An Improved Interference Cancellation Scheme for Two-User MIMO-MAC

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Abstract
Multi-Input Multi-Output (MIMO) Multiple Access Channels (MAC) for two-user suffers from co-channel interference. For this problem, an interference cancellation scheme based on limited feedback is proposed. Through diagonalization processing for transmitted signals according to feedback information, the co-channel interference is eliminated. Not only the reliability is improved, but also each signal can be Maximum Likelihood (ML) decoded separately. Simulation results show that, compared to the existing interference cancellation scheme, the gain of the proposed scheme is 2dB at the Bit Error Rate (BER) of 10^{-3}.
Keywords: *Multi-input Multi-output, Multiple Access Channels, Co-channel Interference, Maximum Likelihood*

1. Introduction

Multiple-Input Multiple-Output (MIMO), which is one of the mandatory techniques for the next generation wireless communication systems, has the features of spatial multiplexing and spatial diversity [1]. MIMO Multiple Access Channels (MAC) offers substantial capacity improvements and has attracted considerable research attention [2]. There is serious co-channel interference over MIMO-MAC since multiple users send signals simultaneously in the same frequency [3]-[7]. It not only affects the system reliability, but can also increase the decoding complexity.

In [5], a multiuser detection method is presented for the problem of co-channel interference over MIMO-MAC, based on interference suppression scheme in single-user MIMO systems. In [6], an improved interference cancellation method is proposed for two-user MIMO-MAC. However, both schemes only eliminate partial co-channel interference at the receiving terminal, and performance can be improved further. Therefore, transmission schemes over MIMO-MAC with limited feedback information are studied, in which partial interference is eliminated through preprocessing at the transmitters.

In [9], an Alamouti code based transmit scheme with a phase feedback is presented for two-user MIMO-MAC. The transmit power, which is feedback information, is derived with the goal of maximizing the Signal-to-Noise Ratio (SNR) at the receiver. However, only partial interference is canceled. The Maximum Likelihood (ML) decoding by single symbol is impossible, and the decoding complexity can be lowered further.

In order to mitigate co-channel interference and reduced decoding complexity, an interference cancellation scheme based on limited feedback is proposed for two users MIMO-MAC. Through diagonalization processing for transmitted signals according to feedback information, the co-channel interference is eliminated. The reliability is improved, and each signal can be ML decoded separately as well. Theoretical analysis shows that the decoding complexity of the proposed code downgrades to 20% and 33% as required by [9] for modulation order of 4 and 16, respectively. Simulation results show that, the gain of the proposed scheme is at least 2dB at the Bit Error Rate (BER) of 10^{-3} compared to the scheme in [9].

2. System Model

The system model is shown in Fig. 1. There are two users and one receiver each with two antennas. Let $\boldsymbol{H}$ and $\mathbf{G}$ denote the channel matrix from user 1 and user 2 to the receiver respectively, which are given by $\boldsymbol{H}=[\boldsymbol{h}_1,\boldsymbol{h}_2]$ and $\boldsymbol{G}=[\boldsymbol{g}_1,\boldsymbol{g}_2]$, where $\boldsymbol{h}_i=[h_{1i},h_{2i}]^T$, $\boldsymbol{g}_i=[g_{1i},g_{2i}]^T$, $i=1,2$.

The codeword of two users are defined as

$$\boldsymbol{S}=\begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \quad \boldsymbol{X}=\begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix}$$

where s_i and x_i are the modulated signals for user 1 and user 2, respectively, $i=1,2$.

Let $\boldsymbol{A}$ and $\boldsymbol{B}$ denote the precoding matrix for user 1 and user 2 respectively, which are defined as

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$$\boldsymbol{A}=\begin{bmatrix} p_1 & 0 \\ 0 & q_1 \end{bmatrix} \quad \boldsymbol{B}=\begin{bmatrix} p_2 & 0 \\ 0 & q_2 \end{bmatrix}$$

where p_1, q_1, p_2 and q_2 are complex numbers, satisfied $|p_1|^2+|q_1|^2=2$ and $|p_2|^2+|q_2|^2=2$. p_1 and p_2 are feedback information, while q_1 and q_2 are calculated at the transmitter according to p_1 and p_2.

