Performance Analysis of Effective Minimum Mean Squared Error Handling Techniques in Multiple Input Multiple Output Wireless Communication

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Abstract: In this modern era of signal processing and communication system, many transmitter pre-coding techniques have been reported in order to mitigate the co-channel interference (CCI) as well as exploiting the spatial multiplexing of the multi client MIMO downlink. In this paper, MU-MIMO broadcast channel is mainly focused and considered the case where the various transmit antennas are used to convey independent data streams to multiple users and compare the performance for linear and non linear precoding technique in terms of Bit Error Rate (BER), SIgnal-to-Noise Ratio (SNR) and complexity point with increase in the number of users and the number of transmit antennas. A novel proposed practical scheme leads with low computation complexity and better BER performance with better system utilization as presented in the simulation result.

Keywords: MIMO, Wireless Communication, Error Rate, Pre-Coding

1 Introduction

The stretch multi user MIMO downlink naturally refers to situation where a multi-antenna transmitter (e.g., a base station) concurrently communicates with numerous co-channel users. In the communications and information theory literature, this state of affairs is referred to as the MIMO broadcast channel [1]. This is to be contrasted with the MIMO uplink problem, where a multiple antenna receiver must separate the signals arriving from several different users. This scenario is often referred to as the MIMO multiple access channel (MAC) or Space-Division Multiple Access (SDMA) [2]. Single-user MIMO systems have generated considerable excitement in the wireless communications literature due to their potential for significant gains in capacity over single antenna links, of particular note is that these gains are often independent of whether or not channel state information (CSI) is available at the transmitter [3]. In MU-MIMO precoding techniques, unlike the received signal in SU-MIMO systems, the received signals of different users in MU-MIMO systems not only suffer from the noise and the inter-antenna interference but are also affected by MUI that affects the BER and sum rate capacity[1, 4–6].

MIMO techniques were first investigated in point to point or SU-MIMO scenarios, that is, the Base Station (BS) or transmitter equipped with multiple transmit antennas and the User Equipment (UE) or receiver equipped with multiple receive antennas [7, 8]. Winters Foschini, and Telatar predicted that remarkable spectral efficiencies for wireless systems with multiple antennas when the channel exhibits rich scattering can be accurately obtained. SU-MIMO is one of the key techniques in Long Term Evolution (LTE) Release 8, which requires 300 Mb/s for Downlink (DL) and 75 Mb/s for Uplink (UL) throughput [9]. However, the LTE Release 10, also known as LTE-Advanced, targets the achievement of 1 Gb/s for DL and 500 Mb/s for UL[15]. One of the key enabling features to meet this DL requirement is MU-MIMO. MU-MIMO systems refer to the case where a BS or a transmitter with multiple antennas services multiple users simultaneously. The benefits offered by MIMO systems are built on two underlying gains spatial diversity and Spatial Multiplexing (SM), which comes with the increased cost for Radio Frequency (RF) hardware [10–14].

2 Related Works

Several algorithms for multi-user MIMO downlink processing can be classified according to a number of criteria: whether they attempt to approach the sum capacity bound, eliminate inter-user interference or achieve minimum QoS constraints (BER), whether the users have single or multiple antennas, whether or not multiple data streams are transmitted to each user [15, 16].

2.1 A Linear Precoding Scheme for Downlink Multiuser MIMO Precoding Systems

Wang *et al.* [17] presented a novel linear MU-MIMO pre-coding scheme for MIMO systems is proved to balance MUI and noise effectively with low complexity. Simulation results show that the proposed algorithm can effectively improve the system's capacity performance with low complexity, compared with several existing methods. MIMO channels with the elements complex Gaussian elements with zero mean and unit variance are adopted. And all simulations are constructed using a QPSK transmit constellation.

2.2 Joint Tomlinson-Harashima Precoding and Scheduling for Multiuser MIMO with Imperfect Feedback

Zhou *et al.* [18] proposed a joint Tomlinson-Harashima Precoding (THP) and scheduling scheme for multi-user MIMO downlink. Compared to some existing scheduling schemes, the proposed scheme greatly reduces the scheduling complexity while simultaneously improves overall system performance. Strictly speaking, the proposed THP-aided multiuser scheduling is not necessarily globally optimal, but we conjecture that the loss in optimality is negligible (when the number of scheduled users is given) and plan to undertake a comprehensive analysis of this approach. Another note is that, there is an inherent limitation on the maximum number of users that can be simultaneously supported for our proposed scheme, due to the geometric structure revealed.

