IBI AND ICI CANCELLATION FOR MIMO OFDM BASED ON TOMLINSON HARASHIMA PRECODER AND DIRTY PAPER CODING

Gowshameed, Chanemougapriya

Abstract— **In multi-user multiple input multiple output (MU-MIMO) system, the problem in transmission of data in Downlink channel is that the particular signal is affected by other user signals. So, interference cancellation at base station (BS) is required. The main aim of this paper is to eliminate the Inter carrier Interference and Inter Block Interference. In this paper, Tomlinson Harashima precoder and Dirty paper coding techniques are considered to eliminate interference due to other signals in the system. In the Existing work channel inversion and regularized channel inversion techniques, which can assist to cancel inter block interference (IBI). In the proposed work, the comparison of inversion and regularized channel inversion techniques with Tomlinson Harashima precoder and Dirty paper coding is discussed. And also discuss the performance comparison of channel inversion, regularized channel inversion, Tomlinson Harashima precoder and Dirty paper coding in terms of bit error rate (BER). In overall dirty paper coding gives better performance in terms of Bit error performance.**

***Index Terms*— Dirty paper coding, Inter block interference, MU-MIMO, Tomlinson Harashima precoder.**

I. Introduction

High data rate wireless communications demands robustness, high spectral efficiency, frequency selective fading, and low computational complexity. Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising technologies to achieve these goals. OFDM can be used in conjunction with a Multiple-Input Multiple-Output (MIMO) transreceiver to increase the diversity gain and/or the system capacity by exploiting spatial domain. Because the OFDM system effectively provides numerous parallel narrowband channels, MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n. OFDM is robust in various channel conditions and gives high spectral efficiency. It effectively reduces performance degradations due to multipath and is capable of combating deep fades in part of the spectrum. OFDM reduces Inter symbol Interference (ISI) by handling with large delay spreads, also by including the guard band in each OFDM symbol ISI can be eliminated completely. But the ICI is the main drawback of OFDM system, in this project two methods are studied to reduce ICI component.

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II. Interference and Precoding

A. Inter symbol interference:

In a multipath environment, a transmitted symbol takes different times to reach the receiver through different propagation paths. From the receiver's point of view, the channel introduces time dispersion in which the duration of the received symbol is stretched. Extending the symbol duration causes the current received symbol to overlap previous received symbols and results in inter symbol interference (ISI) [1] [2]. In OFDM, ISI usually refers to interference of an OFDM symbol by previous OFDM symbols [6]. For a given system bandwidth the symbol rate for an OFDM signal is much lower than a single carrier transmission scheme.

B. Capacity of BC:

The capacity region of Gaussian broadcast channel remains as an unsolved problem [3] [4]. In this subsection, we discuss an achievable downlink channel capacity for a special case of $N_B = 2, N_M = 1$ and K=2 using Dirty Paper coding (DPC). In this case, the received signal is expressed as

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} {H_1}^{DL} \\ {H_2}^{DL} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} Z_1 \\ Z_2 \end{bmatrix} \quad (1)$$

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Where $H_U{}^{DL} \in C^{1x2}$ denotes the channel matrix between the BS and u th user, $U = 1,2, \widetilde{x_U}$ represents the u th user signal while x_i is the signal transmitted by the i th transmit antenna, i=1,2. If the channel information is completely available at BS, the overall channel can be LQ-decomposed as

$$H^{DL} = \begin{bmatrix} l_{11} & 0 \\ l_{22} & l_{22} \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \end{bmatrix} \quad (2)$$

A. Precoding:

Precoding in the downlink of cellular networks, known as network MIMO or coordinated multipoint (CoMP), is a generalized form of multi-user MIMO that can be analyzed by the same mathematical techniques [10].