The received signal vector $[\boldsymbol{r}_1,\boldsymbol{r}_2]$, with dimension of $N\times 1$, can be expressed as

$$[\boldsymbol{r}_1,\boldsymbol{r}_2]=\boldsymbol{HAS}+\boldsymbol{GBX}+[\boldsymbol{n}_1,\boldsymbol{n}_2] \tag{1}$$

where $\boldsymbol{n}_1$ and $\boldsymbol{n}_2$ are $N\times 1$ noise vectors.

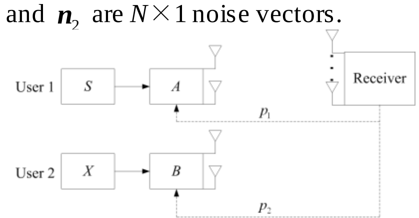

Fig. 1 System model of the proposed scheme

3. Calculation of Feedback Information

The receiver forms a rearranged vector as follows

$$\begin{bmatrix} \boldsymbol{r}_1 \\ \boldsymbol{r}_2^* \end{bmatrix}=\boldsymbol{H}'\begin{bmatrix} \boldsymbol{s} \\ \boldsymbol{x} \end{bmatrix}+\begin{bmatrix} \boldsymbol{n}_1 \\ \boldsymbol{n}_2^* \end{bmatrix} \tag{2}$$

where $\boldsymbol{s}=\begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$, $\boldsymbol{x}=\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$, $\boldsymbol{H}'$ is expressed as

$$\boldsymbol{H}'=\begin{bmatrix} p_1\boldsymbol{h}_1 & q_1\boldsymbol{h}_2 & p_2\boldsymbol{g}_1 & q_2\boldsymbol{g}_2 \\ q_1^*\boldsymbol{h}_2^* & -p_1^*\boldsymbol{h}_1^* & q_2^*\boldsymbol{g}_2^* & -p_2^*\boldsymbol{g}_1^* \end{bmatrix} \tag{3}$$

Multiply both sides of Equation (2) by matrix $(\boldsymbol{H}')^H$ to achieve

$$\boldsymbol{y}=\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}=\begin{bmatrix} \alpha & 0 & \rho & \varepsilon \\ 0 & \alpha & -\varepsilon^* & \rho^* \\ \rho^* & -\varepsilon & \eta & 0 \\ \varepsilon^* & \rho & 0 & \eta \end{bmatrix}\begin{bmatrix} s_1 \\ s_2 \\ x_1 \\ x_2 \end{bmatrix}+\begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{bmatrix} \tag{4}$$

$$\alpha=|p_1|^2\|\boldsymbol{h}_1\|^2+|q_1|^2\|\boldsymbol{h}_2\|^2$$

$$\eta=|p_2|^2\|\boldsymbol{g}_1\|^2+|q_2|^2\|\boldsymbol{g}_2\|^2$$

$$\rho=p_1^*p_2\left(\boldsymbol{h}_1^*\right)^T\boldsymbol{g}_1+q_1q_2^*\left(\boldsymbol{h}_2\right)^T\boldsymbol{g}_2^*e^{j\theta-j\beta}$$

$$\varepsilon=p_1^*q_2\left(\boldsymbol{h}_1^*\right)^T\boldsymbol{g}_2e^{j\beta}-q_1p_2^*\boldsymbol{h}_2^T\boldsymbol{g}_1^*e^{j\theta}$$

$$[n_1,n_2,n_3,n_4]^T=(\boldsymbol{H}')^H\begin{bmatrix} \boldsymbol{n}_1 \\ \boldsymbol{n}_2^* \end{bmatrix}$$

s_i and $x_i\ (i=1,2)$ keeps orthogonal in their transmission if $\rho=\varepsilon=0$, so that, symbol by symbol ML decoding can be realized. Equations (5) can be obtained with $\rho=\varepsilon=0$.

$$\begin{cases} ap_1^*p_2+bq_1q_2^*=0 \\ cp_1^*q_2-dq_1p_2^*=0 \end{cases} \tag{5}$$

where $a=\left(\boldsymbol{h}_1^*\right)^T\boldsymbol{g}_1$, $b=\left(\boldsymbol{h}_2\right)^T\boldsymbol{g}_2^*$, $c=\left(\boldsymbol{h}_1^*\right)^T\boldsymbol{g}_2$, $d=\boldsymbol{h}_2^T\boldsymbol{g}_1^*$. Through solving equation (5), we get

$$p_1=\sqrt{\frac{2bd}{bd-ac}} \qquad p_2=\sqrt{\frac{2bc}{bc-ad}} \tag{6}$$

Thus, q_1 and q_2 are obtained as

$$q_1=\sqrt{\frac{2ac}{ac-bd}} \qquad q_2=\sqrt{\frac{2ad}{ad-bc}} \tag{7}$$

4. Decoding method

From the above analysis, symbol by symbol decoding can be realized when Equation (6) and (7) are satisfied. Specific decoding procedure is as follows.

