system was analyzed for two different values speed ie 100Km/hr and 200Km/hr which correspond to doppler frequency of 324Km/hr and 628Km/hr. Perfect synchronization and perfect channel estimation is assumed at the receiver side.

TABLE I: Simulation Parameters

Parameter Value

Parameter	Value
FFT size	128
Modulation Schemes	16QAM
Carrier Frequency/Bandwidth	3.5GHz/20 MHz
Number of transmit/Receive antenna	2/1,2
H matrix row weight	6
H matrix column weight	3
H matrix size	396 × 792
Code Rate	$\frac{1}{2}$
Mobile Speed	100 Km/h and 200 Km/h
Normalized Doppler Frequency	0.01 and 0.03

V. CONCLUSION

A coded modulation scheme for the WiMAX PHY layer with ICI canceller was presented. The MIMO OFDM system suffers two types of interference namely co channel and inter channel interference. The ZFD method which can effectively suppress the effect of co channel interference is used in the initial stage of cancellation. This is then followed by a parallel interference cancellation stage which estimates and cancels the ICI from the received symbol. Thus a more optimized estimate of the received data is performed. The algorithm detects the transmitted data iteratively, by jointly dealing with channel fading effects, AWGN noise and interferences in the time domain, frequency domain and space domain. With the insertion of cyclic prefix, the time domain ISI can be avoided. With MIMO detector, the space domain inter- antenna interference can be suppressed and with the aid of PIC, the frequency domain ICI can be cancelled. The reliability of the system thus improves significantly.

With the mobile speed and hence the Doppler Effect into consideration the performance was analyzed. It was shown that the performance deteriorates in terms of BER for higher mobile speed due to Doppler shift. This was then effectively improved through the use of two-stage interference cancellation. The first stage zero-forcing cancels the maximum interference. The second stage of iterative cancellation

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