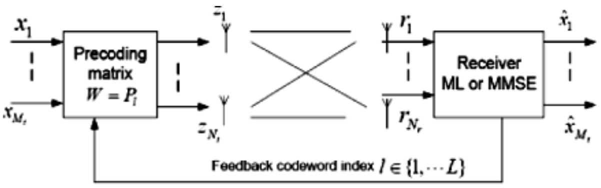

Fig 1: Precoding procedure in MIMO-OFDM

In point-to-point multiple-input multiple-output (MIMO) systems, a transmitter equipped with multiple antennas communicates with a receiver that has multiple antennas. Most classic precoding results assume narrowband, slowly fading channels, meaning that the channel for a certain period of time can be described by a single channel matrix which does not change faster. In practice, such channels can be achieved, for example, through OFDM. The precoding strategy that maximizes the throughput, called channel capacity, depends on the channel state information available in the system.

In multi-user MIMO, a multi-antenna transmitter communicates simultaneously with multiple receivers (each having one or multiple antennas). This is known as space-division multiple accesses (SDMA). From an implementation perspective, precoding algorithms for SDA systems can be sub-divided into linear and nonlinear precoding types [24].

The capacity achieving algorithms are nonlinear, but linear precoding approaches usually achieve reasonable performance with much lower complexity. Linear precoding strategies include maximum ratio transmission (MRT), zero-forcing (ZF) precoding, and transmit Wiener precoding There are also precoding strategies tailored Precoding for low-rate feedback of channel state information, for example random beam forming [12].

III. TRANSMISSION METHODS FOR BROADCAST CHANNEL

The main problem in data transmission in BC is that the signal detection on the receiver side is not that much possible, and thus, interference cancellation at BS is required. In this section, we consider two methods: Dirty paper coding (DPC), and Tomlinson Harashima precoding (THP) [25].

A. Dirty paper coding:

An idea of dirty paper coding (DPC) in the course of deriving the channel capacity of broadcast channel (BC).An interference free transmission can be realized by subtracting the potential interferences before transmission. In theory, DPC would be implemented when channel gains are completely known on the transmitter side.

Dirty paper coding (DPC) is a method of precoding the data such that the effect of the interference can be cancelled subject to some interference that is known to the transmitter.

More specifically, the interferences due to the first up to (k-1) th user signals are cancelled in the course of precoding the kth user signal [17][18]. To simplify the exposition, we just consider the case of $N_B = 3$, K=3 and $N_{M,u} = 1$,u=1,2,3. If the received signal is given by

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} H_1{}^{DL} \\ H_2{}^{DL} \\ H_3{}^{DL} \end{bmatrix} \begin{bmatrix} \widetilde{x_1} \\ \widetilde{x_2} \\ \widetilde{x_3} \end{bmatrix} + \begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \end{bmatrix} \quad (3)$$

Where $H_U{}^{DL} \in C^{1X3}$ is the channel gain between BS and the u th user. If the channel information is completely available at BS, the overall channel can be LQ-decomposed as

$$H^{DL} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ q_3 \end{bmatrix} \quad (4)$$

Where $\{q_i\} i = 1 \in c^{1X3}$ are ortho normal row vectors.

Leaving the lower triangular matrix before transmission, the received signal is given by

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} H_1{}^{DL} \\ H_2{}^{DL} \\ H_3{}^{DL} \end{bmatrix} Q_X{}^H + \begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \end{bmatrix} \quad (5)$$

Note that the selection of the users the largest l_{ii} ensures to minimize the noise enhancement on the receiver side.

B. Tomlinson Harashima Precoder:

DPC on the transmitter side is very similar to decision feedback equalization (DFE) on the receiver side. In fact, combination of DPC with symmetric modulo operation turns out to be equivalent to Tomlinson-Harashima (TH) precoding. The original idea of TH precoding in DFE is to Cancel the post-cursor ISI in the transmitter, where the past transmit symbols are known without possibility of errors. In fact, it requires a complete knowledge of the channel impulse response, which is only available by a feedback from the receiver for time-invariant or slowly timevarying channel.