Step 1, computer $\boldsymbol{H}'$ according to (3);

Step 2, the receiver forms a rearranged vector $\begin{bmatrix} \boldsymbol{r}_1 \\ \boldsymbol{r}_2^* \end{bmatrix}$, and then multiply $\begin{bmatrix} \boldsymbol{r}_1 \\ \boldsymbol{r}_2^* \end{bmatrix}$ by $(\boldsymbol{H}')^H$ to (3) obtain $\boldsymbol{y}=[y_1,y_2,y_3,y_4]^T$;

Step 3, computer α, and obtain the detected symbol of user 1 by Equation (8).

$$s_i'=\arg\min_{\hat{s}_i\in C}\|y_i-\alpha\hat{s}_i\|^2 \tag{8}$$

where C denotes the constellation point set.

Step 4, computer η, and obtain the detected symbol of user 2 according to $y_k\ (k=1,2)$ and η by

$$x_i'=\arg\min_{\hat{x}_i\in C}\|y_i-\eta\hat{x}_i\|^2 \tag{9}$$

4. Computational Complexity of Decoding

In this section, two schemes are compared in terms of computational complexity of decoding.

$(72N+12M-8)$ flop is required in the process of decoding for the proposed scheme, where M is modulation order.

Minimum Mean Squared Error Successive Interference Cancellation (MMSE-SIC) is adopted as detection in [9]. Since there are several kinds of MMSE-SIC,

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We assume [9] uses the low complexity MMSE-SIC presented by [10]. In this condition, $(432N+244)$ flop is required in the process of decoding for [9].
By calculation, the decoding complexity of the proposed code downgrades to 20% and 33% as required by [9] for modulation order of 4 and 16, respectively.

4. Simulation Results

The BER performance of the proposed system and [9] is investigated. We consider uncoded systems with 4QAM and 16QAM constellations. Fully spatially uncorrelated channels are employed. Assume that the elements of channel and noise are obtained from an independent and normal distribution.
Fig. 2 and Fig. 3 show BER versus SNR at the transmitter for different modulation, with N=2 and N=3, respectively. As observed in these figures, the performance of the proposed scheme significantly outperforms that of [9]. The reason is that, the proposed scheme mitigates all interference rather than partial interference, as in the scheme of [9]. The gain of the proposed scheme is 2dB and 3dB at the BER of 10^{-3} for $N=2$ and $N=3$, respectively. Thus, the gain increases with the increment of transmit antennas.

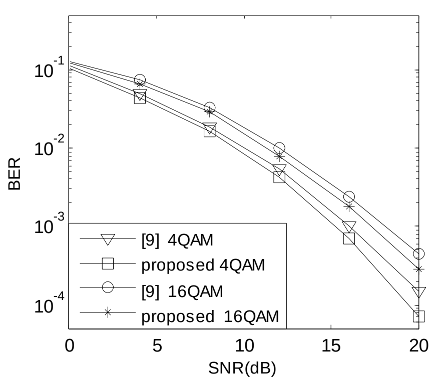

Fig. 2 BER of the two schemes for QPSK with $N=2$

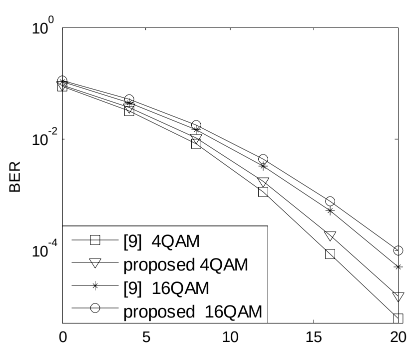

Fig. 3 BER of the two schemes for QPSK with $N=3$

4. Conclusions

A phase is required to feedback to only one transmitter in [9] while one complex number is required to feedback to each transmitter in the proposed scheme. Since every complex number contains two real numbers, the proposed scheme needs three more real numbers as feedback information, which is the disadvantage. However, the system performance is enhanced, and the decoding complexity is also reduced. In addition, the gain increases with the increment of transmit antennas.

Acknowledgments

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