Improved Diversity with Limited Feedback for more than two users

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Abstract—We consider interference cancellation for a system with more than two users when users know each other channels. The goal is to utilize multiple antennas to cancel the interference without sacrificing the diversity or the complexity of the system. In the literature, it was shown how a receiver with two receive antennas can completely cancel the interference of two users and provide a diversity of 2 for users with two transmit antennas. Unfortunately, the scheme only works for two users. Recently it was shown that a system to achieve interference cancellation and full diversity with low complexity for any number of users and with any number of transmit and receive antennas. In this paper our main idea is to design precoders, using the channel information, to make it possible for different users to transmit over orthogonal directions. Then, using the orthogonality of the transmitted signals, the receiver can separate them and decode the signals independently. Next, we extend the result for limited feedback systems to improve the diversity in the applied conditions. Simulation results show that the proposed precoder outperforms the previous work and improved diversity results using limited feedback. This paper is an extension of scheme in [1].

Key words:- Multi-user detection, multiple antennas, interference cancellation, precoder, orthogonal designs

I. INTRODUCTION

Multiple-input multiple-output (MIMO) wireless channels, created by deploying antenna arrays at both the transmitter and receiver, promise high capacity and high-quality wireless communication links [1], [2]. A lot of attention has been given to multi-user detection schemes with simple receiver structures. The multiple transmit and receive antennas are used to improve the gain, rate and reliability of wireless system. In this paper we consider a multiple antenna multi-access scenario where interference cancellation is achieved by channel information.

When there is no channel information at the transmitter, simple array processing methods using orthogonal space-time codes [1] and The quasi-orthogonal space-time block coding approach of Jafarkhani (2001) gives a way of obtaining full-rate (or increased-rate) space-time block coding designs using smaller designs as building blocks, [2, 3] proposed. Even a few bits of feedback at the transmitter can be used to improve the system performance. The capacity and performance of MIMO [13, 14] system increased using limited feedback [10, 9]. In addition the performance of each user also increased using limited feedback. The common goal and the main characteristics of the above multi-user systems are require the less number of required receive antennas and low complexity array decoding [11]. However, by using maximum likelihood detection we achieve full diversity for each user.

But maximum likelihood detection is usually not practical, as number of transmit and receive antennas increases, the of number of users and bandwidth efficiency. To overcome this drawback, in [15, 16], channel information is utilized at the transmitters to increase the diversity of the system while keeping the low complexity of the decoding.

In other words, unlike the above mentioned methods, we do not use receive antennas to cancel the interference. Instead, we use the channel information at the transmitter to design precoders that align different groups of signals along orthogonal directions. As a result, interference suppression is achieved without utilizing the receive antenna resources and therefore full diversity achieved naturally.

In this paper, we extend to show this, we analytically derive the exact bit error rate (BER) of the system and compare it with the performance of the previous work. Finally, we extend the results for limited feedback systems. Simulation results show that our proposed precoding method outperforms the previous limited feedback precoder for QOSTBCs.

In this we introduce our scheme for 4 users each with 4 transmit antennas. Our scheme can simultaneously achieve interference cancellation and full diversity for each user.

We provide the details of and show our scheme can be extended to any number of users each with any number of transmit antennas and any number of receive as well as we have shown the Extension of our scheme with limited feedback. Lastly we have shown the Simulation results and and concludes the paper.

\[ A_3^l = [a_3^l(i,j)]_{4 \times 4}, \quad A_4^l = [a_4^l(i,j)]_{4 \times 4} \] (2)

### III. Encoding:

According to our block diagram we have encoding and decoding part along with the channel, as a channel we are going to use quasi-static flat Rayleigh fading channel model. In this paper we are going to use only for 4, 6, 8 users for results and for explanation we use 4 users, That is for 4 users one receiver and 4 receiving antennas.

The above equation can be derived as we are having 4 users so we assume channel matrices of four users, the four users at four different time slots suppose as \( l = 1, 2, 3, 4 \).

At the lth time slots 1, \( l = 1, 2, 3, 4 \), the input output equation can be written as

\[
y^l = \sqrt{E_s}(H_1A_1^l c(l)) + H_2A_2^l s(l) + H_3A_3^l t(l) + H_4A_4^l c(l) + n^l
\]

\[
= \sqrt{E_s}(H_1 c(l) + H_2 s(l) + H_3 t(l) + H_4 c(l) + n^l)
\] (3)

The procedure of encoding is shown in flow chart from the above equations we can frame the system input output equation as equation as

Here \( n_l \) is the noise of the signal with zero mean and having 1 variance. In the above equation \( H1l \) will have matrices embedded \( H1, H2, H3, H4 \). Here comes the concept of precoding technique this helps in improving the diversity and also removes the interference. Here comes the main concept for four users. At each of the first 2 time slots, 1 and 2, respectively. Due to different characteristics of the precoders each element of users is individual and is still Gaussian. This plays a main role in
achieving the full diversity. Not similarly we will do for 3
and 4 users as we cannot put the symbols in orthogonal to
each other this kind of placing will helps in obtaining
cancelation of interference. Finally after combining 1, 2, 3,
4 they all will not interfere because of the individual
choosing of precoder symbols for 1, 2 and 3, 4 as shown in
the figure they are placed in orthogonal structure in vector
space.