2.3 A Leakage-Based Precoding Scheme for Downlink Multi-User MIMO Channels

Sadek *et al.* [19] considered a performance criterion based on optimizing the signal-to-leakage ratio (SLNR) for designing multi-user transmit beamforming vectors in a MIMO system. The decoupled nature of this criterion allows for a characterization of the solution to the multi-user beamforming problem in terms of generalized eigenvalue problems. The proposed design scheme does not impose a restriction on the number of available transmit antennas, the development and analysis of MIMO focused on the single stream case. They considered at least three extensions, investigating the incorporation of the leakage-based solution to MIMO systems that employ Alamouti coding, they also applied the leakage-based solution to the case of multiple streams per user, and finally, they examined the effect of channel estimation errors on system performance.

2.4 Uplink SINR Analysis in Massive MIMO Systems Using Ginibre Point Process

Ananthi *et al.* [20] derived and analyzed for uplink Massive MIMO system with GPP. This method offers realistic base station deployment compared to Poisson point process. It is inferred that the interference will be reduced while using a user centric than base station centric for the cluster edge users. Coverage probability for various values of threshold SINR is simulated using MATLAB and is compared with theoretical results. By varying the distance from the base station, coverage probability is simulated. Path loss compensation fraction values are increased to get good coverage for long distance. The coverage probability for different received SINR values is also simulated by varying the number of base station antennas.

3 Proposed Approach

Implementation is the stage of the system when the imaginary design is turned out into a working system for estimation. Thus it can be considered to be the most significant stage in achieving a successful new system and in giving the user.Methodology engross careful planning, analysis of the existing system and limitation on evaluation of the system, designing of methods to achieve conversion and evaluation of conversion methods. A well planned methodology for evaluation of the proposed system is the process of converting new system design into operation.

For the line of action about the assessment of the proposed scheme, we first understand the theoretical approach of BD and THP algorithm. By knowing the ability of MMSE precoding which balance the multiuser interference mitigation with noise enhancement and minimizes the total error in the process of precoding? We will implement that advantage of MMSE on to THP. Taking into account the advantage of BD precoding, which eliminates the interference caused from the other user signal gives rise to increase in average power and noise enhancement. To deal with this increase, implementing MMSE THP with BD will improve the performance by eliminating noise via MMSE, increase in average power via modulo THP operation and interference cancellation via BD precoding scheme.

We now describe the design of precoder for hybrid combination of BD and MMSE-THP precoding operation. Since both BD and MMSE-THP are well described schemes, we describe them only briefly. In our scheme, the precoder T_k

designed using BD for the k^{th} user (say) is a function of H^k while the precoder designed using MMSE-THP is a function of H_k and T_k . Hence, we first describe BD and then summarily describe MMSE-THP. A block diagram of the hybrid combination of BD and MMSE-THP system is as shown in Figure 1

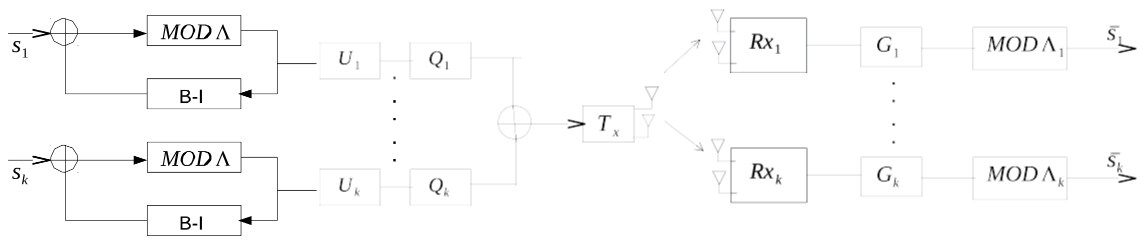

Figure 1: Block Diagram of a MMSE-THP and BD transmitter and receiver for a K user MIMO downlink