The symmetric modulo operation is defined as

$$mod_A(x) = x - 2A\lfloor (x + A + jA)/2A \rfloor \quad (6)$$

The above modulo operation can be interpreted as a method to find inters values, m and n such that the following inequalities are satisfied:

$$-A - jA \le mod_A(x) = x + 2A.m + j2A.m < A + jA \quad (7)$$

The inequality of Complex numbers is defined as

$$x_1 < x_2 <=> Re\{x_1\} < Re\{x_2\} and\ Im\{x_1\} < Im\{x_2\} \quad (8)$$

Then the modulo operation in the above equation can be expressed as

$$mod_A(x) = x + 2A.m + j2A.m \quad (9)$$

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For the transmitted signal $Q^H X^{TH} = Q^H [x_1{}^{TH} x_2{}^{TH} x_3{}^{TH}]^T$, the received signal is given as

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} H_1{}^{DL} \\ H_2{}^{DL} \\ H_3{}^{DL} \end{bmatrix} Q_x{}^H X^{TH} + \begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \end{bmatrix}$$

$$= \begin{bmatrix} l_{11} & 0 & 0 \\ l_{21} & l_{22} & 0 \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} x_1{}^{TH} \\ x_2{}^{TH} \\ x_3{}^{TH} \end{bmatrix} + \begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \end{bmatrix} \quad (10)$$

IV. SIMULATION RESULTS AND DISCUSSION

In this section, we illustrate the performance of the proposed algorithm evaluated through the simulations. The graph is plotted over ber vs. SNR. The channel modeled as Rayleigh model. The Modulation scheme used is QPSK, 16-QAM with $N_t = 2,4,16$ & $N_r = 2,4,16$.

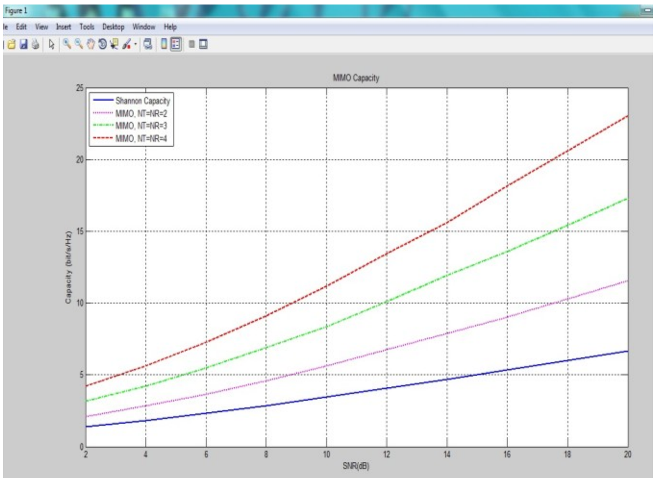

Fig 2: Capacity of MIMO

Figure 2 shows that Capacity of the MIMO system. From the above diagram, it is shown that the capacity of Shannon limit is compared with multi user antenna configuration (N_t=2, 3, 4& N_r=2, 3, 4). The comparison shows that, more the number of antennas more the capacity and it achieves the reasonable signal to noise ratio.

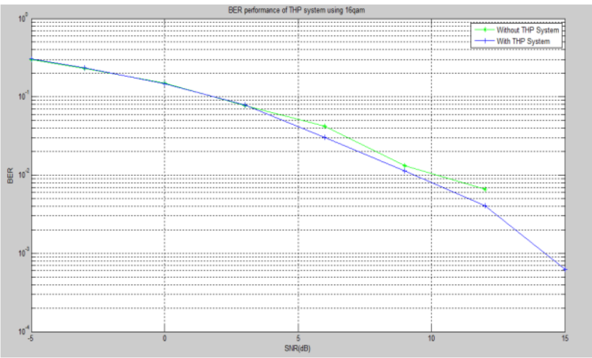

Fig 3: Performance of the MIMO-OFDM with and without THP System.

Figure 3 shows that performance comparison of the MIMO-OFDM system with and without THP System using 16-QAM modulation. From that comparison signal to noise ratio of the without THP system is 12 dB and it can be improved as 15 dB by using THP system.