Fig-2 Orthogonal structure of signal vector

Where H1, H2, H3, and H4 represents the matrix

\[
H_1 = \begin{pmatrix}
    a_1^{(1,1)} \\
    a_1^{(2,1)} \\
    a_1^{(3,1)} \\
    a_1^{(4,1)}
\end{pmatrix},
H_2 = \begin{pmatrix}
    a_2^{(1,1)} \\
    a_2^{(2,1)} \\
    a_2^{(3,1)} \\
    a_2^{(4,1)}
\end{pmatrix},
H_3 = \begin{pmatrix}
    a_3^{(1,1)} \\
    a_3^{(2,1)} \\
    a_3^{(3,1)} \\
    a_3^{(4,1)}
\end{pmatrix},
H_4 = \begin{pmatrix}
    a_4^{(1,1)} \\
    a_4^{(2,1)} \\
    a_4^{(3,1)} \\
    a_4^{(4,1)}
\end{pmatrix}.
\] (5)

The above idea for 4 users can be easily extended to any
number of users. In the next sections, we will illustrate how
to decode and why our scheme can realize interference
cancellation and full diversity.

III. Decoding

Using our precoders, Equation (3) becomes

\[
\bar{y} = \sqrt{E_d} \left( \bar{H}_1 \bar{e}^{(1)} + \bar{H}_2 \bar{e}^{(2)} + \bar{H}_3 \bar{e}^{(3)} + \bar{H}_4 \bar{e}^{(4)} + \bar{n} \right).
\]

(6)

Where \(\bar{y}\) and \(\bar{n}\) are the same with \(y'\) and \(n'\) in Equation (3).

Note that using our precoders, each column of matrix \(H'\)
is orthogonal to each column of matrices \(H_2, H_3, H_4\).

In order to decode symbols from User 1, we multiply both
sides of Equation (6) by matrix \(H_1'\). Similarly for user
2, 3, 4 we can multiply both sides of the equation (6) with
matrix \(H_2', H_3', H_4'\) respectively to remove the signals
of other user and use a similar method to complete the
decoding.

Here, we prove that we can achieve diversity i.e., full
diversity, using our proposed precoding scheme. We only
present the proof for User 1, since the proof for Users 2, 3,
4 is the same. Diversity is defined as

\[
d = -\lim_{\rho \to \infty} \frac{\log P_e}{\log \rho}
\]

where \(\rho\) denotes the SNR and \(P\) represents the probability
of error.
In some applications, while complete CSI is not available for the transmitter, a limited–bandwidth feedback channel is available to send partial CSI from the receiver to the transmitter. For this limited feedback systems, we use a set (codebook) \( \mathcal{F} \) of \( L = 2^{N_b} \) precoders that are pre-known to the transmitter (\( N_b \) is the number of feedback bits). For a given \( \mathbf{H} \), the only feedback parameter is \( I \) which is the index of \( f_i \in \mathcal{F} \), obtained from the following optimization problem:

\[
\begin{align*}
\mathbf{f}_I &= \arg \max_{\mathbf{f}_i \in \mathcal{F}} || \mathbf{Hf}_i ||^2 \\
E_{\mathbf{H}} &\left\{ \min_{\mathbf{f}_i \in \mathcal{F}} \left( || \mathbf{Hv}_R ||^2 - || \mathbf{Hf}_i ||^2 \right) \right\}
\end{align*}
\]

Similar to the codebook structure proposed in [6] that can be very easily implemented, we construct the codebook \( \mathcal{F} \) as follows

\[
\mathcal{F} = \{ \mathbf{e}_1, \Phi \mathbf{e}_1, \ldots, \Phi^{L-1} \mathbf{e} \}
\]

This technique has been implemented in our project to improve the result.

In the figure-4 we just compare our results with limited feedback and without limited feedback and proved that there is better diversity. We compare our scheme using QPSK scheme and Multi user scheme (MUD) [6] which cancels the interfaces and provides a diversity of 16 by utilizing the channel information in the transmitter.

Second figure fig-5 is the simulation results each with different number of transmit antennas and one receiver with four receiver antennas, it shows that our scheme out forms both of the above schemes whose diversity is only 1.

third figure Fig-6 is the graph plotted for simulation for four users each with four transmit antennas and one receiver with different number of receiver antennas, Here we proved that the diversity is always full diversity using our proposed method.

fourth figure fig 7 is the simulation results for different number of users each with four transmit antennas and one receiver with four receive antennas with limited feedback.

In the above all figures there is a vast increase in diversity with increasing in number of users. We just compared with multiple number of users in the graph just for knowledge sake that infer how the diversity related with increasing antennas so we have taken 4, 6, 8 users for example and this can be increased to 12, 16, 18 ... all the simulated results are assumed we assume a quasi-static flat Rayleigh fading channel model.
VI. Conclusion:
We have considered the best interference cancelation system to that system we extended that system with limited feedback with normal conditions and the results are good enough in improving diversity. We just used a normal limited feedback applicable to the channel which is well familiar Rayleigh fading channel, but there may be condition that in the real scenario channel is unknown and if that is the condition limited feedback should be modeled to obtain the required diversity, we have just proven that out general limited feedback had better results than the without feedback. There is also chance of increasing diversity in the Rayleigh fading channel than our result with perfect modeling of limited feedback.

References

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