3.1 Mitigating multi-user interference using Block Diagonalization

For BD, the received signal for the k^{th} user is

$$y_k = H_k T_k x_k + H_k \Sigma_{i/=k} T_i x_i + w_k \tag{1}$$

Here $H_k \Sigma_{i/=k} T_i x_i$ is the interference at the k^{th} receiver due to the superposition of transmitted codewords of $K-1$ users. To mitigate this interference, the design of the precoder T_k for the k^{th} user should satisfy $[H_1^T H_2^T \ldots H_{k-1}^T H_{k+1}^T \ldots H_k^T]^T T_k = 0$ If we denote by $\tilde{H}_k = [H_1^T H_2^T \ldots H_{k-1}^T H_{k+1}^T \ldots H_k^T]^T$, we can equivalently write $\tilde{H}_k T_k = 0$ where 0 is a $(K-1)N_r$ dimensional vector of 0s. Therefore, if T_k is the null space of its corresponding aggregated channel matrix $\tilde{H}^T_k$ inter user interference for the k^{th} user will be mitigated. A QR decomposition of $\tilde{H}_k$ to obtain its null space yields

$$\tilde{H}_k = R_k^T Q_k^T = [R_{k1}^T \; 0_{N_t - L_k x L_k}] \begin{bmatrix} Q_{k1}^T \\ Q_{k2}^T \end{bmatrix} \tag{2}$$

Where R_{k1}^T is $N_t - L_k$ dimensional square right triangular matrix. The unitary matrices Q_{k1}^T and Q_{k2}^T are the dimension $N_t x N_t - L_k$ and $N_t x L_k$ respectively. From the above equation we see that Q_{k2}^T is the null space of $\tilde{H}_k$ and hence we choose $T_k = Q_{k2}^T$. Due to the choice of T_k, the received signal at the k^{th} user's receiver will now be $y_k = H_k Q_k x_k + w_k$. Thus, parallel non interfacing channels are created from base station to ery user. Each parallel channel can now be treated as a single user MIMO channel. We now elaborate on using THPto mitigate the interlayer interference for each user.

3.2 MMSE-THP to mitigate inter-stream interference

After cancelling the inter user interference for each users, the effective channel for each user is $H^k T^k = H^k Q_{k2}$. This can be decomposed as $[H_k T_k] = F_k U_k^H$, where F_k is a lower triangular matrix and U_k is a unitary matrix. The lower triangular characteristics of F can be exploited for interference cancellation.

· If we pre-multiply x_k by U_k , the effective channel will the lower triangular matrix F_k . The superposition of the signals from multiple transmit antennas at each receive antenna will then be due to the lower triangular elements of F_k .

· For the case of computation, if we normalize the diagonal elements of F_k by multiplying the received vector by G_k "" $(diag(F_k))^{-1}$, then the equivalent channel will now be, $B_k = G_k H_k U_k = G_k F_k U_k^H U_k = G_k F_k$

· For M QAM constellation, the modulo operation ensures that the real and imaginary values of the symbol x_k are constrained to lie within the symbol boundaries of the constellation. Thus, the feedback matrix, B-I, the modulo operator and the feed forward matrix U_k at the transmitter and the scaling matrix G_k at the receiver form the key component of MMSE-THP encoder and decoder to cancel the inter stream interference.

4 Proposed Experimental Setup

The simulation parameters for the experimental setup are as below

Table 1: Simulation parameters for the experimental setup

Parameter	Value/Description
No. of transmit antenna	1 to 4
No. of receiving antenna	1 to 4
Modulation	BPSK, QPSK
No. of packets	200
No. of users	10
No. of active user	4
Precoding scheme	ZF, MMSE, BD, DPC, THP, ZF THP, MMSE, THP
SNR value	0 to 20

5 Simulation Results

The simulation performance of proposed technique keeping the data rate for each user is assumed to be proportional to the number of receivesantennas. Comparative performance of the multiple and singleantennausers in a system with the configuration $1, 1, 2, 2 \times 6$ for the MMSE THP, and proposed scheme. Effect of increasing the number of transmit and receive antenna ($N_T = N_R$) is presented in Figure 2.