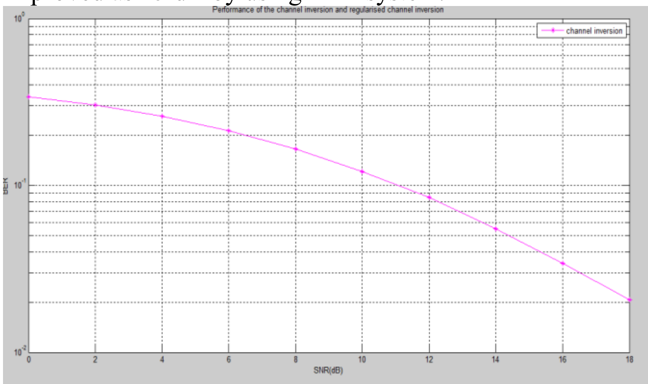

Fig 4: BER Performance of the Channel inversion method.

Figure 4 shows the performance of the channel inversion method for no. of actual users= 4, in which four users with the highest channel norm values are selected out of 20.

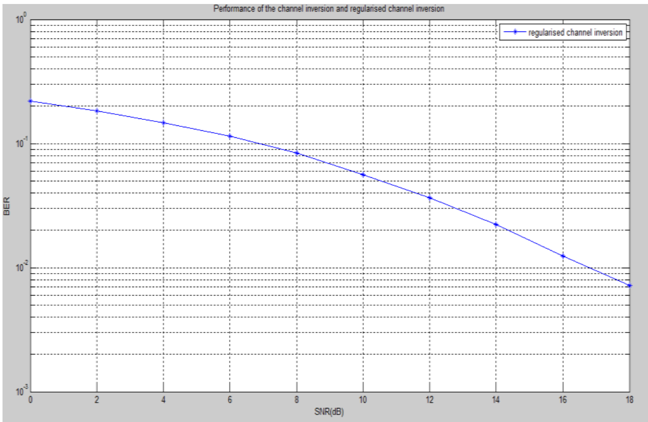

Fig 5: BER Performance of the Regularised Channel inversion method.

Figure 5 shows the performance of the Regularised channel inversion method for no. of actual users= 4, in which four users with the highest channel norm values are selected out of 20.

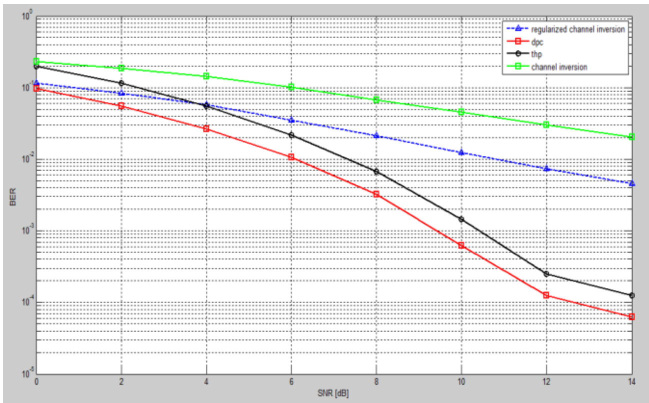

Fig 6: BER Performance of the Different Transmission method.

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"Figure 6 Shows that the BER curve with DPC or TH precoding for 4 actual users are selected out of the ten users by using the criterion. As can be seen in Figure6, the DPC outperforms the THP. In this comparison, however, transmitted power of DPC is higher than that of THP. Note that the reduced transmit power of THP is attributed to modulo operations in the precoding process.

From the above simulations, Dirty Paper Coding achieves better performance in terms of bit error rate than other Transmission methods.

V. CONCLUSIONS

In this paper, Tomlinson Harashima Precoding and Dirty Paper coding techniques are proposed for MIMO OFDM with cyclic prefix. The precoding technique proposed is more bandwidth efficient then other precoding techniques to eliminate the IBI and ICI. It eliminates the interference and performance is analyzed in terms of Bit Error Rate. In this, comparison is done between the Regularised Channel inversion, Channel inversion, Tomlinson harashima precoding and Dirty paper coding methods. Regularised channel inversion gives better performance than the channel inversion method. Tomlinson harashima precoding is also compared with Dirty paper coding. In overall dirty paper coding gives better performance in terms of Bit error performance.

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