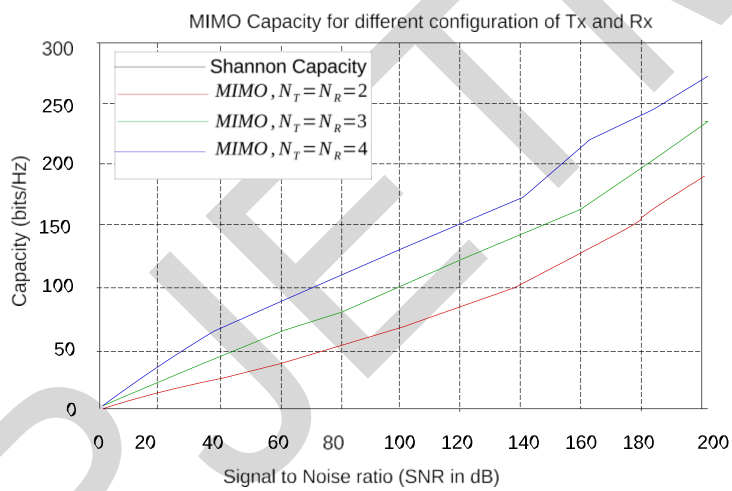

Figure 2: Effect of increasng no. of transmit and receive antenna

5.1 Linear Precoding Methods

Table 2: BER Performance of ZF and MMSE

SNR (in dB)	MMSE(BER)	ZF(BER)
0	0.2343	0.3536
4	0.1605	0.2791
8	0.09513	0.1874
12	0.4462	0.10
16	0.017	0.04562
20	0.006875	0.020

Simulated comparision between ZF & MMSE methods using MATLAB simulation is presented in Figure 3 The BER performance of channel inversion is compared to that of regularized channel inversion for N_B = 4and N_M = 1, in which

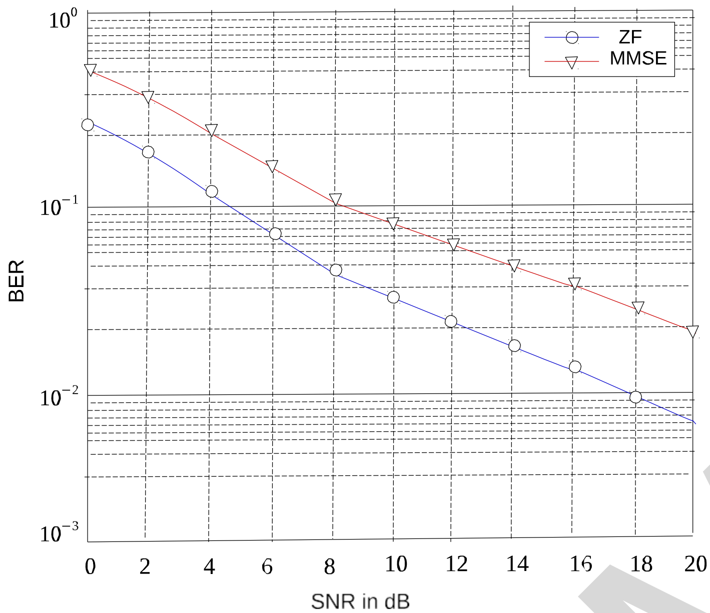

Figure 3: Simulated comparision between ZF & MMSE methods

four users with the highest channel norm values are selected out of $K = 20$. It can be seen and inferred from the simulated graph that regularized channel inversion achieves better BER performance that channel inversion which is due to mitigating the noise enhancement by regularized channel inversion.

6 Conclusion

A novel approach proposed for the spatial equalization of multiuser interference in MIMO system the user equipped with one antenna and better performance for the user equipped with multiple antennas than MMSE, which results in the improvement of the overall system performance. By using BD only for multiple antenna users we effectively eliminate the interference that these users generate to single antenna users. Then by using MMSE THP only for the single anenna users we improve their and the overall system performance.

Currently, the concept of massive MIMO or large MIMO is drawing considerable interest in the research community because of the potential to improve data rates dramatically and to scale down transmit power drastically.

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